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Platform vs. 3PL financing: Strategic choice of lending model for an e-tailer under operational risk

Sambit Brata Rath [a], Preetam Basu [b], Kannan Govindan [c,d,e,*], Prasenjit Mandal [f]

[a] Production, Operations and Decision Sciences, XLRI - Xavier School of Management (Delhi-NCR Campus), Haryana 124103, India
[b] Department of Analytics, Operations & Systems, Kent Business School, University of Kent, Canterbury CT2 7FS, UK
[c] China Institute of FTZ Supply Chain, Shanghai Maritime University, Shanghai 201306, China
[d] Centre for Sustainable Operations and Resilient Supply Chains (CSORSC), Institute for Sustainability Energy and Resources and Adelaide Business School University of Adelaide, Adelaide, Australia
[e] School of Business, Woxsen University, Sadasivpet, Telangana, India
[f] Department of Information Systems, Supply Chain Management, and Decision Support, NEOMA Business School, Reims 51000, France

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ABSTRACT

In addition to providing logistics services, third-party logistics (3PL) firms (e.g., S.F. Express) have recently started extending financial services to capital-constrained e-tailers (referred to as 3PL financing (LF)). Another novel financing mode available for e-tailers is platform financing (PF), in which online platforms such as Amazon and Alibaba provide loans to e-tailers on their platforms. Both LF and PF facilitate trade in a capital-constrained supply chain. However, in the presence of an e-tailer's operational risk, the lenders are exposed to credit risk, which can negatively impact the whole supply chain. Moreover, when both financing modes are available, the e-tailer must develop an optimal borrowing strategy. Multiple factors, such as bankruptcy cost, referral fee, and shipping fee, can significantly influence players' financing decisions. Therefore, this paper examines supply chain members' optimal operational and financing decisions under LF and PF. We study a three-tier supply chain in which an e-tailer, exposed to operational risk, procures a product from a supplier via the 3PL firm and resells it to end customers through the online platform. The e-tailer obtains the working capital either through LF or PF. We find that at low (high) levels of operational risk, the e-tailer chooses LF (PF). Surprisingly, the 3PL firm and the platform do not always benefit from the LF and PF. We recommend a decision support framework for the e-tailer's optimal financing strategy for different product categories based on its operational risk. We show that for products with a low (moderate and high) referral fee, LF (PF) achieves a win-win-win outcome under low (high) operational risk. Further analysis shows that the e-tailer's initial working capital, logistics, and product costs can alter the players' financing decisions.

1. Introduction

Third-party logistics (3PL) serves as the backbone of e-commerce supply chains, encompassing a range of logistics services such as warehousing, order fulfilment, shipping, and transportation (Chen et al., 2018). A vast majority of e-tailers opt to delegate these tasks

* Corresponding author.
E-mail address: kannan.govindan@adelaide.edu.au (K. Govindan).

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to specialised 3PL firms, allowing them to concentrate on their core functions. 3PL firms provide flexibility, scalability, and cost advantage to the e-tailers and, in turn, benefit from the overall growth in online retailing. For example, Capstone Partners reported a year-on-year increase of 22.59 % in the earnings of 3PL firms during the first quarter of 2021, attributed to the shift in consumer purchasing behaviour towards e-commerce (Capstone Partners, 2021). Recently, 3PL firms have also started expanding their business by offering other value-added services like financial services, alongside their conventional logistics offerings. This is referred to as 3PL financing (LF). For example, deep-pocketed 3PL firms such as United Parcel Service (UPS), Eternal Asia, and RAK (Ras Al Khaimah) Logistics have ventured into delivering integrated logistics and financial services to their clientele (Hua et al., 2021). UPS, through UPS Capital, offers global asset-based financing and small business financing to its capital-constrained customers. Similarly, RAK Logistics has partnered with PMF Bancorp to deliver alternative financing solutions to supply chain partners requiring working capital loans.[1]

Similar to 3PL financing, another novel approach to financing for e-tailers is platform financing (PF) (Wang et al., 2019a). Under PF, the e-tailer secures a working capital loan from the platform on which it sells the product (Yan et al., 2020). For example, Amazon.com has introduced the "Amazon Lending" programme to provide financial support to capital-constrained e-tailers. It has funded around 20,000 e-tailers with over 5 billion USD since 2011 (Pylarinou, 2020). Other instances of PF include Flipkart Growth Capital by Flipkart and Pay Later by Alibaba (Rath et al., 2021). PF serves as an additional source of revenue (i.e., interest fee) for the platforms and improves their referral fee revenue[2] by boosting sales. Thus, given two modes of financing choices, capital-constrained e-tailers are concerned about their borrowing strategies: 3PL financing vs. platform financing. The existing literature has independently analysed 3PL financing (Chen et al., 2011; Hua et al., 2021) and platform financing (Wang et al., 2019a; Yan et al., 2020). To the best of our knowledge, none of the existing studies has undertaken a comparison between 3PL financing and platform financing as borrowing choices for capital-constrained e-tailers. This paper aims to fill this research gap.

1.1. Motivation and research context

Online entrepreneurs and small and medium businesses (SMBs) have emerged as significant contributors to the supply side of e-commerce platforms. A considerable number of e-tailers, predominantly SMBs, encounter challenges to carry out their operational activities due to insufficient working capital (Wang et al., 2019a). According to the World Bank's, 2021 Enterprise Survey data, 23.4 % of firms consider a lack of access to finance as a major constraint to conducting business (World Bank, 2021). They also report that over 50 % of firms worldwide need business loans; however, banks only cover 10 % of the overall working capital needs (World Bank, 2021). Due to their limited credit history, e-tailers frequently encounter challenges in securing adequate loans from banks to meet their capital requirements. It is also difficult and costly for financial institutions to monitor e-tailers' loan usage and operational activities. As a prevalent alternative, these firms often turn to supply chain financing (SCF), which involves obtaining financing services from their supply chain partners. Examples of SCF include 3PL financing, platform financing, trade credit financing, etc.

