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FinTech for Supply Chain Operations: Platform Credit Financing

Abstract: Traditionally, in supply chain management, manufacturers such as *HP* and *P&G* fund their downstream retailers through *trade credit financing* (TCF). Recently, with the advance of FinTech, platforms have also implemented innovative financing schemes called *platform credit financing* (PCF). Both TCF and PCF are risky, which expose the lender to operational risks. Motivated by these real-world practices, we model a three-echelon supply chain in which a capital-constrained retailer, exposed to operational risk, orders from the manufacturer and sells on an online platform. We explore TCF and PCF, and determine the retailer's optimal financing options based on her operational risk and the platform's referral fee for the product category. Our results show that PCF becomes profitable for all three entities when the retailer's operational risk level is high. This result justifies the successful adoption of PCF under a high operational risk scenario where it becomes challenging for the retailer to obtain financing through traditional modes. Though TCF does not obtain a win-win-win, it generates more profit for the capital-constrained retailer under low operational risk. We also find that TCF may achieve a win-win-win outcome in the presence of a loss-averse lender or in the partial demand fulfillment scenario. To derive more insights and check for the robustness of core findings, we examine several extended cases.

Keywords: FinTech, platform credit financing, e-commerce, supply chain finance.

1. INTRODUCTION

1.1. Background

With the emergence of various disruptive technologies (Islam 2017) such as blockchain (Islam et al. 2023) and Internet-of-Things (Li et al. 2022), operations in real world have changed a lot. Among them, the emergence of platforms (Jia et al. 2020; Basu et al. 2023) is influential, which leads to all kinds of innovative business models, including financing schemes.

In fact, over the past few decades, online retailing has been witnessing prodigious growth. Worldwide, e-commerce sales grew by a massive 504% between 2010 and 2019 (JILT 2021). In 2020, e-commerce marketplace giants such as *Amazon*, *Alibaba*, and *JD.com* posted 38%, 35%, and 29.3% increase in revenues, respectively (Statista 2021a, 2021b, 2021d). To maintain a sustainable growth trajectory, third-party sellers are becoming increasingly important to e-commerce platforms. For instance, *Amazon* reported that the share of paid units sold by third-party sellers stood at 56% in 2021 (Statista 2021c). Online marketplace platforms maintain a symbiotic relationship with third-party sellers, a large majority of whom are small and medium businesses (SMBs) (Gupta and Chen 2020; Yan et al. 2020). Typically, a platform provides these third-party sellers with an online marketplace to sell their products to end consumers, as well as offers financial, technological, and operational support to overcome the hurdles they face as SMBs (Yan et al. 2020). In return,

the platform charges a fixed commission fee (or "referral fee[1]" or "revenue share") from these sellers for each unit of product sales. For example, *Amazon.in* charges 4% for books, 11% for camera accessories, and 24% for fashion jewelry (Amazon 2023). Many SMBs, including companies in all kinds of industries from agriculture (Pagare et al. 2023) to fashion (Adhikari et al. 2020), face shortages in working capital that may restrain their ability to fulfill customer demand (Yan et al. 2020). They traditionally used asset-based financing modes such as bank credit financing (BCF) to fulfill their working capital requirements (Wang et al. 2019). However, in the absence of sufficient collateral, credit history, operational efficiency, and business transparency, SMBs often fail to secure an affordable loan from banks (Tang et al. 2018; Vandenberg 2003). This restricts SMBs' capability in fulfilling end-market demand and eventually hampers their growth.

To overcome the financing challenge, upstream manufacturers can provide financing services to SMBs (third-party sellers). This financing mechanism is referred to as "trade credit financing" (TCF) (Cheng et al. 2021). For example, as an TCF, *General Motors* (*GM*) provides a 30-day loan to its distributors (GM 2021). Similarly, *Hewlett-Packard* (*HP*) and *Procter &Gamble* (*P&G*) also provide TCFs to their downstream clients (Chen and Cai 2011; Xiao et al. 2017). Similarly, intermediaries such as *idosell.com* help online sellers obtain trade credit from wholesale stores (Idosell.com 2023). Moreover, they provide this service to over 7000 online sellers. As reported by Yang and Birge (2018), the empirical evidence suggests that the terms of trade credit vary across firms and industries. One of the most used forms of trade credit is the two-part trade credit term. Under two-part terms, the trade credit terms are d/N_1, net N_2, where d is the discount rate, N_1 is the discount period for the retailer to take advantage of the cash discount, and N_2 is the credit period for the entire invoice to be paid without late fee or credit agency referrals. We have used this two-part trade credit term in our analysis. It is also called early payment discount trade credit (Kouvelis and Zhao 2012; Yan et al. 2020).

Table 1. Illustrations of practices under TCF and PCF

SCF mode	Borrowing firm	Lender	Description
PCF	*Darlyng & Co.*	*Amazon*	*Amazon* offered them loan when bank loan was not accessible and the loan amount was credited to the borrower account in few hours.(Amazon.com 2023a)
PCF	*Epic Water Filters*	*Amazon*	They received loan from Amazon to purchase items in advance, which helped them reduce lost sales cost.(Amazon.com 2023a)
PCF	*Fantastik Retails*	*Flipkart*	They availed a loan of 5 million INR at an interest rate of 12%.(Indianonlineseller.com 2015)
PCF	*Amazestore*	*Flipkart*	*Amazestore* availed a loan of 20 million INR in a day and a half to procure products ahead of a festival sale.(Shrivastava 2015)

[1] Some other terms are also used for "referral fee", such as *commission fee*, *revenue sharing rate*, and *platform usage fee*.

PCF	*B.A.A.B.S. Beauty*	*Alibaba*	*Alibaba* allows them to buy a product and pay after 60 days.(PYMNTS 2020)
TCF	*Turner Co.*	*Arjowiggins Co.*	*Arjowiggins* started providing trade credit to its retailer Turner Co. in 2009 (Wang et al. 2021b).
TCF	*Haier vendors*	*Hairongyi (a supply chain platform of Haier)*	*Haier* provides SCF to its vendors using loans, factoring, and other financial instruments through *Hairongyi.*(Haier 2015)
TCF	*Findlay Chevrolet in Las Vegas*	*General Motors*	*General Motors* provides 30 days of interest fee financing to the dealer.(GM Financial 2021)
TCF	*Landscape Group*	*Hewlett-Packard (HP)*	*HP* provides integrated financial solutions to the *Landscape Group*, a reseller of HP's next-generation A3 printer.(HP.com 2021)

In recent times, with the advance of FinTech, online platforms have also come forward in offering innovative working capital loans to third-party sellers. This novel financing methodology is referred to as "platform credit financing" (PCF) (Rath et al. 2021; Wang et al. 2019). Using the rich history of transactional data, customer feedback, and reviews, platforms can evaluate the operational efficiency of capital-constrained retailers[2] and check their eligibility for a loan. Amazon Lending is an example of how *Amazon* finances the capital-constrained SMBs selling products on its platform (Megaw 2019). Some other examples of PCF are Jing Bao Bei by *JD.com*(JD.com 2012), Pay Later by *Alibaba* (PYMNTS 2020), and Flipkart Growth Capital by *Flipkart*(Shrivastava 2015). Table 1 illustrates different lending practices under TCF and PCF.

Manufacturers and platforms typically do not demand collateral from borrowers to provide the loan, making it very suitable for SMBs. Thus, unsecured loans such as TCF and PCF are very appealing to a capital-constrained retailer because the lender (a manufacturer in the case of TCF and a platform in the case of PCF) would not liquidate the retailer's assets to recover the loan amount in case of bankruptcy. However, under this setting, TCF or PCF is risky for the manufacturer and the platform, respectively. If the retailer is exposed to risks that may hinder its operational performance leading to unfulfilled orders and financial default, the lender loses the loan amount. This comes under the ambit of operational risk, which is related to the loss owning to failed internal/ external process, people or system Heckmann et al. (2015). Some examples are issues related to product quality and conformity, unstable process or issues related to logistics / procurement operations, which can result in capital loss and customer loss (Chen et al., 2013; Dhingra and Krishnan, 2021; Tang et al., 2018). Due to the operational risk, the retailer fails to fulfil the customer demand successfully and goes bankrupt. In case of the retailer's bankruptcy, the platform loses all the loan amount under PCF as it is an unsecured loan; however, the manufacturer obtains its payment. On the other hand, under TCF, the manufacturer and the platform get no revenue if the retailer goes bankrupt. Therefore, the operational risk

[2] Throughout this paper, we use the term *online retailer* or *retailer* interchangeably to denote the SMBs selling on online platforms

affects the supply chain players differently under both the financing schemes and considering the retailer's operational risk, the lender needs to formulate an appropriate strategy for a successful lending program.

1.2. Research Gaps and Research Questions

As discussed earlier, TCF and PCF are two different modes of financing: under TCF, an upstream player provides the loan to a retailer, whereas under PCF, a downstream-intermediate player provides the financing. Since both TCF and PCF are unsecured loans, the lender (the manufacturer under TCF and the platform under PCF, respectively) is unable to recover the loan amount in case the retailer defaults, i.e., it fails to deliver products to the end customers. The source of such operational risk can be process inefficiencies, logistics issues, or product non-conformity problems (Dhingra and Krishnan 2021; Markou and Corsten 2021; Tang et al. 2018). Hence, a lender needs to evaluate a retailer's operational risk before offering the loan. Existing studies (Kouvelis and Zhao 2012; Yan et al. 2020) have analyzed the optimal lending decision of the manufacturer and the platform separately. However, to the best of our knowledge, no prior research derives the optimal strategy of the manufacturer and the platform when both TCF and PCF are available. We hence fill this hole by determining how the platform or the manufacturer adjusts their respective decision levers, such as interest rates and wholesale prices, based on whether the retailer obtains financing through TCF or PCF. We propose the first research question (RQ1):

RQ1: Under what market scenarios would the manufacturer and the platform be better off in offering financing to a retailer in the presence of operational risk?

Our next task is to analyze how a retailer's choice of financing mechanisms, such as TCF and PCF, impact the overall ecosystem of a three-tier retail supply chain. More specifically, we focus on deriving market conditions under which a retailer opts for an upstream (TCF) or a downstream (PCF) financing option and investigate how the financing choice impacts the overall dynamics of a three-tier supply chain with a manufacturer, a retailer, and a platform. Hence, we propose and address the following research question (RQ2) in our study:

RQ2: What should be the retailerôs optimal financ

Furthermore, Chen (2015) theoretically showed that TCF is always better for the manufacturer and retailer as compared to bank financing. Similarly, Wang et al. (2019) found that both the retailer and platform can be better off under platform financing than bank financing. In our paper, we figure out the market conditions under which all the supply chain members (i.e., the manufacturer, the retailer, and the platform) earn more profit in either TCF or PCF. Moreover, we extend our analysis by relaxing some initial assumptions of our base model to check the robustness of the findings as well as generate some additional insights through answering the following research question.

