OPTIMIZING THE PERFORMANCE OF OPERATIONS-FINANCE INTERFACE BY IMPLEMENTING SUPPLY CHAIN FINANCE SCHEMES

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Optimizing the Performance of Operations-Finance Interface by Implementing Supply Chain Finance Schemes

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CERTIFICATE OF ORIGINALITY

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_________________________ (Signed)

<u>   HUANG Chaorui   </u> (Name of student)

Abstract

Via identifying three significant problems contained in the interface of operations and finance in the supply chains, this research attempts to solve these problems and seeks to optimize supply chain cash flows by implementing supply chain finance (SCF) schemes with different real-life settings. The problems we identified, are largely ignored in the previous literature due to the business environment changing. Therefore, we are motivated to rigorously examine these areas and innovatively raise the appropriate solutions.

Specifically, SCF is an innovative solution dedicated to optimizing financial flows in supply chains. Considering the ever-evolving nature of SCF, we first investigate the novel achievements that have been reported in the current literature. By conducting a systematic literature review (SLR), we build up a novel theoretical foundation that helps us to effectively work on the following problems.

The first problem is related to how to smooth the cash flow in a payment-delayed supply chain. Substantial evidence has shown that payment delays generate negative effects on suppliers' working capital levels. The adoption of emerging solutions such as SCF is considered an innovative approach to overcome this issue. We establish a multi-cycle model and identify the conditions under which extended payments will impact on the supply chain's collaborative cash to cash (CC2C) cycle and the shareholder-value added (SVA). Finally, the numerical analysis not only confirms the major findings but also provides additional insights that can assist practitioners in mitigating the adverse effects caused by payment delays.

The second problem is an extension of the first one by considering the time value of cash accumulated in the payment delay. Some third-party logistics (3PL) companies are now taking on a new financing role to help achieve advance payment for suppliers. By establishing a Stackelberg game model, we find that when players face a homogeneous time value of cash, the advance-payment scheme brings no profit growth for all players. In addition, we identify that the merit of the 3PL's new role in terms of improving profits only exists for the 3PL itself when players face a heterogeneous time value of cash.

The third problem is another extension of the first one by locating the problem in the Chinese electric vehicle (EV) industry. In the current Chinese EV industry, two financing schemes have been adopted commonly to enable EV-makers to obtain financing for purchase if needed, i.e., bank loan financing

(BLF) and trade credit financing (TCF). By examining the EV-maker's moral hazard, we show that, when there is no information asymmetry between the battery supplier (BS) and the bank, each player's performance under BLF and TCF is completely different. In addition, if the EV-maker's asset level is zero, the BS can efficiently signal her private information of the EV-maker's efficiency via the contract under the asymmetric information case, making BLF a better scheme. Nevertheless, when the EV-maker's asset level falls into particular regions, the BS's information advantage over the bank makes TCF a better option when working with an efficient EV-maker and the latter's alternative financing cost satisfies certain conditions.

Publications

Journal Publications:

1. Chaorui Huang, Felix T. S. Chan & S. H. Chung (2022) "Recent contributions to supply chain finance: towards a theoretical and practical research agenda," *International Journal of Production Research*, 60(2), 493-516.

2. Chaorui Huang, Felix T. S. Chan & S. H. Chung (2022) "The impact of payment term extensions on the working capital management of an automotive supply chain," *International Journal of Production Research*, pp.1-24. DOI: 10.1080/00207543.2022.2065549.

Paper Under Review:

3. Chaorui Huang, Xin WEN & S. H. Chung, "Is the financing role of a third-party logistics firm always appealing in a supply chain?" under the 1st round review at *Annals of Operations Research.*

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List of Abbreviations

AJG	Academic Journal Guide
BCBS	Basel Committee on Banking Supervision
BDA	Big Data Analytics
BL	Bank’s Lending
BLF	Bank Loan Financing
BS	Battery Supplier
C2C	Cash to Cash
CC2C	Collaborative Cash to Cash
CDF	Cumulative Distribution Function
DPO	Days Payables Outstanding
DSO	Days Sales Outstanding
EP	EV-maker’s Participation
EV	Electric Vehicle
FSP	Financial Service Provider
GFR	Generalized Failure Rate
OEM	Original Equipment Manufacturer
OM	Operations Management
PBE	Perfect Bayesian Equilibrium
PDF	Probability Density Function
POF	Purchase Order Financing
RF	Reverse Factoring
SCF	Supply Chain Finance
SCM	Supply Chain Management
SLR	Systematic Literature Review
SME	Small and Medium-sized Enterprise
SSCF	Sustainable Supply Chain Finance
SVA	Shareholder-Value Added
TC	Trade Credit
TCF	Trade Credit Financing
VAT	Value-Added Tax
VMI	Vendor Management Inventory
WACC	Weighted Average Cost of Capital
WCM	Working Capital Management
3PL	Third-Party Logistics

Chapter 1: Introduction

The research background and motivations are firstly presented in this chapter. Next, the research scope is refined, and the research objectives are set. Then, the research methods and significance for each specific issue are briefly illustrated. Finally, the organization of this thesis is given with a concise introduction for each chapter.

1.1 Research Background

The essence of this research is an inter-disciplinary subject covering the areas of operations management (OM) filed and finance field. In order to have a comprehensive understanding of the research background, the author introduces the phenomenal issues lying in the interface of operations-finance in practice firstly, followed by recommending innovative solutions named supply chain finance schemes that are used to deal with the practical issues.

1.1.1 The Issues within The Interface of Operations and Finance

Traditional OM literature in the supply chain management (SCM) field mainly focuses on finding optimized operational decisions such as the equilibrium wholesale price and the equilibrium production quantity in an ordinary newsvendor model (Kouvelis and Xu, 2021). The tremendous achievements made by pioneering researchers and the ever-changing global business environment open a new path that recently raised substantial interest from industrial practitioners and researchers, that is called, the interface of operational and financial decisions (Babich and Sobel, 2004; Ding et al., 2007; Kouvelis and Zhao, 2016). The secret of the interface of operations and finance is a scenario when a participant in a supply chain wants to access internal or external financing to conduct its daily operations or survive in the market. Then, all involved parties (e.g., supplier, buyer, a financial institution) in this financing scheme should not only take the operational decisions into account but also the financing parameters such as the interest rate to maximize their respective profits and the whole supply chain's profits. Put differently, the interface of operations and finance captures the interactions of three supply chain flows, i.e., material, information and cash, and it focuses more on the cash flows recently.

The cash flow was previously largely ignored within the SCM field but has been drawing increasing attention from industry and academia since the global economic downturn of 2008 (Zhang et al., 2019; Gelsomino et al., 2016; Bals, 2019). Since then, companies have been struggling to search for solutions for liquidity and working capital needs, especially for small and medium-sized enterprises (SMEs) that have restricted access to capital because of their poor credit ratings (Caniato et al., 2016; Gelsomino et al., 2016). Within real-life transactions, we identify three major problems that all have a tight connection with supply chain cash flows. One of the major problems is payment term extension on SMEs which exacerbates the unsmooth supply chain cash flows (Oliveira and Handfield, 2017). For example, in 2009, 43% of SMEs in Belgium and 50% of SMEs in the Netherlands were reported to have experienced payment delays for their receivables, leading to a shortage of working capital, a decrease in liquidity and an increase in defaults, insolvencies and bankruptcies (OECD, 2009). The suppliers in Hong Kong's construction industry declared in a survey carried out by the Hong Kong government in 2012 that payment delay amounted to 75% of the total outstanding payments, which directly resulted in the delay of both project schedules and the payment of employees' wages. The situation has become even worse recently due to the impact of COVID-19. For instance, based on KPMG's recent report 'COVID-19 Global Tax Developments Summary', payments were delayed more severely on commercial receivables due to the pandemic outbreak, and the entailed longer payment delay urgently raised global firms' liquidity needs by increasing 5 days to 74 days or USD 8tn. Euler Hermes, a global leader in trade credit insurance, reported that the transportation, automotive, textiles and (non-food) retail industries will be the mostly capital-constrained industries, since commerce payment delays induce shipment delays, service delays and final project process delays (Goel et al., 2021). As a result, many companies have suffered plant lockdowns and supply chain disruptions due to a lack of working capital for normal operations (Hermes, 2020). Therefore, we can draw a preliminary conclusion that a payment delay significantly worsens a firm's financial performance, threatens the survival of supply chain participants, and eventually results in liquidation and bankruptcy. Hence, payment delay has gradually become a major concern for today's practitioners who view it as a challenging task in order to avoid supply chain disruptions (Huang et al., 2019a).

The second major problem within this area is closely related to third-party logistics (3PL). In recent years, financial service providers (FSPs)'s supply chain finance (SCF) solutions have been increasingly implemented in industries to help SMEs with low-level credit ratings and deficient asset mortgages easily obtain financing so as to survive in the market. Among these FSPs, 3PLs are attracting growing attention by virtue of their joint and customized services, i.e., traditional delivery services plus financing services. For example, EA[1], one of the largest 3PLs in China providing purchasing, shipping, inventory and financing services, etc., to customers, focuses not only on helping gigantic retailers like Johnson & Johnson relieve their supply chain management burdens, but also in providing financing solutions for capital-constrained suppliers to help them overcome financing difficulties. Among the financing services provided by 3PLs, advance payment financing, which is specifically designed to deal with the negative impact of a retailer's payment delay on capital-constrained small suppliers, has stood out. For

[1] Also known as Yiyatong in Chinese.

example, EA has established its efforts in jointly assisting giant retailers with logistics operations and in helping small suppliers receive payments earlier. To be specific, the retailer will first outsource the non-core businesses such as order settlement and product delivery to EA, so that it can enjoy a series of intangible benefits like evading logistics risks and concentrating on its core business (Gillett, 1994). Then, the retailer pays the ordering cost and services fees ahead to EA once the goods are delivered from the supplier to EA's designated warehouse. After a series of service implementations, EA pays the supplier when the goods are confirmed as acceptable. Due to EA's expertise in supply chain management, the duration for ordering payment will be substantially reduced compared with the case that the retailer makes the (delayed) payment itself. Hence, with EA's support, the capital-limited supplier can obtain a shortened payment cycle rather than waiting for collecting receivables at the end of the selling season, as before. Several successful cases applying the advance payment financing strategy are presented on EA's website[2]. It seems that this strategy can perfectly solve the supplier's dilemma and create an all-win situation for the supply chain participants. Nevertheless, if the time value of cash is considered in the presence of the retailer's payment delay, the advance payment may cause a huge opportunity cost loss, hence whether the advance payment strategy is still appealing to all players is unknown.

The third major problem is occurring in today's Chinese electric vehicle (EV) industry. The current EV market in China reflects several prominent characteristics. The first characteristic is that there are only limited mainstream battery suppliers (BS) operating as mature oligopolies. For example, BYD supplies batteries for BYD Auto, a dominant EV original equipment manufacturer (OEM) in China. CATL, as the world's biggest BS, supplies batteries to Honda, Hyundai, Tesla, etc. The industry shows the concentricity and monopoly of these BSs. Secondly, as the key component in an EV's powertrain system, the battery plays a pivotal role to characterize the quality of an EV, thus these BSs locate themselves in a dominant position in EV supply chains. The relationship between OEMs and component suppliers is thereby started to shift from being OEM-oriented to being BS-oriented. Therefore, different from the traditional automotive supply chain, the BS with sufficient capital resources, now have more bargaining power to determine the contract terms and even decide who to contract with. For example, CATL claimed that they dynamically adjusted the prices of some battery products due to the rising costs of raw materials in the first season of 2022[3]. Besides, CATL agreed to supply certain orders of batteries for Tesla but refused to contract with some other tiny EV-makers (e.g., Leapmotor, a low-end Chinese EV automaker) in terms of production capacity, when considering the economics of scale[45]. The third character is that other than the traditional OEMs who start to invest in the Chinese EV market (e.g.,

[2] Please refer to http://www.logistics-ea.com/Case/
[3] Please refer to https://autonews.gasgoo.com/m/70019937.html
[4] Please refer to https://electrek.co/2021/06/28/tesla-signs-battery-cell-agreement-with-catl-race-secure-large-supply/
[5] Please refer to https://finance.sina.com.cn/tech/2022-07-11/doc-imizirav2835988.shtml?finpagefr=p_114

Honda, Toyota, Volkswagen, etc.), there are also many newcomers stepping into this industry (e.g., NIO, XPENG Motors, Li Auto, etc.), and the competitions among newcomers are drastic while the qualifications with respect to their production capacities, capital resources, market shares, etc., are multi-level (He et al., 2022; Wu et al., 2022). On the one hand, to win in the competition of sourcing from those big BSs and survive in the market, they need to make effort to enhance not only production capacities but also to stabilize cash flows. Put differently, to have the certificate to contract with such dominated BSs, they need to demonstrate their efficiency in operational and financial performance. From the BSs' perspectives, they would like to cooperate with the EV-makers who are more efficient in the interface of operations and finance as well. On the other hand, due to the impact of the eliminated subsidy policies, volatile investment environment, COVID-19, etc., these new EV-makers often suffer unstable cash flows and may encounter capital pressures to pay back to the BSs, sometimes even go bankrupt ultimately. For instance, several EV-makers (e.g., Byton, Leapmotor, HOZON, WM Motor, etc.) are enduring high capital pressures when the investor's funding is delayed, then the payments to suppliers are defaulted inevitably (Liang, 2022). Some others (e.g., Zotye, Zhidou, Byton, etc.) are even on the verge of bankruptcy because of the reduction of government subsidies and city lockdown during COVID-19[6][7]. Therefore, these EV-makers need approaches to relieve their capital pressures.

1.1.2 Supply Chain Finance Schemes

To solve the aforementioned problems, SCF gradually becomes a key instrument in handling these problems (Bals, 2019; Gelsomino et al., 2016; Jia et al., 2020a). "Planning, managing, and controlling of supply chain cash flows" is the dominant focus of SCF (Wuttke et al., 2013a). Lamoureux and Evans (2011) and Hofmann (2005) argued that SCF aimed to help firms cover their daily financing needs so as to optimize the cash flow at the inter-organization level. Since SCF is a relatively novel solution compared with traditional methods (e.g., equity financing or mortgage), the research in this field is rather fresh, and the application of SCF faces various challenges (See More and Basu, 2013). Regarding the specific SCF solutions, one of the most pervasive instruments of SCF is reverse factoring (RF). The terminologies of RF and SCF are often used interchangeably (Demica, 2012). RF is an instrument where the FSP (e.g., bank) provides discounted loans immediately to suppliers based on the buyer's high credit-rating (Liebl et al., 2016; van der Vliet et al., 2015; Wuttke et al., 2013b). Another common instrument has also been used and researched for a long period, which is called trade credit (TC), a short-term financing scheme for suppliers and buyers without involving the third-parties (Wuttke et al., 2013a). Trade credit means the non-cash limited suppliers can provide longer payment terms for buyers in order to avoid buyer disruption on the one hand; on the other hand, the stronger buyers who have

[6] Please refer to https://www.reuters.com/business/autos-transportation/exclusive-china-talks-with-automakers-ev-subsidy-extension-sources-2022-05-18/
[7] Please refer to http://pdf.dfcfw.com/pdf/H3_AP202009231416468578_1.pdf

high bargaining power and larger market share can require suppliers to execute payment extension (Cowton and San-Jose, 2017). Except for these two dominant instruments, there are other emerging approaches such as purchase order financing or inventory financing, etc. All the abovementioned instruments are discussed further in Chapter 2.

1.2 Research Motivations

Since SCF is drawing growing attention nowadays, the literature volume is increasing as well. Xu et al. (2018) discovered an upward trend in publications by year, with an obvious increment after the financial crisis in 2007/2008. Nevertheless, the research on SCF or on the interface of operations and finance is still at the infant stage due to its novel nature. The extant SCF literature primarily deals with the following issues (including but not limited to): SCF instruments, for example, trade credit (e.g., Peura et al., 2017; Cowton and San-Jose, 2017), reverse factoring (e.g., van der Vliet et al., 2015; Liebl et al., 2016); Risk management (e.g., Giannetti and Saidi, 2019; Zhao et al., 2015); SCF concept (e.g., Wetzel and Hofmann, 2019; Blackman et al., 2013); Financial service providers (e.g., Ma et al., 2020; Song et al., 2018); SCF adoption (e.g., Wuttke et al., 2013b; Wang et al., 2020). For the detailed analysis of these research domains, it will be presented in Chapter 2.

In addition, as the cash flow is becoming more and more vulnerable due to the negative impact of global business changes, COVID-19, war and emerging but unstable industries, people are paying more attention to how to ease the frictions embedded in supply chain cash flows so as to survive on the market. Hence, this thesis complements previous works by focusing on the issues happening around the domain of smoothing supply chain cash flows in different environmental settings. Recall that the first problem we raise, i.e., payment term extension, is a prevailing phenomenon occurring in the industries. It results in barriers in supply chain cash flows and threatens the survival of supply chain participants. The second problem which considers the time value of cash accumulated in the payment delays, is thus can be viewed as an extension to study how the time value of cash will impact the supply chain cash flows. The third problem is another extension of the first problem by locating the issues in an emerging industry, i.e., the Chinese EV industry and studying how contract settings can strategically smooth the supply chain cash flows. Therefore, in general, we are motivated to study how innovative SCF schemes can solve the significant problems we identified in different environmental settings.

Particularly, regarding the first problem, we find that industrial practitioners commonly lack adequate knowledge of the impact of payment delay on their financial flow, namely, working capital management (WCM). In addition, it is a typical problem in developing countries such that the low-level credit rating and insufficient collateral of SMEs make it hard for them to obtain financing from financial institutions, such as banks (Nigro et al. 2021). These two reasons explain why supply chain disruption occurs all the time and is even worse during COVID-19 so that both industrial practitioners and researchers urgently need to find a novel solution to handle the payment delay issues. As SCF can effectively mitigate the working capital risk by helping a supplier obtain financing more easily based on a capital-sufficient buyer's credit level from financial institutions, however, due to the novel nature of SCF, how can SCF mitigate the delay incurred risks and how can SCF influence a supply chain's WCM, especially in developing economies such as China, remains unknown. Thus, we attempt to utilize the SCF solution to examine how SCF can improve a supply chain's WCM in the presence of payment delay.

With respect to the second problem, recall that in the traditional payment delay scenario, the retailer could enjoy the time value of cash accumulated in the delayed period, e.g., 60, 90, or 120 days. The time value of cash can be viewed as the opportunity cost where the retailer can use this payment to invest in a risk-free market during these delayed periods before paying to the supplier. However, under the 3PL's advance payment scheme, the retailer has to pay earlier, thus facing an opportunity cost. Accordingly, the retailer may take some actions (e.g., reduce the wholesale price or order quantity) to offset the loss incurred by paying earlier, which in turn hinders the supplier's profitability. Therefore, there is no one-size-fits-all path when the time value of cash is considered. In addition, how the market leadership (i.e., whether the retailer or the 3PL is the market leader) affects the 3PL's financing performance is also unclear. Hence, we aim to examine whether the advance payment financing services provided by the 3PL can truly benefit supply chain participants when the time value of cash is considered.

For the third problem, although there are many available SCF schemes for the EV-makers to obtain financing such as bank loans or trade credit, industry experts are still debating whether a third-party FSP (e.g., banks) or supply chain partners (e.g., supplier or buyer) are in a better position to improve supply chain performance, especially in the emerging EV supply chains. Many practitioners suggest that suppliers should leave financing to experts in the relevant fields (Tang et al., 2018). Alternatively, because the success of bank loan financing (BLF) and trade credit financing (TCF) hinges on the EV-maker's default risk, and because the BS has better control ability and knowledge of an EV-maker in terms of the latter's manufacturing process (Wu et al., 2022), one may argue that the BS can provide financing more efficiently. Further, a BS often has better information than a third party with respect to an EV-maker's intrinsic operational efficiency due to previous experience, substantial auditions, or abundant know-how of the EV industry. This information advantage may help a BS earn more than a third finance provider. Therefore, we want to figure out which financing scheme is preferable in terms of its efficiency in smoothing the supply chain cash flows.

1.3 Research Scope and Objectives

This research attempts to optimize the performance of the operations-finance interface by combining SCF schemes with different real-life settings. We focus on the issues related to supply chain cash flows and identify three major problems as discussed early. Hence, this thesis is dedicated to studying these three problems and concluding instructive results ultimately. Thereby, we present the principal objectives as follows:

(1) To establish a consolidated foundation by deriving a theoretic and systematic framework containing concept expansions and novel findings in up-to-date literature within SCF scope.

(2) To study how an innovative SCF scheme improves supply chain cash flow by investigating the impact of payment term extensions on the WCM of a supply chain, with and without SCF involvement.

(3) To extend the study of supply chain cash flow by considering the time value of cash and examining whether the advance payment financing services provided by the 3PL can truly benefit supply chain participants.

(4) To extend the study of supply chain cash flow by focusing on an emerging EV industry and examining how the BS can incentivize an EV-maker to mitigate his default risk under two types of financing solutions, i.e., BLF and TCF? And to compare these two schemes in the presence of the BS's information advantage about the EV-maker's operational efficiency.

1.4 Research Methods

To achieve the first objective, we conducted a comprehensive and systematic literature review (SLR) and located a total of 99 papers published from 2010.1 to 2021.4, then we made a descriptive analysis in terms of journal characteristics and derived a deep content analysis to acquire detailed information by reviewing the qualified journal papers. To ensure the journal level quality, we referred to the "2018 iteration of the Chartered Association of Business Schools Academic Journal Guide (AJG)" and selected journals based on their ratings ranging from 2 to 4* (Bals, 2019).

To achieve the second objective, we established a three-tier automotive supply chain model including a raw material supplier, a component supplier and an OEM and captured the dynamical variations of two dominant indicators, i.e., collaborative cash to cash cycle (CC2C) cycle and the shareholder-value added (SVA). A detailed analysis of the model, with and without SCF involvement, was conducted, followed by numerical analysis examining whether the derived results could apply to practical numerical settings, given different values of the parameters obtained from the interviews.

To secure the third objective, we modeled a supply chain comprising four parties: a supplier that has an initial capital level and limited liability, a bank that provides loans to the supplier when necessary, a capital-sufficient retailer, and a capital-sufficient 3PL company that can provide both logistics services and financing services for the required party. Based on a Stackelberg game, we compared the cash flows under two funders (bank and 3PL) considering the time value of cash and examined whether the 3PL's financing role is always appealing in a supply chain.

To attain the fourth objective, we studied a game-theoretical model that captures the interactions among three players (a BS, a capital-limited EV-maker who can make costly and unobservable effort to increase repayment probability, and a bank). Specifically, to mitigate the EV-maker's moral hazard in default risk, we established a Stackelberg game to capture cash flows and compared each player's optimal response under two financing schemes. Then, by adopting a signaling game, we concluded optimal contract settings in the presence of the BS's information advantage and made a comparison between these two financing schemes in terms of the players' profits.

1.5 Research Significance

Generally speaking, the insights gained from this research can be of assistance to industrial practitioners who care about the applications of SCF. They can use the results extracted from the research combined with their own requirements and conditions as a guide to learn the benefits generated from SCF adoption, the improved supply chain performance under multiple SCF instruments, the current challenges, risks and opportunities of SCF, etc.

Specifically, regarding the first objective, this research generates theoretical contributions by explaining the principles, terminologies and updated mechanisms based on the latest SCF research so that not only can senior researchers study the current achievements of SCF research but also young researchers can learn about the basics to acquire a whole picture in this field by referring to the updated framework, specific methods used in this field as well as the future directions.

Regarding the second objective, we identify the conditions under which extended payments will impact the supply chain's CC2C cycle and the SVA. We conduct numerical analysis to not only confirm the major findings but also provide some additional insights that can assist practitioners in mitigating the adverse effects caused by payment delays.

With respect to the third objective, we find that when players (i.e., supplier, retailer and 3PL) face a homogeneous time value of cash, the advance-payment scheme brings no profit growth for all players. For the supplier, although receiving the payment earlier, he cannot enjoy a profit increase as the retailer reduces the wholesale price to compensate for the opportunity costs. For the 3PL, it has to lower the service fee to attract the retailer to join the game if the advance-payment scheme is adopted. Finally, we identify that the merit of the 3PL's new role in terms of improving profits which only exists for the 3PL itself when players face a heterogeneous time value of cash.

In view of the fourth objective, we show that when there is no information asymmetry between the BS and the bank, each player's (i.e., BS, EV-maker and bank) performance under BLF and TCF is completely different in terms of the contract terms, the EV-maker's responses and each player's payoff. Moreover, BLF even results in better results irrespective of the BS's control advantage (both acting as a supplier and a lender) and freedom in setting contract terms under TCF. In addition, if the EV-maker's asset level is zero, the BS can efficiently signal her private information of the EV-maker's efficiency via the contract under the asymmetric information case, making BLF a better scheme. Nevertheless, when the EV-maker's asset level falls into particular regions, the BS's information advantage over the bank makes TCF a better option when working with an efficient EV-maker and the latter's alternative financing cost satisfies certain conditions.

1.6 Organization of The Thesis

Chapter 1 introduces the research background, research motivations, research scope and objectives, research methods, research significances and the organization of this thesis.

Chapter 2 presents a systematic literature review to analyze the current research dimensions and provides an integrated framework in the SCF field. Specifically, the related research and findings are presented, and the research gaps are located accordingly.

Chapter 3 analyzes two payment delay-derived problems: the impact of payment delay on the supply chain's WCM and how SCF can mitigate the bankruptcy risk in the presence of payment delay.

Chapter 4 examines whether the 3PL's advance-payment financing role is always appealing if the time value of cash is considered based on game-theoretical analyses.

Chapter 5 analyzes the relative efficiency of the two financing schemes in the context of EV supply chains, i.e., BLF and TCF, via studying a game-theoretical model that captures the interplays among three players (a BS, an EV-maker and a bank).

Chapter 6 concludes the current work and exhibits the findings and limitations. Furthermore, the milestones in future research are scheduled.

Chapter 2: Literature Review

Since SCF aims to optimize the interface of operations and finance in supply chains, we present an SLR related to SCF research first in this chapter. The main steps of SLR include formulating questions, locating papers, selecting and evaluating materials, analyzing, and synthesizing the contents. Next, based on this SLR, we identify the research gaps at the end of this chapter.

2.1 SLR

2.1.1 Method

First, we raise two central research questions hinging on the aim of this SLR:

RQ 2-1: What are the latest mechanisms under SCF practices? What are the new findings contained in these mechanisms?

RQ 2-2: What does the innovative research framework look like and what are the methodologies applied in this field?

Next, we locate the related papers. The search engines, search strings and inclusion and exclusion criteria are presented in Figure 2-1. We set the published time range from January 2010 to April 2021, seeking to cover all recent articles in this field. In addition, the language is limited to English, and the source type is solely for peer-reviewed scholarly journals, and the document type only includes articles, case studies and reviews, excluding conference papers, books and book chapters. As for quality assessment, since we only count journals, whose ratings were 2 to 4*, according to the AJG guide (Xu et al., 2018; Bals, 2019), the number of papers is further reduced. Eventually, after duplicates are removed, we identify 99 papers for further analysis and synthesis.

Once the base of the final samples is identified, we conduct descriptive analysis and content analysis. Finally, we establish nine dimensions in current SCF research.

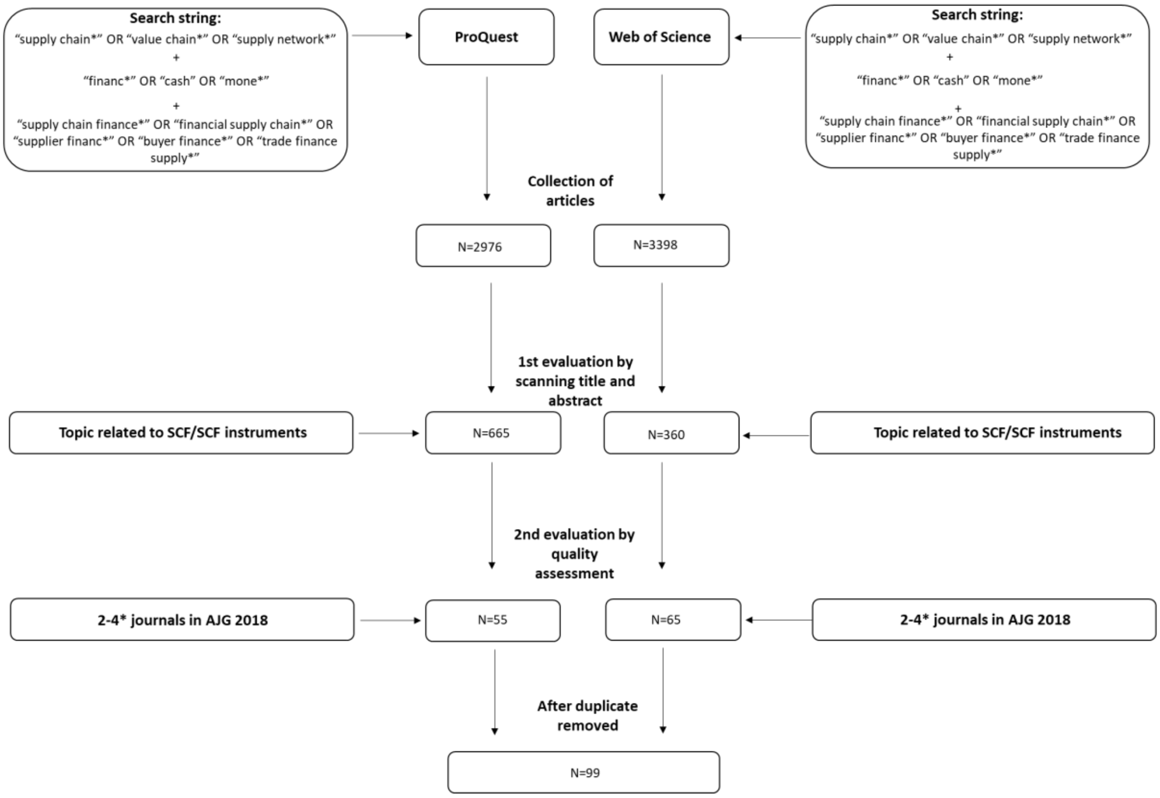


Figure 2-1 Paper Selection Process

2.1.2 Descriptive Analysis

Based on the statistics of the first author's affiliated institution and country, we identify the distribution of the countries showing the most interest in SCF, as illustrated in Figure 2-2. China's paper volume of SCF research is the largest accounting for 23.26%, followed by the U.S. (12.79%) and the UK (12.79%), etc. We extrapolate that this was caused by economic development factors. Since SCF was initially fashioned in developed countries and was diffused in developing regions due to the globalized economy. With the rapid growth of the Chinese economy, China became the main area of SCF applications.