Unlike conventional institutions such as banks, supply chain partners such as 3PL providers readily and economically acquire detailed information, thanks to their extensive engagement in the e-tailer's supply chain activities (Huang et al., 2019). Therefore, they are better placed to provide working capital loans to capital-constrained e-tailers than traditional lenders like banks. 3PL financing (LF) supports trade in the context of an e-tailer's capital limitations, fostering a mutually beneficial opportunity for all participants in the supply chain. As an example, UPS Capital, a subsidiary of UPS, provided financing to WD Music, a prominent retailer of guitar parts, enabling the expansion of its manufacturing capacity (Zhi et al., 2022). Highlighting UPS's role as a lender, Craig Wagner, CEO of Global Glove and Safety Mfg., mentions: "*UPS did everything they said they would; they made us more efficient overall. UPS Capital got us very fair rates, and they operate like a small regional bank…without all the regulations*" (UPS Capital, 2016).[3] Similarly, another logistics firm, OOCL Logistics, partnered with Stenn to provide financial services to its customers.[4] Some other 3PL firms providing integrated logistics and financing services are CEVA Logistics,[5] HK Logistics,[6] A.N. Deringer, ArcBest, etc.[7] Furthermore, Li & Chen (2019) conducted interviews with five Chinese 3PL firms and found that 3PL firms consider SCF a key business sector and aim to gain a competitive advantage by providing financial support to their customers. In the event of an e-tailer's bankruptcy, a 3PL firm recovers the loan amount by utilising the collateral provided by the e-tailer. (Hua et al., 2021). Similarly, other studies indicate that under LF, the e-tailer has limited liability and must transfer the remainder of its assets to the 3PL firm in case of bankruptcy (Chen et al., 2011; Huang et al., 2019). Hence, we categorise 3PL financing as a secured loan in line with the existing literature and practice. Collaterals can take multiple forms, such as finished goods, work-in-progress goods, account receivables or non-monetary physical assets like machines, factories, offices, land, etc. (Tang et al., 2018). For example, RAK Logistics keeps the borrowing firm's account receivables as collateral for providing business loans.[8]

[1] https://info.raklogistics.com/services/value-added-2/financing-2.

[2] Online platform keeps a percentage of the e-tailer's revenue as a fee for selling its products on the platform. It is called a referral fee or consignment fee. It is normally pre-determined and depends on the product category. Other synonymous terms for "referral fee" used under different contexts are *commission fee/rate*, *revenue sharing rate*, and *platform usage fee*.

[3] Trade Finance | Finance solutions | DP World. https://www.dpworld.com/trade-finance.

[4] https://www.joc.com/article/oocl-logistics-joins-growing-group-intrigued-trade-finance-potential_20230905.html.

[5] https://www.bloomberg.com/profile/company/1360915D:NA#xj4y7vzkg.

[6] https://sourcing.hktdc.com/en/Supplier-Store-Directory/Hua-Ke-Logistics-HK-Ltd/1X0AOTMZ.

[7] https://www.inboundlogistics.com/articles/2021-top-100-3pls/.

[8] https://info.raklogistics.com/services/value-added-2.

Alternatively, online platforms offer working capital loans (PF) to e-tailers operating on their platforms. Online platforms possess more information about their e-tailers, including purchase history and customer reviews, allowing them to identify and extend invitations to creditworthy e-tailers in need of working capital. Many SMBs (e.g., Lonolife and Tower) have expanded their business and grown as e-tailers using the Amazon lending programme (Terzo, 2017). According to Celeb Light, VP of Sales for Power Practical, "Traditional funding vehicles wouldn't support our model of direct to consumer… The loans from Amazon Lending enabled us to expand inventory and resulted in us having a very strong and successful 2016" (Alois, 2017). Tara Darnley, the CEO and founder of Darlyng & Co., mentions, "We weren't able to just walk into the bank and get a loan. That was our first loan. It came in our bank account in a few hours. It was incredible.[9]" A list of LF and PF programmes and their operational details are provided in Table 1.

This paper analyses 3PL financing (LF) and platform financing (PF). Although both are new-age financing models and are available for SMBs, there is a subtle difference in their operational and lending characteristics. Under LF, the 3PL firm gets the shipping fee after the selling season, whereas under PF, it gets the shipping fee during the delivery of the products (Chen et al., 2018; Chen and Cai, 2011; Wang et al., 2019b). Another difference between LF and PF is that LF is a secured loan, whereas PF is an unsecured loan. Therefore, PF is riskier than LF from the lender's perspective, in the presence of the e-tailer's operational risk. According to Heckmann et al. (2015), operational risk is "the risk of loss resulting from inadequate or failed internal processes, people and systems or external events." It causes business and financial losses (Guertler and Spinler, 2015). Examples of operational risk include quality issues, delivery issues, process inefficiencies, product issues, and other external events linked to failed retail operations (Chen et al., 2013; Dhingra and Krishnan, 2021; Tang et al., 2018). Due to the operational risk, if the e-tailer fails to fulfil the customer demand successfully, it does not get any revenue to repay the loan and goes bankrupt. In case of the e-tailer's bankruptcy, the platform loses all the loan amount under PF as it is an unsecured loan. On the other hand, under LF, the 3PL firm recovers some portion of the loan from the collaterals. We provide the pictorial presentation of LF and PF to show various activities involved in the operation (please see Figure F1 in online Appendix F).

1.2. Research questions

Based on anecdotal evidence and existing research, it is evident that, in contrast to bank financing, a capital-constrained e-tailer can derive advantages from either LF (Wang et al., 2019b) or PF (Wang et al., 2019a). However, when both financing modes are available, the e-tailer must choose the optimal borrowing strategy, as each strategy affects the e-tailer's operational decisions independently. Several factors can influence an e-tailer's choice between borrowing from a 3PL firm or a platform. The first factor is collateral, which reduces the credit risk under LF compared to PF. Consequently, the 3PL firm can impose a lower interest rate than the platform. Conversely, in the event of bankruptcy, the e-tailer faces greater losses under LF than PF, as the 3PL firm seizes the e-tailer's collaterals, unlike the platform. The second factor is the referral fee levied by the platform. In our paper, the platform generates revenue from two sources: referral fee revenue and interest fee revenue. If the platform imposes a lower interest rate, it can boost the e-tailer's sales and increase its own referral fee revenue. Similarly, a higher interest rate may improve interest fee revenue but could adversely impact referral fee revenue. Therefore, the platform must strike a balance and determine the interest fee. The interest rate can be lower under LF or PF contingent on the market scenario (e.g., high risk, or high referral fee product). Similarly, logistics and product costs can also impact the SCF equilibrium. These costs play a pivotal role in determining the loan amount, directly influencing the credit risk associated with lending. Given the distinct nature of SCF instruments, the same loan amount creates different levels of credit risk under PF and LF, leading to different lending strategies. Another factor that can affect the financing decisions is the lender's loss aversion nature. If the lender becomes more loss-averse, the potential loss from unfavourable events would be higher. In response, the lender increases the risk premium, influencing the entire SCF environment. Our paper incorporates all these characteristics of LF and PF.