RQ3: Under what market scenarios could TCF and PCF achieve a win-win-win outcome for the different supply chain players (i.e., the manufacturer, retailer, and platform)? How robust are the findings?

To address the above research questions, we formally develop a stylized game theoretical model of a three-tier supply chain in which a capital-constrained retailer (she) secures working capital loan through TCF or PCF

while selling her product on the online marketplace. In the TCF, the retailer procures the product from the manufacturer on credit and repays after the selling season. While under PCF, the retailer takes a loan from the platform to procure the product from the manufacturer with cash. We endeavor to determine the optimal lending rates offered by the manufacturer and the platform, derive the retailer's financing mode choice, and identify win-win-win solutions. Finally, managerial insights are provided for the practitioners.

1.3. Contributions

Our work contributes to the emerging field of FinTech (i.e., technology driven supply chain finance) by performing a comprehensive analysis of two dominating forms of financing modes, namely, TCF and PCF. By considering both upstream and downstream financing in the analysis, our research enriches the existing supply chain finance (SCF) literature, which, in contrast, mainly focuses on either upstream or downstream financing. From the analytical findings, we generate valuable insights for engineering managers. For example, we find that for products with a high referral fee (e.g., jewelry, and fine art), all the supply chain members (i.e., the manufacturer, retailer, and platform) would prefer PCF to TCF. The platform should provide financing to the retailer selling products associated with a high referral fee. Thus, PCF naturally achieves a win-win-win outcome for selling these products on the platform. For products with a low referral fee (e.g., book, and laptop), the manufacturer should provide financing to the retailer, and the retailer should choose TCF over PCF. This further leads to a higher consumer surplus. However, under this scenario, TCF cannot obtain a win-win-win outcome as the platform is better off with PCF. Similarly, if a retailer faces a low operational risk and sells a product that has a moderate referral fee (e.g., eyewear and camera accessories), both the retailer and manufacturer are better off under TCF. If a retailer with high operational risk sells a product with a moderate referral fee, PCF is beneficial for both the manufacturer and the retailer. However, the platform prefers TCF to PCF in the above scenario. These findings are novel and can serve as valuable guidance for retailers and other supply chain members to choose the optimal financing mode in the FinTech age.

2. LITERATURE REVIEW

2.1 Supply Chain Finance (SCF)

In SCF, a supply chain member or a third-party financier provides easy and low-cost financing to a capital-constrained member of the chain. A rich amount of operations management (OM) literature has explored traditional SCF techniques such as trade credit financing (TCF) (Dye and Yang 2015), bank credit financing (BCF) (Lu and Wu 2020), and factoring (Yan et al. 2021). Some new SCF methods that have recently gained the attention of OM researchers include third-party logistics (3PL) financing (Hua et al. 2021), platform credit financing (PCF) (Wang et al. 2019; Yan et al. 2020), and equity-based financing (Fu et al. 2021). Most notably, Kouvelis and Zhao (2016), Tang et al. (2018), and Hua et al. (2021) have explored various facets of SCF. Kouvelis and Zhao (2016) formulated various hybrid contracts under BCF to achieve coordination under different types of default costs and bankruptcy risk. Tang et al. (2018) incorporated information asymmetry in the comparative analysis of purchase order financing and buyer direct financing (BDF) in presence of supply

uncertainty. In the same vein, Hua et al. (2021) argued that 3PL financing could be more beneficial than BCF when the working capital is deficient. Choi (2022) compared traditional bank financing with crowdfunding through initial coin offerings (ICO) and found that product pricing is always higher under ICO-based financing than bank financing, but the quality of the product depends on the degree of risk aversion of the bank. Dong et al. (2022) examined the use of blockchain for multi-tier SCF. The authors found that whether or not using blockchain could achieve all-win in the supply chain heavily relies on the specific finance program being implemented. Lee et al. (2022) compared dynamic trade financing with traditional bank financing and showed how fintech benefits dynamic trade financing in the presence of information friction. Similarly, Wang and Xu (2022) found that smart contracts can improve the supply chain profit by reducing the supplier's overpricing behavior and devised a strategy to maximize the benefit of the smart contract in the presence of multiple trade financing methods. In a recent article, Balyuk (2023) showed that the availability of peer-to-peer lending improves the borrower's ability to access higher bank loans. Hertzel et al. (2023) demonstrated how cross-border financing is more advantageous to small firms in the global supply chain. In another study at the operations-finance interface, Gernert et al. (2023) found that in the presence of supplier competition, the manufacturer might procure from the financially distressed supplier to nurture supplier competition. On the other hand, the non-distressed supplier may go for a price premium or predatory pricing depending on the market condition. For a review of the literature at the operations-finance interface, we refer to Wang et al. (2021a). Gao et al. (2024) studied a low-carbon capital-constrained supply chain and demonstrated that peer-to-peer lending complements bank financing and promotes carbon emission reduction policy. Tingbani et al. (2023) empirically established that supply chain finance shortage aggravates the negative impact of environmental tax on the SME's innovation level. Similarly, extending SCF research in a new direction, Long et al. (2024) devised optimal trade credit and bank credit financing schemes for a retailer when a merger occurs. Wei et al. (2024) found that R&D expenses reduce the likelihood of debt financing, but patents help get better debt financing schemes.

Broadly speaking, SCF techniques can be categorized into manufacturer financing (An et al. 2021) and retailer financing (Kouvelis and Zhao 2012), depending on whether the manufacturer or the retailer is capital constrained. Our work primarily falls under the domain of retailer financing. Thus, we study the research related to retailer financing, specifically trade credit financing (TCF) and platform credit financing (PCF).

2.2 Trade Credit Financing (TCF)

Emery (1984) is one of the seminal papers in TCF that explained the pure financial motive of the seller behind providing trade credit and showed that trade credit minimizes the negative impact of market imperfections and generates value for the whole supply chain. Wilson and Summers (2002) reported that a firm's size significantly affects the trade credit decision of small firms and showed that net-term TCF is used for supplier's reputation (product quality inspection) related reasons and two-part term TCF is used to reduce buyer's opportunism and get a competitive advantage at low cost. Wilner (2000) incorporated firm dependency in his analysis of trade credit and argued that a dependent creditor offers more favorable credit terms and reduces the

interest rate more rapidly if the likelihood of default decreases. A detailed analysis of the impact of credit rating on SCF by Kouvelis and Zhao (2018) showed that the manufacturer could provide TCF to the retailer at zero interest rate in some market conditions. Yang and Birge (2018) explored the risk-sharing role of trade credit financing and found that the TCF could improve supply chain efficiency. Wu et al. (2019) observed that the manufacturer could provide TCF to the capital-constrained retailer to diminish the dominant retailer's bargaining power. Furthermore, they reported that even in the presence of bank financing, the manufacturer is better off under TCF under some market scenarios. In another significant study, Li et al. (2020) found that the retailer's optimal financing choice depends on the degree of risk aversion of supply chain players and the initial working capital of the retailer; however, the manufacturer always prefers TCF to the retailer's independent financing mode. Chen et al. (2022) empirically showed that trade credit is crucial for inventory management, and a reduction in TCF availability leads to lower inventory levels and profit. Ning (2022) incorporated buyer competition in the analysis of TCF and found that strategic TCF can improve the total supply chain profit.

Having discussed how TCF could benefit the supply chain, we now provide some contemporary studies that identify different situations under which TCF might not be advantageous for supply chain players. Lu and Wu (2020) found that tax asymmetry between tax jurisdictions could make BCF more attractive than TCF. Similarly, Zhi et al. (2022) showed that third-party logistics (3PL) financing could be better than TCF under low logistics cost, low product cost, and high financing demand. In a recent study, Yang et al. (2021) compared TCF and BCF when the supplier is risk-averse. Contrary to established belief, they found that the TCF might not achieve a win-win situation when the supplier's risk aversion is polarized. Wang et al. (2021b) analyzed the manufacturer's optimal trade credit strategy in the presence of multiple capital-constrained retailers. They reported that retailers with good credit ratings would not prefer the manufacturer's trade credit because borrowing costs go up. However, the manufacturer could provide credit to all the retailers, including those with low credit ratings. In contrast, Deng et al. (2021) argued that the manufacturer should not always provide credit to all the capital-constrained retailers in the presence of demand risk.

The above papers provide valuable insights into the interaction between TCF and other operational decisions in the domain of traditional offline retail. Our study contributes to this stream of research by revealing novel insights via investigating TCF and PCF in an e-commerce marketplace setup.

2.3 Platform Credit Financing (PCF) and FinTech

FinTech is a relatively new term, which arises with the development of digital technologies such as blockchain (Baliker et al. 2023). Earlier research includes initial coin offerings (Choi 2022) as well as secure technology deployment (Baliker et al. 2023). Nowadays, a more common and larger scale of financing with technology is probably related to platforms, i.e., PCF. We review related studies as follows. Gong et al. (2020) evaluated the benefits of PCF and suggested that in the absence of other financing modes, a platform should always provide financing to a cash-constrained retailer. Extending the study to dual-channel retailing, Yan et al. (2020) showed that PCF could improve the retailer's profit by increasing total market share. The platform also obtains higher profit due to the additional revenue source. Taking this research stream forward, Wang et al. (2019) compared

BCF and PCF and concluded that PCF could coordinate the supply chain. They also showed that, with sufficient initial working capital, the retailer prefers PCF. Along similar lines, Zhen et al. (2020) formulated the optimal financing strategy for a capital-constrained manufacturer who sells products through a dual-channel (offline retailer and online platform). They found that the manufacturer always prefers PCF to BCF; however, buyer financing might be attractive in certain market conditions (e.g., high channel competition and low production cost). In a recent article, Liu et al. (2021) theoretically analyzed the financing choice of an overconfident e-tailer under two PCF schemes: fulfillment by platform (FBP) and fulfillment by the retailer (FBR). They found that both the retailer and platform prefer FBP when the fulfillment cost is high, and the extra fee charged by the platform is low. In the comparative analysis of three modes of financing: PCF, platform guarantee financing, and BCF, Yi et al. (2021) analytically showed that the platform's intermediation could improve the welfare of a small-scale farmer who sells online. Rath et al. (2021) systematically compared PCF and BCF in the presence of retailer's performance risk and concluded that the platform is always better off under PCF, whereas the retailer might prefer BCF to PCF under some market scenarios. We also find some recent studies focusing on the platform's referral fee strategies. Mandal et al. (2024) demonstrated that when the referral fee is high, both competing retailers are better off under platform financing. Chen et al. (2022) examined different referral fee/commission fee strategies in an online retailing setup and showed that the design of referral fees can significantly impact the profit and competitive advantage of online retailers. Dai et al. (2024) found that a moderate referral fee can be better for manufacturers and incumbent platforms in the presence of asymmetric competition. Table A1 (Online Appendix A1) shows the literature positioning of this paper.