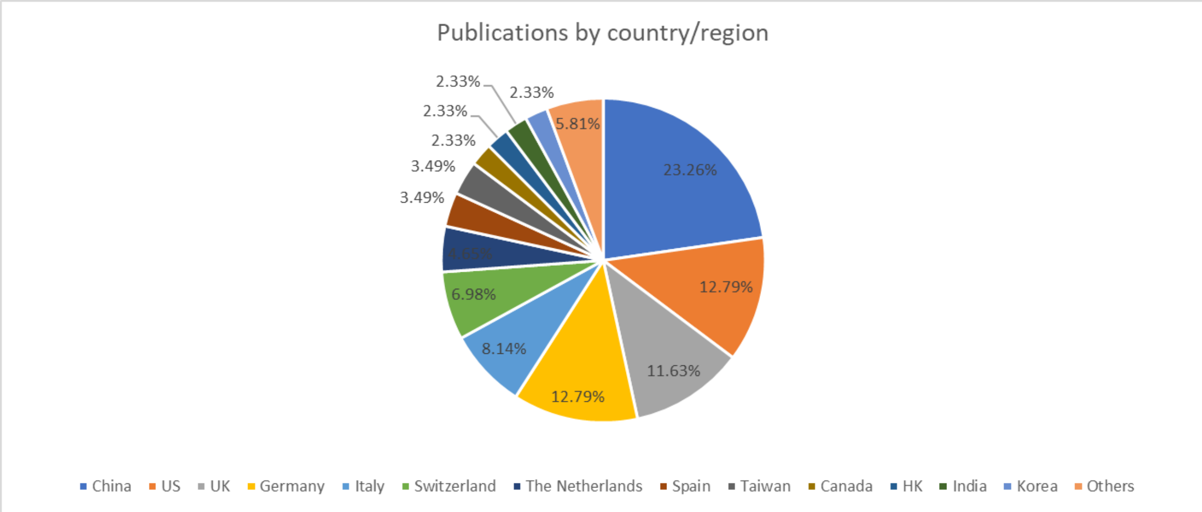


Figure 2-2 Publications by Country/Region

The SCF papers were mainly published in 40 journals, as can be seen from Figure 2-3., with the papers frequently published in the *International Journal of Production Economics* (16), then the *Journal of Purchasing and Supply Management* (9) and the *International Journal of Physical Distribution & Logistics Management* (8), etc.

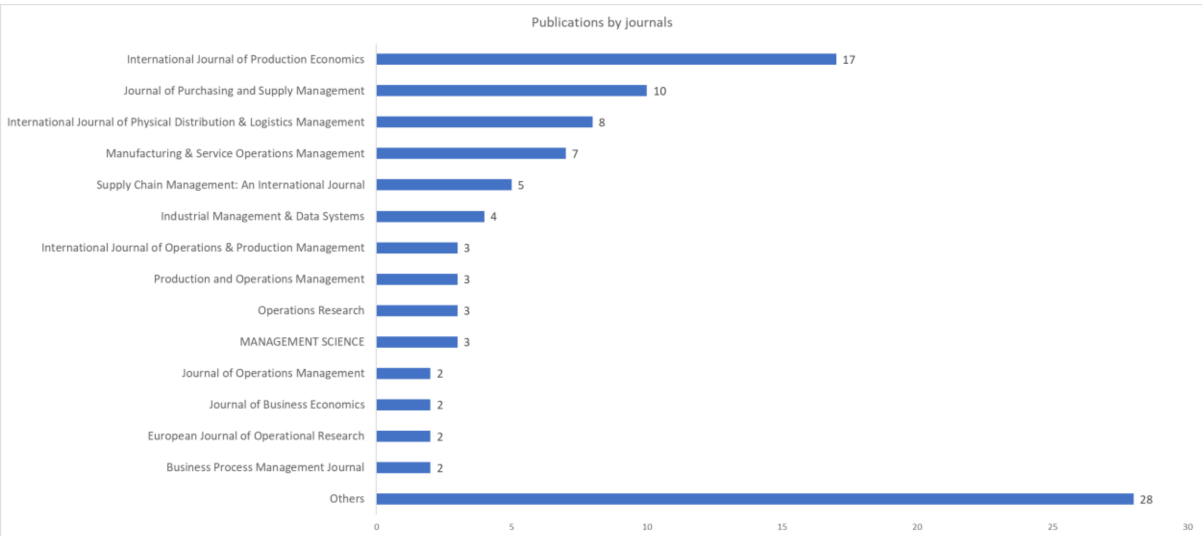


Figure 2-3 Publications by Journal

For journal quality (Figure 2-4.), most of the papers rate 2 to 3 based on the AJG guide, exhibiting the high quality of the selected papers, thus increasing the reliability of the SLR. Interestingly, Figure 2-5 shows the interdisciplinary nature of SCF research, even if the majority of journals lie in the operations and technology fields (61%), and other fields such as operations research and management science (12%), economy (7%) and finance (6%) also play a significant role in contributing SCF research.

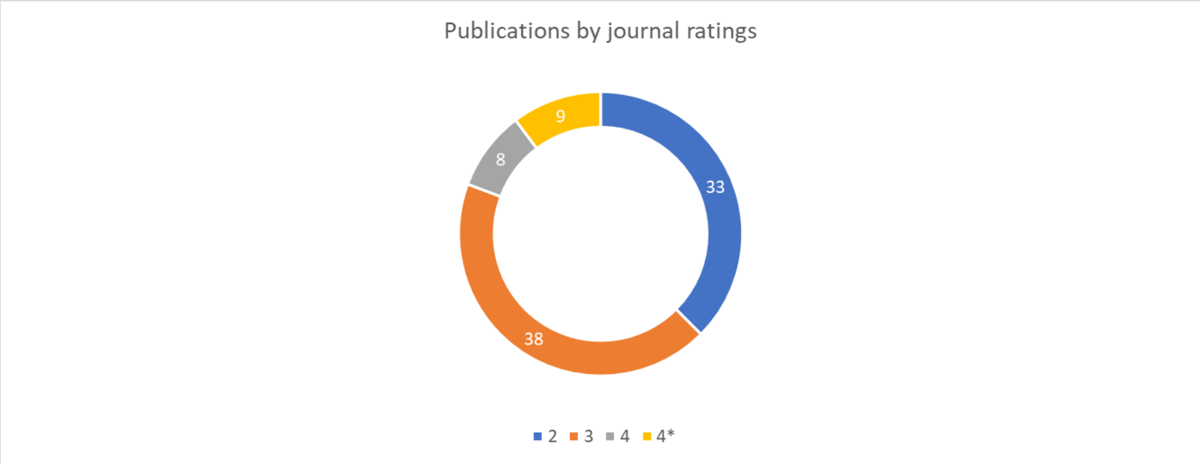


Figure 2-4 Publications by Journal Ratings

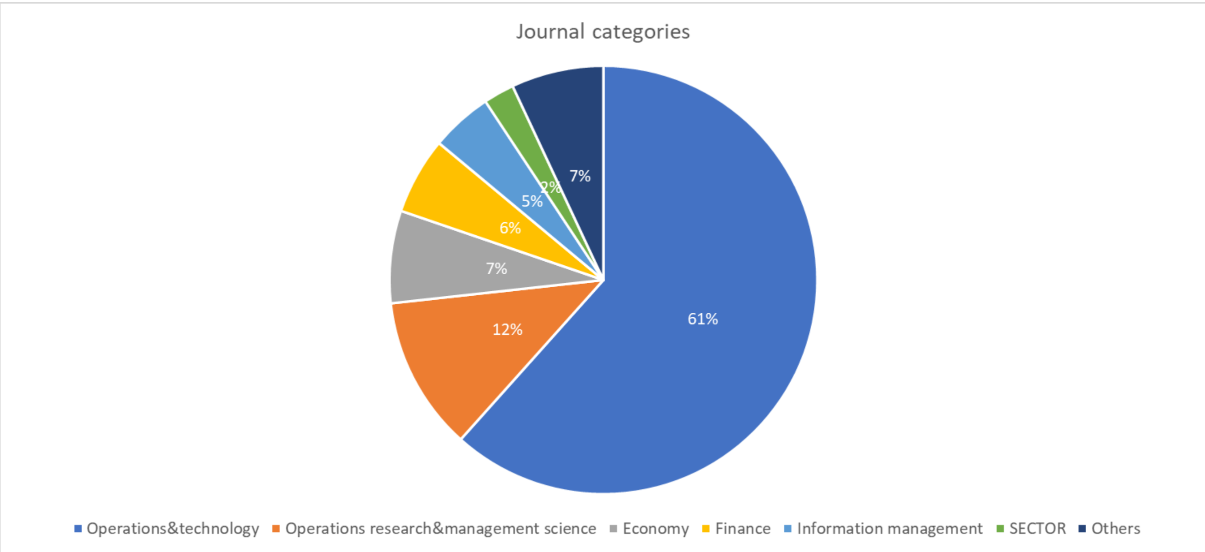


Figure 2-5 Journal Categories

In summary, the descriptive analysis shows distinct features to generalize the overall trends and characteristics of the chosen papers before carrying out content analysis. The details mentioned above can help readers better understand the following content.

2.1.3 Content Analysis

By integrating similar topics in the identified papers, finally, totally nine dimensions emerged, reflecting the current mainstream research directions of SCF: SCF concept definition and exploration, FSP, SCF instruments, SCF adoption, risk management, credit rating, working capital management, SCF combined novel technologies, and SCF performance outcomes. The following sections elaborate on each dimension and thus the first research question of this chapter is answered accordingly. Table 2-1 shows the integrated dimensions.

Table 2-1 Overview of The Merged Dimension

SCF dimensions	Articles	Key coding terms	Key references
(1) SCF concept definition and exploration	18	Supply chain network, corporate performance, concentration of suppliers and customers, reputation, sustainable supply chain finance, theoretical conceptualizations for supply chain and finance integration	Wetzel and Hofmann (2019), Cen et al. (2016), Blackman, Holland, and Westcott (2013), Ali, Gongbing, and Mehreen (2018), Tseng et al. (2018), Hofmann and Johnson (2016), Zhang, Zhang, and Pei (2019), Caniato, Henke, and Zsidisin (2019), Wuttke, Blome, and Henke (2013)
(2) FSP	7	Financial service providers, 3PLs as supply chain orchestrators, the market value of service providers	Ma, Wang, and Chan (2020), Song, Yu, and Lu (2018), Martin and Hofmann (2017), Lam et al. (2019), Wang et al. (2019)
(3) SCF instruments	40	Trade credit model, purchase order financing, vendor managed inventory (VMI) system, buyer investment, the price of reverse factoring, operational decision and financial decision, inventory financing, coordination under SCF, line of credit, supplier finance vs. supplier investment, buyer Finance vs. Bank Finance, financing the newsvendor	Wu, Zhang, and Baron (2019), Reindorp, Tanrisever, and Lange (2018), Peura, Yang, and Lai (2017), Kolay, Lemmon, and Tashjian (2016), Van der Vliet, Reindorp, and Fransoo (2015), Yan and Sun (2013), Liebl et al. (2016), Hoberg, Protopappa-Sieke, and Steinker (2017), Sokolinskiy, Melamed, and Sopranzetti (2018), Cowton and San-Jose (2017), Lekkakos, Serrano, and Ellinger (2016), Li et al. (2019), Yan, He, and Liu (2019), Tunca and Zhu (2018), Deng et al. (2018), Lee, Zhou, and Wang (2018), Kouvelis and Zhao (2012)
(4) SCF adoption	11	Managing the innovation adoption of supply chain finance, optimal introduction and adoption decisions, drivers and outcomes of supply chain finance adoption	Wuttke et al. (2013), Wuttke et al. (2016), Caniato et al. (2016), Martin and Hofmann (2019), Chen, Liu, and Li (2019b), Wang et al. (2020)
(5) Risk management	9	Prediction of business failure, forecast the SMEs' credit risk, moral hazard problem	Giannetti and Saidi (2019), Zhu et al. (2019), Sung and Ho (2019)
(6) Credit rating	4	Credit constraint companies choose low profit trade activities, knowledge spillover, credit rating method in SCF	Song et al. (2019), Moretto et al. (2019)
(7) Working capital management	4	Working capital of suppliers, benefits of working capital sharing in supply chains, working capital management, cash to cash cycle	Vázquez, Sartal, and Lozano-Lozano (2016), Protopappa-Sieke and Seifert (2017), Hofmann and Kotzab (2010)
(8) SCF combined novel technologies	9	Novel technology, big data analytics, information technology, trade digitalisation, machine learning	Song, Li, and Yu (2021), Zhao et al. (2015), Caniato, Henke, and Zsidisin (2019), Yu et al. (2021), Fayyaz, Rasouli, and Amiri (2020), Ying, Chen, and Zhao (2020), Lam and Zhan (2021), Zhu et al. (2019), Ali, Gongbing, and Mehreen (2018)
(9) SCF Performance Outcomes Dimension	11	Empirical study, data availability	Shou, Shao, and Wang (2021), Be Nguema et al. (2021), Song, Li, and Yu (2021), Lam and Zhan (2021), Martin and Hofmann (2017), Tunca and Zhu (2018), Wetzel and Hofmann (2019), Wang et al. (2020), Dekkers et al. (2020), Ma, Wang, and Chan (2020), Zhang, Zhang, and Pei (2019)

2.1.3.1 SCF Concept Definition and The Exploration Dimension

Several studies have been carried out to demonstrate the broad scope of the SCF concept. Chakuu et al. (2019) conducted a review to summarize the basic structure of SCF incorporating actors, instruments, enablers and inhibitors of SCF adoption. Gelsomino et al.'s (2016) research was more inclined to explain the general definitions of SCF. Differentiated from Gelsomino et al. (2016), Hofmann and Johnson (2016) argued that the scope of SCF should build on the foundation of working capital management and envelope any resources financing, risks management and taxes. Dekkers et al. (2020) organized a group of experts in this field to determine the existing theoretical conceptualizations embedded in SCF. Interestingly, after conducting an empirical analysis of 18,448 US firms across 8 industries over 48 years, Zhang et al. (2019) discovered that the predominant role of SCF is to mitigate the bankruptcy risk for focal firms and has nothing to do with the focal firm's financial performance and inventory efficiency.

As we further reviewed the papers in this dimension, we noted three papers that discussed sustainable supply chain finance (SSCF). According to Jia et al. (2020b), there is a growing interest in industry and academia as to whether SCF can bring benefits other than financial benefits, such as the contributions to the environment and social value aspects, thus improving supply chain sustainability. Tseng et al. (2019) constructed a set of measurements and analyzed the benefits and costs when implementing SSCF in the textile industry. In another paper, Tseng et al. (2018) stressed that economic and social aspects are the two most crucial aspects within SSCF.

2.1.3.2 FSP Dimension

Martin and Hofmann (2017) explained why FSPs should be involved in SCF practices and what products FSPs can provide for their customers by surveying 62 companies and conducting expert interviews. Ma et al. (2020) identified that top management support, trust and IT infrastructure are the most paramount factors considered by FSP in China. Lam et al. (2019) employed an event study methodology to examine the impact of SCF initiatives on FSP's market value and to ascertain what are the service features that can improve the abnormal returns generated from SCF initiatives.

In addition, as a result of inadequacy in monitoring real-time transactions of the products, banks, concerned with default risks, are always reluctant to finance cash-constrained firms (Burkart and Ellingsen, 2004), and thus, some other innovative financial institutions emerge. Chen and Cai (2011) adopted a two-stage Stackelberg game where the 3PL played as a leader in determining the interest rate in the first stage, and the retailer acted as the follower in deciding the order quantity accordingly. Chen et al. (2019a) used a Stackelberg model and considered the opportunity cost of players in capturing the cash-flow dynamics in the supply chain. Hua et al. (2021) investigated that under 3PL financing, all parties earn more benefits when the stronger supplier acts as the leader in a Stackelberg game, while both the retailer and the 3PL will be better off but the supplier will be worse off when the leader changes to the 3PL. In contrast, Wang et al.'s (2019) research target was the 3PL providing integrated logistics services and financing budget-limited manufacturers rather than retailers with different risk preferences (i.e., risk-averse, risk-neutral, risk-taking). Other recent studies related to 3PL include (Li and Chen, 2019; Chen et al., 2019c; Wu et al., 2019; Zhou et al., 2020; Huang et al., 2021). Song et al. (2018) adopted in-depth interviews with FSPs (platforms) to study how FSPs help SMEs to access finance compared with banks.

2.1.3.3 SCF Instruments Dimension

1. Trade Credit

Trade credit is the common internal financing method for companies, where internal actors provide financing to others, and it usually refers to suppliers allowing buyers to extend payment terms without an interest charge over a prescribed time range (Kouvelis and Zhao, 2018; Peura et al., 2017; Yang and Birge, 2018; Chen et al., 2018; Chod, 2017). We illustrate the general sequence of events in trade credit as in Figure 2-6. Particularly, the most prevailing terms are net terms, for example, 'net 30' means that the buyer should pay the supplier within 30 days, without an interest charge. Another popular type of payment term involves two-part terms, for example, '2/10, net 30', which means the buyer can still pay the supplier within 30 days without an interest charge; nonetheless, if the buyer pays the supplier in advance (e.g., 10 days), 2 percent discount applies. As a result of trade credit implementation, firms survive and the competitive advantages are improved. The recent contributions on trade credit predominantly lie in several aspects: risk management (Serrano et al., 2018; Kolay et al., 2016; Yang and Birge, 2018; Cowton and San-Jose, 2017), comparison and contrast of two types of financing schemes, e.g., trade credit vs. bank financing (Kouvelis and Zhao, 2012; Yan et al., 2019; Li et al., 2019), trade credit under supply chain competition and decision-making of credit term (Peura et al., 2017; Lee et al., 2018; Wu et al., 2019).

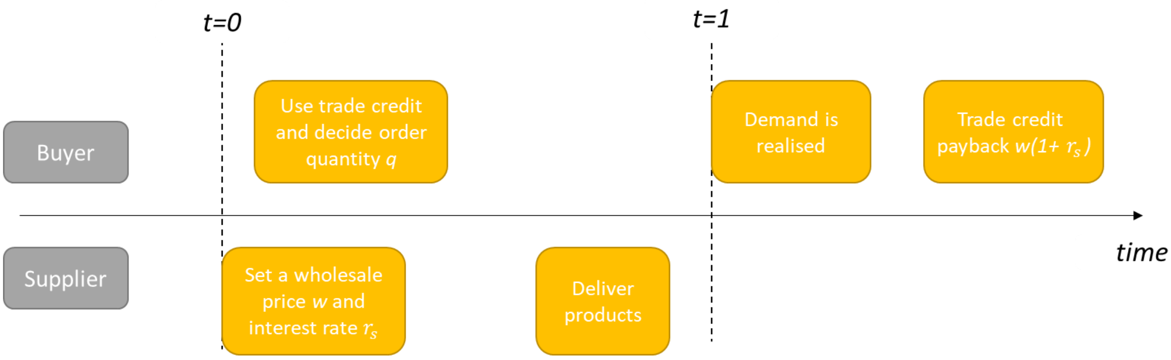


Figure 2-6 Sequence of Events in Trade Credit

2. Reverse Factoring

Another prominent financing instrument is named reverse factoring. Since RF targets accessing financing by using the supplier's account receivables, RF can also be viewed as account receivable financing (Wuttke et al., 2019). Within RF, the buyer approves the invoices and sends the invoice information to FSP for confirmation upon which products are delivered from suppliers, then the supplier sells the account receivables to FSP to obtain immediate financing with a discount. The discount rate is determined by the FSP based on the creditworthiness of the buyer, then the buyer repays FSP the invoice amount after an agreed payment term granted by the supplier (Grüter and Wuttke, 2017; Liebl et al., 2016; van der Vliet et al., 2015; Wuttke et al., 2013a; Wuttke et al., 2019). The FSP provides financing for the supplier based on the buyer's credit level rather than the supplier's. Hence, under this mechanism, transaction risks of the lenders (i.e., FSP) can be lowered. Liebl et al. (2016) showed that the main objectives of RF were to extend the days payables outstanding (DPO) for buyers, exploit working capital improvement and simplify the payment process for suppliers and enlarge the market share for FSPs. Lekkakos et al. (2016) investigated the impacts of RF implementation on a firm's operations and the performance of a cash-limited SME. Kouvelis and Xu (2021) theoretically identified a certain condition for RF adoption, that is the supplier's credit rating should be relatively low. Van der Vliet et al. (2015) answered the question of how long the extensions of payment terms could benefit a supplier in reverse factoring. By signing an RF contract between the three parties, the basic sequence of events of RF and its embedded relationships among the involved actors is shown in Figure 2-7.

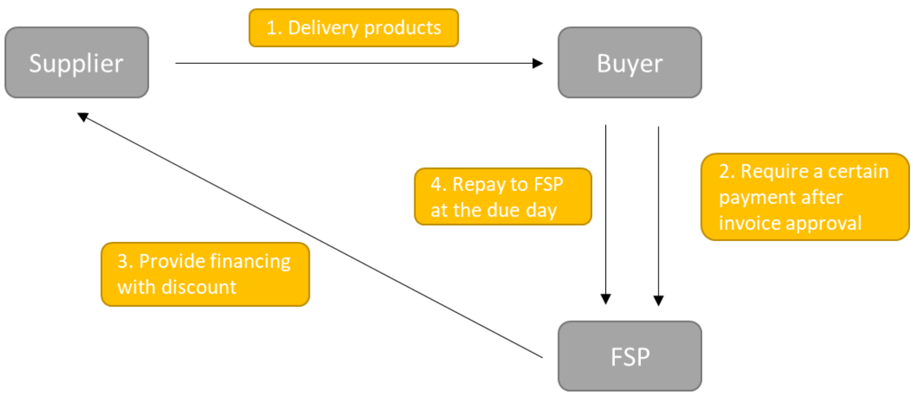


Figure 2-7 Sequence of Events in RF

3. Inventory Financing

We find that the concept of inventory financing has various meanings in the literature, and thus can cause confusion. In some papers, the authors use the term 'inventory financing' to denote a transaction process, for example, the buyer purchases inventories (Yang and Birge, 2018); however, in other papers, like Hoberg et al. (2017), they view inventory financing as a means of inventory management. In this thesis, we regard inventory financing as an SCF instrument. Inventory financing requires a firm to use its current assets as collateral (e.g., account receivables and inventories) to obtain financing from an

FSP or to extend credit lines from buyers by exploiting the value of assets rather than the credit rating (Berger and Udell, 2006; Gelsomino et al., 2019; Yan and Sun, 2013). Inventory financing has recently involved a 3PL as FSP to purchase goods from suppliers and resell them to the buyers after a period of time. Before reselling to buyers, the 3PL retains the ownership of the goods (Chen and Cai, 2011; Hofmann, 2009; Gelsomino et al., 2019). The traditional inventory financing framework and its embedded relationships among the involved actors are shown in Figure 2-8.

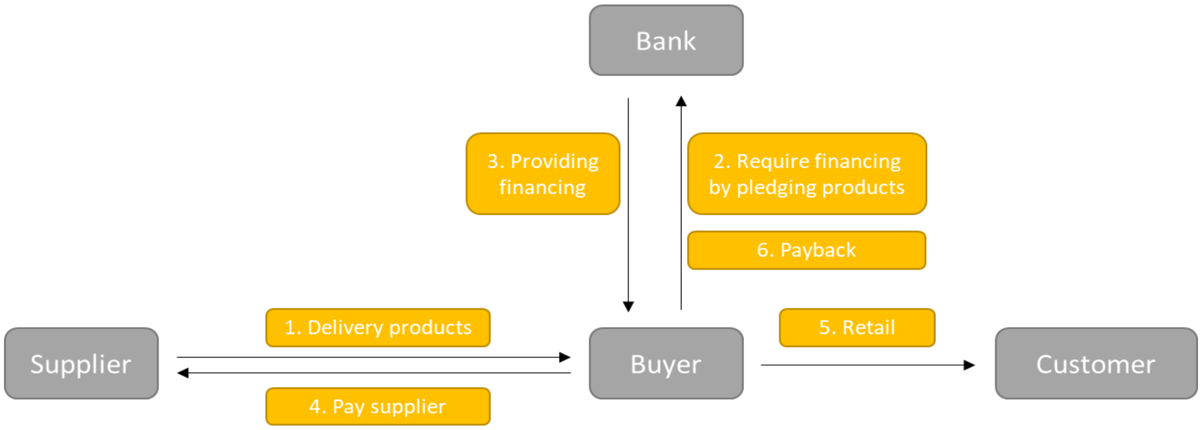


Figure 2-8 Sequence of Events in Inventory Financing

4. Buyer Financing

Buyer financing implies that buyers directly provide financing to suppliers. There are diversified types of buyer financing including early payment, supplier investment and equity investment, etc. Compared with bank loans, buyer financing helps the buyer acquire positive abnormal returns and facilitates a coordinative supply chain (Deng et al., 2018). The recent research, basically, buyer financing is either used to make a comparison with other financing instruments such as bank loans (Deng et al., 2018), or to make a supplement to other financing instruments such as supplier financing (Tunca and Zhu, 2018) under SCF practices. Deng et al. (2018) analyzed the efficiency of buyer financing by comparing it with bank financing with one assembler and various heterogeneous suppliers. They found that the assembler should charge the lowest interest rate on suppliers, and the rate can be even lower than the assembler's capital opportunity cost in buyer finance in order to have higher gains by taking advantage of strengthened inventory backup and lower wholesale prices. Tunca and Zhu (2018) examined the intermediating role of the buyer when the buyer provides intermediated financing to suppliers. They discovered it can significantly improve supply chain performance and benefit all participants. They further selected a Chinese e-business retailer JD.com to conduct a detailed empirical analysis through structural regression estimation, and consequently, they verified that buyer intermediated financing can reduce the interest rates and purchase costs, increase order fill rates and motivate supplier borrowing.

5. **Purchase Order Financing**

Purchase order financing (POF) is a type of pre-shipment financing, where suppliers can gain access to capital provided by the FSP based on the purchased orders issued by their creditworthy and reputable buyers before delivering products. Differing from asset-based financing (e.g., inventory financing), which pledges tangible assets, the repayment of loans is subject to the successful delivery of products meeting the requirements of buyers (Tang et al., 2018; Reindorp et al., 2018; Zhao and Huchzermeier. 2019). Hence, the major risk of POF exists in the supplier's production and delivery performance (Gustin, 2014; Tang et al., 2018). Reindorp et al. (2018) analyzed a scenario in which a retailer purchases products from a cash-limited supplier with information opaque problems. Tang et al. (2018) studied a similar problem but employed two financing instruments: concurrent POF and buyer financing. The sequence of events of POF involving a bank as FSP and the relationships of participants under POF is shown in Figure 2-9.

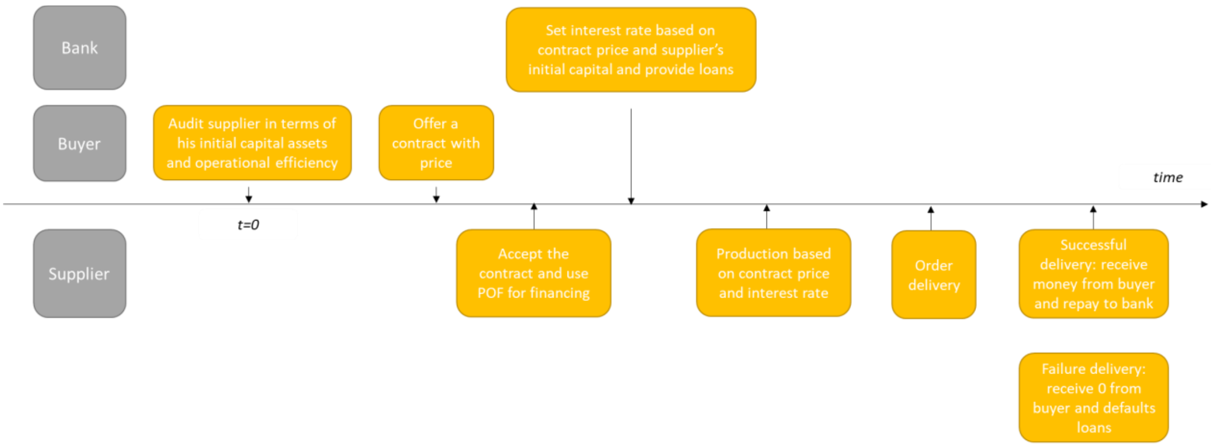


Figure 2-9 Sequence of Events in POF

2.1.3.4 SCF Adoption Dimension

SCF adoption is critically dependent on a set of drivers facilitating successful SCF adoption and several inhibitors that impede the adoption process. Chakuu et al. (2019) and Huang et al. (2019a) summarized the dominant drivers such as a firm's requirement of financial risk management as well as the crucial inhibitors like information asymmetry when considering SCF adoption. Wang et al. (2020) examined the impacts of three drivers: perceived capital pressure, order fulfillment cycle, and inventory turnover cycle on three types of SCF instruments adoption: RF, inventory financing, and account payable financing. Iacono et al. (2015) studied the influence of market dynamics on RF adoption by virtue of a dynamical model. The results indicated that competition, interest rates, receivable volumes and firms' working capital goals were key factors influencing the successful adoption of RF. However, although RF can generate benefits for supply chain partners, the benefit might change over time due to natural economic changes (Iacono et al., 2015). There is also evidence that some firms may appear reluctant and hesitant to adopt SCF, thus resulting in a time lag between the focal firm's introduction and the adoption of its targeted suppliers. Wuttke et al. (2016) employed a diffusion model to study the SCF adoption decisions made by the involved actors. They observed that only successful early adoptions from others support the adoption decisions.

Besides, there are several empirical studies. Martin and Hofmann (2019) used a contingency approach in conjunction with a multiple case study to establish a contingency framework for the SCF adoption on the supply side. They considered the contingencies of application from the endogenous perspective, relationship-related perspective and exogenous perspective and identified two types of practices involving the timing of financing and the source of funds, and finally set up various criteria for the different practices. Chen et al. (2019b) specifically examined JD's practices in SCF adoption. After several field interviews, they demonstrated that the objectives for SCF adoption were to enhance the business ecosystem and improve JD's competitive advantages. JD built up an iterative process and used its financial technologies to enhance trade automation by improving transparency and efficiency, and employed its bargaining power to influence the production process and maintain a closer partnership with its suppliers. Interestingly, Wuttke et al. (2019) further distinguished the adoption drivers into efficiency motive drivers and legitimacy motive drivers. By conducting empirical analysis, Wuttke et al. (2019) found that suppliers tend to adopt SCF faster if they have more difficulties in accessing financing and if the adoption can greatly reduce their financing cost. Additionally, mimetic and normative pressures hasten the speed of SCF adoption, but coercive pressures do not generate a huge impact if the buyer's stakes are high.

2.1.3.5 Risk Management Dimension

1. Credit Risk

The Basel Committee on Banking Supervision (BCBS) defines credit risk as the possibility that a lender will not fulfill his or her legal responsibilities according to the debt contract with the corresponding financial institution (Supervision, 1999). In SCF practice, credit risk is still a major concern, especially for SMEs in developing countries such as China, because of a low-level of credit rating, high probability of fraud and default, and an underdeveloped credit guarantee system (Su and Lu, 2015; Zhu et al., 2019). Credit risks also imply the financial distress of a firm having default risks on bank loans or trade credit, thereafter, generating financial frictions (i.e., cost of default) (Yang and Birge, 2018), moral hazard problems (Sung and Ho, 2019; Chen et al., 2018), and credit rating issues (Sung and Ho, 2019).

As a result of the urgent requirement for forecast accuracy in SCF practices, traditional forecasting models cannot effectively and efficiently predict credit risks for SMEs. Zhu et al. (2019) proposed an enhanced hybrid ensemble machine learning approach to forecast the SMEs' credit risk and verified that it performs better in terms of forecasting accuracy than in traditional approaches. Sung and Ho (2019) examined the moral hazard problems when a bank provides financing for purchasing orders. They showed that the supplier's monitoring task can be included in the procurement contract, thereby mitigating the supplier's credit rating problem and improving banks' underestimation of the supplier's default risk and the overestimation of the retailer's default risk simultaneously. Giannetti and Saidi (2019) provided some novel insights on the reason why lenders provided liquidity for SMEs was dependent on whether the lenders would like to internalize the spillover effects of financial distress. Particularly, in the tourism industry, when a tourism service provider contracts with unfamiliar customers, they need to be conservative under a positive economic condition and remain progressive under a moderate economic condition to decrease the risk of payment default (Chen et al., 2018).