Existing research on 3PL financing (Chen et al., 2011; Hua et al., 2021) suggests that, compared to traditional bank financing, the LF might be better for a capital-constrained e-tailer under some market scenarios (e.g., low interest rate, high initial working capital). In the same line, we find sufficient evidence which concludes that an e-tailer can improve its profit through platform financing (Wang et al., 2019a; Yan et al., 2020). However, to the best of our knowledge, we found no paper comparing LF and PF. Thus, when both LF and PF are available, we pose the following question to understand how an e-tailer chooses its optimal borrowing strategy: *In the presence of operational risk, what should be the e-tailer's optimal borrowing strategy under different market scenarios?*

Similarly, the platform and the 3PL firm need to offer a proper financing mode to reap the benefits of financing in the presence of the e-tailer's operational risk. Although previous studies have separately analysed 3PL financing (Chen et al., 2011; Hua et al., 2021) or platform financing (Wang et al., 2019a; Yan et al., 2020), to the best of our knowledge, in the presence of operational risk, no analysis has compared these lending strategies (LF and PF) together from the platform's and the 3PL firm's perspective. We endeavour to fill this gap through our study by finding a solution to the following research question: *In the presence of operational risk, which financing mode is preferred, and when, by the 3PL firm and the platform?*

Existing research also suggests that, for a given market scenario, the lender (the platform under PF and the 3PL firm under LF) and the borrower (the e-tailer) may not always prefer the same financing mode (Hua et al., 2021; Wang et al., 2019a). For instance, Wang et al., (2019a) showed that the platform is better off under bank financing when the referral fee is low, whereas the e-tailer prefers platform financing. We further extend our analysis to understand if the e-tailer's choice of financing mode can result in a win-win-win outcome for the overall supply chain. To analyse this, we ask the following questions: *Under what market conditions can LF and PF*

[9] https://sell.amazon.com/programs/amazon-lending.

Table 1
Summary of current practices under 3PL financing (LF) and platform financing (PF).

SCF mode	Lender	Example
LF	Eternal Asia	Eternal Asia buys the product from the manufacturer with cash on behalf of the retailer and collects the payment from the retailer after the sale.
LF	UPS Capital	UPS Capital provides loans to its downstream partners, such as Global Glove and Safety Mfg., to fulfil their working capital requirements.
LF	SINOTRANS	It provides financial support to onshore and offshore clients through financial institutions and offers loans to clients for procurement or sales services[1].
LF	RAK logistics	RAK Logistics has partnered with PMF Bancorp to offer alternative financing solutions to its customers.
PF	Alibaba	Alibaba provides buy-now-pay-later loans to e-tailers on its platform, such as B.A.A.B.S. Beauty[2].
PF	Amazon	Amazon offers unsecured loan invitations to e-tailers such as Lonolife, Tower, and Power Practical through its Amazon lending programme.
PF	Flipkart	E-tailers like Amaze stores and Fantastik Retails received working capital loans from Flipkart.

[1]http://https://www.sinotrans.com/col/col5809/index.html.
[2]https://https://www.pymnts.com/news/b2b-payments/2020/alibaba-offers-global-trade-program-for-smbs/.

achieve a win-win-win outcome for all the supply chain players? Additionally, how does the e-tailer's optimal borrowing strategy affect consumer welfare?

To answer these research questions, we develop a stylised game-theoretic model in which the e-tailer (she) obtains a working capital loan from a 3PL firm (it) or a platform (he). Under LF, the 3PL partner procures the product from the supplier on behalf of the e-tailer and delivers it to the e-tailer. After the selling season, the e-tailer repays the loan amount (both product and shipping costs) and the accrued interest. Under PF, the e-tailer takes a loan from the online platform, procures the product with cash, and repays the loan amount with interest after the selling season. We determine the optimal lending rate under each SCF mode, derive the e-tailer's optimal choice of financing mode, and obtain win-win-win outcomes for the supply chain players.

1.3. Key findings and contributions

We summarise the major findings and insights below. First, we focus on developing a risk-based financing strategy for the supply chain agents. We find that the final retail price under LF (PF) is less than that under PF (LF) when the e-tailer's operational risk is low (high). Under high risk, the e-tailer's likelihood of defaulting on loan repayment becomes high, leading to increased capital loss under LF as it is a secured loan. The e-tailer sets a higher price under LF to compensate for the loss. However, as PF is an unsecured loan, the e-tailer can set a lower price under PF than that under LF. Owing to lower retail prices, the e-tailer with high risk gets a higher demand and a higher revenue under PF, which leads to a higher profit. Hence, under high operational risk, the e-tailer chooses PF over LF. In contrast, under low operational risk, the e-tailer is better off with LF than PF as the retail price is low, and demand is high under LF compared to PF.

Next, we compare the lenders' profits (i.e., 3PL firm and platform) under LF and PF. Conventional wisdom suggests that a 3PL firm (platform) should always benefit more from the 3PL financing (platform financing) as compared to the platform financing (3PL financing). In contrast, the 3PL firm's earnings are more under PF than LF when the operational risk is low. When the operational risk is high, the e-tailer's default rate increases, causing more capital loss for the 3PL firm under LF. On the other hand, the 3PL firm does not bear any risk under PF, and profit from core business remains high due to high market demand. Thus, a 3PL firm becomes better off under PF when the operational risk is high. Similarly, our findings suggest that the platform does not always benefit from PF. The platform benefits from the LF when the e-tailer's operational risk is moderate. Owing to higher demand under LF, the platform's referral fee revenue is higher under LF compared to PF. Moreover, the interest fee revenue under PF cannot offset the revenue difference, leading to higher profit under LF. The platform is better off under PF when the operational risk is very low or very high due to very high interest and referral fee income, respectively. From the above profit comparisons, we conclude that PF and LF become the win-win-win strategies for all the supply chain players when the operational risk is very high or low. Considering the significance of customer-centric policy for online marketplaces[10] and growing government regulations to safeguard consumers' interests, we also analyse consumer surplus to check whether the equilibrium financing strategy aligns with the consumer's welfare. We find that the e-tailer's borrowing strategy always maximises the consumer surplus.