3. THE BASE MODEL

3.1. Model Description

We now present the formal model. We analytically explore a supply chain in which a retailer ("she") procures a product from an upstream manufacturer ("it") and sells it to the end consumers through an online platform ("he"). For instance, *Dawntech Electronics* (a retailer) sells electronics products of *LG, Realme, Redmi*, etc., on *Amazon*(Amazon.in 2023). Other examples of similar retailers are *Etrade online*, *Darshita Etel*, and *uRead-Store*. In our analysis, we consider that the retailer is capital constrained, but she can obtain the working capital from the manufacturer (TCF) or the platform (PCF). Table 2 summarizes the notations that we use to represent the model's parameters and decision variables.

Table 2. A list of notations

Subscripts and superscripts	
i	"*R* for the retailer, *P* for the platform, *M* for the manufacturer"
j	"*TCF* for trade credit financing, *PCF* for platform credit financing"
Decisions	
η^{c}	The unit product price under the financing mode *j*

ìᶜ	Interest rate charged by the lender under financing mode *j*
ύᶜ	Wholesale price charged by the manufacturer under financing mode *j*
ύᶜ>	Postponed wholesale price under financing mode *j*
Problem parameters	
ɚ	Operational risk of the retailer
Ŭ	Referral fee charged by the platform
c	Unit production cost for the manufacturer
w	Nominal wholesale price charged by the manufacturer
Demand and profit functions	
ʼΩᶜ	Product demand under financing mode *j*
“ᶜ ᵢ	Supply chain agent *i*'s profit under financing mode *j*

Under financing mode j Í $\{TCF, PCF\}$, the manufacturer incurs a unit production cost ὦ for producing the goods and offers the finished product to the retailer at a unit price ύᶜ. The retailer is cash-constrained and has to secure a loan for buying from the manufacturer. Then she sells the product online at a unit retail price, ὴᶜ. We assume that the retailer is exposed to operational risk and, with probability ‗(π ᵢ ‗ ᵢ ρ)[3], she fails to deliver the product to the end customers (Tang et al. 2018). Here, *ɚ* represents the operational risk associated with product delivery, and it can be of various types, e.g., technological risk, logistics risk (Liu and Ren 2024), and processing risk (Dhingra and Krishnan 2021; Markou and Corsten 2021; Schmidt and Raman 2022), due to which the retailer may not be able to fulfill customer orders successfully. We consider the operational risk to be exogenous in the model (i.e., the retailer puts no effort into changing the operational risk), which is in line with the existing studies (Rath et al., 2021; Shan et al., 2023) . In the later part of the paper, we consider the scenario, where the retailer can keep the operational risk within a limit by putting some additional effort. In the case of non-fulfillment of demand, the retailer will fail to repay the loan amount. Thus, she goes bankrupt, and the lender (either the manufacturer or the platform) loses the loan amount. The platform also does not get any referral fee, which follows real practice. For example, online platforms such as *Amazon* and *Flipkart* have mentioned on their respective websites that they charge the referral fee or commission fee only when the product is sold(Amazon.com 2023b; Flipkart.com 2022). When the product is not sold, they cannot claim the referral fee. Furthermore, as per real-world practice, we consider that the referral fee rate is exogenous as it is preset by the platforms according to the product category (Amazon.com 2023b; Flipkart.com 2022). It is also consistent with existing studies (Gong et al. 2020; Zhen et al. 2020). For analytical tractability, we consider a linear downward-sloping customer demand under financing mode *j* that is denoted by ʼΩᶜ ᵢ ρ ᵢ ὴᶜ. “This comes under the family of linear model of demands (i.e., ʼΩᶜ ᵢ ὦ ᵢ ὦὴᶜ which has been extensively

[3] From our analysis, we find that when the upper bound of ‗ becomes more than a threshold, the demand becomes 0 (see Online Appendix B2 to obtain the value of the threshold).

used in recent studies (Tang et al. 2018; Xu et al. 2021, 2024; Yan et al. 2020). According to a recent empirical study by Yu et al., 2024, the demand function of a food manufacturer selling on Tmall.com is ٰΩ؁سي φ ₹ ήؚ. This justifies our model assumption. We consider the market size and price coefficient to be 1 for simplified equilibrium expressions. We also conduct an analysis by incorporating the price sensitivity coefficient and market size in the demand function and find that the qualitative result does not change (Online Appendix E).

To obtain the working capital, the retailer chooses either TCF or PCF, with the goal of maximizing her profit. We present the analytical details of the two financing schemes as follows.

TCF: The manufacturer provides the product to the retailer on credit. At the end of the selling season, the retailer repays the manufacturer an amount of ύ ˡ ˜ ٰΩˡ ˜ ,ٖ where ύ ˡ ˜ ٖis the wholesale price charged by the manufacturer. Under TCF, it is also called the postponed wholesale price (An et al. 2021), as the payment of the wholesale price is deferred to the end of the selling season. It comprises both the nominal wholesale price, ύ, and the deferment fee (trade credit interest rate), ὶ ˡ ˜ .ٖ Hence, the postponed wholesale price ύ ˡ ˜ ٖis equivalent to ύ ρطὶ ˡ ˜ ٖ. This setup has been used widely in the SCF literature (An et al. 2021; Jing et al. 2012; Rui and Lai 2015). Our modeling framework is similar to the early payment discount models used in the mainstream OM literature, such as Kouvelis and Zhao (2012), Chod (2017), and Chen (2015). In these papers, interest rate is used as a proxy for discount rate. In our model, we derive the effective interest and the discounted wholesale price, which can be easily converted into regular wholesale price and discount rate. Hence, both these financing mechanisms are analogous and can be modeled and converted into each other quite easily. We discuss this in detail in Online Appendix H.

PCF: The retailer obtains a loan amount, ύ ئ ˜ ٰΩئ ˜ ,ٖ from the platform at an interest rate ὶ ئ ˜ ٖand procures the product from the manufacturer by paying instantly. After the selling season, the retailer repays the loan amount ύ ئ ˜ ٰΩئ ˜ ٖρطὶ ئ ˜ ٖ to the platform (Gong et al. 2020; Wang et al. 2019; Yan et al. 2020).

We now state the other assumptions related to the financing models. First, all the supply chain members are economically rational and risk-neutral. The retailer is an SMB and has zero initial working capital. She is unable to avail of suitable bank credit financing due to the lack of data on her business history, credit rating, etc., but she gets sufficient loan under TCF as well as under PCF. We consider that the product price and the problem parameters, e.g., operational risk, production cost, referral fee rate, wholesale price, retail price, and lending rate, are common knowledge. In certain cases (e.g., failure caused by machine failure or inbound logistics issues), the retailer would not be able to fulfill any order. Hence, we assume that in case of failure, the retailer cannot deliver any product to the customer (Rath et al. 2021). Moreover, in Section 6.2, we relax this assumption and analyze a situation in which the retailer can fulfill the demand partially in case of failure. In some business settings, the manufacturer may decide whether to offer trade credit to the retailer first, and then the platform may take his lending decision. We analyze this extended form of the game in Section 6.4.

3.2. Trade Credit Financing (TCF)

We first analyze the scenario in which the retailer avails the financing from the manufacturer (TCF). The manufacturer decides the postponed wholesale price, ύ ا ّ ,ْ where ύ ا ّ ْ سي ύ ρطى ì ا ّ ْ (An et al. 2021; Jing et al. 2012; Rui and Lai 2015). After procuring the product, the retailer starts selling at a per-unit price of ὴ ا ّ .ْ We also derive the equilibrium expressions under TCF in which the manufacturer separately offers the wholesale price and the interest rate instead of the postponed wholesale price. We find that the sequential decision making of the wholesale price and the interest rate does not alter the equilibrium expressions (Online Appendix G). Existing literature, such as Chen (2015), supports this finding. In Chen (2015)'s comparative analysis of TCF and bank financing, the author found that it does not matter whether the manufacturer declares the normal wholesale price and interest rate or the postponed wholesale price. Please see Online Appendix G for a detailed analysis. Upon successful delivery (with probability ρطي ـ), she generates revenues equal to Ὠ ا ّ ὴ ا ّ .ْ The platform keeps an amount of | Ὠ ّ ὴ ا ّ ْ as referral fee and transfers the remaining amount to the retailer. After this, the retailer pays an amount of Ὠ ا ّ ὑ ا ّ ْ to the manufacturer. If the retailer fails to deliver the product, she goes bankrupt and is unable to pay off the financing obtained through TCF. The event sequence is provided in Figure 1 (Online Appendix A2).

The profit functions of the supply chain members are given below.

"ا ّ ْ ὴ ا ّ ْ	=	ρطي ـ Ὠ ا ّ ْ ρطي | ὴ ا ّ ْ طي ύ ا ّ ْ ;	(1)
"ا ّ ْ	=	ρطي ـ | Ὠ ا ّ ὴ ا ّ ,ْ	(2)
"ا ّ (ْ ύ ا ّ ْ	=	ρطي ـ Ὠ ا ّ ὑ ا ّ ْ ὦ Ὠ ا ّ .ْ	(3)

We solve this Stackelberg game with the manufacturer as the leader and the retailer as a follower. The equilibrium expressions in the TCF are provided below.