2. Bankruptcy Risk

Bankruptcy risk usually refers to the business failure of a firm in which the firm can no longer exist due to an inability to absorb negative shocks and respond to all kinds of supply chain environmental changes (Amankwah-Amoah and Debrah, 2010; Watson and Everett, 1993; Zhao et al, 2015). Sokolinskiy et al. (2018) viewed bankruptcy risk as rollover risk which means a financial institution such as a bank has the probability to refuse to finance the debtors. The debtors then will first find alternative costly financing sources in the form of backorder penalties and lost sales, then face a bankruptcy situation and supply chain disruption ultimately, due to the delayed or failed delivery of the products (Sokolinskiy et al., 2018). By developing a prediction model for the business failure of SCF actors and employing a logistics regression method to test the model, Zhao et al. (2015) indicated that taxable sales revenue, frequency of VAT (value-added tax) invoice issuance and firm age are negatively related to business failure. However, the VAT-paid and industry clock-speed are positively associated with business failure.

2.1.3.6 Credit Rating Dimension

First, we introduce several credit rating methods in the current literature. Moretto et al. (2019) suggested a combination of financial and operational indicators to evaluate supply chain credit rating. Song et al. (2019) studied the impact of knowledge spillover and knowledge access in supply chain network effects on SMEs' credit rating when employing SCF solutions. Differing from the aforementioned two articles, Cen et al. (2016) argued that suppliers who had a long-term relationship with their principal customers will potentially generate a reputational consequence in different markets. Under this situation, suppliers can obtain a better credit rating provided by banks because of the long-term relationships with creditworthy customers, thus they can achieve smaller loan spreads and looser loan covenants (Cen et al., 2016).

Next, we illustrate the impact of credit ratings on supply chain decisions. In a situation where both the supplier and the buyer are cash-limited, the retailer can use either trade credit provided by the supplier or bank loans or both to purchase orders, while the supplier can use both the retailer's early payment with discount and bank loans to produce products. Kouvelis and Zhao (2018) studied the impact of different actors' credit ratings under this situation and discovered that the retailer will only use trade credit with zero interest rate if the supplier's credit rating is beyond a certain threshold; otherwise, the supplier will fix a positive interest rate to encourage the retailer to use a combination of trade credit and bank loans.

2.1.3.7 Working Capital Management Dimension

First, we introduce several WCM methods in the current literature. Hofmann and Kotzab (2010) employed a supply chain-oriented method of working capital management to investigate two perspectives: the single company perspective and the supply chain-oriented perspective. They argued that firstly only one firm's (cash-to-cash) C2C cycle improvement would not benefit other participants within the chain; secondly, an optimal C2C cycle enables a minimal cost of tied-up capital and maximum gains of receivables through collaboration; lastly, a firm with higher financing costs needs a shorter C2C cycle while a firm with low capital cost could extend its capital cycle (Hofmann and Kotzab, 2010). Ali et al. (2018) regarded trade digitization as a moderating variable in investigating its function of enhancing working capital management and supply chain performance. The results indicated that trade digitization was a cost-effective way to improve a firm's working capital without pledging any fixed assets, thus increasing visibility and improving the automated transaction process within the supply chain. Vázquez et al. (2016) studied the working capital of two-tier suppliers in the automobile industry by adopting a cooperative approach. Their results confirmed that there are great differences in working capital between the first-tier suppliers and the second-tier suppliers which implies that the working capital management within the supply chain is not cooperative, and ultimately leads to low production efficiency. Hence, similar to Hofmann and Kotzab's (2010) recommendations, Vázquez et al. (2016) proposed that individual supply chain managers should establish long-term and collaborative relationships, especially in managing working capital in a cooperative way, so as to finance weaker members and improve the overall performance instead of only benefiting some of the participants.

Then, the benefits of WCM on supply chain performance are presented as follows. Protopappa-Sieke and Seifert (2017) assumed that if there was a joint pool of working capital allowing capital allocation in a collaborative way rather than each actor having his/her own working capital, it would generate significant cost savings. However, the extended payment terms enforced by a strong buyer on a weaker upstream supplier will cause higher supply chain costs. Wetzel and Hofmann (2019) analyzed the relationship between working capital assets and company performance within an inter-organizational supply chain and found parallel results. By empirical analysis, they discovered that the relationship between working capital assets and company performance resembled an inverted U-shaped curve and this relationship depended on the financial constraints along the chain.

2.1.3.8 SCF Combined Novel Technologies Dimension

Song et al. (2021) used big data analytics (BDA), neural networks and multiple regression to explain how SMEs obtain financing through a digital platform and how FSPs evaluate SMEs' credit levels by conducting data mining analysis on the Chinese mobile manufacturing industry. They verified that the BDA not only has an advantage in identifying the SMEs' quality and potential default risks but also effectively helps the FSPs provide tailored financing schemes to SMEs. Likewise, Zhao et al. (2015) established a prediction model by using the external big data set to improve the predictability of business failure of SCF clients. Caniato et al. (2019) mentioned that the descriptive, predictive and prescriptive analytics in BDA can provide more accurate and reliable decision-making foundation for supply chain actors. Yu et al. (2021b) applied the organizational information processing theory to investigate the positive impact of BDA capability on SCF integration. They identified that the internal SCF integration can fully mediate the relationship between BDA capability and SCF integration.

By applying machine learning methods, Fayyaz et al. (2020) considered the credit risk evaluation from the buyer's perspective (i.e., buyer's ability to repay under trade credit settings) and they also took the supply chain network's impact into consideration thus significantly improving the accuracy of prediction. Similarly, Zhu et al. (2019) proposed enhanced machine learning methods to improve the accuracy of SMEs' credit risk forecasting and identified several crucial factors such as the core enterprise's profit margin when financing SMEs. Interestingly, Ying (et al., 2020) considered that the results acquired in machine learning are hard to be understood by practitioners so that interpretability is extremely important to help supply chain practitioners well manage the risks.

Lam and Zhan (2021) studied how SCF together with IT capability impact the financial risk of FSPs. Their findings highlighted that the risk would be reduced significantly when the FSPs have a higher IT capability, so the FSPs are encouraged to improve their IT infrastructure. Ali et al. (2018) regarded trade digitization as a moderating variable to investigate its function of enhancing working capital management and supply chain performance.

2.1.3.9 SCF Performance Outcomes Dimension

There is also some research focusing on the empirical study to verify the previous results, i.e., the firm's improved performance after implementing SCF, obtained from the theoretical modeling processes, which had been neglected in the initial SCF research due to insufficient data.

Be Nguema et al. (2021) empirically studied the impact of SCF on firm performance and investigated the relationship between SCF and organizational performance by collecting data from a survey of 210 companies in China. They demonstrated that SCF can effectively mitigate the risks contained within a supply chain and can generate a positive effect on a firm's performance, which has been already proven in early modeling works (e.g., Sokolinskiy et al. (2018); Yang and Birge, 2018). Furthermore, Shou et al. (2021) investigated the relationship between RF and operating performance and the related contingency conditions embedded in this relationship based on a sample of 167 Chinese companies who claimed to have implemented RF to finance suppliers. Shou et al. (2021) discovered that RF positively affects the firms' operating margin and cost-efficiency. Again, these results match the early theoretical conclusions (e.g., Liebl et al. (2016); Kouvelis and Xu, 2021). In addition, Song et al. (2021), Lam and Zhan (2021), Martin and Hofmann (2017), Tunca and Zhu (2018), Wetzel and Hofmann (2019), Wang et al. (2020), Dekkers et al. (2020), Ma et al. (2020), and Zhang et al. (2019) which mentioned early in this chapter also used empirical studies to verify the positive impact of SCF on supply chain performance, supply chain capabilities, etc., by providing supportive evidence. By observing these empirical studies, we can see the significance of data availability in leading to more objective and general results. However, the data is unfairly distributed in different regions, e.g., the data is more limited in developing economies due to the lagged implementation than that of developed economies, hence we expect the empirical study used to examine a firm's operational and financial performance after SCF adoption, especially in developing regions is worth further studying in the future.

Ultimately, in order to give a clear picture of the comprehensive content analysis, we summarize the key contributions extracted from the chosen literature across nine research dimensions as presented in Table 2-2.

Table 2-2 Recent Contributions within Each Dimension

SCF dimensions	Sub-dimension	Key contributions from recent research	Supportive key references
(1) SCF concept definition and exploration	SCF Definitions	• Identified the basic structure of SCF incorporating actors, instruments, enablers and inhibitors of SCF adoption.	Chakuu, Masi, and Godsell (2019); Hofmann (2005); More and Basu (2013); Wuttke, Blome, and Henke (2013)
		• Defined the general conception, the predominant role and the scope of SCF.	Caniato et al. (2016); Hofmann and Johnson (2016); Dekkers et al. (2020); Zhang, Zhang, and Pei (2019)
	Financial Supply Chain Management	• Emphasised the difference between FSCM and SCF.	Sugirin (2009); Popa (2013); Wuttke, Blome, and Henke (2013); Liebl et al. (2016); Chakuu, Masi, and Godsell (2019); Caniato et al. (2016); Hofmann and Johnson (2016)
		• Concluded the successful experience of FSCM application.	Blackman, Holland, and Westcott (2013)
	Sustainable Supply Chain Finance	• Combined SCF with sustainable development and summarised the SSCF motives, practices, outcomes, enablers, barriers.	Jia, Zhang, and Chen (2020)
		• Measured and analysed the benefits and costs of SSCF.	Tseng, Lim, and Wu (2019); Tseng et al. (2018)
(2) FSP	Ordinary FSPs	• Understood the role of FSPs when providing SCF services.	Martin and Hofmann (2017); Ma, Wang, and Chan (2020)
		• Identified the challenges of FSPs.	Ma, Wang, and Chan (2020)
		• Identified the benefits of FSPs when providing SCF services.	Lam et al. (2019); Martin and Hofmann (2017)
	Innovative FSPs	• Understood the 3PL's role as a FSP under various settings.	Chen and Cai (2011); Huang et al. (2019); Chen, Cai, and Song (2019); Hua et al. (2021); Wang et al. (2019); Song, Yu, and Lu (2018)
(3) SCF instruments	Trade Credit	• Defined the general conception of trade credit, e.g. net term and two-part term.	Kouvelis and Zhao (2018); Peura, Yang, and Lai (2017); Yang and Birge (2018); Lee, Zhou, and Wang (2018); Devalkar and Krishnan (2019); Chen, Tsai, and Liu (2018); Tang, Li, and Cai (2021)
		• Understood the impacts of trade credit on risk generation, risk propagation, risk sharing, ethical issues.	Serrano, Oliva, and Kraiselburd (2018); Kolay, Lemmon, and Tashjian (2016); Yang and Birge (2018); Cowton and San-Jose (2017)
		• Explored the benefits of trade credit in the presence of competition.	Peura, Yang, and Lai (2017); Lee, Zhou, and Wang (2018); Wu, Zhang, and Baron (2019)
		• Made comparisons between trade credit and other SCF instruments and concluded the benefits of trade credit under certain conditions.	Kouvelis and Zhao (2012); Yan, He, and Liu (2019)
		• Optimised the credit term setting in trade credit contract.	Li et al. (2019)
	Reverse Factoring	• Defined the general conception of RF.	Grüter and Wuttke (2017); Liebl et al. (2016); Van der Vliet, Reindorp, and Fransoo (2015); Wuttke, Blome, and Henke (2013); Wuttke, Rosenzweig, and Heese (2019); Gelsomino et al. (2019)
		• Identified the objectives of RF.	Liebl et al. (2016)
		• Concluded the benefits of RF under certain conditions.	Lekkakos, Serrano, and Ellinger (2016); Kouvelis and Xu (2021)
		• Optimised the payment term setting in RF contract.	Van der Vliet, Reindorp, and Fransoo (2015)
	Inventory Financing	• Defined the general conception of inventory financing.	Yang and Birge (2018); Hoberg, Protopappa-Sieke, and Steinker (2017); Berger and Udell (2006); Gelsomino et al. (2019); Yan and Sun (2013); Chen and Cai (2011); Hofmann (2009); Gelsomino et al. (2019)
		• Optimised the key parameters settings in inventory financing contract such as credit line, wholesale price and order quantity.	Yan and Sun (2013)
		• Made comparisons between different SCF instruments in terms of benefits.	Gelsomino et al. (2019)

(continued)

Table 2-2 Continued

SCF dimensions	Sub-dimension	Key contributions from recent research	Supportive key references
	Buyer Financing	• Identified the immediate role of buying financing.	Deng et al. (2018); Tunca and Zhu (2018)
	Purchase Order Financing	• Defined the general conception of POF.	Tang, Yang, and Wu (2018); Reindorp, Tanrisever, and Lange (2018); Gustin (2014)
		• Concluded the benefits of POF under certain conditions.	Reindorp, Tanrisever, and Lange (2018); Tang, Yang, and Wu (2018)
(4) SCF adoption	Theoretical Analysis of SCF Adoption	• Concluded the drivers and inhibitors of SCF adoption.	Chakuu, Masi, and Godsell (2019); Wang et al. (2020); Huang et al. (2019); Iacono, Reindorp, and Dellaert (2015); Wuttke et al. (2016)
	Case Studies of SCF Adoption	• Found the evident results of SCF adoption and proved the theoretical analysis.	Wuttke et al. (2013); More and Basu (2013); Caniato et al. (2016); Martin and Hofmann (2019); Chen, Liu, and Li (2019b); Wuttke, Rosenzweig, and Heese (2019)
(5) Risk management	Credit Risk	• Improved the forecast methods of credit risk evaluation in SCF.	Zhu et al. (2019)
		• Examined the moral hazard problem contained in SCF.	Sung and Ho (2019)
		• Studied the detailed scenarios that how credit risk could be mitigated in SCF.	Giannetti and Saidi (2019); Chen, Tsai, and Liu (2018)
	Bankruptcy Risk	• Identified different drivers that could induce bankruptcy in SCF.	Sokolinskiy, Melamed, and Sopranzetti (2018); Zhao et al. (2015)
(6) Credit rating	Various Credit Rating Methods	• Formed the effective credit rating methods.	Moretto et al. (2019); Song et al. (2019); Cen et al. (2016)
	Impact of Credit Ratings on Supply Chain Decisions	• Identified the impact of credit rating on supply chain decisions.	Kouvelis and Zhao (2018)
(7) Working capital management	Working Capital Management Methods	• Formed the effective working capital management methods.	Hofmann and Kotzab (2010); Ali, Gongbing, and Mehreen (2018); Vázquez, Sartal, and Lozano-Lozano (2016)
	Benefits of Collaborative Working Capital Management	• Identified the benefits of collaborative working capital management.	Protopappa-Sieke and Seifert (2017); Wetzel and Hofmann (2019)
(8) SCF combined novel technologies	The Explorations of the Role of the Novel Technologies	• Identified the key role of novel technologies in improving the performance in SCF.	Song, Li, and Yu (2021), Zhao et al. (2015), Caniato, Henke, and Zsidisin (2019), Yu et al. (2021), Fayyaz, Rasouli, and Amiri (2020), Ying, Chen, and Zhao (2020), Lam and Zhan (2021), Zhu et al. (2019), Ali, Gongbing, and Mehreen (2018)
(9) SCF performance outcomes		• Found the evident results of improved performance and proved the theoretical analysis.	Shou, Shao, and Wang (2021), Be Nguema et al. (2021), Song, Li, and Yu (2021), Lam and Zhan (2021), Martin and Hofmann (2017), Tunca and Zhu (2018), Wetzel and Hofmann (2019), Wang et al. (2020), Dekkers et al. (2020), Ma, Wang, and Chan (2020), Zhang, Zhang, and Pei (2019)

2.1.4 The Updated Research Framework of SCF

Based on our content analysis, we now form the research framework of SCF to answer the second research question of this chapter. Figure 2-10 shows an overall view of the updated SCF research framework. We split the main body of the framework into two parts: the foundation part and the application part. To establish a stable and solid foundation, knowledge related to the SCF concept definition and exploration dimension consists of three sub-dimensions (SCF definitions, Financial supply chain management and Sustainable supply chain finance) are required. The knowledge related to the FSP dimension containing the topics of ordinary FSPs and innovative FSPs, and the basic knowledge of the current mainstream SCF instruments such as trade credit should be well understood. Compared with previous work, we highlight sustainable supply chain finance and innovative FSPs in our framework in response to environmental requirements and business changes. These three dimensions connect with each other. As for the application part, starting with the SCF adoption dimension, the applications of SCF are constituted in the rest of the dimensions as shown in Figure 2-10. This structure also implies that the research on each dimension is always interwound with other dimensions. For example, the study of one specific SCF instrument will go through the concept dimension, adoption dimension, risk management dimension, etc., thus generating various or uniform results depending on the features of multiple SCF instruments.

Within this framework, we made two reclassifications in this field. Firstly, in relation to the FSP part, we newly classified two categories, i.e., the ordinary FSP (e.g., bank) and the innovative FSP (e.g., 3PL and Fintech) as a result of SCF development. Secondly, in terms of the SCF instruments, we recognized the mainstream instruments dominated current research, i.e., trade credit, reverse factoring, inventory financing, buyer financing and purchase order financing, while others that are not specifically mentioned in this chapter such as dynamical financing, factoring, etc., can be viewed as non-mainstream SCF instruments accordingly. In particular, within the mainstream instruments, we now further reclassify them into two groups. For the instrument which can be achieved through internal arrangement without a third party's involvement, we name it as a non-FSP-dominated financing instrument, like trade credit and buyer financing. For the instrument whose implementation needs an independent third party outside the chain, such as a bank, we name it an FSP-dominated financing instrument. One reason for this classification is that based on our content analysis, the FSP's role is significant in providing capital and determining the critical parameters hence resulting in different payoffs for each party, so, considering each party's own situation, whether choose an outsider or not is a first issue faced by all parties when they are enrolled in an SCF contract. Another reason is that based on our observations, there is so much literature available when discusses the comparisons of these two groups like buyer financing vs. reverse factoring, and trade credit vs. purchase order financing, thus this classification can help researchers well distinguish the two groups and compare their profits in certain conditions further.

According to this framework, future researchers first can have a preliminary view of SCF research. Then, using this framework and combining it with Table 2-2, the researchers can locate the specific papers to know the exact details within each dimension. We suggest that future researchers could learn the basics such as the definitions, the archetypes of SCF instruments, the relationships among each party, etc., from the foundation part at the initial stage if they have no knowledge about SCF. If they have accumulated a fundamental understanding of SCF, no matter from this framework or somewhere else, they also can focus on the application part to know what the current main applied research dimensions are and find a particular topic they are interested in.

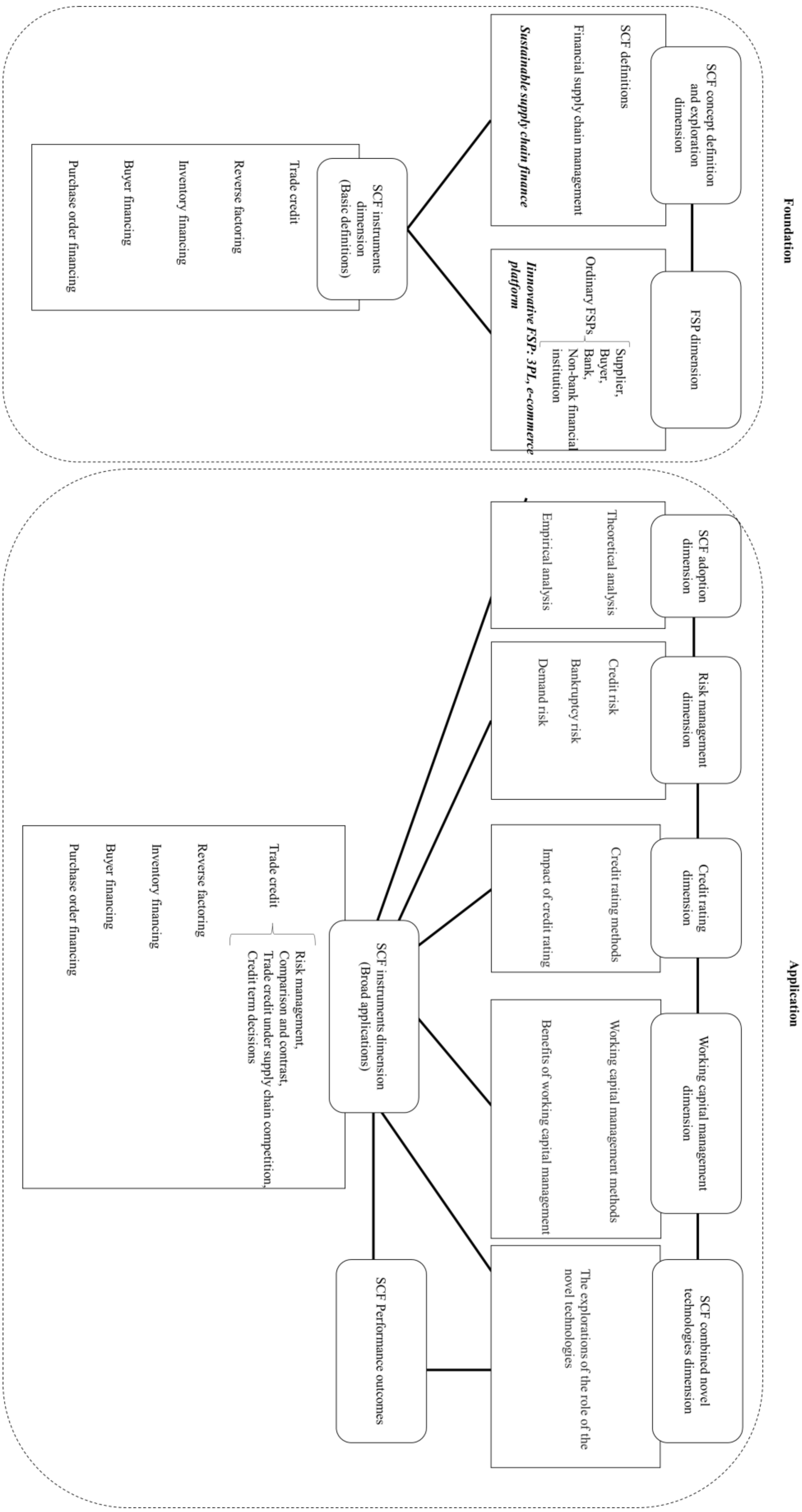


Figure 2-10 The Research Framework of SCF

2.1.5 Current Dominant Methods Used in SCF Research

Regarding the second research question of this chapter, Table 2-3 summarizes the dominant methods applied in SCF studies. It explicitly demonstrates that the intent of these methods is directly split into two perspectives: the empirical analysis perspective and the theoretical perspective. In this thesis, we focus on the theoretical analysis of three major problems by applying game theory to model a Newsvendor/Stackelberg game and to find equilibrium solutions for the involved supply chain participants.

Table 2-3 Dominant Methods Used in SCF Research

Intent	Category	Methods	Articles	Key sources
Empirical analysis	Statistics	Regression analysis	15	Huang et al. (2019), Giannetti and Saidi (2019), Yang and Birge (2018), Ali, Gongbing, and Mehreen (2018), Song et al. (2019), Zhang, Zhang, and Pei (2019), Tunca and Zhu (2018)
		Estimation	3	Tunca and Zhu (2018), Cen et al. (2016)
		Robustness	3	Wuttke, Rosenzweig, and Heese (2019), Lee, Zhou, and Wang (2018)
		χ^2distribution	2	Huang et al. (2019)
		T-test	2	Wang et al. (2020)
		Correlation analysis	2	Wetzel and Hofmann (2019)
		Coefficient of variations	2	Serrano, Oliva, and Kraiselburd (2018)
		Reliability and validity analysis	2	Ali, Gongbing, and Mehreen (2018)
		Common method variance	2	Song et al. (2019)
		Monte Carlo simulation	2	Lekkakos, Serrano, and Ellinger (2016)
	Data collection	Interview	7	Chen, Liu, and Li (2019b), Liebl et al. (2016)
		Questionnaire	4	Huang et al. (2019)
		Interpretive structural modelling	3	More and Basu (2013), Ma, Wang, and Chan (2020)
		Survey	2	More and Basu (2013)
Theoretical analysis	Stochastic process	Stochastic model	5	Wang et al. (2019), Yan and Sun (2013),
		Innovation adoption model	2	Wuttke et al. (2013)
		Diffusion model	2	Iacono, Reindorp, and Dellaert (2015)
	Game theory	Newsvendor model	11	Deng et al. (2018), Chen, Cai, and Song (2019), Kouvelis and Zhao (2012), Wu, Zhang, and Baron (2019), Reindorp, Tanrisever, and Lange (2018), Yang and Birge (2018), Serrano, Oliva, and Kraiselburd (2018), Lekkakos, Serrano, and Ellinger (2016)
		Equilibrium	9	Tunca and Zhu (2018), Deng et al. (2018), Chen, Cai, and Song (2019), Wang et al. (2019), Wu, Zhang, and Baron (2019), Yang and Birge (2018)
		Stackelberg game	9	Chen and Cai (2011), Yan and Sun (2013), Li et al. (2019), Yan, He, and Liu (2019), Kouvelis and Zhao (2018), Deng et al. (2018), Chen, Cai, and Song (2019)
		Backward induction	4	Yan and Sun (2013), Sung and Ho (2019)
		Principal-agent theory	3	Martin and Hofmann (2019)
		Pareto improvement region	3	Yan, He, and Liu (2019), Deng et al. (2018), Chen, Cai, and Song (2019)

2.1.6 Future Directions in The Macroscopic Domain of SCF Research

By checking through our coding system, we identify that current researchers hope to conduct further analysis in several new directions:

(1) New technologies applied in this field (machine learning, blockchain, etc.). Although we regard technology-related research as one of the current research dimensions, i.e., the SCF combined novel technologies dimension, the technology is continuously updating and evolving. We still consider technology-induced SCF research as a promising and everlasting future direction. For

example, since credit risk is viewed as the dominant risk in SCF, thus yielding some critical issues like a lower credit rating, a high probability of fraud, and an undeveloped credit guarantee system, which severely impairs the overall supply chain performance and even results in supply chain disruptions. By applying data-driven technology such as machine learning, researchers expect that credit risk can be forecast more accurately so that the risk can be mitigated. In addition, to improve the efficiency and security of numerous daily transactions, blockchain technology can be applied in the SCF settings to acquire additional benefits under different financing schemes (Yu et al., 2021a; Pournader et al., 2020; Kamble et al., 2019).

(2) The adoption of multiple SCF instruments. We found that in light of the SCF adoption, current research is more concentrated on the study of the relatively earlier SCF instruments (i.e., trade credit and reverse factoring). Since different instruments have distinct characteristics, for example, a supplier will accept a POF contract only when the supplier is profitable under this setting with proper appropriate parameters such as the wholesale price and the bank interest rate. Whereas for buyer financing, a buyer may finance suppliers with a higher interest rate than that with a bank to obtain more benefits, impeding the supplier's participation. Moreover, we find the industrial features may influence the types of SCF adoption and the involved parties may customize the financing schemes depending on their essence for conducting business. For instance, a recent research study by Yi et al. (2021) examined the profits and the preferences of various financing schemes for different parties in an agricultural supply chain. We thereby suggest that all supply chain actors' adoption behaviors of various financing types or even their combinations should be investigated further to acquire a more exhaustive understanding of SCF adoption.

(3) Comprehensive empirical analysis is still needed. Due to the emerging essence of SCF, limited available data results in limited empirical analysis on SCF. Thus, we recommend that more empirical analysis should be conducted in the future to verify the efficiency of various financing instruments and the associated theories that emerged from the previous/existing research when multiple data sources are available. Further, the emerging findings obtained from the empirical study should also pay equal attention to their theoretical justification.

(4) The applications of SCF under various environmental contexts. We found most of the papers concentrate on a single market condition, e.g., the developed economies, due to the early expansion in these developed regions. Hence, the results of SCF application may be different

in emerging markets, i.e., developing economies, due to government policy and cultural differences. In addition to the market condition, the industry variations (e.g., manufacturing industry, service industry, agricultural industry, etc.), model settings (e.g., dynamic vs. static, simultaneous game vs. sequential game), supply chain settings (i.e., lean vs. agile) may generate distinct results when implementing SCF schemes. We expect further research in diverse settings could both enlarge the generalizability of the overall findings and provide additional and surprising insights.

(5) The impacts of SCF on supply chain capabilities. We found that almost all of the selected papers yielded results based on an essential assumption that there are no significant environmental disruptions in the supply chain. However, as we all know, COVID-19 has caused enormous problems across the globe, especially for the global supply chains, i.e., production and logistics stagnation, payment delay, stockout, etc. This previously omitted disaster exposes the frail and weak supply chain capabilities in handling emergent and severe supply chain disruptions. Therefore, supply chain capabilities including supply chain flexibility and supply chain resilience need considerable attention nowadays. As an innovative solution, how SCF can better revitalize the global supply chains and how SCF can improve the supply chain capabilities in the presence of global disasters are worth further and comprehensive studying.

2.2 Research Gaps

After a comprehensive SLR, we now summarize the research gaps we identified in the existing literature regarding the three major problems:

(1) For the first problem, due to the novel nature of SCF, how can SCF mitigate the delay-incurred risks and how can SCF influence a supply chain's WCM, especially in developing economies such as China, remains unknown in the existing literature. Thus, we attempt to utilize the SCF solution in this research to examine how SCF can improve a supply chain's WCM in the presence of payment delay.

(2) For the second problem, recent research into 3PL's role in supply chains mainly examines the benefits and advantages brought by a 3PL who positively intermediates the supply chain. However, these previous studies did not consider the retailer's payment delay-induced scenario which may generate different and more counter-intuitive findings. Our research focus is on a supplier who faces a bankruptcy risk and is positioned in a retailer-dominated supply chain in

the presence of the retailer's payment delay. In our model, the 3PL provides joint services. i.e., logistics service plus finance service (i.e., advance payment), which has been commonly implemented in various industries recently. Moreover, instead of applying the traditional wholesale price contract in the previous research, to further reflect the reality, we consider a pair contract in which the retailer makes decisions on the wholesale price and the order quantity. Furthermore, to capture the dynamical flow of cash, we introduce the time value of cash so as to comprehensively understand the interactions among each party.

(3) For the third problem, many studies illustrate the negative effects of defaults on supply chain performance and suggest relevant solutions. Our findings complement a scenario that happens in the EV supply chain where the EV-makers have a high probability to default on either the bank or the BS because of the nature of this emerging industry. To complement the solution for the default risk literature, via observing the practice in the current EV industry, we investigate the success of BLF and TCF under default risk as well as information asymmetry by solving a moral hazard problem and a signaling game. To differentiate our findings from previous SCF literature, we apply the basic form of BLF that is contingent on the EV-maker's repayment probability. This is in line with the anecdotal evidence that BLF is a widespread form implemented in the current Chinese EV industry. In addition, similar to recent research such as Wang and Xu (2022), we focus on designing a contract and examining how this contract can incentive the capital-limited EV-maker to improve performance and enable the EV-maker's commitment to repay the loans.

2.3 Summary

This chapter presents an SLR in the domain of the interface of SCF and summarizes the research gaps of this thesis. Specifically, we first conduct a descriptive analysis to demonstrate the features of the current research. Following comprehensive content analysis, we totally identify nine research dimensions revolving around the SCF topic. One of the most significant findings emerging from the content analysis is that it overall illustrated the current research achievements containing the detailed mechanisms among all participants in SCF practices. Finally, we integrate these new achievements to form an updated SCF research framework consisting of the foundation part and the application part, summarize the dominant methods used in current SCF research, and provide future directions. The research gaps in the existing literature are located precisely at the end of this chapter.

Chapter 3: The Impact of Payment Term Extensions on The Working Capital Management of an Automotive Supply Chain

In this chapter, we establish a multi-cycle model and identify the conditions under which extended payments will impact the supply chain's CC2C cycle and SVA. Finally, the numerical analysis not only confirms the major findings but also provides some additional insights that can assist practitioners in mitigating the adverse effects caused by payment delays.