Next, we recommend a decision support framework that aids the e-tailer in choosing the optimal financing mode based on product categories. For product categories with very low (high and very high) referral fee rates, the e-tailer obtains higher profit under LF (PF) irrespective of the operational risk level. For other product categories, the e-tailer's preference depends on the level of operational risk. She prefers PF (LF) when her operational risk is high (low). Therefore, we suggest that the product-based financing strategy gives a better picture than the risk-based strategy. Similarly, when the referral fee is low or very low, and the operation risk is high (low), the 3PL firm is better off under PF (LF). For products with higher referral fees (i.e., moderate, high, and very high referral fees), it always prefers PF. On the other hand, the platform earns more profit under PF when the referral fee is very low or very high. For different

[10] https://www.forbes.com/sites/forbestechcouncil/2022/12/30/why-a-customer-centric-approach-is-key-to-e-commerce-at-scale/?sh=6444615a293f.

values of the referral fee, he prefers PF to LF only for higher values of the operational risk. From the above findings, we conclude that PF (LF) achieves a win-win-win outcome for all the supply chain players under a very high (low) referral fee scenario.

For robustness checking and deriving more insights, we analyse multiple model extensions. We conduct the comparative analysis with a generic demand function and find the results remain unchanged. First, we inspect the impact of the e-tailer's initial working capital on the equilibrium financing scenario. The findings suggest that initial working capital alters the player's financing preferences when the referral fee is low. However, the lenders and the e-tailers might be on the same page for high referral fee products. For example, the 3PL firm and the platform may profit more under 3PL financing, but the e-tailer prefers platform financing. Next, we analyse the impact of product and logistics costs on the supply chain player's financing decisions. Conventional wisdom suggests that with higher loan amounts, unsecured loans like platform financing become riskier for the lender. Therefore, the lender should charge a higher risk premium, making it unfavourable for the borrower. However, when production or logistics costs are high, the e-tailer gets a better offer under platform financing, and all the supply chain players obtain higher profits. Our next extension is related to the behavioural aspect of the lender. We observe that with an increase in the loss aversion nature of the lender, the behavioural aspect of lending overpowers the technical aspect of the lending, and the equilibrium financing strategy can differ significantly. Our second observation is that if both lenders have a similar loss aversion nature, then the equilibrium financing strategy of the supply chain players does not change compared to the base case. Therefore, we conclude that the lending strategies depend on the relative loss aversion nature (instead of absolute loss aversion) of one lender with respect to another. The findings presented in the paper challenge the conventional notion of lending and simultaneously provide unique and implementable strategies for supply chain managers.

First, the results suggest that 3PL service providers should not always try to provide integrated logistics and financing services. Due to the associated credit risk, they may lose huge capital, as mentioned by some 3PL firms in Li and Chen (2019). Second, the platforms need not be antagonistic to 3PL firms providing integrated services and vice versa. We identify market conditions where the platform and the 3PL firm earn more under LF and PF, respectively. Third, the e-tailer should go for a product-based strategy instead of a risk-based strategy, as suggested in Table 4. The operational risk does not affect the choice of SCF mode for some product categories. Finally, we propose that the supply chain players should consider behavioural aspects like the risk appetite of the lenders in their analysis because we find that the risk appetite of the players has the power to impact their financing decisions significantly.

The rest of the paper is organised as follows: Section 2 reviews existing literature relevant to the paper. In Section 3, we develop the model for LF and PF and calculate the equilibrium expressions. Section 4 presents the analytical results of comparing these two SCF modes. We conduct numerical experiments in Section 5. Finally, in Section 6, we state additional managerial insights from the numerical experiment, summarise the main findings, and explore the future scope of research. We provide the mathematical proofs in the online Appendix.

2. Literature review

Our work contributes to the emerging field of supply chain finance (SCF) that lies at the interface of operations, finance, and risk management (Wang et al., 2021). A majority of SCF research has examined traditional SCF methods such as bank financing (BF) (Jing and Seidmann, 2014), trade credit (Soni and Patel, 2012), and purchase order financing (Tang et al., 2018). Jing and Seidmann (2014) compared bank financing and trade credit in the presence of demand risk and found that trade credit reduces the double marginalisation effect better than bank financing when the production cost is low. Later, Tang et al. (2018) analysed purchase order financing and buyer-direct financing in the presence of supply uncertainty. For a comprehensive review of traditional SCF modes, see Chakuu et al. (2019) and Wang et al. (2021). Recently, a few new-age financing modes have drawn the attention of the research community, such as peer-to-peer (P2P) financing (Ma et al., 2018; Serrano-Cinca and Gutiérrez-Nieto, 2016), platform financing (Wang et al., 2019a), 3PL financing (Hua et al., 2021), and equity-based financing (Zhang and Zhang, 2021). Wang et al., (2022a) analysed peer-to-peer (P2P) online lending under different credit guarantee services and showed that P2P lending could coordinate the supply chain under an adventurous credit guarantee scheme. Bi et al. (2022) discussed debt-sharing BCF, where the supplier shares the loan amount and the interest amount of the retailer's debt. They concluded that the debt-shared BCF could improve the supplier's profit and supply chain efficiency. Most of the research in SCF has compared different traditional SCF modes or traditional SCF modes with new-age SCF modes. Comparisons between novel financing techniques are rare in the SCF literature. Our study fills this gap and compares two new-age SCF modes: 3PL financing and platform financing. Next, we review the existing research related to platform financing and 3PL financing and summarise the findings in the following subsections.