"ا ّ ـُ	=	ه٩ظ٩ت٩ف٨ظف٩ / ه٤ه٩ظ ه٩ف ,	(4)
"ا ّ ـُ	=	ظ ١٨ت٩١ظ ه٩ف٩١ف ه٩ت٩ظ ه٩ف٩ / ه٤ه٩ظ ه٩ف ,	(5)
"ا ّ ـُ	=	ه٩ظ٩ت٩ف٨ظف٩ / ٦ه٩ظ ه٩ف ,	(6)
ὴ ا ّ ـُ	=	١ه٩ظ ه٩ف٨ت / ٢ه٩ظ ه٩ف ,	(7)
ύ ا ّ ـُ	=	ه٩ظ٨ت٩ف٨ظف / ٠ه٩ف .	(8)

3.3. Platform Credit Financing (PCF)

In this subsection, we derive the optimal equilibrium expressions for platform credit financing. Under PCF, the retailer obtains the loan amount, Ὠ ئ ّ ὑ ئ ّ ,ْ from the platform at an interest rate ì ئ ّ ْ and procures the products from the manufacturer. The retailer generates revenue equal to Ὠ ئ ّ ὴ ئ ّ ْ upon successful delivery of the items. At the end of the selling period, the retailer pays the loan amount, Ὠ ئ ّ ὑ ئ ّ ْ ρطى ì ئ ّ ْ ĥ and the referral fee, | Ὠ ئ ّ ὴ ئ ّ ,ْ to the platform. However, this is only possible if the retailer successfully delivers the product to the customer; otherwise, neither the platform nor the retailer earns anything. The event sequence is provided in Figure 2 (Online Appendix A2). The profit functions are written below.

$$\pi_M^{PCF} = p_M D(p_M, p_R) - \rho_M \left[D(p_M, p_R) - \beta_M \left(\theta_M D(p_M, p_R) + \theta_R D(p_M, p_R) \right) \right], \quad (9)$$

$$\pi_R^{PCF} = p_R D(p_M, p_R) - \rho_R \left[D(p_M, p_R) - \beta_R \left(\theta_M D(p_M, p_R) + \theta_R D(p_M, p_R) \right) \right], \quad (10)$$

$$\pi_P^{PCF} = \left(\rho_M - \rho_R \right) \left[D(p_M, p_R) - \beta_M \left(\theta_M D(p_M, p_R) + \theta_R D(p_M, p_R) \right) \right]. \quad (11)$$

Under PCF, at the first stage, the manufacturer and platform simultaneously decide the optimal wholesale price (w_M^{PCF}) and the optimal interest rate (r_M^{PCF}), respectively (Figure 2 (Online Appendix A2)). Then the retailer optimizes her retail price (p_R^{PCF}). We consider a simultaneous wholesale price and lending decision because both are operational decisions in a short time period. Therefore, simultaneous decision-making is more apt than the sequential decision-making process, which is more suitable for strategic decision-making. Furthermore, Kouvelis & Zhao (2012) and Kouvelis & Zhao (2016) clearly mentioned that the manufacturer provides the normal/ discounted wholesale price and interest rate simultaneously. As a remark, we also conduct an analysis in which the manufacturer decides the wholesale price first, and then the interest rate is decided by the lender (Online Appendix F). We find that the core result does not vary when we change the decision-making process from simultaneous to sequential.

The equilibrium expressions are provided below:

$$\pi_M^{PCF} = \frac{\left(\alpha - \beta_M \theta_M \right) \sqrt{\left(\alpha - \beta_M \theta_M \right)^2 + 4\beta_M \theta_M \left(\alpha + \beta_M \theta_M \right)} + \left(\alpha - \beta_M \theta_M \right)^2 + 2\beta_M \theta_M \left(\alpha + \beta_M \theta_M \right)}{4\beta_M \theta_M}, \quad (12)$$

$$\pi_R^{PCF} = \frac{\left(\alpha - \beta_R \theta_R \right) \sqrt{\left(\alpha - \beta_R \theta_R \right)^2 + 4\beta_R \theta_R \left(\alpha + \beta_R \theta_R \right)} + \left(\alpha - \beta_R \theta_R \right)^2 + 2\beta_R \theta_R \left(\alpha + \beta_R \theta_R \right)}{4\beta_R \theta_R}, \quad (13)$$

$$\pi_P^{PCF} = \frac{\left(\rho_M - \rho_R \right) \left(\left(\alpha - \beta_M \theta_M \right) \sqrt{\left(\alpha - \beta_M \theta_M \right)^2 + 4\beta_M \theta_M \left(\alpha + \beta_M \theta_M \right)} + \left(\alpha - \beta_M \theta_M \right)^2 + 2\beta_M \theta_M \left(\alpha + \beta_M \theta_M \right) \right)}{\left(\alpha - \beta_M \theta_M \right) \sqrt{\left(\alpha - \beta_M \theta_M \right)^2 + 4\beta_M \theta_M \left(\alpha + \beta_M \theta_M \right)} + \left(\alpha - \beta_M \theta_M \right)^2 + 4\beta_M \theta_M \left(\alpha + \beta_M \theta_M \right)}, \quad (14)$$

$$\theta_M^{PCF} = \frac{\left(\alpha - \beta_M \theta_M \right) \sqrt{\left(\alpha - \beta_M \theta_M \right)^2 + 4\beta_M \theta_M \left(\alpha + \beta_M \theta_M \right)} + \left(\alpha - \beta_M \theta_M \right)^2 + 4\beta_M \theta_M \left(\alpha + \beta_M \theta_M \right)}{4\beta_M \theta_M}, \quad (15)$$

$$\theta_R^{PCF} = \frac{\sqrt{\left(\alpha - \beta_M \theta_M \right)^2 + 4\beta_M \theta_M \left(\alpha + \beta_M \theta_M \right)}}{2}, \quad (16)$$

$$r_M^{PCF} = \frac{\sqrt{\left(\alpha - \beta_M \theta_M \right)^2 + 4\beta_M \theta_M \left(\alpha + \beta_M \theta_M \right)} - \left(\alpha - \beta_M \theta_M \right)}{2\beta_M \theta_M}. \quad (17)$$

4. EQUILIBRIUM ANALYSIS

In this section, we characterize the equilibrium choices of the manufacturer, retailer, and platform under TCF and PCF. We compare the postponed wholesale price and the retail price under TCF and PCF in different market scenarios. Further, we focus on the retailer's optimal choice of financing mode. We also analyze the impact of financing on consumer surplus. It is important to mention here that in our analysis, we consider that $\theta_M < \frac{\alpha}{\beta_M}$ because when the operational risk becomes very low, the optimal PCF interest rate becomes negative, and under high operational risk, the demand for the product becomes negative. As both are unrealistic, we do not include these cases in our analysis. It is in line with the existing SCF literature (Kouvelis and Zhao 2012). Please see Online Appendix B for further information. In the proof of propositions, we also show that the respective thresholds remain in the feasible region. Moreover, we also demonstrate that the

optimal profit expressions are concave with respect to the decision variables (i.e., the retail price, the interest rate, and the wholesale price) (Online Appendix A)

We represent the postponed wholesale price as ύ؟ج. Under TCF, the postponed wholesale price is same as the wholesale price charged by the manufacturer, which includes the nominal wholesale price as well as the payment deferment fee (An et al. 2021; Rui and Lai 2015). Similarly, under PCF, the equivalent postponed wholesale price can be represented as ύ ئ ّ ْ ρ طى ìئ ّ ْ. In Proposition 1, we compare the postponed wholesale price (ύ؟ج) under TCF and PCF.

Proposition 1. *When the operational risk of the retailer is low*[4] *(ـــ جى ـــ سي ρ طي ـــت / ٥٩١ظ٨٠ظ ـــ), the optimal postponed wholesale price under TCF is less than that under PCF (ύ؟ا ّ ُ جى ύ؟ئ ّ ُ). Otherwise, when ـــ حي ـــ, then ύ؟ا ّ ُ حي ύ؟ئ ّ ُ.*

Proof of Proposition 1: <u>All proofs in this paper are placed in the online appendix.</u>

Under TCF, the manufacturer provides the product as well as financing to the retailer. So, the manufacturer uses two decision levers, namely, operational (by setting the unit wholesale price) as well as financial (by controlling the interest rate), based on the retailer's operational risk. When the retailer's operational risk is low (i.e., the operational risk is lower than a threshold value (ـــ جى ـــ), the manufacturer knows that the likelihood of the retailer's default is also low. So, it charges a low-risk premium. Therefore, to incentivize the retailer to order more and set a low retail price, the manufacturer either keeps a lower value of wholesale price or charges a low interest rate, leading to a lower postponed wholesale price under TCF ύ؟ا ّ ُ. Similarly, under PCF, the platform keeps the interest rate low so that the retailer procures larger quantities from the upstream manufacturer, which eventually leads to higher revenues from referral fee. However, the manufacturer has no incentive to lower the nominal wholesale price under PCF as it is not affected by the retailer's default risk. Hence, the postponed wholesale price under PCF (ύ؟ئ ّ ُ remains higher compared to that under TCF ύ؟ا ّ ُ 8Therefore, we conclude that when the operational risk of the retailer is lower than a threshold (ـــ جى ـــ , the postponed wholesale price under TCF ύ؟ا ّ ُ is less than that under PCF ύ؟ئ ّ ُ.

With operational risk, the likelihood of the retailer's default increases. Due to this, the manufacturer and the platform face higher potential losses under TCF and PCF, respectively. Hence, they charge a higher risk premium, increasing the postponed wholesale price under TCF and PCF. Under TCF, the manufacturer tries to compensate for its loss by charging the retailer higher ύ؟ا ّ ُ as the risk increases. However, under PCF, the manufacturer does not share the risk and hence, does not increase the wholesale price. This moderates the incremental impact of the platform's risk premium on ύ؟ئ ّ ُ. This moderation effect is absent under TCF. Hence, with an increase in the retailer's operational risk, ύ؟ا ّ ُ increases at a higher rate than ύ؟ئ ّ ُ and

[4] It should be noted that when the operational risk ـــ is lower than a threshold value ـــ سي ρ طي ـــت / ٥٩١ظ٨٠ظ ـــ , we consider the operational risk to be low.

eventually, the postponed wholesale price under TCF ύ ُ ِ becomes more than that under PCF ύ ُ ِ for higher values of operational risk (ـــ ـــ .

Our findings are in line with existing research. For instance, Cheng et al. (2021) showed that the wholesale price in TCF is less than that in bank financing. The postponed wholesale price has a direct impact on the retail price. Next, we present the dynamics of the retail price in Proposition 2.

Proposition 2. *The retailer sets the retail price lower under TCF than under PCF* ή ُ ِ ـــ ـــ ή ُ ِ *when her operational risk is low* ـــ ـــ . *Otherwise, when* ـــ ـــ *we have* ή ُ ِ ـــ ـــ ή ُ ِ .