3.1 Problem Description

To verify the significance of SCF in improving a supply chain's WCM in the presence of payment delay, we first select three common indicators that appeared in the WCM literature: CC2C cycle, SVA and the weighted average cost of capital (WACC) as our research focus. The CC2C cycle is derived from the C2C cycle which measures the time duration from the payment of cash for materials or components through to the receipt of cash for the sale of the finished product from a company's perspective, while CC2C collaboratively measures the same time duration from a centralized supply chain's perspective and equals to the summation of involved individual company's C2C value (Hofmann and Kotzab, 2010). For example, if there is a raw material supplier as company C, a component supplier as company A, and an OEM as company B, Figure 3-1 illustrates the essence of these two concepts.

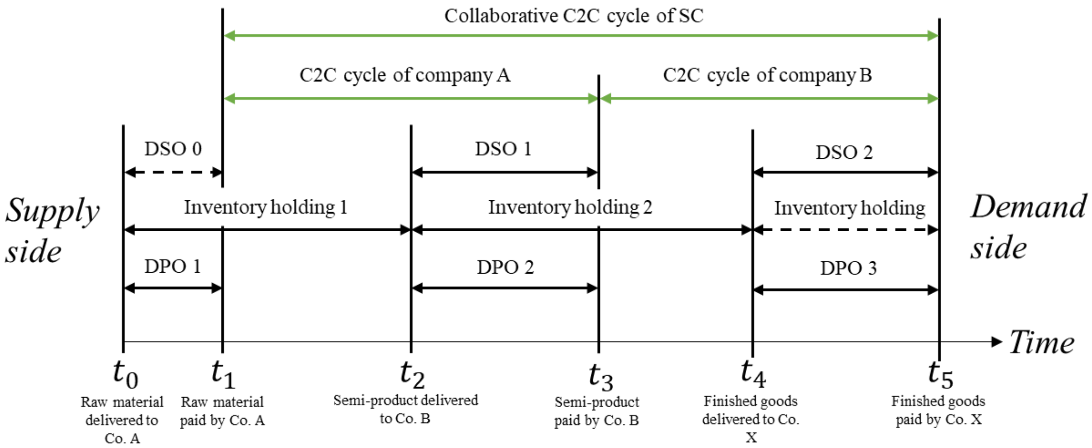


Figure 3-1 The CC2C Cycle of The Supply Chain

A decrease in the CC2C cycle reflects an improvement of the supply chain's operational and financial performance while an increase means a deterioration. SVA reflects to the economic profits generated by a business above and beyond the minimum return required by all providers of capital (Rappaport, 1999). WACC calculates the weighted average interest expected by the company's shareholders and debt holders together (Hofmann and Kotzab, 2010). Second, Chinese automotive supply chains were chosen as our research target since they are substantially impacted by COVID-19. Several carmakers such as Volkswagen, General Motors, Toyota, and Honda, established strong relationships with China for joint production and car components supply over the last two decades (Kumar and Managi, 2020;

Sharma et al., 2020). Payment issues emerged since almost all these plants in China inevitably closed during the outbreak of COVID-19. Hence, as a giant industry contributing to the Chinese GDP growth, compared with other industries, research on their supply chain cash flows has top priority. In light of these issues, we elaborate on the following research questions:

RQ 3-1: How will the CC2C cycle and SVA be influenced by payment term extensions under different conditions, with and without SCF?

RQ 3-2: How will the CC2C cycle and SVA be influenced by the operational and financial parameters in the presence of payment delay, with and without SCF?

To answer these two questions, we firstly interviewed the management of several Chinese car brands to acquire the basic transaction settings of purchasing. Based on the know-how extracted from the interviews, we establish a three-stage automotive supply chain: a raw material supplier, a component supplier and an OEM and capture the dynamical variations of two dominant indicators (i.e., CC2C cycle and SVA). A detailed analysis of the model, with and without SCF involvement, is undertaken, followed by numerical analysis examining whether the derived results can apply to practical settings.

3.2 Model

3.2.1 Preliminaries

Based on the content obtained from the interviews, we illustrate the critical issues as follows. We define a raw material supplier as company C, a capital-limited component supplier as company A, and an OEM as company B, as shown in Figure 3-1. The inventory holding period includes production duration, delivery duration, and inspection duration. The DSO (days sales outstanding, measures the duration of receiving receivables) period includes the duration in sending invoices to the OEM, the OEM's invoice reconciliation, and the audit and approval process. We clarify some basic pre-settings in Figure 3-2:

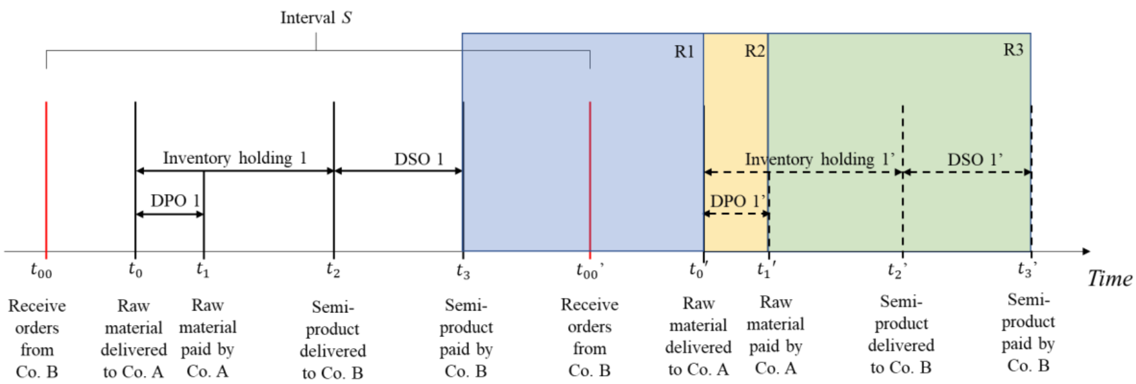


Figure 3-2 The Impact of DSO 1 Extension on Next C2C Cycle

We define t_{00} as the start point of the first purchasing cycle and t'_{00} as the start point of the next cycle. The delay occurs when the t_3 epoch falls into different locations on the timeline. If the t_3 epoch falls into region R1, the delay has no impact on Co. A's next C2C cycle; if the t_3 epoch falls into region R2, it may affect the production in the next cycle; if the t_3 epoch falls into region R3 (the total length of the next C2C cycle), it may affect both the production and DPO (days payables outstanding, measures the duration of paying payables) of the next cycle.

Now, we elaborate on the purchasing process. Co. A receives orders from Co. B at time t_{00}. The normal duration for DSO 1 is denoted by T as regulated in the contract. If there are delays, the additional extended time is denoted by $d, d \geq 0$. At time t_0, the raw materials are delivered to Co. A, and Co. A pays an amount B to Co. C after DPO 1, which could be affected by the extended DSO 1 $(T + d)$ occurring in the last cycle. DPO 1's duration is fixed as τ. At time t_2, Co. B receives all the semi-products with the required quantity q and the length of I_1 equals the summation of the production time (P) and the delivery time of Co. A (α) and the inspection time of Co. B (β). The latter two are fixed if there is no delay, and P will be affected by $T + d$. We set P as a function of $T + d$, denoted by $P = F(T + d)$. At time t_4, the total finished goods are delivered to the retailers and Co. B receives money after a fixed DSO 2 (δ). The inventory period I_2 is fixed as ε. Moreover, the current capital level of Co. A is A and its maximum amount of production per day is m, the unit production cost for Co. A is c, and the unit wholesale price is w $(w \geq c)$. In addition, the interval length of two consecutive orders made by Co. B is S, and the cash tax rate is r. The notations are presented in Table 3-1 and key conceptions are summarized in Table 3-2. Two extra assumptions have to be made in our research:

Assumption 3-1. The overhead fees, human and resource fees and other non-production fees are all ignored for the three companies, which will not qualitatively affect the final result.

Assumption 3-2. We assume the extra time value of cash is zero. The rationale behind this assumption is based on industrial practice. Usually, the payment delay will not be beyond 60 days for each purchasing cycle in reality, so both the unstable effects of the economics in the local market and the opportunity cost for investment within such a short time window can be ignored, and hence the present value of cash stays the same.

Table 3-1 Notations

Variables/Parameters	Notations
Extended payment terms	$d, d \geq 0$
The collaborative cash to cash cycle of the SC	$CC2C$
The collaborative cash to cash cycle of the SC under SCF	$CC2C_{SCF}$
Production duration function	$P = F(\cdot)$
Shareholder-value added of the SC	SVA
Shareholder-value added of the SC under SCF	SVA_{SCF}
Order quantity	$q, q \geq 0$
Order quantity of last time	$q', q' \geq 0$
Weighted average cost of capital	$WACC_i, i = 1,2,3$
Weighted average cost of capital under SCF	$WACC_i^{SCF}, i = 1,2,3$
The delivery duration in inventory period 1	$\alpha, \alpha > 0$
The inspection duration in inventory period 1	$\beta, \beta > 0$
The normal duration of DSO 1	$T, T > 0$
The normal duration of DPO 1	$\tau, \tau > 0$
The normal duration of I_2	$\varepsilon, \varepsilon > 0$
The normal duration of DSO 2	$\delta, \delta > 0$
The normal duration of DPO 2 under SCF	$\sigma, \sigma > 0$
The current capital level of Co. A	$A, A > 0$
The unit production cost of Co. A	$c, c > 0$
The maximum production amount per day	$m, m > 0$
The order interval of Co. B	$S, S > 0$
The payment amount to Co. C	$B, B > 0$
The cash tax rate	$r, 0 < r < 1$
The unit wholesale price of Co. A	$w, w \geq c$
The normal duration of bank payment	$t, t < T$
The discount rate under SCF	$\epsilon, 0 < \epsilon < 1$
The fixed time between order release from Co. B and Co. A's production start epoch	$L, L \geq 0$

Note: 1. The subscript i=1,2,3 for WACC denote the three companies in an order of Co. C, Co. A and Co. B respectively.

Table 3-2 Summary of Key Conceptions

CC2C (Collaborative Cash to Cash Cycle)	CC2C measures time duration from the payment of cash for materials or components through to the receipt of cash for the sale of the finished product from a supply chain's perspective.
SVA (Shareholder-Value Added)	SVA stands for the economic profits generated by a business above and beyond the minimum return required by all providers of capital.
WACC (Weighted Average Cost of Capital)	WACC calculates the weighted average interest expected by the company's shareholders and debt holders together.
DPO (Days Payables Outstanding)	DPO measures the duration of paying payables.
DSO (Days Sales Outstanding)	DSO measures the duration of receiving receivables.
SCF(Supply Chain Finance)	SCF is a mechanism when a participant in a supply chain wants to access internal or external financing to conduct its daily operations or to survive in the market.
RF (Reverse Factoring)	RF is an instrument where the financial service provider will provide discounted loans instantly to suppliers based on the buyer's high credit-rating and favourable reputation. Therefore, the buyer frees-up its capital from the extended payment terms, and the cash-limited suppliers who have a low credit-rating can have easy access to financing, and the bank can transfer the credit risk from the low-credit rating suppliers to high-qualified buyers with cost reduction.

3.2.2 The Process without SCF Involvement Modeling

Firstly, we consider the scenario when the chain does not use the SCF solution. Referring to Figure 3-1, the CC2C cycle of this SC equals the summation of the two separated C2C cycles:

$$CC2C = (I_1 + DSO\ 1 - DPO\ 1) + (I_2 + DSO\ 2 - DPO\ 2)$$

$$= F(T + d) + \alpha + \beta + \delta + \varepsilon - \tau \qquad (3\text{-}1)$$

For $P = F(T + d)$, the location of d end epoch will result in different values of P (refer to Figure 3-2). If $t_0' \leq d \leq t_1'$ (For ease of exposition, the term d can also be viewed as the end epoch of the payment delay through the remaining context), it falls into region R2 (Figure 3-3).

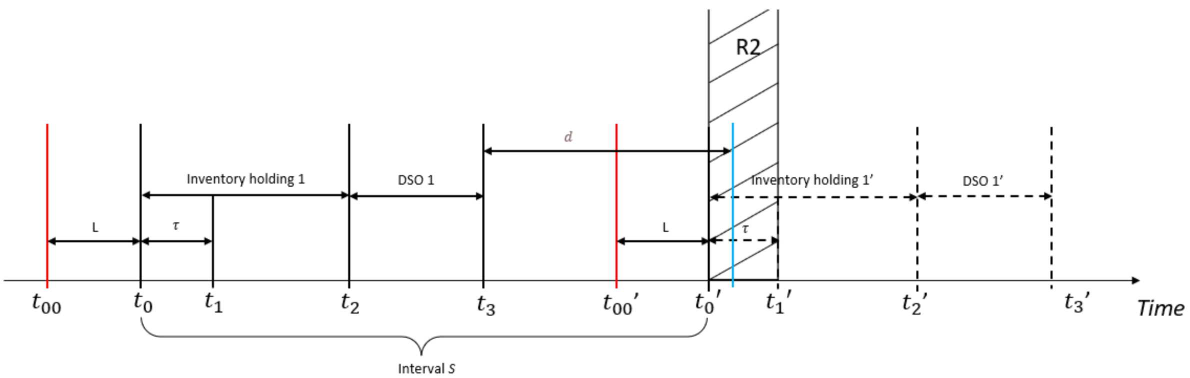


Figure 3-3 The Payment Extension (R2) on Next C2C Cycle

When $q \leq \frac{A}{c}$, it implies that Co. A can fulfill the order quantity without any difficulty, therefore, the production days are equal to $\frac{q}{m}$. When $q > \frac{A}{c}$, Co. A's current capital level will be completely used for production. Hence, the current capital could produce $\frac{A}{c}$ products in $\frac{A}{mc}$ days; we call this the initial production time. Based on the value of $\frac{A}{mc}$, there are several sub-situations that should be discussed. If $\frac{A}{mc} \geq \tau$, the production time will still be $\frac{q}{m}$ (see Figure 3-4 (a)). If $\frac{A}{mc} < \tau$, when the extended payment happens ahead of or just on the time epoch of finishing the initial production, there is no negative impact. In other words, the production time will still be $\frac{q}{m}$ (see Figure 3-4 (b)). However, when the extended payment happens after the time epoch of finishing the initial production, the production time will change to $\frac{q'}{m} + \alpha + \beta + T + d - S + \frac{\left(q - \frac{A}{c}\right)}{m}$, where q' is the order quantity in the last cycle. It implies that Co. A will wait till the money is received and then continue the production (see Figure 3-4 (c)).

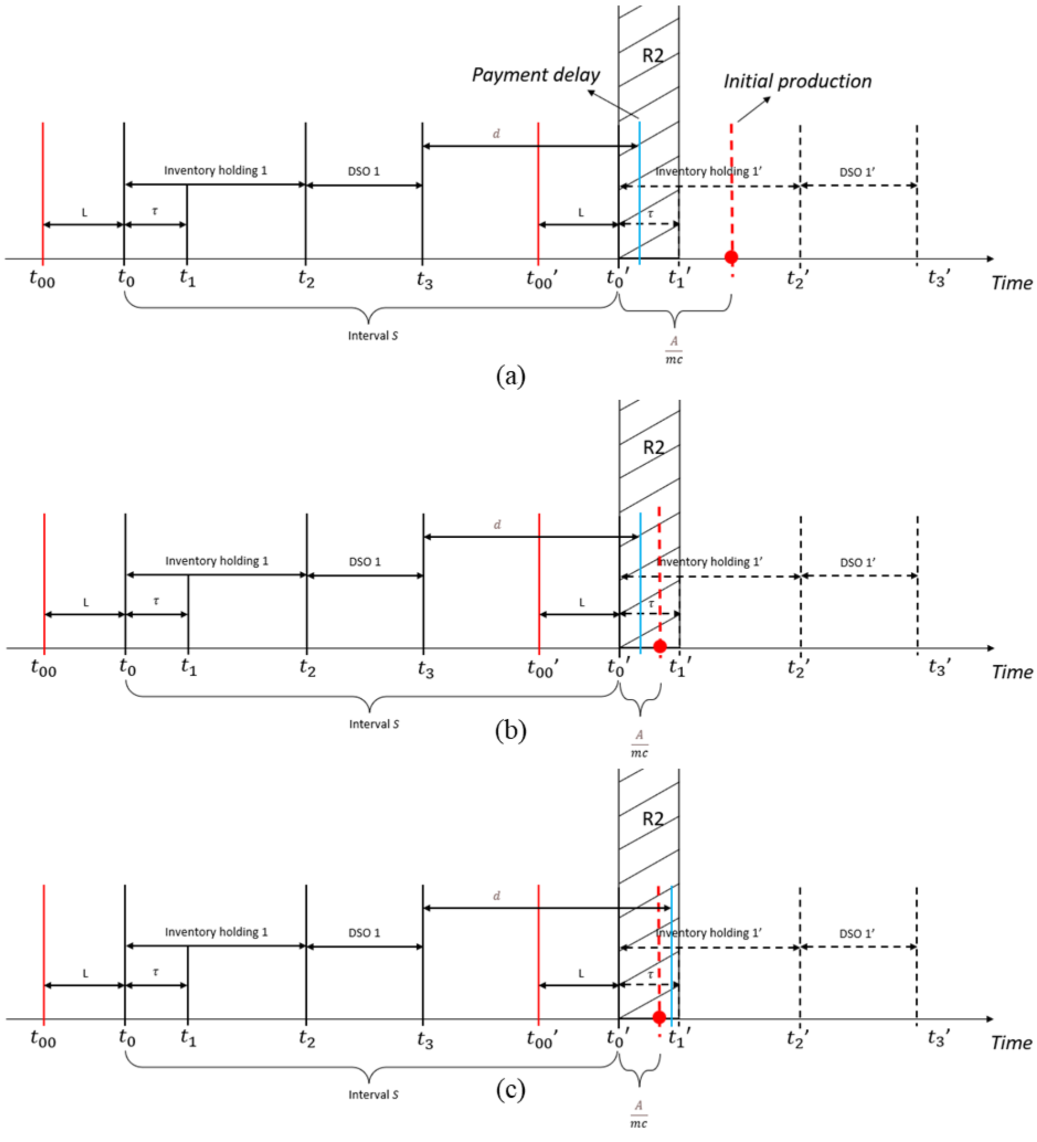


Figure 3-4 The Impact of DSO 1 Extension (R2) on Next C2C Cycle

When the payment is extended further, that is, if $d \geq t_1'$, it falls into region R3, the analysis is similar to that in region R2, thus we omit this part here. Table 3-3 summarizes the different conditions and their associated production duration values:

Table 3-3 The Values of Production Duration P Under Various Situations

The region in which d end epoch falls in	Capital conditions	Order conditions	Initial production conditions	d end epoch conditions	Production durations	Impact on the production of next cycle
R2	$A > 0$	$q \leq \frac{A}{c}$	-	-	$\frac{q}{m}$	No
		$q > \frac{A}{c}$	$\frac{A}{mc} \geq \tau$	-	$\frac{q}{m}$	No
			$\frac{A}{mc} < \tau$	In advance of or just on the time epoch of finishing production of $\frac{A}{c}$	$\frac{q}{m}$	No
				After the time epoch of finishing production of $\frac{A}{c}$	$\frac{q'}{m} + \alpha + \beta + T + d - S + \frac{\left(q - \frac{A}{c}\right)}{m}$	Yes
R3	$A > B$	$q \leq \frac{A-B}{c}$	-	-	$\frac{q}{m}$	No
		$q > \frac{A-B}{c}$	$\frac{A-B}{mc} \geq \tau$	In advance of or just on the time epoch of finishing production of $\frac{A-B}{c}$	$\frac{q}{m}$	No
				After the time epoch of finishing production of $\frac{A-B}{c}$	$\frac{q'}{m} + \alpha + \beta + T + d - S + \frac{\left(q - \frac{A-B}{c}\right)}{m}$	Yes
			$\frac{A-B}{mc} < \tau$	-	$\frac{q}{m} + \alpha + \beta + T + d - S + \frac{\left(q - \frac{A-B}{c}\right)}{m}$	Yes
	$A = B$	-	-	-	$\frac{q'}{m} + \alpha + \beta + T + d - S + \frac{q}{m}$	Yes
	$A < B$	-	-	-	Bankrupt	Yes

Therefore, we obtain the following proposition for the impact of extended payment on the firm's production schedule.

Proposition 3-1. *The extended payment accumulated in the last CC2C cycle will not impact the firm's production schedule in the consequent cycle when:*

(1) The d *end epoch will not occur after the end of the initial production in region R2.*

(2) Or the firm has a sufficiently high initial capital level: $A \geq \tau mc$ *in region R2;* $A \geq \tau mc + B$ *and the* d *end epoch will not occur after the end of the initial production in region R3;*

(3) Or the order quantity is relatively small: $q \leq A/c$ *in region R2, and* $q \leq (A - B)/c$ *in region R3;*

Proof: it is easy to discover the rules in Table 3-3 thus the proof process can be ignored.

Proposition 3-1 shows the intuitive reflection in practice. If a firm has a significant market share and adequate capital resources, the firm will not be concerned with payment delays caused by its customers. Moreover, it is reasonable to conclude that as long as the payment is given before or at the end of the initial production, then the supplier acquires sufficient capital from the buyer to continue production for the remaining unfinished goods.

In light of SVA values, referring to Hofmann and Kotzab (2010)' s equation, we obtain:

$$SVA = (T + d)\frac{(1-r)}{365}\left(WACC_1(-B) + WACC_2(B - wq) + WACC_3(wq)\right), \tag{3-2}$$

3.2.3 The Process with SCF Involvement Modeling

In this setting, Co. A and Co. B adopt reverse factoring as their financing solution. The bank provides financing to Co. A immediately with a certain discount as a service fee after receiving the requirement from Co. B. Then, Co. B extends the payment to the bank on condition of an agreed term. Thus, Co. A's DSO 1 period turns shorter, and Co. B's DPO 2 period turns longer simultaneously, compared with a supply chain without SCF involvement. Therefore, both companies' C2C durations are reduced; finally, the supply chain's CC2C is decreased as well. From Figure 3-5, we can directly see the CC2C cycle is decreased after adopting reverse factoring:

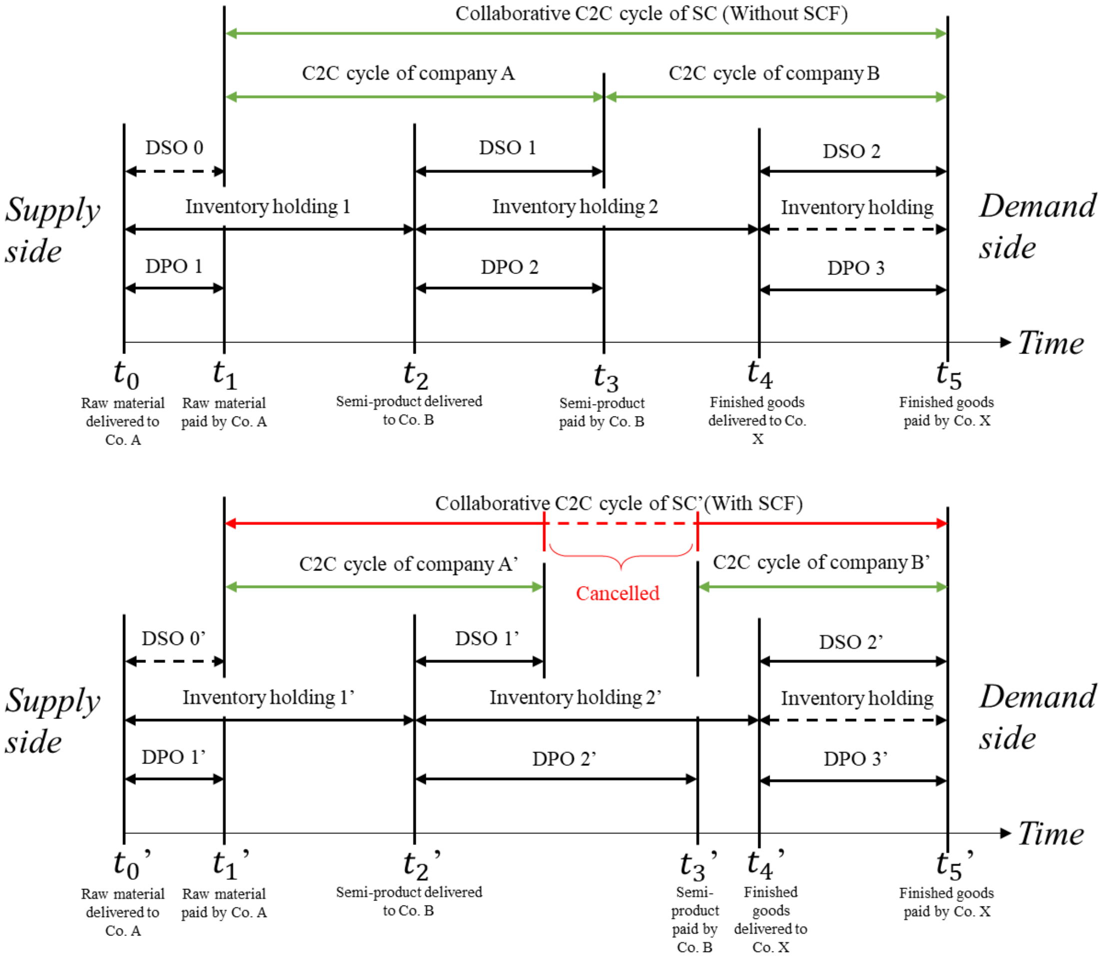


Figure 3-5 The Comparison of CC2C Cycle with and without SCF

In the theoretical part, we show the CC2C cycle under SCF changes to:

$$CC2C^{SCF} = (I_1^{SCF} + DSO\ 1^{SCF} - DPO\ 1^{SCF}) + (I_2^{SCF} + DSO\ 2^{SCF} - DPO\ 2^{SCF})$$

$$= \frac{q}{m} + \alpha + \beta + t - \tau + \varepsilon + \delta - \sigma, \quad (3\text{-}3)$$

and

$$SVA^{SCF} = t\frac{(1-r)}{365}\left(WACC_1^{SCF}(-B) + WACC_2^{SCF}(B - \epsilon wq) + WACC_3^{SCF}(\epsilon wq)\right), \quad (3\text{-}4)$$

where ϵ is the discount rate charged by the bank.

3.3 Model Analysis

3.3.1 When The Chain Does Not Adopt SCF

3.3.1.1 When The Payment Delay Falls into Region R2

Based on Equation (3-1), we show that if there is no delay(s), the CC2C cycle is simplified to

$$CC2C = \frac{q}{m} + \alpha + \beta + \delta + \varepsilon - \tau, \tag{3-5}$$

We set Equation (3-5) as our benchmark case, and compare the CC2C cycle under different conditions with the benchmark. Referring to Table 3-3, we know the production time will either be $\frac{q}{m}$, then the CC2C cycle will not change even if there is a delay; or change to $\frac{q'}{m} + \alpha + \beta + T + d - S + \frac{\left(q - \frac{A}{c}\right)}{m}$, whereby the CC2C cycle will be:

$$CC2C = \frac{q'}{m} + \alpha + \beta + T + d - S + \frac{\left(q - \frac{A}{c}\right)}{m} + \alpha + \beta + \delta + \varepsilon - \tau \tag{3-6}$$

Subtracting (3-5) from (3-6), the difference between them is $\frac{q'}{m} + \alpha + \beta + T + d - S - \frac{A}{mc}$, and if we let $K = \frac{q'}{m} + \alpha + \beta + T - S - \frac{A}{mc}$, then the difference becomes $d + K$. It implies that the difference is increasing in d and there could be three situations (>0, <0, =0). Given a known d_0 ($d_0 > 0$) within region R2, when K is greater than 0, given the initial CC2C cycle is greater than 0, it is worth noting that a surge effect will occur (see Figure 3-6), then the value of the CC2C increases in the extended payment for all possible delays after d_0; when K equals to 0, the value of the CC2C will continuously increase in the following d; when K is less than 0, there will be a dive effect, and the CC2C increases in the extended payment. Therefore, we make the following proposition to illustrate the impact of extended payment falling in region R2 on the supply chain's CC2C cycle.

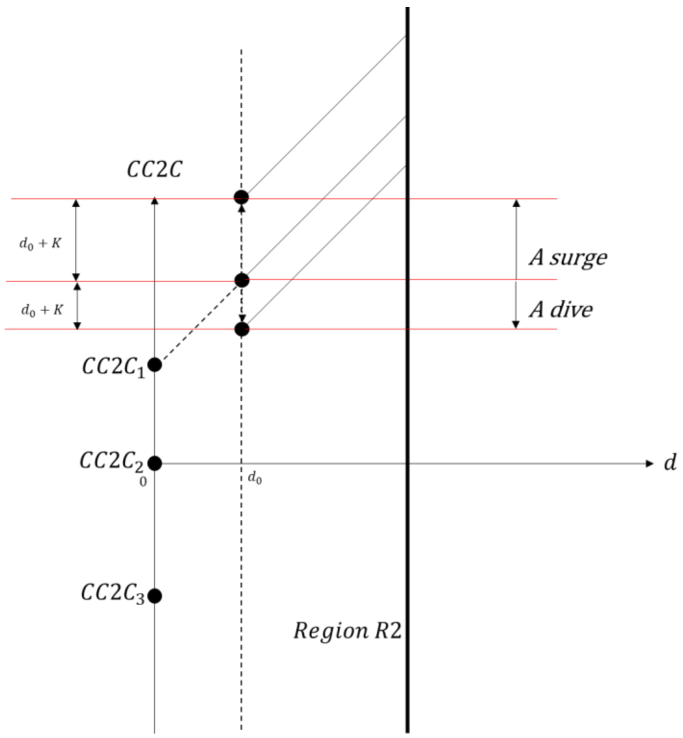


Figure 3-6 An Example of The $d + K$'s Impact on The CC2C Cycle

Proposition 3-2. *The impact of extended payment falling in region R2 on the supply chain's CC2C:*

(1) Given $q \leq \frac{A}{c}$*, or* $q > \frac{A}{c}$ *and* $\frac{A}{mc} \geq \tau$*, or* $q > \frac{A}{c}$ *and* $\frac{A}{mc} < \tau$ *and the* d *end epoch is in advance of or just on the time epoch of finishing production of* $\frac{A}{c}$*, then the CC2C stays the same in* d*;*

(2) Otherwise, the variations of the CC2C will depend on the value of $K + d$*, where* $K = \frac{q'}{m} + \alpha + \beta + T - S - \frac{A}{mc}$

Proof: it is easy to find the reasons from the above analysis thus the proof can be ignored.

Proposition 3-2(1) shows, under certain conditions, even if there is a delay, it will generate zero effect on the supply chain's CC2C cycle. Therefore, the supply chain is indifferent to the payment delay, so the buyer could enforce delayed pay satisfying the specific conditions for optimizing its own C2C cycle. In proposition 3-2(2), it is surprising to find that the next CC2C cycle may equal the initial CC2C or even decrease under some Ks in the extended payment delays, i.e., the dive effect is significant.

3.3.1.2 When The Payment Delay Falls into Region R3

The analysis of when the payment delay falls into region R3 is similar to that in region R3. We come up with a new proposition as follows:

Proposition 3-3. *The impact of extended payment falling in region R3 on the supply chain's CC2C:*

(1) When $A \geq B$*, given* $q \leq \frac{A-B}{c}$*, or* $q > \frac{A-B}{c}$ *and* $\frac{A-B}{mc} \geq \tau$ *and the* d *end epoch is in advance of or just on the time epoch of finishing production of* $\frac{A}{c}$*, the value of the CC2C remains unchanged in* d*;*

(2) Otherwise, the variations of the CC2C will depend on the $d + K + \frac{B}{mc}$*, where* $K = \frac{q\prime}{m} + \alpha + \beta + T - S - \frac{A}{mc}$

Proof: it is easy to find the reasons from the analysis thus the proof can be ignored.