2.1. Platform financing (PF)

Gong et al. (2020) analysed the value of platform financing (PF) in the absence of other financing modes and found that PF improves the profit of the platform and the capital-constrained e-tailer. Similarly, Yan et al. (2020) showed that PF benefits the e-tailer and the platform even in a competing channel. Wang et al., (2019a) established that PF could achieve coordination in the presence of demand uncertainty and bank financing. Extending the study to dual-channel retailing, Zhen et al. (2020) showed that a manufacturer always prefers PF to bank financing; however, e-tailer financing might be better. Gupta and Chen (2020) investigated the effect of debt seniority on PF. They identified that the total supply chain profit could surpass the first best option if the platform becomes the senior leader. In a recent article, Rath et al. (2021) analysed PF and bank financing under supply-side risk and devised an optimal financing strategy under different market conditions. In another study related to PF, Liu et al. (2021) incorporated e-tailer's overconfidence in their analysis. They found slight overconfidence is better for the e-tailer, whereas severe overconfidence reduces the e-tailer's profit. Chang et al. (2022) compared bank and platform financing under the platform's reselling and marketplace modes. They reported that

the retailer is better off in marketplace mode and bank financing, whereas the platform's profit is more under marketplace mode and platform financing. Yi et al. (2021) compared three modes of financing: platform direct financing (same as PF), platform guarantee financing, and bank financing and derived the optimal choice of the retailer under different market scenarios (with respect to production cost and commission fee). They showed that the platform's intermediation could improve the total supply chain profit. Extending the SCF research into green supply chain management, Qin et al. (2021) formulated the optimal financing strategy for capital-constrained e-tailers who need capital for procurement and carbon emission reduction. They found that PF is better for both the manufacturer and the platform under an endogenous referral fee rate. In contrast, if the referral fee is exogenous, the platform can induce the manufacturer to choose PF by charging a low referral fee rate. Yan et al. (2021) incorporated free-riding behaviour in their analysis of PF. Contrary to popular belief, free-riding can enhance the total supply chain profit. All the above papers provide plenty of insights regarding the efficacy of PF under different market setups. However, most existing research under PF either focuses on comparing PF and bank financing or studies PF under different market scenarios. On the other hand, we focus on comparing PF and 3PL financing to supplement the PF research stream.

2.2. 3PL financing (LF)

Lately, 3PL financing (LF) has generated interest within the academic community (Zhi et al., 2022). Chen et al. (2011) conducted a comparative analysis of LF, BF, and trade credit financing. They concluded that LF could achieve higher profits for all the supply chain members. Similarly, Huang et al. (2019) showed that wholesale price contracts achieve coordination under 3PL financing. Wang et al. (2019b) showed that a 3PL firm prefers a risk-averse manufacturer by investigating the effect of risk preference and demand volatility on 3PL financing. Taking this research stream forward, Chen et al. (2018) analysed LF in different leadership setups and showed that LF performs better under 3PL firm leadership than manufacturer leadership. Similarly, Hua et al. (2021) compared LF and BF under different supply chain leadership. They suggested that the 3PL firm should always charge a low interest rate to improve channel performance and profit. Zhou et al. (2020) investigated the efficiency of 3PL guarantor financing under different leadership mechanisms and found that retailers are better off under this than bank financing. In a recent study, Zhi et al. (2022) examined LF in a fully capital-constrained supply chain (all the supply chain members need financing) by adopting a channel competition model. They proved that LF could decrease the financing fee in all cases. Ji et al. (2023) analysed the effect of 3PL financing on the supply chain players when the manufacturer or the retailer is capital-constrained. They suggested that the retailer and the manufacturer should consider the 3PL firm's logistics service level and price before taking the loan. 3PL financing might not be beneficial for them under all the market circumstances. Shi et al. (2016) empirically established that 3PL firms are more likely to offer integrated financing and logistics services under low uncertainty. Wang et al., (2022b) examined 3PL financing in the presence of logistics-retail integrated service and spillover effect. The 3PL firm prefers providing the integrated retail-financing service in most cases (except for positive spillover effect and low and high logistics cost); however, the supplier prefers this arrangement under low spillover effect and low logistics cost. Dang et al. (2021) found that when the retailer is risk-averse (optimistic), bank (3PL) financing is the optimal financing choice in a customised product business. It is evident from the low volume of existing publications that the research on 3PL financing is still at a nascent stage. We contribute to this research stream by analysing 3PL financing in the presence of PF.

Our study differs from the existing literature in three ways. First, we supplement the SCF literature by analysing the effect of LF and PF on an e-commerce supply chain. Second, we consider both the supply and demand-side aspects of the e-commerce supply chain in the financing decisions. Most of the SCF literature focuses only on a single aspect, either demand-side or supply-side dynamics. Lastly, we expand the SCF horizon by comparing two novel supply chain financing mechanisms (i.e., PF and LF) in the presence of e-tailer's operational risk. We summarise the key papers related to our work in Table 2 (Appendix H).

3. The model and analysis

3.1. Model description

We develop a stylised game-theoretic model for an online supply chain in which an e-tailer (she) procures products from a supplier through a 3PL firm (it) and sells on an online platform (he). The e-tailer faces a working capital shortage to pay for the procurement operations (product fee and shipping fee); however, she can arrange a loan through 3PL financing (LF) or platform financing (PF). The 3PL firm in our model provides inbound logistics service (transportation of goods/products from the supplier to the e-tailer) and offers financing to the e-tailer.

We discuss the sequence of events under each financing mode and calculate the equilibrium expressions in the following subsections. We present the notations used throughout the paper in Table 3.

In the model, we consider that the e-tailer has some inherent operational risk (λ), due to which she fails to deliver the product to the end consumer with a probability λ. In practice, the sources of operational risk can be process mismanagement and product non-conformance issues with customer order fulfilment (Dhingra and Krishnan, 2021; Schmidt and Raman, 2022). It is important to mention that in case of failure, the platform does not get any referral fee revenue as the e-tailer obtains no revenue. We follow a linear

Table 3
Summary of the key notations.

i	Subscript used to denote a player. E for the e-tailer, P for the platform, and L for the 3PL firm.
j	Superscript used to denote the lending mode. LF for 3PL financing, PF for platform financing
p^j	Price of the product sold by the e-tailer under lending mode j
d^j	Demand for the product under lending mode j
r^j	Lending rate charged by the lender under lending mode j
w_s^j	Unit shipping fee charged by the 3PL firm under lending mode j
λ	Operational risk of the e-tailer
γ	Collateral value expressed as a percentage of the total loan
α	Referral fee charged by the platform
c_p	Unit product cost incurred by the e-tailer
c_l	Unit logistics cost incurred by the 3PL firm
π_i^j	Profit of player i under lending mode j

Table 4
Product-based Financing Strategy of the E-tailer for different levels of Operational Risk.