Proposition 2 states that the retail price is lower under TCF or PCF when the operational risk is low or high, respectively. Previously, in Proposition 1, we ascertain that the postponed wholesale price is lower under TCF when the operational risk of the retailer is below a certain threshold ـــ . The postponed wholesale price paid by the retailer includes all the costs related to purchasing (i.e., the nominal wholesale price and the lending cost). Due to this, the effective unit purchasing cost is lower under TCF when the operational risk is low. The retailer can set a lower retail price under TCF due to lower purchasing cost when the operational risk is lower than the threshold. However, under higher values of operational risk ـــ ـــ , the retailer's purchasing cost becomes higher under TCF, which leads to a higher retail price under TCF.

Our findings contribute to the existing literature on SCF. Yan et al. (2020) and Zhen et al. (2020) found that the retail price under PCF can be higher than that under bank credit financing. Cheng et al. (2021) also showed that the retail price under TCF can be lower than that under bank financing. The existing papers compare the retail price under secured and unsecured financing schemes. In contrast, our findings are related to two unsecured loans (i.e., PCF and TCF). We find that the retail price under TCF is low when the risk is low; otherwise, it is lower in PCF. Thus, our finding extends the horizon of e-commerce SCF by providing insights into the comparison of two unsecured loans. Rath et al. (2021) found that the retail price under PCF can be more than the retail price under bank financing under high risk when the production cost is high. In contrast, we find that when only TCF is available instead of bank loan, the retail price under PCF is always low under the high-risk condition. Next, we focus on analyzing profits of supply chain players. We first present the manufacturer's profit and then focus on the retailer's and platform's profit.

Proposition 3. (a) *The manufacturer's profit under PCF is higher than that under TCF when the retailer's operational risk is high* ـــ ـــ . *Otherwise, when* ـــ ـــ *we have* ِ ُ ِ ـــ ـــ ِ ُ ِ . *(b) When the operational risk of the retailer is low* ـــ ـــ *, the retailer chooses TCF as she obtains higher profit as compared to PCF* ِ ُ ِ ـــ ـــ ِ ُ ِ . *Otherwise, when* ـــ ـــ *, we have* ِ ُ ِ ـــ ـــ ِ ُ ِ . *(c) The platform earns more profit under PCF when the operational risk is low* ـــ ـــ *or high* ـــ ـــ . *because his optimal profit under PCF is more than that under TCF in these market scenarios* ـــ ـــ ِ ُ ِ ـــ ـــ ِ ُ ِ *Otherwise, when the operational risk is moderate* ـــ ـــ ـــ ـــ . *, we have* ِ ُ ِ ـــ ـــ ِ ُ ِ .

Remarks: The value of ـــ ـــ ρ ـــ ـــ and ـــ ـــ can be obtained by solving the following equation: ـــ ـــ π , where ـــ ـــ ـــ ـــ

Comparing between TCF and PCF: Proposition 3 (a) states that when the operational risk of the retailer is low, the manufacturer obtains more profit under TCF; otherwise, its profit under PCF is more. Under TCF, the manufacturer earns through two revenue sources: The nominal wholesale price and the interest fee. Whereas under PCF, it earns only through the nominal wholesale price. From Proposition 1, we find that the postponed wholesale price is lower under TCF compared to that under PCF when operational risk is low $\theta < \theta_{low}$. This leads the retailer to increase the order quantities from the manufacturer under TCF. As a result, the manufacturer earns higher sales revenues under TCF. Additionally, under TCF, the manufacturer expects to earn higher revenues from the lending business as the retailer's default risk is low. Thus, when the retailer's operational risk is low, the manufacturer's profit is higher under TCF. However, under higher values of operational risk $\theta > \theta_{high}$, the manufacturer's expected loss in lending becomes very high due to the higher likelihood of the retailer's default. Moreover, the manufacturer's sales revenue under TCF is also less than that under PCF due to lower order volume from the retailer. By contrast, the manufacturer does not bear any risk under PCF due to the retailer's operational inefficiencies, as the retailer pays him through platform lending. Hence, the manufacturer's profit under TCF becomes less than that under PCF when the operational risk of the retailer is above a certain threshold θ_{mid}. The findings may explain why manufacturers such as *HP* and *Haier* provide unsecured loans to downstream retailers (Haier 2015; HP.com 2021). The manufacturers not only facilitate the trade through TCF but also generate more value for themselves.

From Proposition 3(b), the retailer chooses TCF (PCF) when her risk is low (high). In Proposition 2, we show that in the low-risk scenario, the retail price is less under TCF than under PCF due to the lower the value of ω. Thereby resulting in higher demand under TCF compared to PCF. Furthermore, we find that the retailer's per-unit profit margin is higher under TCF than under PCF (P.S.: The proof is provided in Online Appendix C4). When the retailer's operational risk is low, the manufacturer sets the postponed wholesale price so that the per-unit profit margin of the retailer becomes higher under TCF compared to PCF. Hence, the retailer obtains higher profit under TCF than PCF due to high demand and per-unit profit margin. On the other hand, when the operational risk is sufficiently high (i.e., higher than the threshold θ_{mid}), the manufacturer has no motivation to incentivize the retailer to choose TCF as the manufacturer is better off under PCF (Proposition 3 (a)). Therefore, the retailer's per-unit profit margin under PCF becomes higher than that under TCF. Moreover, it is easy to derive that total demand under PCF is also higher than that under TCF in this market condition. Due to these factors, the retailer earns a higher profit under PCF as compared to TCF under higher risk. Therefore, the retailer prefers TCF to PCF if the operational risk is low; otherwise, she is better off under PCF.

Though PCF has become popular among retailers, we find that it is not always better for the retailer. This is also evident from the retailers' testimonials about different PCF modes. For instance, some retailers find the

loan terms of *Amazon lending* unfavorable and the cost of borrowing high[5]. Hence the retailer needs to analyze all the available borrowing options before taking the loan. From Proposition 3(a) and 3(b), we infer that the manufacturer's preference always aligns with the optimal choice of the retailer. Therefore, when the operational risk is low, the manufacturer should provide financing to the capital-constrained retailer, and the retailer should also choose it irrespective of the platform's offer. However, in the rest of the scenarios, both the retailer and the manufacturer earn higher profits if the platform provides financing to the retailer. Existing SCF literature, such as Chen (2015), showed that TCF is always better for the retailer and the manufacturer. In contrast, we find that when the risk is high, both the retailer and the manufacturer are better off under PCF. Next, we explore the scenarios in which the platform benefits from PCF and TCF, respectively.

In Proposition 3(c), we find that unlike the retailer and the manufacturer, the platform benefits from the PCF when the operational risk is low or high. This result can be explained as follows. Under PCF, the platform has two critical sources of income, namely the "referral fee" and "interest fee". Whereas under TCF, he can only earn through a single source which is the referral fee. When the risk is low, the platform obtains high referral fee revenue under TCF than under PCF due to the higher sales revenue of the retailer (Proposition 3 (b)). However, the platform's interest fee revenue under PCF is high in this condition as the chance of the retailer defaulting is low. Due to this additional revenue source, the total profit of the platform under PCF surpasses that under TCF when the operational risk is low.

When the operational risk is moderate $\theta_{mod} \in [\theta_{low}, \theta_{high})$, the retailer earns higher revenues under PCF than under TCF (Proposition 3(b)). So, the platform's referral fee revenue becomes more under PCF. However, his expected loss from lending becomes high because the retailer fails to repay the loan. Due to this, even with higher referral fee revenue, the platform's profit under PCF becomes less than that under TCF when operational risk is moderate. Therefore, the platform is better off not providing PCF in this market condition.

However, if the operational risk is high $\theta_{high} \in [\theta_{mod}, 1]$ the platform is better off under PCF because his profit becomes higher under PCF than that under TCF. Under high operational risk, the manufacturer charges a very high-risk premium, leading to lower revenues for the retailer. As a result, the platform loses a significant amount of referral fee. On the other hand, under PCF, the platform can judiciously use both the interest rate and the referral fee under high operational risk. He counterbalances the possible loss from high operational risk using the two sources of revenue. Thus, the platform prefers PCF to TCF when the retailer's operational risk is high. In contrast to existing studies (Gong et al. 2020; Yan et al. 2020), which reported that PCF always improves the platform's profit, our findings suggest that PCF is not always beneficial. This may be one of the reasons behind *Amazon*'s restructuring of lending policy and less aggressive loan disbursement post-2017 (Rath et al. 2021). After analyzing the individual profit of the supply chain players under TCF and PCF, we focus on finding the market condition under which the financing choices of the manufacturer, retailer, and platform are aligned. We present the result in Corollary 1.

[5] https://www.merchantmaverick.com/reviews/amazon-lending-review/

Corollary 1. *The manufacturer, the retailer, and the platform all are better off under PCF than under TCF when the operational risk is high, i.e.,* ـــ جي ـــ.

Corollary 1 states that under high operational risk, all three supply chain players (i.e., the manufacturer, retailer, and platform) achieve higher profit under PCF than under TCF. From Propositions 3(a) and 3(b), we find that the manufacturer and the retailer's financing choices are always aligned. However, the platform's choice differs from that of the retailer and the manufacturer under certain market conditions. When the operational risk is low ـــ جى ـــ , both the retailer and the manufacturer are better off under TCF; however, the platform prefers PCF to TCF (Proposition 3(c)). Similarly, for other values of operational risk (ـــ حي ـــ , the retailer prefers to borrow from the platform (Proposition 3(b)), and the manufacturer is also better off under PCF (Proposition 3 (a)). However, Proposition 3(c) states that the platform prefers providing PCF loans only when the operational risk is high (ـــ جي ـــ. . Therefore, we conclude that when the operational risk is high ـــ جي ـــ. , all the supply chain members prefer PCF to TCF.