Proposition 3-3 shows that if Co. A has a sufficiently high initial capital level, it will generate an absorption effect which means that even if the payment delay is longer, the delay effects will not be more severe due to the high capital level. Furthermore, even if the payment extends further, these are the same situations as presented in Proposition 3-2.

3.3.1.3 The Impact of Payment Delay on Supply Chain's SVA

Based on Equation (3-2), we derive that the variations of SVA in d depend on the value of $WACC_1(-B) + WACC_2(B - wq) + WACC_3(wq)$. We let $U = WACC_1(-B) + WACC_2(B - wq) + WACC_3(wq)$, and Equation (3-2) changes to $SVA = (T + d)\frac{(1-r)}{365}U$. Thus, we can obtain lemma 3-1 by stating that:

Lemma 3-1 *The SVA value will have varying monotonicity depending on the WACC of the three companies, the total payment in DPO 1 (B), wholesale price (w) and the order quantity (q).*

3.3.2 When The Chain Does Adopt SCF

By adopting an SCF solution, the complicated conditions are directly simplified. For Equation (3-3) minus Equation (3-5), the difference is $t - \sigma$. Since t is the immediate payment by the bank while σ is the extended payment approved by the three parties, thus $t - \sigma$ is always less than 0. Therefore, the CC2C cycle employing SCF will absolutely decrease.

For the SVA value under SCF, according to Equation (3-4), whether the term $WACC_1^{SCF}(-B) + WACC_2^{SCF}(B - \epsilon wq) + WACC_3^{SCF}(\epsilon wq)$ is positive or negative or equals 0 is unknown. Hence, the specific difference of the SVA values between using SCF and not using SCF is hard to measure. Moreover, the WACC will be changed under SCF according to Randall and Farris (2009). In addition to the four parameters mentioned in Lemma 3-1, the discount rate ϵ will also impact on the monotonicity of the SVA value. Therefore, we give the following proposition to illustrate the impact of extended payment on the supply chain's CC2C cycle when the chain adopts an SCF solution:

Proposition 3-4. *The CC2C cycle employing SCF will be decreased regardless of the payment delay. The SVA value will have different monotonicity depending on the WACC of the three companies, the total payment in DPO 1 (B), wholesale price (w), order quantity (q) and the discount rate (ϵ).*

Proof: it is easy to find the reasons thus the proof process can be ignored.

Two comments for Proposition 3-4. First, this result mathematically demonstrates the advantages of RF/SCF in helping the supply chain reduce its CC2C cycle so that the financial and operational performance can be further improved. Second, regarding the SVA value, the difference between the SVA value under SCF practice and the SVA value not under SCF practice is non-measurable unless specific numerical analysis is conducted, which is discussed in the next section.

3.4 Numerical Analysis

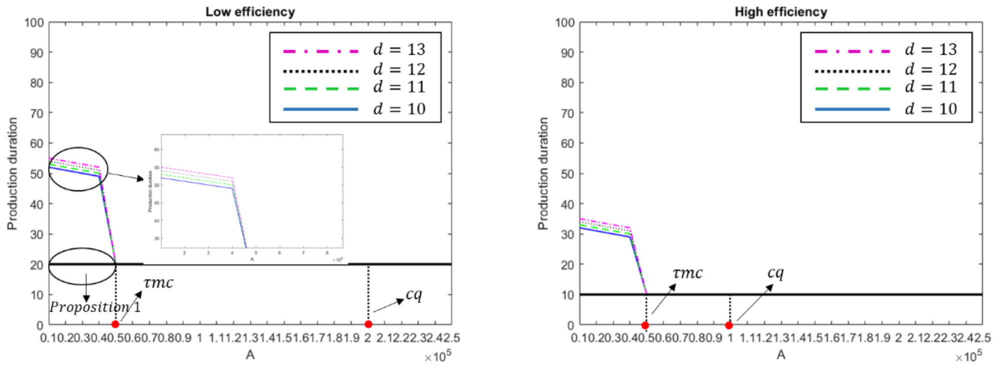
In this section, we further investigate the impact of some key parameter variations to acquire additional findings by performing sensitivity analysis. When the supply chain does not employ an SCF solution, we investigate a) how a firm's initial capital level impacts on the supply chain's CC2C cycle; b) how the supplier's wholesale price impacts on the SVA. When the supply chain does employ an SCF solution, we want to determine c) how the contracted duration of DPO 2 under SCF impacts on the chain's CC2C cycle and d) how the determined discount rate and the wholesale price under SCF impact on the SVA respectively.

We set the values of the parameters by referring to the practical settings concluded from the interviews: the middle firm (i.e., the component supplier) receives a stable order quantity in multiple periods for $q = 10{,}000\ sets$ per month from the OEM, $WACC_{1,2,3} = 11\%\ \text{(raw material supplier)}, 10\%\ \text{(middle firm)}, 9\%\ \text{(OEM)}$, $\alpha = 20\ days$, $\beta = 3\ days$, $T = 30\ days$, $t = 1\ day$, $\tau = 5\ days$, $\varepsilon = 90\ days$, $\delta = 1\ day, L = 3\ days, B = \$20{,}000, r = 40\%$, $S = 30\ days$.

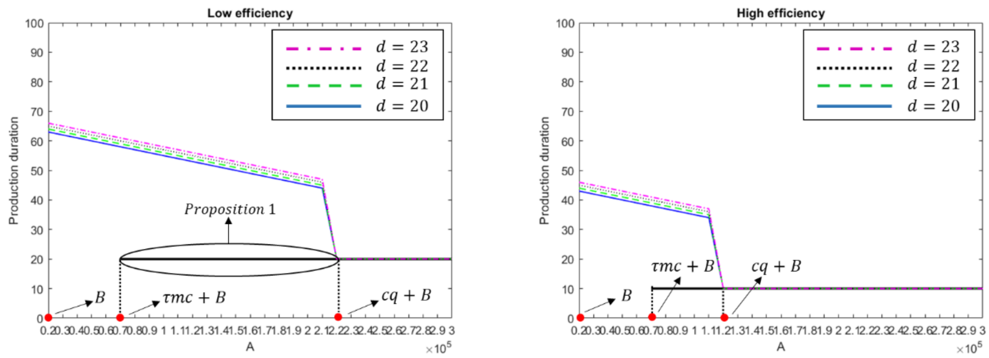
3.4.1 Sensitivity Analysis without SCF Solution

In order to observe the impact of a firm's initial capital level on the supply chain's CC2C cycle, we first define two scenarios that signal the operation efficiency of the middle firm. If the firm has a high operation efficiency, its unit production cost c is relatively low and the capacity for maximum production per day m is higher, e.g., $c =$\$10, $m =$1000 units/day; if the firm has a low operation efficiency, then c is higher and m is lower, e.g., $c =$\$20, $m =$500 units/day.

Firstly, we observe the influence of A when the d end epoch falls into region R2, and the relationship between the production duration P and A is shown in Figure 3-7 (a). Since the trend of the production duration is the same as the CC2C cycle, therefore, the CC2C cycle increases in d or stays the same if the d end epoch is in advance of the epoch of the initial production. If A goes beyond a certain threshold τmc, the CC2C cycle will always stay the same, namely, the absorption effect of A. Further, there are several extra findings: 1) the CC2C cycle decreases in A firstly and remains unchanged when $A \geq \tau mc$ or stays the same without having a relationship with A, 2) the significance of d's impact and the CC2C cycle are both smaller under high efficiency than that under a low efficiency setting, and 3) Proposition 3-1 only applies to A in the range of (0, τmc]. If the d end epoch falls into region R3, the relationship between the production duration and A is shown in Figure 3-7 (b). Apart from identical insights, Figure 3-7 (b) indicates that 4) the payment amount B should be counted, and 5) Proposition 3-1 applies to A in the range of $[\tau mc + B, cq + B]$. Therefore, we find that the high operation efficiency and high working capital level always benefit the firms.



(a) The d end epoch falls into region R2



(b) The d end epoch falls into region R3

Figure 3-7 The Influence of A When The d End Epoch Falls into Different Regions

Next, we consider how a firm's wholesale price w impacts on the SVA. Based on Equation (3-2), we observe the influence of w, as shown in Figure 3-8.

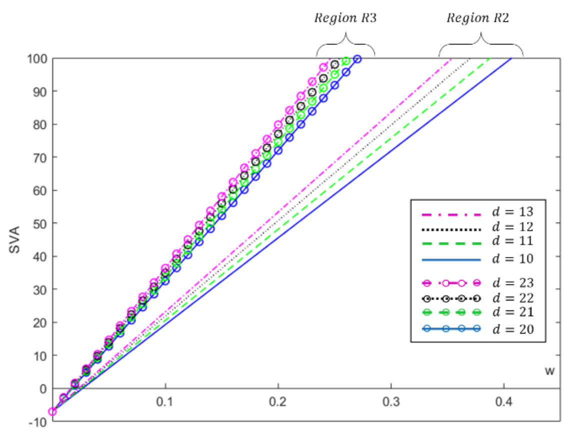


Figure 3-8 The Influence of w on The Supply Chain's SVA

Figure 3-8 shows that SVA increases in both d and w under the given numerical settings. The delayed payment d directly affects the slope of the SVA (w). The longer the d, the higher the SVA. It is interesting to find that both a higher wholesale price and a longer payment term will lead to an increase in SVA.

3.4.2 Sensitivity analysis with SCF solution

When SCF is adopted, we observe how σ can influence the supply chain's CC2C value. Moreover, according to Jemdahl (2016), the WACC of the supplier and its focal firm will be considerably reduced after SCF adoption. Figure 3-9 shows the influence of σ. Compared with the chain that does not adopt SCF, whether there is a payment delay or not, the CC2C cycle will be significantly reduced. We also observe that 1) the CC2C cycle is decreasing in σ and 2) given a σ, the CC2C value is smaller under high operation efficiency than under low efficiency.

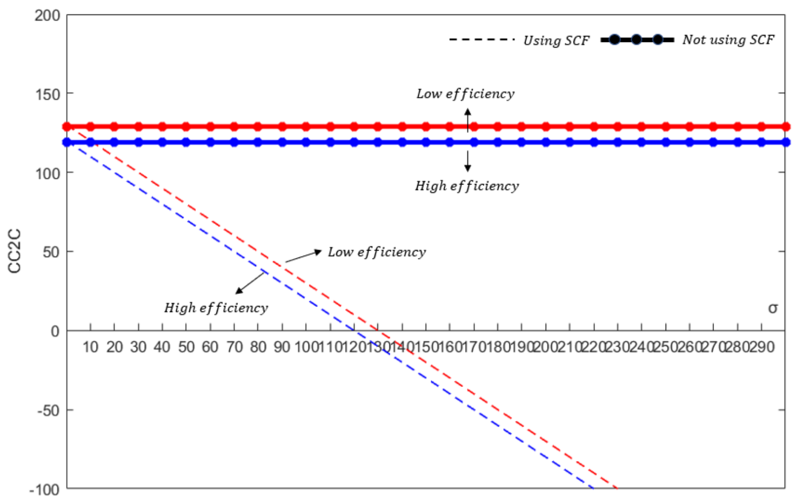


Figure 3-9 The Influence of σ on The Supply Chain's CC2C

When the chain adopts the SCF solution, we consider how the discount rate ϵ and wholesale price w impact the SVA value. Based on Equation (3-4), the values of $WACC_2^{SCF}$ and $WACC_3^{SCF}$ are critical since they determine the monotonicity of the SVA value. Therefore, we list three sub-scenarios to analyze the influence of w and ϵ. Scenario A: $WACC_2^{SCF} > WACC_3^{SCF}$, e.g., $WACC_2^{SCF} = 7\%, WACC_3^{SCF} = 5\%$; Scenario B: $WACC_2^{SCF} = WACC_3^{SCF}$, e.g., $WACC_2^{SCF} = 5\%, WACC_3^{SCF} = 5\%$; Scenario C: $WACC_2^{SCF} < WACC_3^{SCF}$, e.g., $WACC_2^{SCF} = 5\%, WACC_3^{SCF} = 7\%$.

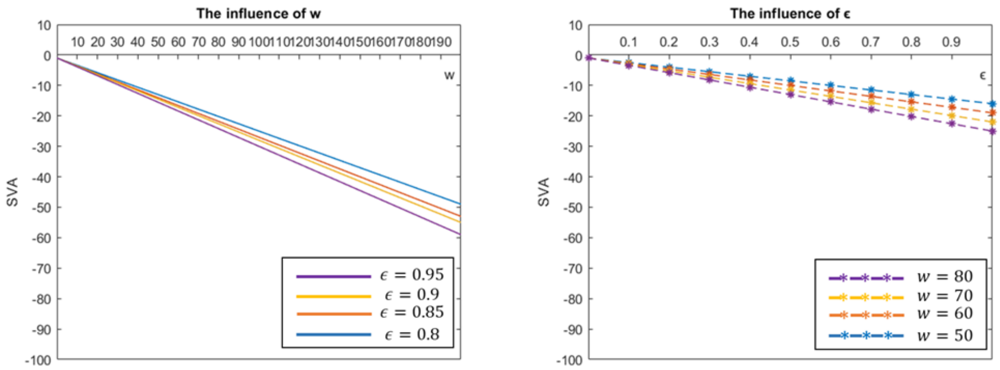
Figure 3-10 shows the influence of w and ϵ on SVA. When the middle firm's $WACC$ is larger than its focal firm's $WACC$ (Figure 3-10 (a)), the SVA decreases both in w and ϵ and the influence of w is more significant than that of ϵ. This mechanism should be considered when the bank makes decisions on ϵ and the middle firm's decision on w in order to maximize the SVA. When the $WACCs$ changes to scenario B, we find that the SVA will become a constant with a value of:

$$SVA^{SCF} = t\frac{(1-r)}{365}\left(WACC_1^{SCF}(-B) + WACC_2^{SCF}(B - \epsilon wq) + WACC_3^{SCF}(\epsilon wq)\right)$$

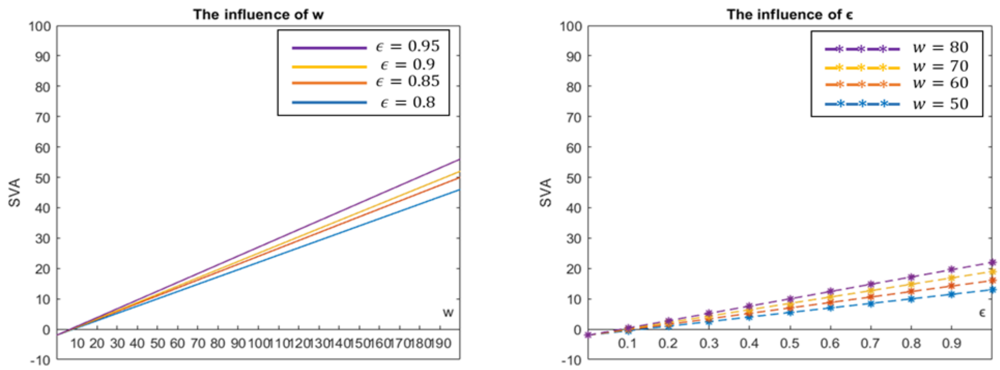
$$= t\frac{(1-r)}{365}\left(WACC_1^{SCF}(-B) + WACC_2^{SCF}B\right)$$

$$= 1 * \frac{(1-40\%)}{365}(11\% * (-20000) + 5\% * 20000) = -2.$$

When the $WACC$ changes to scenario C, Figure 3-10 (b) shows that the SVA is monotonically increasing in w and ϵ.



(a) When $WACC_2^{SCF} > WACC_3^{SCF}$



(b) When $WACC_2^{SCF} < WACC_3^{SCF}$

Figure 3-10 The Influence of w and ϵ on SVA

3.5. Managerial Insights and Real-Life Evidence

A decrease in a supply chain's CC2C cycle reflects an improvement of the supply chain's operational and financial performance while an increase means a deterioration. Given all the information related to the participants' operational and financial parameters, the supply chain managers of each firm can achieve coordination in mitigating the negative impacts derived from the payment delay and maximizing the profits for the whole supply chain.

The assembly line, as the kernel element of lean production in the automotive industries, safeguarding its continuous running is the highest priority for normal supply chain operations (Inamizu et al., 2014). However, in practice, the supplier's production stops when confronting a shortage of capital resources for manufacturing. This would further impact on the OEM's production schedule and result in severe consequences such as demand losses and penalties. To avoid capital-induced supplier production stagnation, we proposed that as long as the supplier's initial capital is above a certain threshold, e.g., $A \geq \tau mc$ in region R2 or the d end epoch satisfy certain conditions mentioned in Proposition 3-1, then the production duration may not be impacted even if there is a payment delay. Otherwise, the supplier can require advance payment or find alternative financing solutions to better facilitate working capital management.

Furthermore, to dynamically examine a supply chain's cash flows, often ignored in SCM (Yazdimoghaddam, 2020; Emtehani et al., 2021; Zhang et al., 2019; Bals, 2019), we not only modeled different scenarios that so the delay may happen (i.e., payment delay occurs in region R2/R3) but also proposed under what conditions the CC2C cycle will be impacted by payment delays, as well as how the value of CC2C is related to the supply chain's operational and financial parameters. For example, if the downstream customer (e.g., the OEM) informs the supplier that the payment will be extended to region R2/R3, by referring to Propositions 3-2 and 3-3, based on operation parameters such as production capacity, order quantity, etc., and financial parameters like initial capital level, unit production cost, etc., the supplier can estimate how the payment delay will influence the production schedule and the CC2C cycle. If the payment extension impairs the whole supply chain cash flows, the supply chain managers can then make some reactions to mitigate the delay-induced risks.

Regarding the specific countermeasures, the firms have options to either adopt SCF schemes to increase the capital level immediately or manage to improve their own operational efficiency to reduce the length of the CC2C cycle. High operational efficiency is a glaring signal to demonstrate better performance in the presence of payment delay as presented in our numerical study. Since the cash flow is intertwined with the materials flow, and the materials flow is subject to the company's operational efficiency, hence, the operational efficiency improvement of a company will benefit the whole supply chain cash flows as well. Another way to optimize cash flows is the implementation of the SCF scheme, as SCF can significantly improve working capital management, speed up supply chain cash turnover, and enhance supply chain competitiveness (Pan et al., 2020). In the model analysis, we visually and mathematically explained how the length of a supply chain's CC2C is reduced with SCF involvement, from a theoretical view. In addition, based on the observations of how the key decision variables in SCF could impact on CC2C and SVA in the numerical studies. From a practical view, supply chain managers can set a reasonable payment extension term in the SCF contract to reduce the CC2C cycle so as to enhance smooth cash flows along the chain. Further, based on the cost of capital, the supplier can have guidance in determining the wholesale price w to balance the effects of payment delay and SVA maximization, and the bank can also set a feasible discount rate when providing financing via considering the balance between the return of investment and SVA value to let both parties i.e., supplier and OEM, have incentives to participate in the SCF contract.

In addition, some recent news also provides confirming evidence with respect to our findings. *MarcoPolo* reported that global buyers had started extending payment delays due to the COVID-19, resulting in rapidly depleting the supplier's own working capital for production, thus prolonging the supply chain's CC2C cycle. (**Proposition 3-1, 3-2 and 3-3**). *INVU* which is an electronic document service provider specified that a survey indicated that at least 20% of firms in the UK complained that late payments were a 'significant problem' for their business during the COVID-19.[8] (**Proposition 3-2 and 3-3**) In addition, according to PWC's report '*Optimising Working Capital for Growth 2019 Malaysia Working Capital Study*', the C2C cycle can be improved by managing payable performance (i.e., shortening the payment duration) and can be lowered by adopting SCF. (**Proposition 3-4**)

3.6 Summary

As a pioneering work to examine the impact of payment delay on the supply chain's working capital management, we studied under what particular conditions the payment term extension will negatively impact on the supply chain's CC2C cycle, investigated how the CC2C cycle and the SVA perform with the variations of payment term extension, and explored how the CC2C cycle and SVA value will change when the chain adopts an SCF solution. This study identified the conditions under which the extended payment will not impact on the firm's production schedule in the consequent cycle and elaborated on the distinct impacts of payment delay on the CC2C cycle and SVA when it falls into different time

[8] Please refer to https://www.invu.net/2020/07/21/working-capital-management-or-chaos/

regions. This research also illustrated the reasons why SCF can significantly reduce the impact of payment delay and the variations of SVA value under SCF (RQ 3-1). In addition, the numerical analysis not only confirms the major findings but also provides some novel insights with respect to the decisive parameters (RQ 3-2).

Chapter 4: Is The Financing Role of a 3PL Firm Always Appealing in a Supply Chain?

In this chapter, we examine whether the 3PL's advance-payment financing role is always appealing if the time value of cash is considered based on game-theoretical analyses.

4.1 Problem Description

This study aims to examine whether the advance payment financing services provided by the 3PL can truly benefit supply chain participants when the time value of cash is considered. Specifically, a pair contract is established by the retailer, while the market can be led either by the 3PL or by the retailer. We thus model a supply chain comprising four parties: a supplier, a retailer, a bank and a 3PL that provides both logistics services and financing services. The supplier can be either capital-sufficient or capital-constrained. When suppliers are capital-constrained, they could borrow money from the bank to cover the production cost.

4.2 Model

4.2.1 Initial Settings

In this study, we consider a supply chain comprising four parties: a supplier that has an initial capital level A and limited liability, a bank that provides loans to the supplier when necessary, a capital-sufficient retailer, and a capital-sufficient 3PL company that can provide both logistics services and financing services for the required party. For simplicity, we denote the supplier as "he", the retailer as "she" and the 3PL as "it" in this chapter. In the traditional payment delay scenario, the 3PL only provides logistics services for the retailer. Within each single-selling period, the 3PL announces a unit service fee w_l to the retailer, then the retailer offers a contract (w_r, q) to the supplier[9]. w_r denotes the wholesale price, while q indicates the order quantity for a single product to satisfy the uncertain market demand. The supplier provides products at t_0 with a unit production cost c_s and collects the order payment at the end of the selling season, i.e., at time epoch t_3. The duration for such a payment term is d_0 $(d_0 = t_3 - t_0)$. That is, d_0 measures the payment delay between the supplier and the retailer. After the products are available at t_0[10], the 3PL company helps transport the products to the retailer which induces a unit operation cost c_l $(c_l < w_l)$ within d_s periods, ending at t_1 $(t_1 = t_0 + d_s)$. When receiving the products at t_1, the retailer pays a service fee to the 3PL. Ultimately, the retailer sells the products to the end customers with an exogenous unit retail price p within d_r periods and collects the revenues from the end customers at t_3 $(t_3 = t_1 + d_r)$. The customer realized demand x has a PDF (probability density function) $f(x)$ and a CDF (cumulative distribution function) $F(x)$. The

[9] We first consider the 3PL is the leader in Section 4.3, and then consider the retailer is leader in Section 4.4.
[10] We assume the production duration for the supplier is zero, this does not qualitatively affect the results (Chen et al. 2019a).

corresponding hazard function is $h(x) = \frac{f(x)}{\bar{F}(x)}$ and the GFR (generalized failure rate) is $H(x) = xh(x)$, where $\bar{F}(x) = 1 - F(x)$. We assume $F(x)$ has a convex and increasing GFR which means $H(x)$ increases in x. This is a common assumption that can be satisfied by many distributions (Lariviere and Porteus, 2001). In addition, several further assumptions are made accordingly. First, for simplicity, all delivered products are assumed to be of the required quality without any defects, as adding the scenario of unqualified products only deteriorates the supplier's capital level by penalty, while the results are similar to the scenario where all products are non-defective. Second, we assume the unmet demand is lost and the leftovers (if any) have no salvage value at the end of the selling season, which is also a common assumption in operations management (Chen et al. 2019a; Tunca and Zhu, 2018; Hua et al., 2021). Third, we assume that the information in terms of the cost and demand distribution is common knowledge among all parties. Fourth, all parties are risk neutral. Fifth, as considering the bankruptcy cost will make the model extremely complicated and hard to solve, we assume the financial market is perfect. Hence, the bankruptcy cost is ignored in our study.

4.2.2 Cash Flow in Two Models

We consider two scenarios. In the first traditional scenario (Model T), as introduced in the initial settings, the 3PL only provides logistics services to deliver the goods from the supplier to the retailer. In this scenario, the supplier is obliged to fulfil the order q by depleting his capital A first for production and receives the delayed payment from the retailer at t_3. If the supplier's capital level is insufficient to cover the production cost, he can borrow from a bank with an interest rate r_b and returns the loan amount plus the interest to the bank at the end of the selling period (if he could). If he cannot fully repay the loan, the supplier has to file for bankruptcy and his remaining assets are transferred to the bank due to his limited liability. In Model T, the retailer's payment delay is d_0. Besides, in accordance with the common settings in the literature (see, e.g., Chen et al., 2019a; Hua et al., 2021; Kouvelis and Zhao, 2012), the bank lies in a competitive financing market with a risk-free interest rate r_f.

In the second financing scenario (Model F), in addition to the same operations in Model T, referring to EA's practices, the retailer will entrust the 3PL to help her manage the order settlement issues with the upstream supplier. Then, the 3PL submits the order quantity q to the supplier on behalf of the retailer and delivers the finished goods to its designated warehouse, as well as collects the ordering payment plus the service fee from the retailer at t_1. We assume the delivery durations d_s are identical in the two models as the 3PL's warehouse is near to the retailer. In practice, EA establishes VMI (Vendor Management Inventory) warehouses near to the downstream retailer for timely goods supply[11]. Then,

[11] Please refer to http://eascs.com/innovation/service/

the 3PL will conduct a series of services implementations, and pass the order payment to the supplier when the quality of the goods is examined. Therefore, the supplier receives the cash from the 3PL at time epoch t_2, which is later than t_1 but is in advance of t_3 (i.e., $t_1 < t_2 < t_3$). We denote the duration from t_0 to t_2 as $d_g \left(d_s < d_g < d_0\right)$. Note that d_0 represents the duration between the supplier's starting point and the end of the selling season, while d_g stands for the early payment duration in Model *F*. The incentives for these three parties' willingness to participate are clear. Under this scheme, the supplier benefits from the 3PL's early payment, the retailer can evade the logistics risk and concentrate on her core business, and the 3PL can not only earn service fees but also hold the cash paid by the retailer within a period from $t_1$to t_2 so as to obtain the additional time value-added profits. Further, for easy comparison of the two models, we assume that $t_{0T} = t_{0F}$, $t_{1T} = t_{1F}$, and $t_{3T} = t_{3F}$. That is, d_s, d_r, and d_0 are identical in the two models. Figure 4-1 shows the time epoch with each party's payoff and the durations of relevant activities under the two models. See Table 4-1 for a summary of the notation.

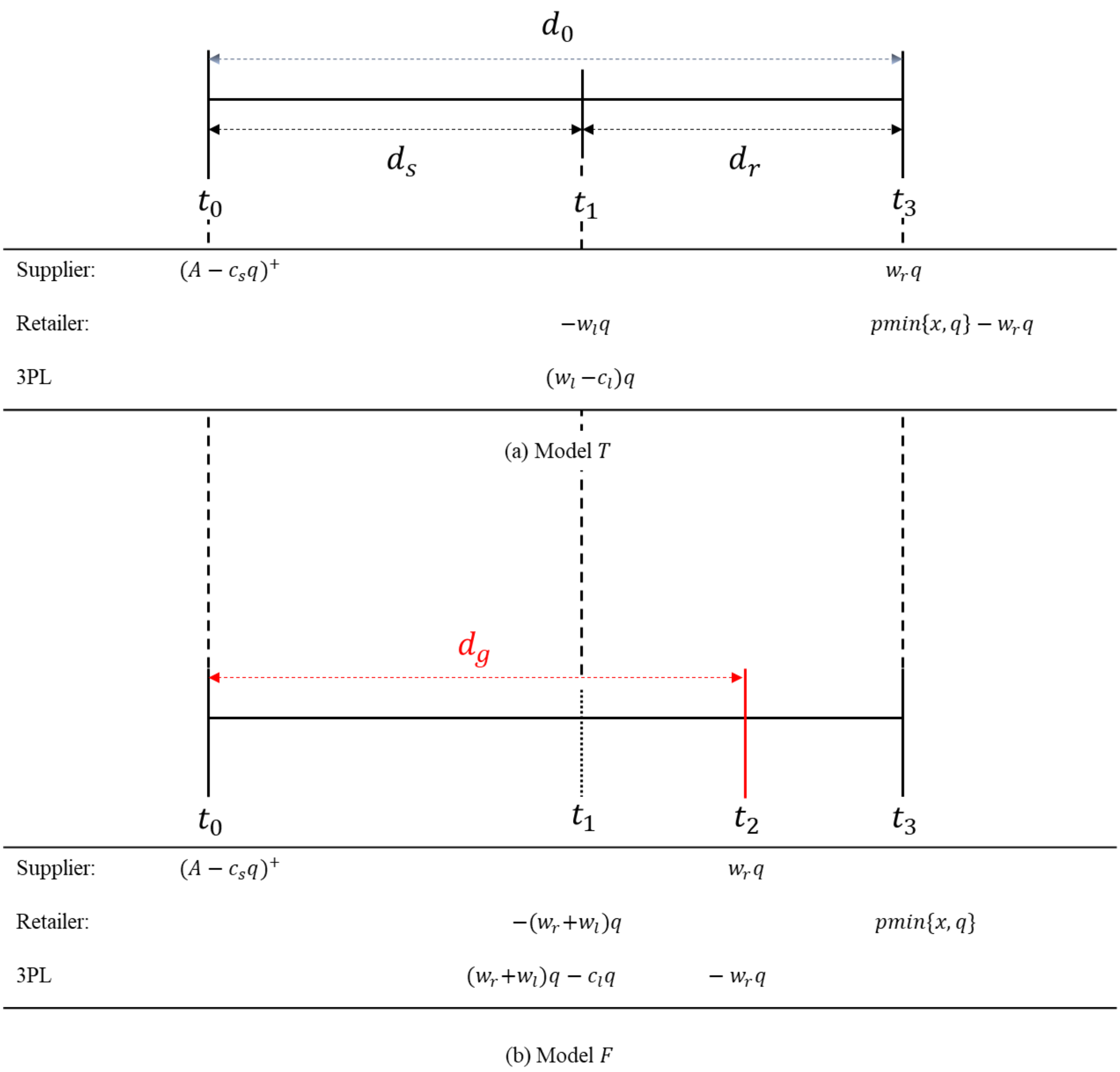


Figure 4-1 Time Length of Operations and The Payoffs at Each Epoch (Before Repaying to Bank)

Table 4-1 Notations

j	Player index: $j = s, r, l, b$ represents the supplier, the retailer, the 3PL, and the bank, respectively
i	Model index: $i = T, F$ represents Model T, F, respectively
x	Customer demand
A	Supplier's initial capital level
r_{bi}	Bank's interest rate charge in Model i
r_f	Risk-free interest rate
p	Unit retail price
q_i	Order quantity in Model i
w_{ri}	Unit wholesale price of supplier in Model i
w_{li}	Unit delivery fee of 3PL in Model i
c_j	Player j's unit operations cost
a_j	Player j's unit cash opportunity cost per unit time
d_0	The duration between time epoch t_0 and t_3
d_s	Delivery duration between time epoch t_0 and t_1
d_g	Advanced payment term between time epoch t_0 and t_2
d_r	Selling season between time epoch t_1 and t_3
π_{ji}	Player j's profit in Model i

4.2.3 The Unit Cash Opportunity Rate

To demonstrate the time value of cash, consistent with Chen et al. (2019a), we introduce the unit cash opportunity cost per time unit for player j as $a_j \in (0,1), j = s, r, l$. That is, a unit of cash at time 0 is worth $1 + a_j d$ at time d to player j. From the supply chain's perspective, we assume $p - c_s(1 + a_s d_0)(1 + r_f) - c_l(1 + a_l d_r)(1 + r_f) > 0$. The first term represents the supply chain's (unit) revenue at t_3, while the second term and the third term represent the (unit) opportunity cost for the supply chain at t_3.