		Referral Fee				
		Very Low	Low	Moderate	High	Very High
E-tailer's Operational Risk	Low	LF	LF	LF	PF	PF
	High	LF	PF	PF	PF	PF

and downward-sloping demand function of the retail price, denoted by $d^j = 1 - p^j$ (Yan et al., 2020).[11]

Now, we provide some other assumptions related to the models. We assume that the e-tailer has zero working capital. Our zero working capital assumption is in line with the prior research in SCF, such as Kouvelis and Xu (2021), Rath et al. (2021), Tang et al. (2018) and Zhen et al. (2020). Moreover, a survey by the Global Alliance for Mass Entrepreneurship (GAME) mentions that 57 % of SMBs have zero cash reserve post-COVID-19.[12] Thus, our zero initial working capital assumption is justified. In specific market conditions, such as machine failure or product damage, she would not be able to fulfil any order. Hence, it is justified to assume that she is unable to deliver any product in case of failure (Rath et al., 2021). We consider that the 3PL firm provides the inbound logistics, and the outbound logistics service is outsourced to another 3PL firm. The 3PL firm's operations do not contribute to the e-tailer's operational risk. In our study, the operational risk is solely due to the e-tailer's internal inefficiencies. The supply chain players are assumed to be rational and risk-neutral profit maximisers. Problem parameters (e.g., operational risk, product fee, shipping fee, and lending rate) are common knowledge to all the supply chain players. The above assumptions help in the analytical tractability without affecting the nature of the results.

We solve this three-stage game by backward induction. In the third stage, for a given shipping fee (w_s^j) and interest rate (r^j), we calculate the e-tailer's optimal retail price (p^{j*}) that would maximise her profit (π_E^{j*}). In the second stage, for any shipping fee (w_s^j) and the e-tailer's optimal retail price (p^{j*}), we determine the lender's optimal interest rate (r^{j*}). In the end, for the lender's optimal interest rate (r^{j*}) and the e-tailer's optimal retail price (p^{j*}), we calculate the 3PL firm's optimal shipping fee (w_s^{j*}), which would maximise its profit (π_L^{j*}). Then, we characterise the equilibrium outcomes. The calculation steps are the same under LF ($j = LF$) and PF ($j = PF$).

3.2. Platform financing (PF)

First, we analyse the platform financing case, in which the online platform finances the e-tailer. We use backward induction to obtain the equilibrium expressions (Gao et al., 2018). Here, the 3PL firm acts as a leader and decides the shipping fee (w_s^{PF}) first. Then, the platform acts as the subleader and sets the lending rate (r^{PF}). After observing the shipping fee and interest rate, the e-tailer sets the final retail price (p^{PF}). The e-tailer takes a loan of $d^{PF}(c_p + w_s^{PF})$ from the platform to pay the product fee and the shipping fee. During the selling season, due to operational risk, she manages to sell the product successfully only with a probability $1-\lambda$. After successful order fulfilment, she obtains revenue of $d^{PF}p^{PF}$. Then she pays the loan plus interest amount, $d^{PF}(w_s^{PF}+c_p)(1+r^{PF})$ and the referral fee, $\alpha d^{PF}p^{PF}$, to the platform. However, in case of failure, the e-tailer does not get any revenue, and the platform loses all the loan amount as platform financing is an unsecured loan. We provide the event timeline in Fig. 1. The profit functions are given below.

$$\pi_E^{PF} = (1-\lambda)d^{PF}\left((1-\alpha)p^{PF} - (w_s^{PF} + c_p)\left(1 + r^{PF}\right)\right), \tag{1}$$

[11] We also conduct the analysis by considering the generic demand function ($d^j = x - bp^j$) and find the qualitative results remain unchanged. Please see online Appendix E.

[12] https://thewire.in/business/sme-covid-19-economy-india.

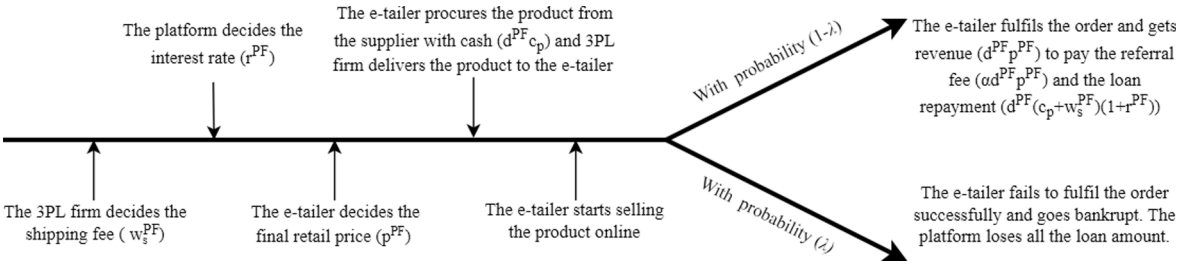


Fig. 1. Sequence of Events under PF.

$$\pi_P^{PF} = (1-\lambda)d^{PF}\left(\alpha p^{PF} + (w_s^{PF} + c_p)\left(1 + r^{PF}\right)\right) - d^{PF}(w_s^{PF} + c_p), \tag{2}$$

$$\pi_L^{PF} = d^{PF}w_s^{PF} - c_l d^{PF}. \tag{3}$$

We solve the multilevel sequential game with the 3PL firm as the leader, the platform as the subleader, and the e-tailer as the follower, and derive the following equilibrium expressions:

$$\pi_E^{PF*} = (1-\alpha)\left(1-\lambda-c_l-c_p\right)^2 \Big/ \left(16(2-\alpha)^2(1-\lambda)\right), \tag{4}$$

$$\pi_P^{PF*} = \left(1-\lambda-c_l-c_p\right)^2/(16(2-\alpha)(1-\lambda)), \tag{5}$$

$$\pi_L^{PF*} = \left(1-\lambda-c_l-c_p\right)^2 \Big/ (8(2-\alpha)(1-\lambda)), \tag{6}$$

$$p^{PF*} = (c_l + c_p + (7-4\alpha)(1-\lambda))/(4(2-\alpha)(1-\lambda)), \tag{7}$$

$$w_s^{PF*} = \left(1-\lambda+c_l-c_p\right)/2, \tag{8}$$

$$r^{PF*} = (2(1-\alpha)^2(1-\lambda) - (1-(2-\alpha)\lambda)(1-\lambda+c_l+c_p))/\left(\left(1-\lambda+c_l+c_p\right)(2-\alpha)(1-\lambda)\right). \tag{9}$$