Apart from supply chain profit comparison, we also study the consumer surplus (CS) from a social responsibility perspective. With the rise in government regulations regarding consumer protection(FTC.gov 2024) and customer centric policy of online marketplaces (Nussenbaum 2022), online supply chain players such as the platforms and online retailers are taking customer welfare into consideration in the policy-making process. Therefore, it is essential to examine whether any policy is reducing consumer welfare or not. Existing studies (Guo et al., 2022, Geng et al., 2023) suggest that in some cases the retailer's policy might not be in line with consumer welfare. Hence, in this section we examine the SCF strategies that generates more consumer surplus under different market conditions. Consumer surplus is the economic measure of consumers' net welfare. A consumer gains a surplus of ùطي ήᶜᶻ from the consumption of one unit of the product, where ùis the intrinsic value associated with the product and uniformly distributed between 0 and 1. To derive the total surplus, we take the summation of the non-negative utility surplus of all the consumers in the market. We derive the consumer surplus from the utility model as follows:

ö "Ÿسي ـ ـ ـ

From Proposition 4 (a), we can see that total consumer surplus is high under TCF (PCF) when the operational risk is low (high). In Proposition 2, we find that when the operational risk of the retailer is low, the final retail price ή^{ᶜz} is low under TCF. Due to low retail price, a consumer derives a higher utility surplus ù طي ή^{ᶜz} under TCF. Furthermore, the demand is also higher under TCF owing to the lower retail price. Therefore, the consumer surplus is higher under TCF when the operational risk is low. In the rest of the scenarios, the demand and the surplus become higher under PCF due to the low retail price (Proposition 4 (a)).

Proposition 4 (b) states that the total supply chain profit is higher under TCF when the operational risk is low. The reason may be explained as follows. Under a low-risk scenario, total demand for the product is more under TCF, leading to a higher profit for the manufacturer and the retailer (Propositions 3 (a) and 3(b)). Due to this, the total profit of the supply chain is more under TCF under low risk. However, in case of high risk, the retailer and the manufacturer earn more profit under PCF, leading to higher supply chain profit under PCF. Previous studies in SCF have analyzed total supply chain profit Chen 2015; Lee and Rhee 2010; Yan et al. 2016). For example, Lee and Rhee (2010) showed that TCF could improve total supply chain profit and even achieves supply chain coordination in a revenue-sharing contract. Similarly, Chen (2015) reported that the TCF, along with the wholesale price contract, obtains more supply chain profit than BCF in the presence of demand risk. Moreover, they found that with an increase in demand variability, the efficiency of TCF goes down. In contrast to these studies, we consider the operational risk of the retailer, and we show that the total supply chain profit is higher under TCF when risk is low. Further, in Section 6.3, owing to the importance of supply chain contracts (Ghosh et al. 2018; Adhikari et al. 2020), we propose a contract (Sales Enhancement Contract) that can increase the total supply chain profit under both TCF and PCF.

Corollary 2. *The manufacturer, the retailer, the platform, and the consumer all are better off under PCF when the operational risk is sufficiently high, i.e.,* ═ جي ═.

Previously in Corollary 1, we show that when the operational risk is high (i.e., ═ جي ═.) the manufacturer, the retailer, and the platform prefer PCF to TCF as they all obtain higher profits under PCF than under TCF. Similarly, from Proposition 4 (a), we find that total consumer surplus is high under PCF when operational risk is moderate or high ═ جي ═ه). Therefore, in Corollary 2, we conclude that when the operational risk is high, all the supply chain members and consumers are better off under PCF. Hence, PCF achieves an all-win situation in this case.

5. FURTHER ANALYSES AND DISCUSSIONS

In this section, we conduct numerical experiments and analyze the findings to further derive critical managerial insights. We determine the market conditions under which each supply chain player is better off in the two financing mechanisms[6]. We find the win-win-win outcome for all three supply chain players. In our numerical experiments, we consider the unit production cost *c* to be 0.4. This value is used only for the purpose of

[6] In our numerical experiments, we have excluded unrealistic market scenarios such as negative demand and negative interest rates from our analysis. In the following figures, we denote these unrealistic market scenarios as 'Infeasible zone'.

presentation. We conduct the analysis for other values of production cost (e.g., $c = 0.2$, $c = 0.3$, and $c = 0.5$). We obtain similar results in all the different numerical experiments. The other parametric values in the model, namely, the operational risk ( ) and the referral fee ( ), are considered based on the feasibility conditions. Please see Online Appendix B2 for more details. Moreover, prior SCF research, such as Wang et al. (2019) and Zhen et al. (2020), used similar parametric values in their numerical analysis.

5.1 Impact of the Platform's Referral Fee Rate and the Retailer's Operational Risk

We first analyze the impact of the referral fee rate and the retailer's operational risk on the financing decision of the retailer. The referral fee rate is pre-decided by the platform based on the product category. It ranges from 6% to 45% on *Amazon.in*. However, for most product categories, *Amazon*'s referral fee rate lies between 8% and 15% (Gupta and Chen 2020). Similarly, *Walmart*'s referral fee rates are in the 8%- 15% range. The low referral fee product categories include prescription medicine, books, gold coin, and laptops**Error! Bookmark not defined.**. On the other hand, platforms charge a high referral fee for products like fashion jewelry, fine art, and kindle device.

We begin our investigation by analyzing interest rates and the retail price. We calculate the implicit TCF interest rate using the postponed wholesale price under TCF and the nominal wholesale price under PCF. Under TCF, the postponed wholesale price charged by the manufacturer includes the fee for deferred payment, which is equivalent to the TCF interest rate, whereas, under PCF, the retailer buys the product with an upfront payment. So, the manufacturer charges a nominal wholesale price. Therefore, the equivalent TCF interest rate, ; is equal to $\frac{\text{ـهـ ـج ـز ـد ـهـ ـج ـهـ ـي ـد}}{\text{ـهـ ـج ـز ـد}}$ (Yang and Birge 2018). From Figure 3 (Online Appendix A2), we find that the interest rate under TCF is lower than that under PCF when the referral fee rate is low. The retail price also follows the same pattern as the interest rate.

Under PCF, the platform makes money from both the referral fee and interest earnings. When the referral fee rate is low, the platform charges a high interest rate to compensate for the low income from the referral fee. Therefore, the interest rate under PCF remains higher than that under TCF for low-referral fee products. When the referral fee is high, the platform charges a lower interest rate to induce high demand so that his revenue from the referral fee goes up. For moderate values of the referral fee, if the retailer has a high operational risk, then the platform's interest earning becomes low due to the retailer's high default rate. Hence, he charges a lower interest rate under PCF to increase his revenue from the referral fee. On the other hand, if the retailer's operational risk is low then, then the platform tries to generate more revenue from the lending business by charging a higher interest rate under PCF. Therefore, for a product with a moderate referral fee, the interest rate under PCF (TCF) is more than that under TCF (PCF) under low (high) operational risk.

For a product in the low referral fee rate category (e.g., baby products, books), the retailer incurs a lower unit cost under TCF due to a lower interest rate compared to PCF. Therefore, she sets the retail price lower under TCF compared to that under PCF. However, when the referral fee rate is high, the retailer's unit cost is higher under TCF due to the high interest rate charged by the manufacturer. Hence, she sets a high retail price

under TCF compared to PCF if the referral fee is high. Similarly, if the referral fee is moderate, the retailer charges a higher retail price under PCF (TCF) under low (high) operational risk owing to higher costs under PCF (TCF).

Next, Figure 4(a) (Online Appendix A2) presents the optimal financing choice for the retailer under various market conditions. A retailer chooses TCF (PCF) if the product is in the low (high) referral fee category, irrespective of her operational risk. Interestingly, the retailer's financing choice shifts from TCF at low operational risk to PCF under moderate and high operational risk for a moderate referral fee. When the referral fee is low, the retailer charges a higher retail price under PCF, decreasing the total demand for the product. Due to this, the retailer's total revenue and total profit under PCF become lower than that under TCF when the referral fee is low. However, when the referral fee is high, the retailer sets a lower retail price under PCF, leading to both higher demand and profit for the retailer under PCF. Therefore, the retailer prefers PCF to TCF when she sells a product in the high referral fee category (i.e., the referral fee is higher than a certain threshold). We also observe that this threshold decreases with the operational risk. We infer from Proposition 3(b) that the retailer's profit falls more acutely under TCF than PCF as the operational risk increases. Hence, with a rising operational risk, the retailer's profit under PCF becomes higher than that under TCF at a moderate referral fee rate. The above findings can be used to derive product-based financing strategies for the retailer at different levels of operational risk. For products such as books and personal computers with a lower referral fee (10%), it is optimal for the retailer to choose TCF. For products with a higher referral fee (20%), such as jewelry and furniture, the retailer should opt for PCF. It is for products such as pet supplies and video game consoles with a moderate referral fee (15%), where the extent of operational risk drives the financing choice. TCF is a better choice for low operational risk, and PCF becomes optimal for moderate and high operational risk. The finding is presented in Table 3.

Table 3. Product-based optimal financing strategy of the retailer

		Referral Fee		
		Low	Medium	High
Operational Risk	Low	TCF	TCF	PCF
	High	TCF	PCF	PCF

Figure 4(a) (Online Appendix A2) also presents the manufacturer's profit under TCF and PCF at different levels of operational risk and referral fee. We find that the manufacturer's profit is higher under TCF than PCF at lower referral fee levels. As discussed, for a product with a low referral fee, the demand under TCF is higher than that under PCF due to the lower interest rate under TCF. Therefore, the manufacturer gets more orders from the retailer under TCF. Furthermore, the manufacturer earns additional revenue from the lending business under TCF. Thus, the manufacturer's total profit is higher under TCF when the referral fee is low. However, when the referral fee is high, the scenario changes. The manufacturer gets more orders under PCF than TCF. Moreover, the interest income under TCF also goes down due to the high referral fee rate, which becomes

insufficient to compensate the lower sales revenue under TCF as compared to PCF. Therefore, the manufacturer's profit is higher under PCF when the referral fee rate is high. For a moderate referral fee rate, if the retailer's risk is low, the manufacturer gets more order and interest fee revenue under TCF. Therefore, it is better off under TCF in this case; otherwise, it prefers PCF to TCF due to higher order size and guaranteed payment under PCF.

Now let us focus on the platform's decision. From Figure 4(b) (Online Appendix A2), we find that the platform is always better off under PCF when the referral fee rate is either low or high. Under PCF, both the referral fee and the interest fee are revenue sources for the platform, whereas under TCF, he has only a single source of income (i.e., the referral fee). From Figure 3 (Online Appendix A2), we know that the platform charges a high interest rate under PCF if the referral fee rate is low. Due to the high interest rate, the extra revenue earned from the lending business becomes very high under PCF, leading to a higher profit under PCF than under TCF. Similarly, when the referral fee is high, the platform charges a very low interest rate to induce high demand, making his profit higher under PCF than TCF.

Hence, it is better off under PCF when the referral fee rate is high or low. In the rest of the scenarios (for a moderate value of the referral fee), the platform prefers not to provide PCF because the revenue from the referral fee is insufficient to offset the platform's loss due to the retailer's default in these market scenarios.