4.2.4 Each Party's Cash Flow Under Different 3PL Service Modes

We aim to understand whether Model F outperforms Model T in the presence of a time value of cash. Since the revenues from the end customers are collected at epoch t_3, the early payment for operations before t_3 induces opportunity cost that is a type of time length-accumulated cost to the associated parties. Therefore, we compare the present cash values of each party at the end of the selling period (i.e., t_3 epoch) under both models. Let π_{ji} be the present profit of player j under model i at t_3, $j = s, r, l, i = T, F$.

By referring to Figure 4-1, given the order quantity, the wholesale price and the service fee, $w_{rT} - c_s(1 + a_s d_0)(1 + r_f) \geq 0$ must be satisfied to ensure that the supplier has incentive to participate in the contract in Model T. Likewise, $w_{rF}\left(1 + a_s(d_0 - d_g)\right) - c_s(1 + a_s d_0)(1 + r_f) \geq 0$ must be satisfied in Model F. Although the supplier may not have the sufficient influence to determine the length of payment delay d_0, we still want to figure out how this value can affect the supplier's performance. In this regard, we suppose the retailer's payment delay is exogenously determined. Recall that the supplier receives the payment and returns the loan amount plus the interest to the bank at t_3. Thus, the supplier's total assets as a function of payment delay before repaying to the bank can be modeled as:

$$\pi'_{si}(d_0, d_g, q_i, w_{ri}),$$

$$= \begin{cases} \left(A - c_s q_i\right)^+ \left(1 + a_s d_0\right) + w_{ri} q_i, \\ \qquad if \ i = T, \\ \left(A - c_s q_i\right)^+ \left(1 + a_s d_0\right) + w_{ri} q_i \left(1 + a_s \left(d_0 - d_g\right)\right), \\ \qquad if \ i = F \end{cases} \tag{4-1}$$

By knowing the order quantity and wholesale price, then the cash that the supplier can pay back to the bank is

$$\min\left\{\pi'_{si}, \left(c_s q_i - A\right)^+ \left(1 + a_s d_0\right)\left(1 + r_{bi}\right)\right\}, \ i = T, F \tag{4-2}$$

Based on the assumption that the bank operates in a competitive financing market, then the bank's optimal interest rate r_{bi} satisfies

$$\mathbb{E}[\min\{\pi'_{si}, (c_s q_i - A)^+(1 + a_s d_0)(1 + r_{bi})\}] = (c_s q_i - A)^+(1 + a_s d_0)(1 + r_f), i = T, F \tag{4-3}$$

Therefore, the supplier's expected profit at t_3 is

$$\pi_{si}(d_0, d_g, q_i, w_{ri}, w_{li})$$

$$= \mathbb{E}[\pi'_{si} - \min\{\pi'_{si}, (c_s q_i - A)^+(1 + a_s d_0)(1 + r_{bi})\}] - A(1 + a_s d_0)(1 + r_f), i = T, F \tag{4-4}$$

Given the payment delay term, $p - w_{rT}(1 + r_f) - w_{lT}(1 + a_r d_r)(1 + r_f) \geq 0$ in Model T and $p - (w_{rF} + w_{lF})(1 + a_r d_r)(1 + r_f) \geq 0$ in Model F must be satisfied to ensure that the retailer will participate in the game. Then the retailer's expected profit as a function of order quantity q_i and wholesale price w_{ri} at epoch t_3 is

$$\pi_{ri}(q_i, w_{ri}|w_{li}) = \begin{cases} p\mathbb{E}[min\{x, q_i\}] - w_{ri}q_i - w_{li}q_i(1 + a_r d_r), \\ \qquad if\ i = T, \\ p\mathbb{E}[min\{x, q_i\}] - (w_{ri} + w_{li})q_i(1 + a_r d_r), \\ \qquad if\ i = F \end{cases} \tag{4-5}$$

Similarly, $w_{lT} - c_l(1 + r_f) \geq 0$ must be satisfied to ensure that the 3PL will participate in Model T and $(w_{rF} + w_{lF})(1 + a_l d_r) - c_l(1 + a_l d_r)(1 + r_f) - w_{rF}\left(1 + a_l(d_0 - d_g)\right)(1 + r_f) \geq 0$ in Model F. Ultimately, given the wholesale price and the retailer's order quantity, the 3PL's expected profit as a function of its service fee is

$$\pi_{li}(w_{li}|w_{ri}, q_i) = \begin{cases} (w_{li} - c_l)\, q_i\left(1 + a_l d_r\right), \\ \qquad if\ i = T, \\ (w_{li} - c_l)\, q_i\left(1 + a_l d_r\right) + w_{ri} q_i a_l (d_g - d_s), \\ \qquad if\ i = F \end{cases} \tag{4-6}$$

In the next section, we assume the 3PL is the leader who determines the service fees first in this three-stage Stackelberg game, while the retailer is the subleader who decides the wholesale price and the order quantity, and then the supplier participates as a follower to examine the impact of payment delay, given the above three parameters, and applies for a bank loan, if necessary. We solve the game backwardly.

4.3 Equilibrium Solutions Under The 3PL's Leadership

We now analyze the equilibrium solutions for each party under this Stackelberg game. We first assume all parties' unit cash opportunity costs are homogeneous, i.e.,

$$a_s = a_r = a_l = a \tag{4-7}$$

The settings of the heterogeneous unit opportunity costs are discussed at the end of this section.

4.3.1 The Bank's Problem

If the supplier needs bank loans to cover his production cost at the initial time epoch, the bank firstly sets the interest rate based on the retailer's pair contract (Huang et al., 2020). According to Equation (4-3), the bank's equilibrium solutions can be obtained as follows.

Lemma 4-1. *Assume $a_j = a$ for all j. For any given q_i and w_{ri}, $i = T, F$, under the 3PL's leadership, we have*

$i = T$, bank's optimal interest rate is

$$r_{bT}^{*}(d_0) = \begin{cases} r_f, \text{ if } A \geq c_s q_T, \\ r_{bT} \in \left(r_f, \dfrac{w_{rT} q_T}{(c_s q_T - A)(1 + a d_0)} - 1 \right] \text{that solves Equation (3)}, \text{ if } A < c_s q_T, \end{cases}$$

$i = F$, bank's optimal interest rate is

$$r_{bF}^{*}(d_0) = \begin{cases} r_f, \text{ if } A \geq c_s q_F, \\ r_{bF} \in \left(r_f, \dfrac{w_{rF} q_F (1 + a(d_0 - d_g))}{(c_s q_F - A)(1 + a d_0)} - 1 \right] \text{that solves Equation (3)}, \text{ if } A < c_s q_F. \end{cases}$$

Lemma 4-1 shows that irrespective of the service mode, as long as the bank would like to provide finance to the supplier, there is a unique interest rate depending on the supplier's initial capital level. If his capital is larger than the production cost, in view of the competitive finance market, the bank sets the interest rate as r_f. If his capital cannot cover the production cost, then the bank's decision on r_{bi} will be greater than or equal to the risk-free interest r_f and less than or equal to a certain threshold in both models. This result is also supported by the previous literature (e.g., Tunca and Zhu (2018), Hua et al. (2021)). Further, it is intriguing to find that the bank considers the impact of the retailer's payment delay (if any) circumstances when setting interest rates in both models. This exactly reflects a newly developed bank-intermediated trade finance scheme, which is called dynamic trade finance, under which banks dynamically adjust interest rates as orders go through different procedures in the trade process (Lee et al., 2022). In our model, the payment delay term covers the entire trade process. In addition, given $q_T = q_F$ and the value of w_{rT} and w_{rF} as presented in later sections, we observe that the range for setting r_{bi} when $A < c_s q_i$ in Model F is the same as that in Model T. In other words, the

3PL's financing role has no impact on the bank's decisions for determining the range of the interest rate.

4.3.2 The Supplier's Problem

According to Equations (4-4), the impact of the retailer's payment delay on the supplier can be obtained as follows.

Lemma 4-2. *Assume $a_j = a$ for all j. For any given q_i and w_{ri}, $i = T, F$, under the 3PL's leadership, we have:*

(1) For $i = T$, given an exogeneous d_0, π_{sT} decreases in payment delay d_0 and the optimal acceptable payment delay which could help maximize the supplier's profit is $\hat{d}_0 = 0$. To avoid the supplier's bankruptcy, $d_0 \in \left[0, \frac{w_{rT} q_T}{a\left(c_s q_T - A\right)\left(1 + r^*_{bT}\right)} - \frac{1}{a}\right]$.

(2) For $i = F$, given an exogeneous d_g, π_{sF} decreases in advance payment d_g and the optimal advance payment term which could help maximize the supplier's profit is $\hat{d}_g = 0$. To avoid the supplier's bankruptcy, $d_0 \in \left[0, \frac{w_{rF} q_F\left(1 + a\left(d_0 - d_g\right)\right)}{a\left(c_s q_F - A\right)\left(1 + r^*_{bF}\right)} - \frac{1}{a}\right]$.

In Lemma 4-2, we mathematically prove that no matter which model is adopted, the supplier would like to be paid as early as possible to maximize his profit, i.e., $\hat{d}_0 = \hat{d}_g = 0$, and the payment delay reduces the supplier's profit in both service modes. However, in practice, the retailer always wants to enforce a payment delay to increase her liquidity while a long payment delay may result in bankruptcy for the supplier. Considering this contradictory point, we demonstrate that in Model T, when $A \leq c_s q_T$, $0 \leq d_0 \leq \frac{w_{rT} q_T}{a(c_s q_T - A)(1 + r_{bT})} - \frac{1}{a}$ must be satisfied; otherwise, the supplier goes bankrupt. This range on d_0 can thus be regarded as the *acceptable payment delay range*. Lemma 4-2 (2) then presents the acceptable payment delay range for Model *F*. It should be noted that in Model *F*, the supplier receives payment at t_2 through the advance payment scheme, so that the "delay term" is d_g, instead of d_0. To distinguish the two models, d_0 is named as the *payment delay term*, while d_g is named as the *advance payment term*. In addition, if the bank raises the interest rate, the burden of the supplier to repay the loan plus the interest increases. So, to mitigate the bankruptcy risk, the supplier needs to collect money quickly to enhance his working capital level and cash flow. Then, the acceptable payment delay range will be shortened in both models. In addition, one may assume that to relieve the supplier's bankruptcy risk, the 3PL's financing role (in Model *F*) may be able to help the supplier obtain a wider acceptable payment delay range, compared with that in Model T. However, given $q_T = q_F$ and the value of w_{rT} and w_{rF} as presented in later sections, we find that the acceptable payment delay ranges are the same in the two models if the bank sets identical interest rates in the two models. Thus, under this circumstance, the 3PL's financing role cannot help widen the supplier's acceptable payment delay range.

4.3.3 The Retailer's Problem

According to Equation (4-5), the retailer's equilibrium solution can be obtained as follows.

Lemma 4-3. *Assume $a_j = a$ for all j. For any given w_{li}, $i = T, F$, under the 3PL's leadership, we have*

(1) $q_i^*(w_{ri}^*, w_{li})$,

$$= \begin{cases} \bar{F}^{-1}\left(\dfrac{c_s\left(1+ad_0\right)\left(1+r_f\right)+w_{li}\left(1+ad_r\right)}{p}\right), & if\ i=T, \\ \bar{F}^{-1}\left(\dfrac{\left(c_s\eta_s\left(1+r_f\right)+w_{li}\right)\left(1+ad_r\right)}{p}\right), & if\ i=F. \end{cases}$$

(2) w_{ri}^*

$$= \begin{cases} c_s\left(1+ad_0\right)\left(1+r_f\right), & if\ i=T, \\ c_s\eta_s\left(1+r_f\right),\ where\ \eta_s=\dfrac{1+ad_0}{1+a(d_0-d_g)}, & if\ i=F; \end{cases}\ , and\ w_{rT}^* > w_{rF}^*$$

Lemma 4-3 shows that the retailer would set a higher wholesale price in Model T. This is because early payment to the 3PL results in opportunity costs for the retailer in Model F. Thus, she would like to lower the wholesale price to mitigate the loss of opportunity cost. As for the optimal order quantity, since the calculation needs the information regarding the logistics service fee w_l set by the 3PL, we discuss q_T^* and q_F^* in later sections.

4.3.4 The 3PL's Problem

Lemma 4-3 (1) indicates that there is a one-to-one mapping between $q_i^*(w_{ri}^*, w_{li})$ and w_{li} in both models, as $\bar{F}^{-1}()$ is a monotonic and decreasing function. We transform the 3PL's equilibrium solution of the optimal service fee to the solution of the retailer's optimal order quantity from the 3PL's perspective. We denote the optimal order quantity under this circumstance as q_{sci}, i.e., $q_{sci} \equiv q_i^*(w_{ri}^*, w_{li})$. Substituting q_{sci} and w_{ri}^* obtained from Lemma 4-3 in Equation (4-6) yields

$$\pi_{li}(q_{sci})=\left(p\bar{F}(q_{sci}) - c_s\left(1+r_f\right)(1+ad_0) - c_l(1+a_l d_r)\right)q_{sci}, i = T, F \tag{4-8}$$

Then we acquire the 3PL's optimal solution as follows.

Lemma 4-4. *Assume $a_j = a$ for all j. Under the 3PL's leadership, the system's equilibrium order quantity q^*_{sci}, $i = T, F$, solves the following function:*

$$p\bar{F}(q_{sci})\big(1 - H(q_{sci})\big) - c_s\big(1 + r_f\big)(1 + ad_0) - c_l(1 + ad_r) = 0, i = T, F.$$

Lemma 4-4 indicates that $\pi_{li}(q_{sci})$ is unimodal and concave in $q_{sci} \geq 0, i = T, F$. Based on the value of q^*_{sci}, the 3PL's service fee can be deduced accordingly. Therefore, to conclude the above findings, we form our first main result as in Proposition 4-1.

Proposition 4-1. *Assume $a_j = a$ for all j. Under the 3PL's leadership,*

(1) $q^*_{scT} = q^*_{scF}$;

(2) $$w^*_{li} = \begin{cases} \dfrac{p\bar{F}(q^*_{sci}) - c_s(1 + ad_0)(1 + r_f)}{1 + ad_r}, & if\ i = T, \\ \dfrac{p\bar{F}(q^*_{sci})}{1 + ad_r} - c_s\eta_s\big(1 + r_f\big), & if\ i = F; \end{cases}$$ *,and $w_{lT} > w_{lF}$;*

(3) $\pi_{lT} = \pi_{lF}$; $\pi_{rT} = \pi_{rF}$.

Proposition 4-1 demonstrates that, under identical unit opportunity costs, the 3PL's joint services cannot improve the performances of the retailer and 3PL (i.e., $\pi_{lT} = \pi_{lF}$; $\pi_{rT} = \pi_{rF}$). Both these two players are indifferent to the service mode. Hence, the 3PL's financing role fades under this scenario. There are two further observations. First, the retailer's order quantity is identical in both models (i.e., $q^*_{scT} = q^*_{scF}$). Therefore, it is seen that the retailer chooses to lower only the wholesale price, instead of the ordering quantity, to mitigate the loss of opportunity cost caused by paying earlier. The reason for not reducing the order quantity is explained as follows. The retailer can offset its loss by either reducing the wholesale price or ordering less. The former only affects the supplier, while the latter would impose direct impacts on both the supplier and the 3PL. Thus, the retailer tends to only reduce the wholesale price. Second, for the 3PL, it holds an extra revenue $w_{rF}q_F a_l(d_g - d_s)$ between $t_1$and t_2 (See Figure 4-1) in Model F. In order to enjoy the added time value of cash during this period and let the retailer agree to participate in the game, the 3PL has an incentive to proactively lower the service fee (i.e., $w_{lT} > w_{lF}$) given $q^*_{scT} = q^*_{scF}$. Consequently, the lower service fee and the lower wholesale price plus the identical order quantity result in the final profits being unchanged in Model F for the 3PL and the retailer.

4.3.5 The Preference of The Supplier

The next question is what the supplier's preference is. The following proposition gives the answer.

Proposition 4-2. *Assume $a_j = a$ for all j. Under the 3PL's leadership,*

(1) For a capital-constrained supplier (i.e., $A < c_s q$), $\pi_{sT} = \pi_{sF} = 0$,

(2) For a capital-sufficient supplier (i.e., $A \geq c_s q$), π_{si} increases in q^*_{sci}, $i = T, F$, and $\pi_{sT} = \pi_{sF}$.

Proposition 4-2 shows that the supplier's profit and the preference of the service modes heavily depend on his initial capital level. Proposition 4-2(1) shows that if the supplier is constrained by the initial capital (implying he needs to borrow money from the bank), his optimal profit is zero in both models. This is an extreme case as all the profit of the supplier is extracted by the powerful retailer. On the other hand, if he has a relatively high initial capital level ($A \geq c_s q$), Proposition 4-2(2) shows the supplier benefits from the increasing order quantity but earns identically in both models. This implies that in Model *F*, although the supplier benefits from the 3PL's advance payment and accumulates the time value of cash from time epoch t_2 to t_3, the lower wholesale price offered by the retailer still limits his earnings and eventually leads to the same level of profit in both models. In general, this phenomenon further demonstrates that, compared with its traditional role, the 3PL's financing role does not realize profit improvement for the retailer, the 3PL, and the supplier.

4.3.6 When The Unit Opportunity Cost Rate Is Heterogeneous Under The 3PL's Leadership

In this section, we examine the impact of heterogeneous unit opportunity cost rates on the equilibrium solutions considering that companies may have different costs of capital (Modigliani and Miller, 1958) and distinct ROIs (i.e., return on investment) (Kwak and Ibbs, 2000). The unit cash opportunity costs for the supplier, retailer, and 3PL are denoted as a_s, a_r, a_l, respectively. For ease of exposition, we define $a_{max} = max\{a_s, a_r, a_l\}$ and $a_{min} = min\{a_s, a_r, a_l\}$.

We solve the game backwardly as well to obtain the equilibrium solutions and give Lemma 4-5.

Lemma 4-5. *For any given a_s, a_r, a_l, under the 3PL's leadership, the equilibrium order quantity q^*_T and q^*_F solves the following function iff $a_s > a_l > a_r$:*

$$\begin{cases} p\bar{F}(q^*_T)\frac{1+a_l d_r}{1+a_r d_r}\left(1 - H(q^*_T)\right) - c_s(1 + a_s d_0)\left(1 + r_f\right)\frac{1+a_l d_r}{1+a_r d_r} - c_l(1 + a_l d_r) = 0, \\ p\bar{F}(q^*_F)\frac{1+a_l d_r}{1+a_r d_r}\left(1 - H(q^*_F)\right) - c_s\left(1 + r_f\right)\left(1 + a_l(d_0 - d_g)\eta_s - c_l(1 + a_l d_r\right) = 0 \end{cases}$$

Lemma 4-5 shows more complicated results compared with the case where the unit cash opportunity costs for the three players are the same. We observe that Lemma 4-5 is also a general form of Lemma 4-4 by distinguishing the various unit cash opportunity costs. In addition, it is rather interesting to find that the uniqueness of the equilibrium optimal order quantity is dependent on the value of each party's unit cash opportunity cost, i.e., $a_s > a_l > a_r$. That is, the retailer's opportunity cost rate should be the smallest among the others, although the 3PL is the leader in this game. It can be intuitively hypothesized that a firm's opportunity cost may be related to the firm's capital level. That is, the financially strong retailer who does not need to be concerned about the investment failure could have a low unit opportunity cost rate, followed by a 3PL with sufficiently high capital level (but lower than the retailer), then by the supplier. We infer that the supplier always has an incentive to earn more profits from other places to relieve his financial stress, so he may pay much more attention to the investment. That is, for the supplier, success or failure is a big deal, thus inducing a larger opportunity cost rate. All values of $a_j, j = s, r, l,$ satisfying the above mechanism can induce a unique optimal order quantity in both models. The model preference for each party under the 3PL's leadership given different unit cash opportunity costs are presented as in Proposition 4-3.

Proposition 4-3. *For any given a_s, a_r, a_l and $a_s > a_l > a_r$, under the 3PL's leadership, the preference of the model for the 3PL and the retailer is non-measurable. The supplier's circumstance is the same as Proposition 4-2, except that a is replaced by a_s.*

Proposition 4-3 demonstrates the problem complexity when the unit cash opportunity costs are heterogeneous. The relationship between q_T^* and q_F^* is no longer clear in a general form, and this results in incommensurable profits in Model T and Model F for the retailer and the 3PL. While for the supplier, its profit is zero in both models as in the homogeneous cash opportunity cost setting when he is capital constrained. Moreover, when the supplier is capital sufficient, he is indifferent in the two models as he earns equally. These findings are consistent with Proposition 4-2. Thus, we conclude that the heterogeneous cash opportunity cost setting does not qualitatively change the preferences of the supplier under the 3PL's leadership.

4.4 Equilibrium Solutions Under The Retailer's Leadership

To explore the effects of the party's leadership, ceteris paribus, we now study the scenario when the retailer becomes the leader in both models. Similarly, we first analyze the homogeneous unit opportunity cost rates and then the heterogeneous rates.

4.4.1 When The Unit Opportunity Cost Rate Is Homogeneous

In order to avoid redundant notations, we do not differentiate the decision variables under different leaderships. We solve the game backwardly as well to obtain Proposition 4-4.

Proposition 4-4. *Assume $a_j = a$ for all j. Under the retailer's leadership,*

(1) $q_{scT}^* = q_{scF}^* = \bar{F}^{-1}\left(\frac{1}{1+r_f}\right)$;

(2) $w_{lT}^* > w_{lF}^*$;

(3) $\pi_{rT} = \pi_{rF}$; $\pi_{lT} = \pi_{lF}$; $\pi_{sT} = \pi_{sF}$.

Proposition 4-4 demonstrates an interesting result: referring to Propositions 4-1 and 4-2 that are obtained from the homogeneous opportunity cost rates setting, we find that whether the market is led by the 3PL or the retailer does not qualitatively affect the effect of 3PL's financing role. The 3PL's financing advantage diminishes for these participants under the retailer's leadership as well. In addition, we observe that the optimal order quantity is only related to the risk-free interest r_f and demand distribution F. Furthermore, the 3PL also reduces the service fee to attract the retailer to join the game.

4.4.2 When The Unit Opportunity Cost Rate Is Heterogeneous

We now examine the case with different unit opportunity cost rates for the three parties.

Proposition 4-5. *For any given (heterogeneous) a_s, a_r, a_l, under the retailer's leadership, the results remain the same as in Proposition 4-4, except that: When $a_s \geq a_l \geq a_r$, we have $\pi_{lT} \geq \pi_{lF}$; When $a_r \geq a_l \geq a_s$, we have: $\pi_{lF} \geq \pi_{lT}$.*

Proposition 4-5 implies that other than the 3PL, the impact of the different unit opportunity cost rates is minor in terms of the participants' performance. Nevertheless, for the 3PL, it is interesting to find that given different conditions of the opportunity cost setting, the 3PL's preference of the service mode changes. That is, the 3PL's (advance payment) financing role helps improve its profit when the three parties' unit opportunity cost rates satisfy $a_r \geq a_l \geq a_s$, under the retailer's leadership. This result is different to the case under the 3PL's leadership, where the preference of the model for the 3PL and the retailer is incommensurable (recall Proposition 4-3).

4.5 Summary

In the presence of the retailer's payment delay, we theoretically analyze the value of the 3PL's financing role and compare it with its traditional role in a supply chain. In the wholesale price and order quantity pair contract established by the retailer, the 3PL provides either the traditional delivery service mode (Model T) or the delivery service plus the financing service mode (Model F). Considering the time value of cash, we characterize the equilibrium solutions in both models and show that the 3PL's financing role is not always appealing for the participated parties in terms of profit improvement.

Under either the 3PL's leadership or the retailer's leadership when the three parties face a homogeneous unit opportunity cost rate, the retailer, the 3PL, and the supplier's profits in Model T are the same as in Model F. Therefore, given the homogeneous unit opportunity cost rate setting, it is striking to find that the 3PL's financing role does not generate improvements for these supply chain participants. In particular, no matter who is the market leader, the retailer orders identically in the two models and sets a lower wholesale price to deal with the opportunity cost loss in Model F. In order to induce the retailer to be involved in the contract, the 3PL would like to reduce its service fee. If the retailer joins the game, the 3PL can enjoy an extra time value of cash from time epoch t_1 to t_2. These factors are intertwined and finally result in no profit increase for the 3PL and the retailer. As for the supplier, his profit depends on his initial capital level. However, no matter whether he is a capital-constrained supplier or a capital-sufficient supplier, his profit is unchanged in Model F due to the retailer's lower wholesale price. Moreover, we observe that the supplier's optimal acceptable payment delay is 0 in both models. To help the supplier avoid bankruptcy, we identify a certain range of payment delay within which the supplier can be safe if the delay occurs in both models. In addition, in the presence of the retailer's payment delay, we find the bank, the retailer, and the 3PL will all consider the payment delay effects when making optimal decisions (i.e., d_0/d_g appears in their equilibrium solutions) in both models. Lastly, we find that under the retailer's leadership, the 3PL's financing significance in terms of the profit improvement only exists for the 3PL itself if the heterogeneous unit opportunity cost rates can satisfy certain conditions.

Chapter 5: Contracting with Chinese Electric Vehicle Makers with Capital Constraints and Default Risk

In this chapter, we study a game-theoretical model that captures the interplays among three players (a BS, a capital-limited EV-maker who can make costly and unobservable effort to increase repayment probability, and a bank).

5.1 Problem Description

To satisfy the financing needs of the EV-makers, two available financing schemes are adopted in the current market. The first is known as BLF, under which banks lend to an EV-maker after a comprehensive evaluation. BLF is a common and easy financing scheme for both lenders and debtors, and the repayment of a BLF loan hinges on the EV-maker's capital level at the end of the selling season. Hence, in order to avoid default risk, the EV-maker should make effort to improve his operational efficiency by strengthening external retailing channels to increase revenue and improve the internal manufacturing process to save costs simultaneously. Because as a giant BS whose goods delivery is stable, the major risk related to BLF is not the BS's performance risk but the EV-maker's default risk, i.e., the EV-maker's inability to pay back to the bank (Yan and Sun, 2013). The second scheme, TCF, under which the BS performs as both the supplier and the lender and directly lends to the EV-maker by delayed payment. TCF is economically significant, and the amount of trade credit owed by buyers to suppliers is almost as same as bank loans on the aggregated balance sheet of nonfinancial U.S. businesses (Federal Reserve Board 2022). Astvansh and Jindal (2022) provide a list of examples of companies that adopted TCF as their payment methods in various regions and industries. In the EV industry, TCF is widely implemented as well. For example, Panasonic regulates the trade credit terms with Tesla in light of the battery orders[12]; Byton, a start-up EV-maker in China, secured trade investment from CATL in 2018[13].

We thus raise two research questions in this chapter:

RQ 5-1. By playing a role of a supplier under BLF, and a role of both a supplier and a lender under TCF, how the BS can incentivize an EV-maker to mitigate his default risk under these two types of financing schemes?

[12] Please refer to https://www.sec.gov/Archives/edgar/data/1318605/000119312510017054/dex1033.htm
[13] Please refer to https://www.electrive.com/2018/06/11/byton-secures-investment-from-catl-closes-with-500m/

RQ 5-2. Can TCF, under certain conditions, become a superior financing option due to the BS's information advantage on the EV-maker's operational efficiency?

By establishing a Stackelberg game with three players: a BS, a capital-limited EV-make with the potential to make costly and unobservable effort to increase repayment probability, and a bank lying in a competitive financing market (under the BLF scheme), we are able to answer the first question in the following ways. Two available financing schemes, i.e., BLF and TCF, can be used by the EV-maker to pay his purchase price. We initially assume that there is no information asymmetry between the BS and the bank in terms of the EV-maker's operational efficiency in order to concentrate on the BS's control advantage. Then we extend the abovementioned model by considering the BS's information advantage over the bank regarding the EV-maker's efficiency type to answer the second question. The EV-maker thus can either be an efficient one or an inefficient one based on his operational capability. When reaching the same loan repayment probability, the efficient EV-maker expends less work than the inefficient EV-maker. Furthermore, the bank only knows the probability distribution of the EV-maker's type, whereas the BS is aware of the true type of the EV-maker. The results of TCF under information asymmetry remain unchanged since the BS realizes the true type of the EV-maker and the bank does not take part in TCF. However, it is unclear how BLF will act in this situation.

5.2 Supplying with BLF

We first focus on how the BS's supply contracts and two common financing solutions can reduce the moral hazard for the EV-maker. In Section 5.2, we first examine this issue under the BLF scheme, then in Section 5.3, we examine it under the TCF scheme. In later parts, it will be addressed how these two financing options compare when moral hazard and information asymmetry are presented.

5.2.1 The Model

We investigate a supply chain with three risk-neutral participants: a BS (she), an EV-maker (he), and a bank (it). In subsequent sections, we first demonstrate the model's foundations before moving on to the financing solution.

5.2.1.1 Preliminaries

To satisfy the market demand, the EV-maker finds the BS who would like to supply batteries and offer a supply contract to the EV-maker. We denote the BS's unit production cost as c_p>0. We assume that the EV-maker only has fixed assets (such as manufacturing facilities and equipment) and no readily available cash, thus he will default on the payment to the BS. Hence, he is motivated to access financing from a bank. The BS audits the EV-maker's assets level before going to the contracting stage. The scaled value of the assets $a \geq 0$ is then disclosed to all participants. To focus on the EV-maker's default risk, without losing generality, the order that the BS promises to supply is normalized to 1. The wholesale price $p > 0$ is determined by the BS. We adopt the assumption that a is not more than the EV-maker's purchasing cost p ($a \leq p$) in order to avoid trivial instances.

In addition, the EV-maker is intrinsically unreliable and can only return the loan with a specific likelihood. The EV-maker can boost the likelihood of payback by making costly and unobservable effort to else parties (e.g., enhancing sales channels to increase revenues). We scale the basic repayment chance to 0 without losing generality. The EV-maker must exert effort that is associated with a disutility (cost of effort) in order to raise the repayment likelihood from 0 to e, where $e \in (0,1)$. The disutility of EV-maker's effort e is characterized by an increasing convex function ge^2 with $g > 0$ (Tang et al., 2018; Li, 2013). Nature determines that there are two types of EV-makers: efficient and inefficient. The operational efficiency of the EV-maker is captured by the cost (effort) factor g: an efficient EV-maker (i.e., with a lower g) can accomplish the same repayment likelihood with less work than an inefficient EV-maker (i.e., with a higher g).

To study the EV-maker's moral hazard, we assume that g is revealed to all participants. Nevertheless, this model will be extended to account for the case where the EV-maker and the BS are the only parties who are aware of the true value of g, leaving the bank with merely the distribution in Section 5.4.