3.3. 3PL financing (LF)

In this subsection, we analyse the optimal strategies of all supply chain players under 3PL financing, in which the logistics partner provides shipping service as well as financing to the e-tailer for procuring the product from her supplier. First, the 3PL firm decides the shipping fee (w_s^{LF}) and the interest rate (r^{LF}) sequentially. Then, the e-tailer decides the final retail price (p^{LF}) and starts selling after procuring the product. The e-tailer fulfils the order successfully (with probability $(1-\lambda)$) and obtains adequate revenue ($d^{LF}p^{LF}$) to pay the loan repayment amount ($d^{LF}(w_s^{LF}+c_p)(1+r^{LF})$) to the 3PL firm and referral fee ($\alpha d^{LF}p^{LF}$) to the platform. However, if the e-tailer fails to fulfil the order due to operational risk, she will not obtain any revenue and will go bankrupt. In that case, the 3PL firm seizes the collateral and recovers some loan amount ($\gamma d^{LF}(w_s^{LF}+c_p)$) as 3PL financing is a secured loan. The value of the collateral can be lesser or higher than the loan amount. In our analysis, we consider the collateral to be less than the loan amount ($\gamma \leq 1$) because when the collateral is higher than the loan amount, the lender does not face any credit risk while providing the loan. This leads to a trivial scenario and nullifies our aim to analyse the impact of operation risk on the SC players' SCF strategies. Hence, we consider the collateral value less than the loan amount, which aligns with existing research such as Tang et al. (2018). The timeline is presented in Fig. 2.

We present the profit functions of the supply chain players below:

$$\pi_E^{LF} = (1-\lambda)(1-\alpha)d^{LF}p^{LF} - (1-\lambda)d^{LF}(w_s^{LF}+c_p)\left(1+r^{LF}\right) - \lambda d^{LF}\gamma(w_s^{LF}+c_p), \tag{10}$$

$$\pi_P^{LF} = (1-\lambda)\alpha\, d^{LF}p^{LF}, \tag{11}$$

$$\pi_L^{LF} = (1-\lambda)d^{LF}(w_s^{LF}+c_p)\left(1+r^{LF}\right) + \lambda\gamma d^{LF}(w_s^{LF}+c_p) - \left(c_l+c_p\right)d^{LF}. \tag{12}$$

We solve this multilevel sequential game and obtain the following equilibrium expressions[13]:

[13] Under LF, the optimal shipping fee is an implicit function of the interest rate and vice versa. Hence, we mention only the equilibrium expression of the interest rate. Its managerial significance is that the 3PL firm has the flexibility to set interest rate (or shipping fee) as per the shipping fee (or interest rate).

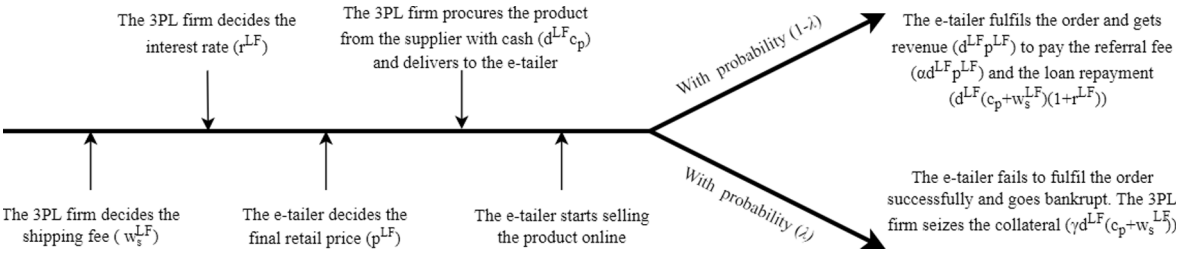


Fig. 2. Sequence of Events under LF.

$$\pi_E^{LF^*} = \left(1-\alpha-c_p-c_l-\lambda+\alpha\lambda\right)^2/(16(1-\alpha)(1-\lambda))\Big), \tag{13}$$

$$\pi_P^{LF^*} = \alpha\left(3+c_p+c_l-3\alpha(1-\lambda)-3\lambda\right)\left(1-c_p-c_l-\alpha(1-\lambda)-\lambda\right)/(16(1-\alpha)^2(1-\lambda)), \tag{14}$$

$$\pi_L^{LF^*} = \left(1-\alpha-c_p-c_l-\lambda+\alpha\lambda\right)^2\Big/(8(1-\alpha)(1-\lambda)), \tag{15}$$

$$p^{LF^*} = (3(1-\alpha)(1-\lambda)+c_p+c_l)/(4(1-\alpha)(1-\lambda)), \tag{16}$$

$$r^{LF^*} = \left(1-\alpha+c_l-w_s^{LF}-\lambda+\alpha\lambda-(1-2(1-\gamma)\lambda)\left(c_p+w_s^{LF}\right)\right)/(2(1-\lambda)\left(c_p+w_s^{LF}\right)) \tag{17}$$

4. Equilibrium analysis

In this section, we analyse the optimal strategies of the supply chain players under both financing modes. First, we compare the final retail price under LF and PF. Afterwards, we characterise the e-tailer's optimal borrowing choice under different market conditions. We also focus on the lending strategies of the 3PL firm and the platform under LF and PF, respectively. It is important to mention that, in our analysis, we consider only the feasible region where the retail price, demand, interest rate, and individual profits are non-negative because other cases (such as negative profit or negative interest rate) are impractical in real-life business scenarios. The feasible range of operational risk (λ) is $(\lambda_{t1}, \lambda_T)$[14]. For a detailed report on feasibility analyses, we refer readers to Appendix C. Next, in Proposition 1, we compare the final retail price under both the financing modes and present the findings.