5.2 Win-Win-Win Scenario

From the analysis presented in section 5.1, we conclude that the retailer's financing choice always aligns with that of the manufacturer; however, the platform's preference may differ in some market conditions. When the referral fee is high, all the players are better off with PCF (Figure 4(c) (Online Appendix A2) for the win-win-win region). However, under the rest of the scenarios, there is discord in the optimal financing choices of the supply chain players. When the referral fee is low, the manufacturer and the platform earn more profit under TCF and PCF, respectively; however, the retailer prefers TCF to PCF. Similarly, when the referral fee is moderate, the manufacturer and the retailer are better off under PCF (TCF) under high (low) risk, but the platform is better off under TCF (PCF). Hence, neither the manufacturer nor the platform prefers to provide financing.

6. EXTENDED MODELS AND ANALYSES

In this section, to drill deeper on the problem under investigation as well as test for robustness of the main qualitative findings, we extend our base model in several ways as detailed below. Note that all these extensions relate to some observed real-world practices.

6.1. Sales Enhancement Contract (SEC)

In this sub-section, we analyze the efficiency of a sales enhancement contract (SEC), in which the platform puts extra effort to enhance the market demand for the product. In return, the retailer provides an additional referral fee to the platform. From a practical perspective, the platform can improve the visibility of the retailer's

product through additional marketing efforts, which leads to higher demand for the product. For instance, *Amazon* displays products based on consumer search and can push retailer's product to the top of the search result (under the category "*Amazon*'s Choice" or "*Prime badge*"), leading to higher visibility and enhanced product demand (Amazon.com 2021). *Fulfillment by Amazon* is another initiative through which the retailer's product demand is increased (Amazon.in 2022.). In this sub-section, we analyze the scenario where the platform increases the demand for the product by an amount Ώ in the expense of an effort cost Ώ̃Ώ. The demand for the product with additional marketing effort becomes Ώ̃ ρ ὴ Ώ The retailer pays an additional portion of the sales revenue to the platform (Liu et al. 2021). We provide the profit functions of the supply chain players below.

Under the trade credit financing (TCF) mode:

ὴ = ρ Ώ ρ ὴ Ώ ,

= ρ Ώ ὴ Ώ̃Ώ,

= ρ Ώ ὴ Ώ̃Ώ.

Under the platform credit financing (PCF) mode:

ὴ = ρ Ώ ρ ὴ Ώ ρ ὴ ,

= ρ Ώ ὴ Ώ ρ ὴ Ώ̃Ώ,

= Ώ ὴ Ώ̃Ώ.

In this model, the platform first decides the optimal effort level Ώ Then the sequence of events remains the same as in the base case. We solve the model using backward substitution and get the equilibrium expressions under PCF and TCF (Online Appendix D3). We compare the impact of the sales enhancement contract (SEC) on the supply chain players' maximum profit. Owing to the high complexity of the equilibrium expressions, we conduct numerical analysis and provide the results below.

We find that under TCF, SEC improves the manufacturer's profit when the unit effort cost is low (Figure 7 (a) (Online Appendix A2)). In contrast, the manufacturer is always better off with SEC under PCF. Under TCF, when the effort cost is high, the manufacturer lowers the postponed wholesale price because a high wholesale price would increase the retailer's total cost, leading to a high retail price and low demand. Moreover, the platform cannot put high effort under high effort cost. Due to low postponed wholesale price and low demand, the manufacturer's total profit decreases under high effort cost. On the other hand, the platform strategically manages the interest rate and effort level under PCF, which does not impact the manufacturer's wholesale price significantly. Hence, under PCF, the manufacturer manages to earn higher profits with SEC, even with a marginal increment in demand.

From Figure 7 (b) (Online Appendix A2), we find that the retailer's profit is always more with SEC under PCF, whereas, under TCF, she earns more profit with SEC only when the effort cost is low. Under TCF, the higher effort cost leads to a higher retail price, decreasing the demand for the product. Hence the retailer obtains lower revenue leading to a lower profit with SEC. However, under PCF, the platform decides both the interest rate and the effort level and can counterbalance the effort cost more effectively, which in turn leads to higher

revenue and higher profit for the retailer. Figure 7(c) (Online Appendix A2) shows that the platform is always better off with SEC, irrespective of the effort cost. As the platform decides the effort level, he sets the level at which he earns more profit, irrespective of the financing mode. Hence, he is always better off with the additional effort. In Figure 7(d) (Online Appendix A2), we show SEC improves the total supply chain profit under TCF under low effort cost. When the effort cost is low, the manufacturer, the retailer, and the platform earn more profit with SEC. Hence total supply chain profit improves with SEC. Under high effort cost, SEC reduces the profit of the retailer and the manufacturer, which causes a decrease in total supply chain profit. However, under PCF, all the three supply chain members obtain higher profits with SEC; hence SEC always improves the total supply chain profit under PCF.

6.2. Non-Zero Initial Working Capital

Our base model assumes that the retailer has zero working capital to run her business. We extend our base model by considering that the retailer has some working capital ά with her. She takes a loan equal to the total capital requirement less the initial working capital ’Ωᶜύᶜ طي ά. We provide the profit functions under PCF and TCF below.

Under the trade credit financing (TCF) mode:

[illegible] = [illegible]

[illegible] = [illegible]

[illegible] = [illegible].

Under the platform credit financing (PCF) mode:

[illegible] = [illegible],

[illegible] = [illegible],

[illegible] = [illegible].

We obtain the equilibrium expressions following the same method as the base model. The equilibrium expressions are provided in Online Appendix D1. Owing to the high complexity, we examine this case numerically and find that the initial working capital plays a role in affecting the decisions. To be specific, under low working capital, the results of the base model are robust. Under high working capital, the manufacturer’s choice remains the same as in the base model; however, unlike the base model, the retailer prefers PCF when she has high working capital. The platform prefers TCF for moderate values of the working capital; otherwise, his choice remains the same as the base model.

6.3. Partial Demand Fulfillment

In certain scenarios, the retailer may fulfill a portion of the demand under operational failure. Hence, we extend the base case by relaxing the assumption that the retailer fulfills no order in case of failure. The retailer manages to fulfill ‘ proportion of total demand under failure, where ‘ represents the rate of partial demand fulfillment. One important point to note here is that the retailer might avoid bankruptcy even under operational risk with

partial demand fulfillment when the revenue from the partial sales minus the platform's commission ‘ is more than the loan repayment amount. Whereas if the former is less than the latter, the retailer goes bankrupt. In case of bankruptcy, the lender keeps the revenue from the sales. The demand functions in both the financing modes are given below.

Under the trade credit financing (TCF) mode:

Under the platform credit financing (PCF) mode:

We solve the profit functions and obtain optimal equilibrium expressions under TCF and PCF. The optimal expressions are provided in Online Appendix D2. We conduct various numerical experiments and provide the findings below. For expositional brevity, the following parameter values are presented: We find that the nature of the result remains the same as in the base case (Figure 4, Online Appendix A2). Under a low referral fee, the manufacturer and the retailer are better off under TCF, whereas the platform is better off under PCF (Figure 6(a),6(b) &6(c), Online Appendix A2). If the product is in the high referral fee category, all the players are better off under PCF. Hence it achieves a win-win-win situation naturally. However, we find that if the retailer can fulfill the demand partially, then TCF can also achieve a win-win-win situation (Figure 6(d), Online Appendix A2), unlike in the base model (Figure 4(c), Online Appendix A2).

In Table A2 (Online Appendix A1), we summarize the key takeaways of our analytical models. First, we present the findings of the basic model and then check the robustness of these findings by comparing them with the results of the extended models.

6.4 Impact of loss aversion nature of lenders

In the base model, we assume that the lenders (i.e., the manufacturer in TCF and the platform in PCF) are risk-neutral. However, in reality, the lenders might be loss averse, which means for the same amount of loss, different lenders may react differently based on their degree of loss aversion. This may lead to a change in the SCF equilibrium established in the base model. Therefore, we relax the assumption and consider the lenders are loss averse. Following the existing literature on loss aversion (Bai et al. 2019; Rath et al. 2024), we characterize the lender’s loss aversion utility function as given below:

The loss aversion coefficient —ᵢ is less than 1. With the decrease in —ᵢ the loss aversion nature of the lender increases. In our base model —ᵢ سي ρ The loss aversion utility functions of the manufacturer and platform under TCF and PCF, respectively, are as follows. The rest of the profit functions remain unchanged.

ᵀYحت"ؤ ّ تخ = ρطي ⎯ Ωا ّ ˚-ن ا ّ تطي ΩّΩ- ⎯ ΩّاΩّ ؤ—ؤ.

ᵀYحت"ئ ّ تخ = ρطي ⎯ Ωئ ّ † ήئ ّ تطن ئ ّ ˚-ρطي ائ ّ ˚-طي ن ئ ّ ؤΩئ ّ ˚-طي ⎯ن ئ ّ ؤΩئ ّ ؤ—ئ

The first term in the profit functions is the positive profit in case of a favorable outcome (i.e., successful order fulfillment). The second term in the profit functions is the negative profit (or loss) in case of unfavorable outcome (i.e., operation failure). It can be observed that when a lender becomes more loss-averse, it gives higher weightage to the loss than positive profit. We follow the same methodology as the base model and calculate the equilibrium expression under TCF and PCF. It is provided in online Appendix D4.

We conduct numerical analyses to derive insights into the financing strategies of the supply chain players in the presence of loss-averse lenders. For the numerical analysis, we consider c=0.4,λ=0.1,α=0.1. We find that whenever a lender's loss aversion increases, the retailer switches to another lender (Figure 9 (a), Online Appendix A2). For example, if the manufacturer's loss aversion increases, the retailer switches her financing mode from TCF to PCF. When the manufacturer becomes more risk averse, it is more concerned about the capital loss due to the retailer's bankruptcy. Hence it increases the interest rate. When the interest rate under TCF exceeds that under PCF, the retailer earns more profit and switches to PCF. Similarly, the retailer prefers TCF to PCF when the platform becomes more loss-averse. We also observe that when the manufacturer becomes more loss-averse, it obtains more profit under PCF than its own financing mode (i.e., TCF) (Figure 9 (b), Online Appendix A2). Under TCF, the manufacturer's disutility due to capital loss increases with its degree of loss aversion, whereas it has no risk of capital loss under PCF. When the degree of loss aversion becomes significantly high, the disutility due to capital loss becomes more than the gain from lending. Hence, a highly loss-averse manufacturer obtains more profit under PCF than TCF. Due to the same reason, a highly loss-averse platform is better off under TCF (Figure 9(c), Online Appendix A2). Based on the above findings, we can conclude that when the manufacturer (the platform) has high loss aversion, PCF (TCF) obtains a win-win-win situation for the whole capital-constrained supply chain (Figure 9(d), Online Appendix A2). It shows that though loss aversion can reduce the optimal profit level of individual players, it can help in achieving a win-win-win situation.