5.2.1.2 Modeling BLF

The BS, who plays as the leader in this Stackelberg game, sets the contract term p. The EV-maker, as the follower, receives the wholesale price p that is acceptable to him after considering his operational capacity[14]. Upon successful delivery, as shown in Figure 5-1, the EV-maker goes to the bank and applies for a loan of p. By considering the contract p and the EV-maker's asset level a, the bank decides

[14] Generally, the BS offers a huge amount of orders to decrease her marginal production cost to customers. So, the purchasing cost is huge as well. If the EV-maker's operational capacity cannot digest these orders sufficiently (e.g., limited production capacity), the EV-maker needs to consider the feasibility of the participation. For example, due to the limited production capacity and the increasing battery price, a Chinese EV brand GAC AION refuses to source batteries from CATL (https://www.163.com/dy/article/HCSH8SB90511B8LM.html). However, after estimating the effort the EV-maker himself will make, which may fill the capacity gap, the EV-maker still wants to source from this giant BS.

whether to lend p to the EV-maker and, if so, how to charge the interest rate i_B[15]. Then, if appropriate, the bank pays the BS p amount[16]. Therefore, the BS aims to maximize her payoff π_S, where

$$\pi_S = p - c_p. \tag{5-1}$$

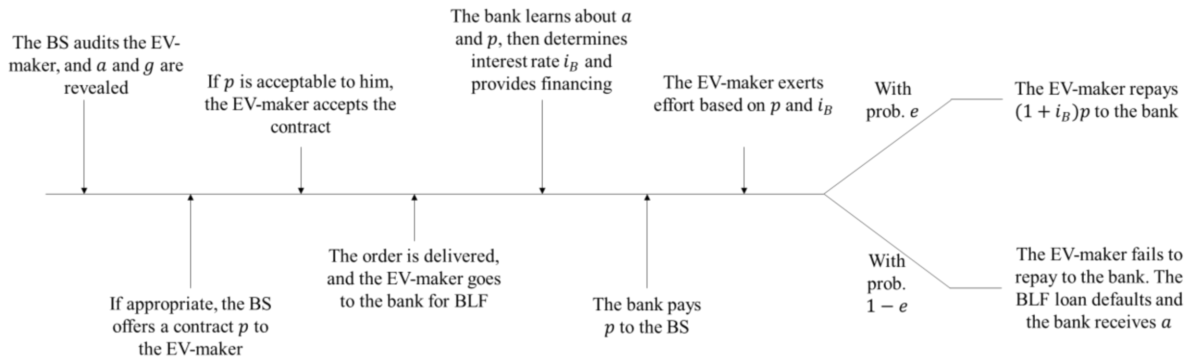


Figure 5-1 Sequence of Events Under BLF When There Is No Information Asymmetry

Under this BLF scheme, if the EV-maker repays the principal and interest $(1 + i_B)p$ successfully, he can survive on the market, and the BS may continuously contract with him. If the repayment is failed, the bank does not get paid, and the BLF loan defaults, then the bank confiscates the EV-maker's fixed assets a. In the case of repayment failure, the EV-maker will access financing via an alternative funder emergently with a cost of $c_e > 0$. Therefore, the EV-maker's payoff π_M can be counted as the expected cost savings via financing through the bank under BLF, where

$$\pi_M = c_e - [e(1 + i_B)p + (1 - e)(c_e + a) + ge^2]. \tag{5-2}$$

As presented, π_M contain four parts: the alternative emergency cost c_e, the expected purchasing cost upon successful repayment to the bank (i.e., the loan amount plus interest) $e(1 + i_B)p$, the expected loss of assets to the bank plus the alternative emergency cost in the occurrence of repayment failure $(1 - e)(c_e + a)$, and the cost of effort ge^2. Since we focus on a capital-limited EV-maker who is eager to source from the big BS so as to obtain qualified and stable battery supplies, we assume that, once the contract is offered, the EV-maker affirmatively accepts the offer without outside options. Therefore, without loss of generality, the EV-maker accepts a contract only when $\pi_M \geq 0$.

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[15] There is another terminology for this type of lending that commonly occurs in industries, i.e., contract financing, referring to a trade receives advance financing on an awarded contract that is yet to complete.

[16] In practice, if the EV-maker cannot pay the BS in due course, the BS stops the battery supply and presses for a payment. Even worse, the BS prosecutes an appeal if the EV-maker defaults on the contract in the end. For example, a case of Byton is given at https://www.electrive.com/2021/09/16/foxconn-suspends-plans-with-byton/.

Finally, to concentrate on the EV-maker's default risk, as long as the contract is accepted, we assume that the BS will produce and deliver the batteries with no delivery risk. The bank manages the interest rate in order to ensure that the payback amount equals its expected profits in a risk-free market with a risk-free interest that is normalized to 0. This setting is reasonable because the bank is assumed to lie in a competitive lending market.

5.2.1.3 The First-Best Benchmark

We first demonstrate the benchmark model, i.e., the first-best scenario, where the supply chain is centralized. Hence, the EV-maker does not need to pay the BS (i.e., $e = 0$) and access financing either. The expected cost savings are equal to $\pi_{FB} = c_e - [c_p + ge^2]$.

Lemma 5-1. *In a centralized supply chain, the BS contracts with the EV-maker if and only if* $c_e \geq c_p$. *The corresponding payoff of the chain is* $c_e - c_p$.

From Lemma 5-1, to avoid triviality, we assume that $c_p < c_e$ throughout this chapter.

5.2.2 The EV-Maker's Response Under BLF

As shown in Figure 5-1, we now solve this Stackelberg game backwardly. First, given the contract price p and the interest rate i_B, solving the first-order condition of (5-2), the EV-maker's optimal effort is as follows

$$e(p, i_B) = \frac{c_e + a - (1 + i_B)p}{2g}. \tag{5-3}$$

By substituting (5-3) into the EV-maker's payoff π_M given in (5-2), we have

$$\pi_M = \frac{(c_e + a - (1 + i_B)p)^2}{4g} - a. \tag{5-4}$$

Therefore, the EV-maker's participation constraint, i.e., $\pi_M \geq 0$, is

$$p \leq \frac{c_e + a - 2\sqrt{ga}}{1 + i_B}. \tag{5-5}$$

5.2.3 The Bank's Response Under BLF

The bank can estimate the EV-maker's effort $e(p, i_B)$ as given in (5-3) after taking note of the contract p provided by the BS. Then the bank sets the interest rate i_B to break even its expected profit in a risk-free market. Namely, the loan amount p equals the bank's expected payoff $e[(1+i_B)p] + (1-e)a$. We may derive the bank's breakeven condition, often known as the bank's lending (BL) constraint, by substituting e given in (5-3), and we have $c_e \geq \sqrt{8g(p-a)}$. This constraint implies that, to trigger the bank's lending behavior, the alternative cost c_e faced by the EV-maker must be adequately high with respect to $(p-a)$, the EV-maker's net financing need. Hence, to help release the EV-maker's financial burden, the bank is willing to provide loans to the EV-maker when necessary. This phenomenon is consistent with the implementation of the Chinese *"dual credit"* policy in the EV industry[17]. Therefore, given the contract price p and the BL constraint being met, the bank determines the optimal interest rate at[18]

$$i_B(p) = \frac{\sqrt{8g(p-a)}}{2p} + \frac{a}{p} - 1. \tag{5-6}$$

5.2.4 The BS's Optimal Contract Under BLF

Then we can have the EV-maker's best effort response by substituting the bank's equilibrium interest rate in (5-6) to (5-3), it thus becomes

$$e(p) = \frac{2c_e - \sqrt{8g(p-a)}}{4g} \tag{5-7}$$

and the EV-maker's participation (EP) constraint in (5-5) can be rewritten as $p \leq \frac{2p(c_e + a - 2\sqrt{ga})}{\sqrt{8g(p-a)} + 2a}$, or equivalently,

$$p \leq \frac{(c_e - 2\sqrt{ga})^2}{2g} + a \tag{5-8}$$

which defines the joint participation constraint under which the EV-maker will accept the contract and the bank will lend to the EV-maker. Considering the joint participation constraint (5-8), the BS's payoff in (5-1) can be rewritten as

$$\pi_S = (p - c_p) \cdot \mathbf{1}_{\{p \leq \frac{(c_e - 2\sqrt{ga})^2}{2g} + a\}}. \tag{5-9}$$

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17 Please refer to https://cnevpost.com/2021/07/25/chinas-dual-credit-policy-what-you-need-to-know/

18 The competitions between financial institutions induce the bank to offer the lowest interest rate.

The goal of the BS is to choose the best contract term $p^B > 0$ that will maximize her payoff as specified in (5-9)[19]. Proposition 5-1 gives the corresponding equilibrium outcomes.

Proposition 5-1. *The description of the equilibrium solutions and the optimal contract* p^B *under BLF are:*

1. When $a = 0$ *and* $g \leq \frac{{c_e}^2}{8c_p}$, *the BS contracts with the EV-maker and offers* $p^B = \frac{{c_e}^2}{2g}$, *the bank lends to the EV-maker and charges an interest rate* $i_B^B = \frac{2g}{c_e} - 1$, *and the equilibrium repayment probability* $e^B = 0$. *In addition, the BS's and the EV-maker's payoffs are given as* $\pi_S^B = \frac{{c_e}^2}{2g} - c_p > 0$, $\pi_M^B = 0$, *respectively.*

2. When $a \geq \max\left(\frac{8gc_p - {c_e}^2}{8g}, \frac{6gc_p + {c_e}^2 + 2c_e\sqrt{12gc_p - 2{c_e}^2}}{18g}\right)$ *and* $g > \frac{{c_e}^2}{8c_p}$, *the BS contracts with the EV-maker and offers* $p^B = \frac{(c_e - 2g)^2}{2g} + a$, *the bank lends to the EV-maker and charges an interest rate* $i_B^B = \frac{2g(c_e - 2g + a)}{(c_e - 2g)^2 + 2ga} - 1$, *and the equilibrium repayment probability* $e^B = 1$. *In addition,* $\pi_S^B = \frac{{c_e}^2}{2g} - c_p + a + 2(g - c_e) > 0$, $\pi_M^B = g - a \geq 0$, *respectively.*

3. When $a \in \left(\frac{\left(c_e - \sqrt{2g(c_p - a)}\right)^2}{4g}, \frac{(c_e + \sqrt{2g(c_p - a)})^2}{4g}\right)$ and $a < \frac{8gc_p - {c_e}^2}{8g}$ *the BS does not contract with the EV-maker* ($p^B = \infty, i_B^B = \infty, e^B = 0$), *and* $\pi_S^B = \pi_M^B = 0$.

Proposition 5-1 shows that whether the BS would like to contract with the EV-maker, is heavily depending on the EV-maker's asset value a and the cost factor g after auditioning under BLF. When the EV-maker has a relatively small cost factor (i.e., $g \leq \frac{{c_e}^2}{8c_p}$, the EV-maker is thus viewed as a strictly efficient type by the BS), although he has no asset value[20], the BS would like to cooperate with him based on his potential. These strictly efficient EV-makers usually hire excellent technology and management teams, benefit from numerous government subsidy policies, and attract a bunch of investors to join in. Hence, the BS considers that they have better competitive advantages than their rivals and is willing to bear the financial risk and contract with such EV-makers. For example, CATL invested in a start-up company Byton Motor, whose car designer was previously employed at BMW; and co-invested with NIO Motor (whose management teams mostly were used to work in the world-

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[19] In order to prevent notational abuse, we utilize superscript *B* to express the associated optimal results under BLF in the case of symmetric information. In Section 5.3, we utilize superscript *T* for optimal outcomes under TCF and superscript *A* for BLF in the case of asymmetric information in Section 5.4.

[20] These EV-makers usually cooperate with other OEMs to use their plants for EV production in the initial stage, such as NIO and XPENG.

renowned automakers such as Volvo and Ford) in the establishment of a battery asset company[21]. Both Byton Motor and NIO are Chinese government-funded companies that will benefit from the nationwide and local policies. However, these start-ups who have little assets greedily enjoy consistent investments from investors mainly for R&D, which leads them to have an awareness that they are nothing to lose (e.g., the asset) and do not attach importance to paying back the loans to the bank (if any). For instance, CHINA EVERGRANDE NEW ENERGY VEHICLE, a Chinese EV brand, stated they have a high default risk on bank loans in 2021 but made little effort on repaying the loans[22]. Therefore, the EV-maker does not exert effort to repay the loan under this scenario. However, under the "*dual credit"* policy, these EV-makers can still have the opportunity to obtain financing from the bank, hence it charges an interest rate at $i_B^B = \frac{2g}{c_e} - 1$[23]. To offset the EV-maker's financial burden, the BS should fix the wholesale price at $p^B = \frac{{c_e}^2}{2g}$ to maximize her profit.

Next, when the EV-maker is not viewed as a strictly efficient type (i.e., $g > \frac{{c_e}^2}{8c_p}$), but his asset value is raised to a certain range as presented in Proposition 5-1(2), the BS still wants to contract with him because of the guarantee of the EV-maker's substantial assets. In practice, the BS would like to provide batteries for some big but stereotypical car brands, especially for those traditional ICEV-makers who have several established plants but old-fashioned equipment. Compared with the new EV-makers, these ICEV-makers are less efficient in transforming from ICEV production into the EV production process. This is supported by the anecdotal evidence that the high efficiency of the manufacturing process makes Tesla a great success in the global automobile sector (Perkins and Murmann, 2018). Besides, considering the trend of EV development, policy, environment protection, etc., these factors push the ICEV-makers to start EV production as well and they are eager to source batteries from well-known suppliers. For instance, Honda and CATL signed a battery supply agreement in 2020[24]. For these EV-makers, they will make full effort to repay the bank if loans exist in order to protect fixed assets and maintain their reputations. Observing this, the BS sets the optimal contract price $p^B = \frac{(c_e-2g)^2}{2g} + a$, that is acceptable to the EV-maker. As the EV-maker's asset level is huge and the repayment probability is one, the bank charges a rate $i_B^B = \frac{2g(c_e-2g+a)}{(c_e-2g)^2+2ga} - 1$. As such, both the BS and the EV-maker's payoffs are increased when the EV-maker's asset level falls into this region.

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[21] Please refer to https://www.chinamoneynetwork.com/2021/01/26/chinese-battery-leader-catl-makes-vast-investments-in-evs-self-driving-and-chips.

[22] Please refer to https://finance.sina.com.cn/roll/2021-08-30/doc-iktzscyx1309549.shtml.

[23] An example can be found at http://hb.china.com.cn/2021-12/01/content_41807662.htm. Besides, this phenomenon implicitly reflects one of the rationales of why the central government is reducing subsidy policies recently because of the high default risk borne by the bank.

[24] Please refer to https://www.bestmag.co.uk/catl-and-honda-sign-agreement-develop-new-energy-vehicle-batteries/#:~:text=CATL%20and%20Honda%20sign%20agreement%20to%20develop%20new%20energy%20vehicle%20batteries,16%20Jul%202020&text=Battery%20maker%20Contemporary%20Amperex%20Technology,vehicles%20as%20well%20as%20recycling.

Finally, when the EV-maker's asset level lies in a certain range (implicit form) and the EV-maker's efficiency is uncertain, the BS cannot determine the optimal price to maximize her profit and satisfies (5-8). Specifically, consider the case when $a < \frac{8gc_p - {c_e}^2}{8g}$, the BS's boundary condition $(p \geq c_p)$ and the bank's lending condition $c_e \geq \sqrt{8g(p-a)}$ cannot be satisfied. It implies that if the EV-maker's asset level is in this region, it is interesting to find that any contract the BS offers cannot make the BS earn positive profits as well as it is not economical for the bank to lend. Therefore, contracting with such an EV-maker is simply unprofitable.

In addition, we observe that when the conditions of Proposition 5-1(1) are satisfied, the total supply chain payoffs $(\pi_S^B + \pi_M^B)$ are less than the comparable payoff under the first-best benchmark in Lemma 5-1. We are aware that the principal (BS) can create a contract to attain the first-best benchmark and take all profits if the agent (EV-maker) has sufficient financial resources (Laffont and Martimort 2009, Section 4.2). Nevertheless, when facing a capital-limited EV-maker (i.e., $a = 0$), according to Proposition 5-1(1), the financial constraints on the EV-maker lower the profitability of the supply chain. Further, when the conditions of Proposition 5-1(2) are satisfied, the total supply chain payoffs $(\pi_S^B + \pi_M^B)$ exceed comparable payoff under the first-best benchmark. It is acknowledged when the effort is observable $(e = 1)$ in a complete information optimal contract, the expected payoff could be larger than the first-best outcome (Laffont and Martimort 2001, Section 4.2.3). Proposition 5-1(2) not only confirms that our results are consistent with the previous theorems but also implies that with a sufficiently high asset level and full effort, the BS's contract with such an EV-maker can create an all-win situation.

5.3 Joint Supplying and Financing Under TCF

Proposition 5-1 shows that the total supply chain payoff can be either lower or higher than the first-best solution under the BLF scheme. Is such a phenomenon result from the fact that, the contracting price and the lending interest rate are respectively decided by the BS and the bank? It is generally recognized that a trade credit arrangement in which the supplier sets both the selling price and the interest rate can enhance supply chain performance through demand risk sharing (Kouvelis and Zhao, 2018; Yang and Birge, 2018; Tang et al., 2018; Kouvelis and Xu, 2021). Does the same phenomenon happen in a trade credit scheme with the default risk of the EV-maker? In this section, we investigate whether TCF, where the BS controls both the interest rate and the wholesale price, enhances supply chain performance.

Under TCF, the BS extends the credit terms instead of receiving the payment after battery delivery as shown in the BLF scheme, and the EV-maker thus can enjoy a payment delay to ease his cash flow. The BS stipulates the payment terms that are exogenous to the market, such as 30-120 days after goods delivery, and the EV-maker repays to the BS with an interest charge then. The interest rate is charged to discourage further payment extensions within this prespecified time window (Kouvelis and Zhao, 2018)[25]. Hence, under TCF, the BS decides the contract price p and the interest rate i_S (or equivalently, lends p to the EV-maker) without the involvement of the bank. Then the EV-maker makes effort to pay the BS with probability e. If he pays the BS within the stipulated time window, the BS receives $(1 + i_S)p$. If the EV-maker fails to pay, the BS seizes the EV-maker's asset a.

The interaction between the BS and the EV-maker under TCF is analogous to that under BLF. First, given (p, i_S), the EV-maker's optimal effort response $e(p, i_S)$, and his participation constraint are given in (5-3) and (5-5), respectively, with i_B being replaced by i_S. Forecasting this, the BS determines p and i_S to maximize her payoff $\pi_S = e(1 + i_S)p + (1 - e)a - c_p$, the sum of the expected financing earnings minus the production cost under the TCF scheme, subject to (5-3) and (5-5), with i_B being replaced by i_S.

Proposition 5-2. *The description of the equilibrium solutions and the optimal contract* $(p^T, {i_S}^T)$ *under TCF are:*

1. When $\max\left(\frac{{c_e}^2}{16g}, \frac{{c_e}^2 - c_e\sqrt{{c_e}^2 - 4gc_p}}{2g} - c_p\right) \leq a \leq \frac{{c_e}^2 + c_e\sqrt{{c_e}^2 - 4gc_p}}{2g} - c_p$*, the BS contracts with the EV-maker,* $(p^T, {i_S}^T)$ *is optimal if and only if* $p^T = \frac{c_e + a - 2\sqrt{ga}}{1 + {i_S}^T}$*, the equilibrium repayment probability* $e^T = \sqrt{\frac{a}{g}}$*. In addition, the BS's and the EV-maker's payoffs are given as* $\pi_S^T = c_e\sqrt{\frac{a}{g}} - a - c_p$*,* $\pi_M^T = 0$*, respectively.*

2. When $\frac{{c_e}^2 - c_e\sqrt{{c_e}^2 - 4gc_p}}{2g} - c_p \leq a \leq \min\left(c_p, \frac{{c_e}^2}{16g}\right)$*, the BS contracts with the EV-maker,* $(p^T, {i_S}^T)$ *is optimal if and only if* $p^T = \frac{c_e + 2a}{2(1 + {i_S}^T)}$*, the equilibrium repayment probability* $e^T = \frac{c_e}{4g}$*. In addition, the BS's and the EV-maker's payoffs are given as* $\pi_S^T = \frac{{c_e}^2}{8g} + a - c_p$*,* $\pi_M^T = \frac{{c_e}^2}{16g} - a$*, respectively.*

[25] We do not consider the case in this chapter that the buyer's early payment results in discounted wholesale price which commonly occurs in a trade credit contract as well. The reasons are multi-perspectives. First, since the price of raw materials for producing batteries is volatile. The increase in the raw material price induces the increase in the battery price, e.g., CATL raised the battery prices due to the rising raw material costs (https://www.reuters.com/article/china-autos-catl-idINB9N2VI00I). Hence, the BS will not lower the battery price just because of the early payment. Second, the BS always has sufficient capital resources, so she has no demand to obtain the early payment to ease her cash flow. Third, the BS who has a couple of customers and lies in a leading position in the EV supply chain, will not worry that the batteries cannot sell out, so the price will not be reduced. Fourth, as the capital-limited EV-maker, he has no incentive to pay the BS early.

3. When $a < \frac{c_e{}^2 - c_e\sqrt{c_e{}^2 - 4gc_p}}{2g} - c_p$ or $a > \frac{c_e{}^2 + c_e\sqrt{c_e{}^2 - 4gc_p}}{2g} - c_p$*, the BS does not contract with the EV-maker (*$p^T = \infty, i_B^T = \infty, e^T = 0$*), and* $\pi_S^T = \pi_M^T = 0$.

Proposition 5-2 states whether the BS is willing to contract with the EV-maker, solely depends on the EV-maker's asset value a under TCF. When the EV-maker's asset value a is relatively large, the EV-maker is motivated to make more effort to increase his repayment likelihood in order to protect his assets. As we explained later in this section, TCF always occurs in developing economies. Therefore, although the EV-maker needs to protect his assets by exerting effort to repay the loans, due to the unknown constraints in emerging markets, he cannot make full effort like what he will do under BLF. Further, suppose a scenario that the EV-maker's asset value a decreases within this range, then the equilibrium repayment probability also decreases. To offset the danger of the EV-maker defaulting, the interest rate $i_S{}^T$ will increase due to the decline in both asset level a and the likelihood of repayment e. Identifying this, the BS will set an optimal battery price at p^T to mitigate the EV-maker's financial burden, where $p^T = \frac{c_e + a - 2\sqrt{ga}}{1 + i_S{}^T}$. Next, when the EV-maker's asset a value drops below $\frac{c_e{}^2}{16g}$, with less to lose, the EV-maker is less driven to take steps to raise the likelihood of payback. His effort level then becomes a constant and has nothing to do with his asset level. As such, the BS's payoff is decreased as the EV-maker's asset value a declines. Finally, when the EV-maker's asset level is sufficiently small, it is not economical for the BS to offer a contract that can help her earn positive profits (e.g., the EV-maker has no incentive to make effort to protect his asset, and thus the repayment probability is lower down to zero). For example, Faraday Future, a Chinese EV start-up without a manufacturing plant, due to its long-lasting debt issues, BSs are afraid to collaborate with them and the firm's EV production process is delayed indefinitely[26]. When the EV-maker's asset level is substantially huge, the EV-maker may not accept the contract as well. Because after recognizing the EV-maker's capital resources, the BS may charge a higher price plus a higher interest rate that are unacceptable to the EV-maker[27].

In addition, we discover that the total supply chain payoffs ($\pi_S^T + \pi_M^T$) under TCF are lower than that under the first-best case in Lemma 5-1. It means that, despite the BS having a certain control advantage that allows her to jointly choose the contract price and the interest rate, TCF does not enhance supply chain performance in relation to the first-best benchmark either. Moreover, Proposition 5-2 implies that TCF offers the BS more freedom to choose the contract price and the interest rates. To elaborate, p^T and $i_S{}^T$ can result in optimal outcomes if $p^T(1 + i_S{}^T)$ keeps constant. Such freedom can also be

[26] Please refer to https://www.cnbc.com/2021/11/15/faraday-future-looking-into-claims-of-inaccurate-disclosures.html.
[27] For some EV-makers, they digest the negative impact of the increasing battery price by raising the EV prices on the market, such as XPENG Motors, WM Motor, and Tesla. However, the study of the EV price is beyond our research scope and thus is omitted here.

meaningful for a supplier to better control the default risk borne by the buyer (Yang and Birge,2018; Sung and Ho, 2019). For example, when the EV-maker's asset value is low, the bank charges a higher interest rate under BLF to hedge the EV-maker's default risk. Nevertheless, confronting a high interest rate equals a rejection signal for the EV-maker, rendering BLF infeasible. Yet, under TCF, the BS can optimize the financing scheme by reducing the interest rate and raising the contract price instead. Hence, facing the pressure of a high contract price, the EV-maker has incentives to make more effort to increase his repayment probability and enjoys a favorable interest rate in the meantime. In addition, we assume that the bank lies in a perfect financing market under BLF. However, in a less perfect financing environment, BLF may result in double marginalization (Tang et al., 2018), thus making TCF more appealing. Hence, the BS should consider financing the EV-maker directly in a less perfect financing environment which is also in line with rumors that TCF more commonly appears in emerging markets (Hill et al., 2017).

5.4 The Significance of Information Asymmetry on BLF

Despite the BS's control advantage in TCF, the BS still cannot obtain extra benefits compared with the first-best scenario according to the previous analysis. Nevertheless, in addition to having more control than the bank, the BS has an advantage over it in terms of information when she comes to finance EV-makers in practice. In many real-life cases, the BS has more private knowledge of the EV-maker than the bank because of her domain expertise in evaluating the EV-maker's operational efficiency[28].

In Sections 5.4 and 5.5, we examine under what circumstances, the BS's information advantage makes TCF the favored financing solution. In doing so, the model is extended to the scenario where the BS has an advantage over the bank in terms of the EV-maker's information. Recall that in Section 5.2, we assume g is known to every party, while in the following, the EV-maker's cost factor g is only known to the BS (and the EV-maker) and the bank only has prior knowledge regarding the EV-maker's type: the proportion of the efficient EV-maker is θ and the inefficient EV-maker is $1-\theta$. We use subscript $\mu \in \{H, L\}$ to reflect the relevant value under type μ EV-maker to indicate the EV-maker's type in the notation. Thereby, we denote the efficient EV-maker ($\mu = H$) with cost factor $g = g_H$ or an inefficient EV-maker ($\mu = L$) with cost factor $g = g_L$, where $g_L > g_H > 0$. p_H^B (or p_L^B) serves as the optimal wholesale price as presented in Proposition 5-1 where $g = g_H$ (or g_L).

[28] For instance, CATL evaluates EV-makers prudently before stepping into the contracting stage. Via such evaluations, CATL observes the comprehensive performance of the EV-maker's operations (human resources, facilities, equipment, EV models, manufacturing process, production capacity), and capital level. These observations are often ignored by banks. In addition, the BS has a better understanding of a particular purchase order, e.g., cylindrical cells, required by the EV-maker.

Since the information asymmetry about the EV-maker's true type μ only happens between the BS and the bank, and the bank is not participated in TCF. Namely, the equilibrium results under TCF remain unchanged as presented in Proposition 5-2, with g being replaced by g_{μ}, $\mu \in \{H, L\}$. Therefore, we focus on studying BLF in the presence of the BS's information advantage.

5.4.1 The Signaling Game Under BLF

We build a signaling game that captures the interactions between the BS, the bank, and the EV-maker in accordance with the sequence of events under BLF as shown in Figure 5-1. The BS (the signal sender), who is the player and is fully aware of the true type of the EV-maker, first provides a contract price p (the signal) to the EV-maker. Second, the EV-maker utilizes the contract to apply BLF financing from the bank (the signal receiver). Third, after observing the signal p, the bank uses Bay's rule to update its posterior knowledge about the EV-maker's type and adjusts the interest rates as necessary. It is worth noting that the purpose of the signal p only serves for distinguishing the efficient EV-maker and the inefficient EV-maker within this game and it may create inefficiency for the parties' payoffs in an otherwise efficient market (Spence, 2002). The posterior belief of the bank that the EV-maker is efficient is represented by λ.

Similar to the classical signaling literature, we choose the concept of perfect Bayesian equilibrium (PBE) as the equilibrium outcome in our analysis. A PBE contains the posterior knowledge of the bank as well as a profile of the sequentially rational strategy. The strategy profile includes the contract price (p_{μ}) provided by the BS to a type μ EV-maker, the interest rate ($i_{B,\mu'}$) provided by the bank knowing that the EV-maker is of type μ', and the EV-maker's repayment likelihood e_{μ} determined by a type μ EV-maker in response to p_{μ} and $i_{B,\mu'}$.

We only discuss pure strategy equilibria in this section. There are two types of PBE derived from the abovementioned signaling game: separating equilibria (different types of EV-makers induce different contract prices) and pooling equilibria (different types of EV-makers induce identical contract prices). To avoid situations where, in the case of symmetry information, the BS refuses to contract with any EV-maker irrespective of his type, we raise an assumption to confine the range of a in the following cases in this section and the next.

Assumption 5-1. *The EV-maker's asset level a satisfies*

$$a = 0 \; or \; a \geq \max\left(\frac{8g_Lc_p - {c_e}^2}{8g_L}, \frac{6g_Lc_p + {c_e}^2 + 2c_e\sqrt{12g_Lc_p - 2{c_e}^2}}{18g_L}\right) \tag{5-10}$$

Note that Assumption 5-1 corresponds to the case when $g = g_L$ in Proposition 5-1(1) and (2). Therefore, Assumption 5-1 ensures that the BS will at least contract with the inefficient ($\mu = L$) EV-maker under asymmetric information. Next, we examine the separating equilibria in Section 5.4.2 before turning to Section 5.4.3 to examine the pooling equilibria. Finally, in Section 5.4.4, we derive the stable equilibria and related optimal contract settings.

5.4.2 Separating Equilibria Under BLF

In a separating equilibrium, the solutions, i.e., contract prices, should meet two criteria. First, the true type of the EV-maker leads to the different contract prices p_μ ($\mu = H, L$) that are set by the BS, and $p_H \neq p_L$. Second, the bank views the contract price p_μ sent by the BS as a credible signal and believes that the EV-maker is of type μ after observing p_μ. Put differently, in this signaling game, upon observing p_μ, $\mu = H, L$, the posterior belief of the bank regarding the efficiency of the EV-maker is $\lambda = 1$ (efficient) if observing p_H and is $\lambda = 0$ (inefficient) if observing p_L.

5.4.2.1 The EV-maker's Response Profile

Following the way of backward induction in finding a separating equilibrium, we initially investigate the EV-maker's optimal responding strategies regarding his effort level $e_\mu(p, i_{B,\mu'})$ of a type μ EV-maker when the BS offers p and the bank offers $i_{B,\mu'}$ with the knowledge that the EV-maker is of type μ', where μ', $\mu \in \{H, L\}$. Since the BS knows the EV-maker's true type irrespective of the existence of the asymmetric information between the BS and the bank, the EV-maker makes the exact identical effort as presented in Section 5.2.2 for any given price p and interest rate $i_{B,\mu'}$. By taking into account (5-3) and (5-5), the best response from the EV-maker can be phrased as

$$e_\mu(p, i_{B,\mu'}) = \frac{c_e + a - (1 + i_{B,\mu'})p}{g_\mu} \cdot \mathbf{1}_{\{p \leq \frac{c_e + a - 2\sqrt{g_\mu a}}{1 + i_{B,\mu'}}\}}, \tag{5-11}$$

where the indicator function $\mathbf{1}_x$ includes the EV-maker's participation constraint (5-5).