6.5 When the operational risk is endogenous:

Unlike the base case, a supply chain player can control its operational risk with strategic and tactical inventions, which takes significant effort and cost. For example, in our model, the retailer can improve operational efficiency by investing in better logistics systems, warehousing facilities, or ERP software. In this extension, we assume the retailer exerts some effort to keep the operational efficiency at level ⁋ سي ρطي ⎯ for which she incurs disutility cost is equal to ‰ΩΨ ˙ (Tang et al., 2018), where ‰is per unit disutility cost. In this case first the lender decides the interest rate followed by the retailing deciding the optimal effort level and selling price.

We consider the wholesale price to be exogenous for calculation feasibility. The profit functions under TCF and PCF are given below:

Trade credit financing (TCF)

$$\pi_r^{TCF} = (p - w - c_r)\left(a - bp + \theta\left(\frac{1}{1+r} - \frac{1}{1+\rho}\right)\right),$$
$$\pi_m^{TCF} = (w - c_m)\left(a - bp + \theta\left(\frac{1}{1+r} - \frac{1}{1+\rho}\right)\right),$$
$$\pi_l^{TCF} = \left(\frac{r}{1+r} - \frac{\rho}{1+\rho}\right)\theta\left(a - bp + \theta\left(\frac{1}{1+r} - \frac{1}{1+\rho}\right)\right).$$

Platform credit financing (PCF)

$$\pi_r^{PCF} = (p - w - c_r)\left(a - bp + \theta\left(\frac{1}{1+r} - \frac{1}{1+\rho}\right)\right),$$
$$\pi_m^{PCF} = (w - c_m)\left(a - bp + \theta\left(\frac{1}{1+r} - \frac{1}{1+\rho}\right)\right),$$
$$\pi_l^{PCF} = \left(\frac{r}{1+r} - \frac{\rho}{1+\rho}\right)\theta\left(a - bp + \theta\left(\frac{1}{1+r} - \frac{1}{1+\rho}\right)\right).$$

The equilibrium expressions are given below in Online Appendix D5. We find that when the effort cost is lower (higher) than a threshold, the retailer earns more under PCF (TCF) due to a lower interest rate. Thus, she prefers PCF (TCF) under low (high) effort cost (Figure 10 (a), Online Appendix A2). On the other hand, the platform and the manufacturer are better off under PCF and TCF, respectively, when the effort cost is less (Figure 10 (b) & 10 (c), Online Appendix A2. The lenders benefit from the lowered operational risk only if the effort cost is lower than a threshold; otherwise, the cost of lower operational risk overshadows the benefit of the lower operational risk.

6.6 Wholesale price is exogenously given:

In the base model., we assume that the manufacturer sets the wholesale price which maximizes its profit. However, in reality, the manufacturer may not have the power to alter the wholesale price owing to fierce competition or long-term contracts with the retailer (Sun et al., 2024; Yang and Birge, 2020). Therefore, in this section, we consider that the manufacturer is a price-taker and does not change the wholesale price. It can only alter the interest rate. The profit function for the supply chain players remains the same. Under TCF (PCF), the manufacturer (platform) and the retailer decide the interest rate and the selling price, respectively. The equilibrium expressions of the price, interest rate and profit functions are given in the Online Appendix D6. We present the findings from the numerical analysis below.

When the wholesale price is less than a threshold, the interest rate is lower under PCF than TCF. The platform can charge lower interest rates because the decrease in interest fees can be offset by the increase in referral fees due to increased demand. On the other hand, the manufacturer has no incentive to reduce the interest rate as the wholesale price is already low. Thus, when the wholesale price is low the interest rate is lower under PCF. When the wholesale price exceeds the threshold, the manufacturer lowers the interest rate as the wholesale price is sufficiently high, leading to a lower interest fee under TCF. when the wholesale price is lower (higher), owing to lower interest rates, the price is lower under PCF (TCF), and the retailer earns more

under PCF (TCF) (Figure 11 (a), Online Appendix A2). Figure 11 (b) (Online Appendix A2) states that the manufacturer earns more under TCF due to additional revenue source (i.e., interest fee). However, when the operational risk is high, such that the wholesale price and the interest rate are insufficient to recover the loss due to the retailer's bankruptcy, it is better off under PCF. Similarly, we find that the platform earns more profit under TCF when the wholesale price is high (Figure 11 (c), Online Appendix A2) because the demand under TCF becomes significantly high leading to high referral fee revenue under TCF compared to PCF.

6.7 Remarks: Other Extensions

In our base model, we analyze the optimal financing strategies of the supply chain players when both TCF and PCF are available to the retailer. Our inherent assumption is that the retailer can take a loan through either of these financing modes. However, in some practical scenarios, the manufacturer and/or the platform may not provide a loan to the retailer. In that case, the retailer has no other choice but to go for the available financing mode. In this sub-section, we consider some related possible scenarios.

First, the manufacturer decides its credit granting strategy (Figure 8, Online Appendix A2). We find that the manufacturer only provides TCF when the operational risk of the retailer is lower than a certain threshold حى ا ّ سيْ ρطي ت ظ٥٩ . The platform offers PCF only when the retailer's risk حى ئ ّ سيْ ρطي ۜ From the comparison of the credit granting strategy of the manufacturer and platform, we conclude that under some market scenarios ئ ّ حيْ حي ا ّ ْ; the manufacturer does not provide TCF to the retailer; however, she can take a loan through PCF. This suggests that PCF improves the financial inclusion of the retailers and facilitates more trade on the online platform. On the other hand, when the retailer's risk is very high حي ئ ّ ْ; the platform and the manufacturer should not offer financing to the retailer as the likelihood of her default is very high. Hence platforms like *Amazon* and *Flipkart* should consider this factor carefully while aggressively expanding their lending business. Next, we move to the other branch of the tree حى ا ّ حىْ ئ ّ ْ; in which the manufacturer offers TCF to the retailer. In this case, the retailer has both financing options (PCF and TCF) available. This is like our base case models. In this case, the retailer would opt for TCF when حى م; otherwise, she would take PCF. We summarize the mechanism in Figure 8 (Online Appendix A2). The findings from our analysis here justify the applicability of PCF as a novel financing tool in presence of traditional SCF instruments like TCF. It not only increases the financial inclusion of capital constrained SMBs and facilities trade but also improves the total SCF landscape even when TCF is available to the retailer.

7. CONCLUDING REMARKS AND MANAGERIAL IMPLICATIONS.

In the digital age, FinTech is critical to supply chain operations. PCF has hence established as an important financing mode. In this paper, we analyze a three-tier supply chain comprising a manufacturer, a retailer, and a platform and compare the optimal financing choice of the retailer under various market conditions.

From the engineering manager's perspective, we provide valuable insights on product-based financing strategies for the retailer at different levels of operational risk. We find that it is optimal for the retailer to choose TCF for products such as books and personal computers with a lower referral fee (10%). On the other

hand, the retailer should opt for PCF for products with a higher referral fee (20%), such as jewelry and furniture. The extent of operational risk becomes a deciding factor in the financing choice for products such as pet supplies and video game consoles with a moderate referral fee (15%). TCF is a better choice at lower operational risk values, and for higher operational risk, PCF becomes the preferred choice for the retailer.

Moreover, we demonstrate that platform can improve every supply chain member's profit under PCF by providing some additional paid services to the retailer through a sales enhancement contract. Hence the retailer should always buy the additional service under PCF. However, under TCF, she should take this service only when the cost is low; otherwise, though her sales improve, the total profit goes down.

As a remark, existing research on TCF has analyzed impacts of different supply chain risks. In particular Wang et al. (2021b) found that under low bankruptcy risk, bank financing is better for the retailer and the supply chain than trade credit. Similarly, Ning(2022) showed that the retailer never prefers trade credit when the demand uncertainty is low. In contrast, our results show that TCF is preferred under low performance risk scenarios even when a non-conventional financing method such as PCF is available. Similarly, in the PCF domain, Rath et al. (2021) demonstrated that under specific market conditions (i.e., high production cost and low goodwill loss), PCF can be more beneficial (as compared to BCF) for the retailer and platform when the performance risk is low. In contrast, we show that PCF benefits the retailer and the platform even when the retailer's performance risk is high. We hence supplement this stream of research. We summarize the important findings and their managerial implications in the table given below.

Table 4. Important findings and managerial implications

Research Question	Findings	Managerial implications
Under what market scenarios would the manufacturer and the platform be better off in offering financing to a retailer in the presence of operational risk?	The manufacturer is better off offering TCF when the retailer's operational risk or the referral fee is lower than the threshold. The platform earns more profit under PCF when the operational risk or referral fee is low or high.	The findings may explain why manufacturers like HP and Haier or online platforms like Amazon and Alibaba provide unsecured loans to downstream retailers. Our results suggest a strategic lending policy for such lenders to maximize their return from lending.
What should be the retailer's optimal financing choice when both TCF and PCF are available?	A retailer chooses TCF (PCF) if the product is in the low (high) referral fee category, irrespective of her operational risk. Interestingly, the retailer's financing choice shifts from TCF at low operational risk to PCF under moderate	It is optimal for the retailer to choose TCF for products such as books and personal computers with a lower referral fee (10%). The retailer should opt for PCF for products with a higher referral fee

	and high operational risk for a moderate referral fee.	(20%), such as jewelry and furniture.
Under what market scenarios could TCF and PCF achieve a win-win-win outcome for the different supply chain players (i.e., the manufacturer, retailer, and platform)? How robust are the findings?	The manufacturer, the retailer, and the platform are all better off under PCF (TCF) when the operational risk or referral fee is high (low).	The findings show that both the financing modes, TCF and PCF, can co-exist. Due to this, neither the platforms nor the manufacturers should prohibit each other from financing the retailer.

Nevertheless, we do admit some limitations, which would call for future research. In this paper, we do not consider the impact of disruption risks, which occur frequently nowadays. Future studies can consider the presence of disruptions and explore how technological capability may be able to address them (Wang et al. 2018).

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