5.4.2.2 The Bank's Response Profile

According to its perception of the type of the EV-maker, the bank calculates the interest rate $i_{B,\mu'}$, after estimating that the EV-maker's effort response will be provided in (5-11). Hence, the bank's interest rate can be stated as by referring to (5-6) and changing g to $g_{\mu'}$, i.e., the EV-maker's cost factor in the bank's estimation, then it is possible to rewrite the bank's interest rate as

$$i_{B,\mu'}(p)$$

$$= \begin{cases} \frac{\sqrt{8g_{\mu'}(p-a)}}{2p} + \frac{a}{p} - 1 \text{ } if \text{ } c_e \geq \sqrt{8g_{\mu'}(p-a)} \\ \infty \qquad \qquad \qquad \qquad otherwise. \end{cases} \tag{5-12}$$

5.4.2.3 The BS's Strategy Profile

We now elaborate the BS's payoff when the EV-maker's true type is $\mu \in \{H, L\}$, when the bank believes that the EV-maker is of type $\mu' \in \{H, L\}$, and when the BS provides the contract price p. By referring to (5-11) and (5-12), we have

$$\pi_S\ (\mu, p, \mu') = (p - c_p) \cdot \mathbf{1}_{\{p \leq \frac{(c_e - 2\sqrt{g_\mu a})^2}{2g_{\mu'}} + a\}}. \tag{5-13}$$

Akin to the symmetric information scenario in (5-8), the indicator function in (5-13) implies the joint participation constraints of the EV-maker and the bank. Hence, the BS's payoff, as presented in Proposition 5-1, can be rewritten as $\pi_S\ (\mu, p, \mu)$ with g being replaced by g_μ, $\mu \in \{H, L\}$ and $p_\mu^B = \arg max_p \pi_S\ (\mu, p, \mu)$.

5.4.2.4 Separating Equilibria

We provide an illustration of the separate equilibria under BLF based on the BS's payoff in (5–13).

Lemma 5-2. *An EV-maker type-oriented contract price pair and the bank's posterior belief* $(p_H, p_L, \lambda = 1)$ *is part of a separating PBE if and only if,*

1. the BS offers the contract price p_H *to an efficient EV-maker (*$\mu = H$*), where* $p_H = p_H^B$ *and satisfies*

$$\pi_S(H, p_H^B, H) \geq max_{p \neq p_H^B} \pi_S(H, p, L); \tag{5-14}$$

2. the BS offers the contract price p_L *to an inefficient EV-maker (*$\mu = L$*), where* p_L *satisfies*

$\pi_S(L, p_L, L) \geq max_{p \neq p_L} \pi_S(L, p, H)$. (5-15)

From (5-13), we can conclude that regardless of the EV-maker's true type μ, the BS's optimal payoff is unchanged. Since the BS knows the EV-maker's exact type, therefore, she can directly offer p_μ^B, $\mu \in \{H, L\}$ for different types of EV-makers, which is optimal under symmetric information as depicted in Proposition 5-1, with g being replaced by g_μ, $\mu \in \{H, L\}$. Observing the BS's pricing choice, the bank simply knows the EV-maker's type.

Additionally, it is worth further discussing two scenarios. If the EV-maker is efficient (i.e., $\mu = H$), the BS's payoff must satisfy (5-14) which ensures that if the EV-maker is actually efficient, the BS would be worse off without fixing the contract price at p_H; otherwise, the BS would have the motivation to persuade the bank that this is an inefficient EV-maker by offering $p, p \neq p_H^B$, to an efficient EV-maker. Namely, p_H is a credible signal for the bank. Similarly, when the BS faces an inefficient EV-maker ($\mu = L$), to ensure that p_L is a believable signal, the BS's payoff must meet (5-15), which secures that the BS would be better off by establishing the contract price at p_L if the EV-maker is genuinely inefficient (i.e., $\mu = L$); otherwise, the BS would deceive the bank that this is an efficient EV-maker by offering $p, p \neq p_L$ to an inefficient EV-maker. Both deceptions on the bank would contradict the optimal results in (5-13) and violate the conditions for a part of PBE, thus they should be eliminated in (5-14) and (5-15).

5.4.3 Pooling Equilibria Under BLF

The BS offers the same contract price p_Z and is indifferent to the EV-maker's true type in a pooling equilibrium[29]. Observing the uninformative price p_Z, the bank determines the interest rate $i_{B,Z}$ in accordance with its posterior belief which is unchanged, i.e., $\lambda = \theta$.

Akin to the aforementioned analysis in Section 5.4.2, given the contract price p_Z and the interest rate $i_{B,Z}$, a type μ EV-maker's best effort response e_μ is given in (5-11) with p being replaced by p_Z and $i_{B,\mu'}$ being replaced by $i_{B,Z}$. The bank believes that the cost factor of the EV-maker is g_H with probability θ and g_L with $1 - \theta$, thus we can show that the bank offers the interest rate $i_{B,Z}$ at:

[29] The subscript Z denotes the relevant values when the bank's posterior knowledge remains unchanged, such that $\lambda = \theta$.

$$i_{B,Z} = \frac{\sqrt{8g_Z\,(p_Z - a)}}{2p_Z} + \frac{a}{p_Z} - 1, \tag{5-16}$$

where $g_Z = (\frac{1-\theta}{g_L} + \frac{\theta}{g_H})^{-1}$. g_Z here can be viewed as the cost factor in relation to a weighted average EV-maker. Substituting p_Z and $i_{B,Z}$ into (5-11), we can have the corresponding $e_\mu(p_Z, i_{B,Z})$. Finally, the BS's payoff under the pooling equilibria can be determined as

$$\pi_S\,(\mu, p_Z, Z) = \left(p_Z - c_p\right) \cdot \mathbf{1}_{\{p_Z \le \frac{(c_e - 2\sqrt{g_\mu a})^2}{2g_Z} + a\}}, \mu \in \{H, L\}. \tag{5-17}$$

Then we have the subsequent outcome:

Lemma 5-3. *A contract price* p_Z *is part of a pooling PBE if and only if*

$$\pi_S(\mu, p_Z, Z) \ge max_{p \ne p_Z} \pi_S(\mu, p, L). \tag{5-18}$$

Given p_Z, the bank still cannot distinguish whether the EV-maker is efficient or not. Put differently, the bank will assign some probabilities to believe that this EV-maker is inefficient. Otherwise, the BS offers p_H directly and the bank believes that the EV-maker is efficient. Hence, (5-18) ensures that p_Z is an equilibrium solution and the BS who faces an inefficient EV-maker will not deviate from offering p_Z. If the BS's opponent is an inefficient EV-maker, and her payoff under this situation is less than the payoff by offering, for example, p_L, the BS would rather offer p_L than p_Z. Hence, (5-18) should be held for p_Z is part of a pooling PBE. In other words, the BS benefits more by providing p_Z when the bank believes that this is a weighted average EV-maker than she would be if providing any other prices so that the bank believes that the EV-maker is inefficient.

5.4.4 The Optimal Supplying Contract

Since there is no restriction on an off-equilibrium path of a PBE, there might be some irrational beliefs for the bank along this path. To further refine the equilibria established in Lemma 5-2 and Lemma 5-3, we apply Pareto dominance and the intuitive criterion (Cho and Kreps 1987) in the following. Refer to Tang (et al., 2018), as the bank lies in a competitive market and the EV-maker has a strong desire to work with the excellent BSs without caring about the payoffs, we thus stipulate that Equilibrium A is Pareto-dominant over Equilibrium B if and only to the extent that the BS's payoffs when dealing with the efficient and inefficient EV-makers are both higher in Equilibrium A than that in Equilibrium B.

This approach is commonly adopted in the signaling literature (Bolton and Dewatripont, 2005). Finally, for each a satisfying Assumption 5-1, we find the stable equilibria as presented in Proposition 5-3.

Proposition 5-3. *For any a that satisfies Assumption 5-1, under BLF, considering the EV-maker's moral hazard, the optimal contract prices achieve various stable equilibria:*

1. When $a = 0$, the BS only contracts with the strictly efficient EV-maker and provides the same contract as presented in Proposition 5-1 (1): $p_H^A = p_H^B = \frac{{c_e}^2}{2g_H}$.

2. When $a \in [\frac{{g_L}^2}{g_H}, min(g_L - \frac{g_L c_e}{g_H} + \frac{{c_e}^2(g_L - g_H)}{4{g_H}^2}, g_H - \frac{g_H c_e}{g_L} - \frac{{c_e}^2(g_L - g_H)}{4{g_L}^2})]$, the BS provides the same contract as presented in Proposition 5-1(2): $p_H^A = p_H^B = \frac{(c_e - 2g_H)^2}{2g_H} + a, p_L^A = p_L^B = \frac{(c_e - 2g_L)^2}{2g_L} + a$.

3. When $a \le \frac{g_L}{g_H}(g_Z - c_e) - \frac{{c_e}^2(g_Z - g_L)}{4g_H g_Z}$, the BS offers a similar contract as characterized in Proposition 5-1(2) without distinguishing the EV-maker's type: $p_Z^* = \frac{(c_e - 2g_Z)^2}{2g_Z} + a$.

4. Otherwise, there exists no equilibria contract price for the BS.

Proposition 5-3 gives stable equilibrium solutions for the BS. First, when facing a poor EV-maker ($a = 0$), considering the EV-maker's uptight financial status, the BS will offer the contract but only contract with the strictly efficient EV-maker. As a result, the BS can simply offer the same price as in the symmetric information case because the conclusion is compatible with Proposition 5-1. If the bank observes this is a poor EV-maker and the BS still offers a contract, then the price is a credible signal for the bank to believe that this EV-maker is definitely a strictly efficient EV-maker. Hence, the bank has slightly higher confidence in receiving the loans and determines the interest rate accordingly. In doing so, signaling is costless to the BS since under asymmetric information, the BS's payoff is the same as that under symmetric information.

Second, when facing a relatively wealthy EV-maker and the EV-maker's asset level falls into the specific region as stated in Proposition 5-3(2), the bank can effectively treat (p_H^A, p_L^A) as credible signals to distinguish the EV-maker's type. As presented in Figure 5-2(a), in this region, as long as the BS offers p_H^A (or p_L^A), the bank considers that the EV-maker is efficient (or inefficient). Specifically, Figure 5-2(a) shows that $\pi_S(H, p_H^A, H) > \pi_S(H, p_{IH}^A, L)$, where p_{IH}^A is calculated from the indicator function in (5-13), is the highest price that an efficient EV-maker would accept and the bank would lend. Similarly, $\pi_S(L, p_L^A, L) > \pi_S(L, p_{IL}^A, H)$, where p_{IL}^A's definition is corresponding to p_{IH}^A when the EV-maker is inefficient. Therefore, the incentive compatibility constraint (5-14) and (5-15) are satisfied, rendering

(p_H^A, p_L^A) as part of a separating PBE and the BS has no incentive to deviate from this. As such, the BS's payoff is unchanged and signaling is costless as well.

Third, when the EV-maker's asset level is below a certain threshold as presented in Proposition 5-3(3), there is a pooling equilibrium for the BS. Akin to the above analysis, the incentive compatibility constraint (5-18) is also satisfied as shown in Figure 5-2(b). As such, the BS simply offers p_Z^*, irrespective of the EV-maker's type. Observing this, the bank's response is treating all EV-makers as a weighted average EV-maker with the same cost factor g_Z and thus setting a single interest rate according to (5-16). In addition, from Figure 5-2(b), it can be directly observed that the pooling equilibrium is cost-effective for the BS facing an inefficient EV-maker while is cost-ineffective for the BS facing an efficient EV-maker. Recall that the proportion of an inefficient EV-maker on the market is $1-\theta$, thus for a BS who offers a pooling price, the lower population of the efficient EV-maker (θ is lower), the higher amount of the inefficient EV-maker, then the BS will benefit more. This is a rather interesting and counter-intuitive phenomenon, as intuitively, the BS would have gained more if the population of the efficient EV-maker is higher, which usually occurs in a developed country (Tang et al.,2018). As such, we can extrapolate that, in an emerging market such as China, with a larger number of inefficient EV-makers, it is better to provide pooling prices for the BS.

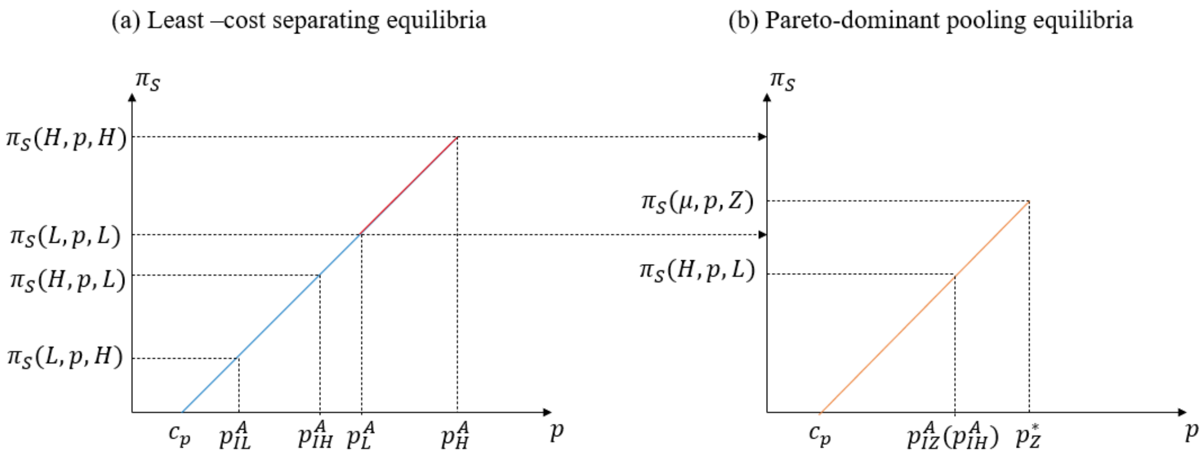

Figure 5-2 An Illustration of The BS's Payoff as a Function of Contract Price p in Various Equilibrium ($\mu \in \{H, L\}$)

Note: $p_\mu^A = p_\mu^B = \arg max_p \pi_S(\mu, p, \mu), \mu \in \{H, L\}. p_{I\mu}^A = \frac{(c_e - 2\sqrt{g_\mu a})^2}{2g_{\mu'}} + a,\ \mu, \mu' \in \{H, L\}. p_Z^* = \arg max_p \pi_S(\mu, p, Z),\ \mu \in \{H, L\}.$

We now briefly summarize the significance of information asymmetry on the performance under BLF. Based on this three-players signaling game, we discover that the kernel of the BS's equilibrium strategy selection is crucially depending on the EV-maker's asset level. Put differently, the various asset levels induce bifurcating outcomes in equilibria. When the EV-maker's asset level equals 0 or lies in a certain range (Statement 1 and 2 of Proposition 5-3), signaling the EV-maker's type via the contract to the bank is costless. Nevertheless, when the EV-maker's asset level is below a certain threshold (Statement 3 of Proposition 5-3), the BS offers a pooling price, hence signaling a weighted average EV-maker is costly if the latter's true type is efficient; signaling a weighted average EV-maker is better off if the latter's true type is inefficient.

5.5 The Advantage of TCF When Information Asymmetry Exists

As stated in Proposition 5-3, we already have stable equilibria for the signaling game under BLF. In this section, we compare two financing solutions and examine the conditions under which TCF is preferable in the presence of the BS's information advantage over the bank.

As we explained previously, the performance of TCF is unaffected by the informational asymmetry between the BS and the bank. Therefore, the difference in the BS's payoffs between Propositions 5-2 and 5-3 captures the TCF's advantage that is derived from information asymmetry for the BS (compared to BLF). In the remainder of this section, we focus on the situation that the BS contracts with the efficient EV-makers. This situation satisfies a common practice where the BS is more willing to contract with efficient EV-makers with great potential and talents. Further, according to Proposition 5-3(3), the BS might have to pay certain expenses when facing an efficient EV-maker ($\mu = H$) under BLF due to the inefficiency caused by the signaling game. Then, it is reasonable to state that, TCF will be more attractive if the signal expense is greater under BLF. We consider the following two scenarios in light of the equilibrium findings in Proposition 5-3.

First, when the EV-maker's asset value a equals zero, according to Proposition 5-2(2), the BS's payoff under TCF is $\pi_S^T = \frac{{c_e}^2}{8g_H} - c_p$, while according to Proposition 5-3(1), the BS's payoff under BLF is $\pi_S^A = \frac{{c_e}^2}{2g_H} - c_p$. It can be directly observed that $\pi_S^T < \pi_S^A$. Proposition 5-3(1) claims that the BS can provide the bank with a costless and credible signal under BLF when facing an efficient EV-maker, and hence the BS achieves the same payoff. Therefore, under the information asymmetry scenario, BLF is the only financing choice when facing an efficient but poor EV-maker. Put differently, even armed with an information advantage, TCF cannot induce a higher payoff for the BS.

Second, when the EV-maker's asset value a is greater than zero, Proposition 5-3(2) and (3) assert that, although BLF behaves identically as if no information asymmetry exists and hence remains a suitable choice, the BS has to pay certain expenses as illustrated in Figure 5-2(b) when facing an efficient EV-maker. Because in the pooling equilibrium, the contract price towards an efficient EV-maker is lower than that in the separating equilibrium, which the efficient EV-maker deserves. To elaborate on the benefit of the BS's information advantage under TCF when the EV-maker's asset value a is greater than zero, we examine the term $\Delta_S = \pi_S^T - \pi_S^A$, where π_S^T is the BS's payoff in the information symmetry scenario under TCF as characterized in Proposition 5-2, and π_S^A is the BS's payoff corresponding to the information asymmetry case under BLF as characterized in Proposition 5-3. For ease of comparison, we confine the following range of a.

Assumption 5-2. *Although the ranges of* a *in Proposition 5-2 and Proposition 5-3 are independent, there are possibilities for the intersections of these ranges to exist for any given values in setting the range of* a.

Assumption 5-2 assures that the BS's payoffs under BLF and TCF are comparable. We argue that this assumption is reasonable, i.e., an efficient EV-maker's asset level satisfies the range as presented in Propositions 5-2 and 5-3. The BS thus can compare the outcomes and select one scheme leading to a higher payoff. Otherwise, the BS's payoffs under BLF and TCF are incomparable which makes the benefit of TCF under information asymmetry non-measurable. Therefore, we give the comparison results as shown in the following proposition.

Proposition 5-4. *Consider the scenario where the efficient EV-maker's asset value is greater than zero and the BS has an information advantage over the bank. When Assumption 5-2 is satisfied, TCF is strictly preferable to BLF for the BS, i.e.,* $\Delta_S > 0$, *under certain conditions as summarized in Table 5-1.*

Table 5-1 The Comparisons Between TCF and BLF Under Information Asymmetry When $a > 0$

The ranges of a	$\boldsymbol{\pi_S^T}$	$\boldsymbol{\pi_S^A}$	**Conditions for $\Delta_S > 0$**
The intersection beteen Proposition 5-2(1) and Proposition 5-3(2)	$c_e\sqrt{\frac{a}{g_H}} - a - c_p$	$\frac{(c_e - 2g_H)^2}{2g_H} + a - c_p$	$\sqrt{ag_H} + 2g_H - \sqrt{2g_H\sqrt{ag_H} - 3ag_H} < c_e < \sqrt{ag_H} + 2g_H + \sqrt{2g_H\sqrt{ag_H} - 3ag_H}$
The intersection beteen Proposition 5-2(1) and Proposition 5-3(3)		$\frac{(c_e - 2g_z)^2}{2g_z} + a - c_p$	$2g_Z + \frac{g_Z\sqrt{ag_H} - \sqrt{g_H g_Z(a(g_Z - 4g_H) + 2g_Z\sqrt{ag_H})}}{g_H} < c_e < 2g_Z + \frac{g_Z\sqrt{ag_H} + \sqrt{g_H g_Z(a(g_Z - 4g_H) + 2g_Z\sqrt{ag_H})}}{g_H}$
The intersection beteen Proposition 5-2(2) and Proposition 5-3(3)	$\frac{c_e^{\,2}}{8g_H} + a - c_p$	$\frac{(c_e - 2g_z)^2}{2g_z} + a - c_p$	$\begin{cases} 0 < c_e < \frac{4g_z\sqrt{g_H g_Z} - 8g_H g_Z}{g_z - 4g_H}, & \text{if } g_Z > 4g_H; \\ g_z < c_e, & \text{if } g_Z = 4g_H; \\ 0 < c_e < \frac{-(4g_z\sqrt{g_H g_Z} + 8g_H g_Z)}{g_z - 4g_H}, & \text{if } g_Z < 4g_H. \end{cases}$

As stated in Proposition 5-3, signaling contract price causes inefficiencies for the BS who faces an efficient EV-maker, thus the BS direct financing may avoid such inefficiencies by flexibly offering a contract $(p,\, i_S)$. Incorporating the findings from Proposition 5-4 (for the scenario where $a > 0$) with the previous analysis (for the case where $a = 0$), the conditions for the preference of TCF is straightforwardly presented in Table 5-1. It is interesting to find that TCF is more beneficial to the BS if the EV-maker's alternative financing cost lies in certain ranges and the ranges are controlled by the efficient EV-maker's cost of factor (g_H), the weighted average EV-maker's cost of factor (g_Z) and his asset value (a). Based on Table 5-1, before the contracting stage, the BS can firstly estimate whether both financing schemes are feasible according to the EV-maker's asset value as well as learn his efficiency type after initial auditions. If both are feasible, then the alternative financing cost is assumed as common knowledge to both the BS and the EV-maker. Observing this, whether the conditions stated in Table 5-1 are satisfied can be examined by the BS. Finally, the BS can select TCF to finance the EV-maker if appropriate. Consistent with the anecdotal evidence, after a thorough audition, some BSs would like to adopt TCF for transactions to earn more especially facing efficient EV-makers such as the transactions between Panasonic and Tesla.

In addition, as we mainly pay attention to the advantages of TCF for the BS because of her dominant position in the supply chain, TCF further improves the efficient EV-maker's profitability. We characterize this point in the following corollary.

Corollary 5-1. *Consider the scenario where the EV-maker's asset value is zero and the BS has an information advantage over the bank. When Assumption 2 is satisfied, TCF is preferable to BLF for an efficient EV-maker.*

Intuitively, when $a = 0$, it is hard for an EV-maker to lend from a bank because of no pledge. Information asymmetry thus allows the efficient EV-maker to convince the BS and lend from her by using this information asymmetry, i.e., the EV-maker knows that the BS understands his efficiency. Therefore, the BS's information advantage also can be utilized by the efficient EV-maker to prohibit himself from contracting with a BS under BLF that he could obtain under TCF otherwise. Therefore, the poor but efficient EV-maker would straightforwardly benefit from TCF when information asymmetry exists, which contradicts the BS's case.

5.6 Summary

Applying a three-player model to capture the interplays among a BS, a capital-limited EV-maker and a bank, we discover that, on the one hand, without the BS's information advantage, the performance under BLF and TCF is completely different. Under BLF, the BS utilizes both the EV-maker's asset level and efficiency to determine the contract terms, while she solely uses the asset level in the TCF scheme. Furthermore, the BS's control advantage by itself does not elevate TCF to a more desirable financing plan compared to BLF in terms of the comparisons with the first-best benchmark case. Put differently, the extra lever of the interest rate raised from the BS who is an internal player, can still cause double marginalization and can be even worse for the supply chain under certain conditions. Hence, because of the contingent nature of the contract, TCF may not be able to further prevent the EV-maker's moral hazard in this circumstance.

On the other hand, if considering both the BS's information advantage and control advantage, the relative benefits of TCF over BLF are multi-perspectives. First, when the EV-maker's asset level equals zero or lies in a certain range (Statement 1 and 2 of Proposition 5-3), signaling the EV-maker's type via the contract to the bank is costless. In this case, TCF is less efficient than BLF when the EV-maker's asset level equals zero, while TCF is better than BLF when the alternative financing cost lies in this certain range as presented in Table 5-1. Second, when the EV-maker's asset level is below a certain threshold (Statement 3 of Proposition 5-3), signaling the EV-maker's efficiency type is costly if the latter's true type is efficient, while signaling is better off if the EV-maker's true type is inefficient. In this case, to induce TCF to have an advantage over BLF for the BS, our findings also reveal that, the EV-maker's alternative financing cost should lie in certain ranges as presented in Table 5-1.

Chapter 6: Conclusions and Future Work

In this chapter, the main contributions of this thesis are presented, the embedded limitations are stated and future research directions are illustrated specifically.

6.1 Main Contributions

This thesis studies the impact of payment delay on a supply chain's WCM by implementing an SCF scheme, and analyzes the 3PL's financing role in the presence of the retailer's payment delay, and examines the EV-maker's moral hazard problem under both BLF and TCF schemes and how the BS can signal the EV-maker's type in a supply contract through BLF. The research of all these issues has a significant impact on the supply chain management field, operations management field, risk management field and definitely, the field of the interface of operations and finance. Therefore, we contribute the existing literature in the abovementioned research fields in the following ways:

(1) For the first objective, firstly, from the theoretical contributions' perspective, the SLR synthesized nine research dimensions in the SCF domain, summarized the recent contributions extracted from the chosen papers, updated the SCF research framework, reclassified the category of FSPs and SCF instruments, summarized the dominant methodologies used in recent research and proposed five future research directions from a macroscopic view. In addition, compared with the previous literature reviews, our work comprehensively studied all aspects of SCF rather than focusing narrowly, especially during the last decade. By referring to our framework and Table 2-2, future researchers can certainly know what others have already done and which part is still inadequate and worth further studying, thus avoiding repetition and simultaneously making more contributions in this field. Secondly, from the practical contributions' perspective, industrial practitioners may pay closer attention to the application part of SCF research. Hence, they can regard the present research as a guide to learning the benefits generated from SCF adoption, the improved supply chain performance under multiple SCF instruments, and the current challenges and opportunities of SCF, etc., via referring to the upgraded SCF research framework and the content analysis.

(2) For the second objective, considering the capital-constrained supplier having difficulties in accessing bank loans in the presence of the OEM's payment delay, we innovatively came up with theoretical conditions under which the supply chain's CC2C cycle and SVA are impacted by the delayed payment, and concluded the certain advantages of RF in solving payment delay problems and optimizing the supply chain cash flows, and illustrated the mechanisms of how key operational and financial parameters such as the order quantity and supplier's initial capital

influence the CC2C/SVA value. By following these findings, the supply chain managers can observe whether the supply chain's CC2C will be impacted if there are payment delays so as to take appropriate actions if needed to optimize the cash flow and improve the supply chain's operational and financial performance. Second, current research on RF mainly considers its objectives (e.g., Liebl et al., 2016), benefits (e.g., Van der Vliet et al., 2015; Tunca and Zhu, 2018; Devalkar and Krishnan, 2019; Gelsomino et al., 2019), and adoption process (e.g., Lekkakos et al., 2016; Kouvelis and Xu, 2021). We complement RF's advantage in helping the supply chain improve the working capital management in the presence of payment delay which is ignored in previous studies. Third, the established model reflects the genuine situation in the existing automotive industry by applying the actual operations and finance settings acquired from the interviews to model formulation, thus the results yielded in this research can have practical significance in helping automakers optimize their supply chain cash flows and avoid suppliers disruptions in the post-COVID-19 era.

(3) For the third objective, our study contributes to the extant literature in the following aspects. First, we complement the applicable scenario that under a pair contract, the 3PL can provide both the delivery service and the advance payment financing to the supplier. Further, we consider the retailer's payment delay in a supply chain. Second, we study the payment delay-induced bankruptcy risk for the supplier and explore how to mitigate the bankruptcy risk by identifying the acceptable payment delay range in both models, which are not considered in the current literature. Third, we introduce the time value of cash to capture the dynamical cash flow in a supply chain so as to comprehensively understand the interactions among each party. Fourth, in contrast to the current literature, we achieve a rather counterintuitive result that the 3PL's financing role is not always alluring under either the 3PL's leadership or the retailer's leadership. We discover that the 3PL's financing significance only exists for the 3PL itself in the heterogeneous time value of cash setting under the retailer's leadership, given certain conditions.

By involving a 3PL as a proactive decision-maker and by capturing the payment delay-induced cash flow in a supply chain, we show that the 3PL's financing scheme that is usually considered as an innovative and beneficial solution, however, is only attractive for the limited party under certain conditions. Put differently, the robustness of the 3PL's financing role is weak under different model settings, especially considering the time value of cash. The time value of cash derived from the retailer's payment delay is a critical factor that can significantly alter the final results. In addition to the value comparison, from a risk management's perspective, although the optimal acceptable payment delay is identified for the supplier, the retailer may persist in enforcing a payment delay to enhance her cash conversion cash cycle in reality. Therefore, the acceptable payment delay range raised in this study shows how the length of the range can be determined when coordinating with other parties to avoid the supplier's bankruptcy.

(4) For the fourth objective, in the context of the Chinese EV industry, our research attempts to explain the relative efficiency of two common financing solutions (BLF and TCF). As such, this study discloses two significant managerial implications. First, the BS's information advantage rather than her control advantage determines how efficient TCF is in comparison with BLF. Second, via a theoretical analysis, considering the information asymmetry between the BS and the bank, we show the BS's and the EV-maker's operational and financial performance under both financing schemes and identify the circumstances under which the BS may benefit more by financing the EV-makers directly.

6.2 Limitations and Future Work

The limitations and future work are presented as follows:

(1) For the SLR, partially consistent with Bals's (2019) limitations, due to the rigorous selection criteria, we did not review papers that were not included in qualified journals and other types, such as official reports and conference papers, which might shed further light on the SCF topic. As such, the present research seeks to serve as a verified and sufficiently mature study supported by theoretical conclusions in the existing literature. The research framework may also be ever evolving, depending on future developments.

(2) For the first study, one limitation is that we assume that information transparency is achieved with respect to the participants' key operational and financial parameters. In doing so, the effects of payment delay can be easily exposed, and all parties can coordinate to ease the problems. In practice, due to inadequate supply chain visibility and unbalanced bargaining power, such information is always incomplete so that the analysis will be more complicated with information asymmetry. Hence, in the presence of payment delays, considering information asymmetry within a decentralized supply chain is a promising research direction. In addition, as we elucidated in Section 3.2 'Model formulation', the payment delay will result in bankruptcy for capital-constrained SMEs in extreme cases. In order to avoid supply chain disruption, the buyers' payment strategy may be affected. We already explained how SCF can deal with the delay issues in this study, and how SCF can mitigate the bankruptcy risk of cash-limited suppliers in the presence of payment delays is worth studying further as well. Thereby, we regard this point as the second research direction. Further, we select RF as an innovative

solution in improving the supply chain's WCM due to its popularity in today's industries, but can other financing schemes also yield the same positive results? This will be the third future research direction. Finally, the model is established based on the interviews of the selected automakers in China, and as the fourth direction, we intend to enlarge the scope to wider automotive supply chains and even other industries when data is available so as to test the robustness of our model in the future.

(3) For the second study, our research could be further developed in several directions. First, this study assumes that all parties are risk-neutral. Given the complexity of different parties' various risk attitudes, the operational decisions and financing terms may be impacted. For example, the 3PL's early payment to the supplier occurs before the goods are delivered to the designated warehouse, i.e., $d_g < d_s$. This is worth studying for a risk-taking 3PL who would like to bear the delivery risk. Second, the choice of financing scheme could be further enriched to examine whether other supply chain finance instruments such as dynamical discounting could help the 3PL revitalize its financing role. Third, we assume that information transparency is achieved among all participants. In practice, information asymmetry may arise and complicate the model. Fourth, to focus on the 3PL's functioning act, we do not take the bankruptcy cost into account in our model. In practice, there are usually two alternatives for a firm's bankruptcy process: reorganization or liquidation (e.g., see Zhao and Huchzermeier (2019)). Each option induces a distinct cost structure and thus could, in turn, impact the supplier's operational decision and the 3PL's financial decision. Therefore, considering the supplier's bankruptcy cost may hopefully obtain more managerial insights in the future.

(4) For the third study, first, extensions to theoretical models such as multiple transaction periods, competitions among multiple EV-makers, and various risk profiles of players may offer promising paths for further study. Second, we list substantial daily-life practices in the Chinese EV industry as evidence to support our results. In the future, once data availability is achieved, the theoretical findings from this study can be tested and verified via empirical studies.

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