Proposition 1. The retail price is lower under PF as compared to LF (i.e., $p^{PF^*} \le p^{LF^*}$) when the operational risk of the e-tailer is high ($\lambda \ge \lambda_1 = 1-(c_l+c_p)/(1-\alpha)^2$). Otherwise, when $\lambda < \lambda_1$, then $p^{PF^*} > p^{LF^*}$.

Proposition 1 states that the e-tailer sets a lower retail price under PF when her operational risk is high; otherwise, the retail price is lower under LF. We may explain it as follows. From the point of view of the e-tailer, the main difference between LF and PF is that LF is secured, unlike PF. In case of default, the e-tailer loses the collateralised assets under LF. This cost of default is amplified when the operational risk is high. We call this collateral effect. When the likelihood of the e-tailer's bankruptcy is high (i.e., $\lambda \ge \lambda_1$), the expected procurement cost is higher under LF than PF due to the collateral effect, leading to a higher retail price under LF. On the other hand, when the likelihood of the e-tailer's bankruptcy is low (i.e., $\lambda < \lambda_1$), her expected cost of default is low, leading to a lower interest rate under LF compared to PF. This is because LF is a secured loan, whereas PF is unsecured. Therefore, the total procurement cost is low under LF when the risk is low, and the e-tailer charges a lower retail price under LF than PF.

The retail price is directly linked to the e-tailer's profit. Next, we present optimal borrowing choices for the e-tailer in Proposition 2.

Proposition 2. When the e-tailer has high operational risk ($\lambda \ge \lambda_1$), she obtains a higher profit under PF than that under LF ($\pi_E^{PF^*} \ge \pi_E^{LF^*}$). Hence, she prefers PF to LF. Otherwise, when ($\lambda < \lambda_1$), $\pi_E^{PF^*} < \pi_E^{LF^*}$.

According to Proposition 2, the e-tailer's profit is more under PF than under LF when the risk is high; otherwise, she earns a higher profit under LF when the risk is low. Proposition 1 shows that the e-tailer charges a lower retail price under PF when operational risk is high. Due to the low retail price, the demand for the product is higher under PF, which leads to higher revenue for the e-tailer under PF. Furthermore, unlike LF, she does not incur bankruptcy-related costs under PF. Due to higher revenue and lower default cost, her profit under PF is higher than that under LF. Hence, the e-tailer prefers to obtain financing from the platform in case of high operational risk. However, when the e-tailer has a lower operational risk, she charges a low retail price under LF (Proposition 1), leading to a higher profit under LF than under PF. Therefore, the e-tailer chooses LF over PF in case of low operational risk; otherwise, she prefers PF. In contrast to Hua et al. (2021), that suggests LF is always better for a firm with bankruptcy risk, we find that in the presence of platform financing, the e-tailer can be better off under PF under certain market scenarios. The difference in the results can be explained in two

[14] $\lambda_{t1} = \min(\lambda_{t4}, \lambda_{t5}); \lambda_T = 1-\frac{c_l+c_p}{1-\alpha}$; $\lambda_{t4} = \frac{1-\alpha+c_l-c_p-2w_s^{LF}}{1-\alpha-2(1-\gamma)\left(c_p+w_s^{LF}\right)} = \frac{(1-\alpha+c_l+c_p)-2(w_s^{LF}+c_p)}{(1-\alpha)-2(1-\gamma)\left(c_p+w_s^{LF}\right)}$; $\lambda_{t5} = \frac{1+3\alpha-2\alpha^2+(2-\alpha)\left(c_l+c_p\right)-\sqrt{1+3\alpha-2\alpha^2+(2-\alpha)\left(c_l+c_p\right)^2-4(2-\alpha)\left(1-4\alpha+2\alpha^2-c_l-c_p\right)}}{2(2-\alpha)}$.

ways. Firstly, Hua et al. (2021) compared 3PL financing with bank financing, whereas we compared 3PL financing with platform financing. Though 3PL financing is always better than bank financing, platform financing might provide contrasting results under certain market conditions. Secondly, in our paper, the 3PL firm is the leader, unlike Hua et al. (2021), in which the supplier is a leader in the decision-making sequence. According to Hua et al. (2021), when the supplier sets the wholesale price under the 3PL financing for which his profit is maximum, the followers (i.e., 3PL firms and retailers) also profit more under 3PL financing. On the other hand, in our paper, when the 3PL firm sets the shipping fee and interest rate, it is not always best for the e-tailer. In certain cases, the platform offers better interest rates to the e-tailer.

After determining the optimal strategy for the borrower (the e-tailer), we focus on the lenders. We start with the 3PL firm and then move to the platform. We present the 3PL firm's profit comparison in Proposition 3.

Proposition 3. The 3PL firm is better off under LF than under PF ($\pi_L^{LF^*} \geq \pi_L^{PF^*}$) when the operational risk of the e-tailer is low[15] ($\lambda \leq \lambda_2$). Otherwise, $\pi_L^{PF^*} > \pi_L^{LF^*}$ if $\lambda > \lambda_2$.

The value of $\lambda_2 = 1 - ((1-\alpha)^2 + \sqrt{(2-\alpha)(1-\alpha)}\alpha)(c_l + c_p)/((1-\alpha)(1-(3-\alpha)\alpha))$.

From Proposition 3, we find that the 3PL firm obtains more profit under LF when the operational risk is low; otherwise, it earns higher profit under PF. The 3PL firm has a single revenue stream under PF that it obtains from the shipping fee. In contrast, under LF, it has two streams of revenue: the shipping fee and the interest fee. However, under LF, the 3PL firm needs to consider the e-tailer's operational risk while deciding the shipping fee and interest rate, as the e-tailer defaults on the payables in case of failure. On the other hand, the 3PL firm always obtains its payment under PF. To compensate for the loss due to the greater operational risk, the 3PL firm charges a higher shipping fee from the e-tailer under LF than PF. Therefore, the operational risk has a larger negative effect on the shipping fee under LF compared to PF, which we call the risk effect. Under low operational risk ($\lambda < \lambda_2 < \lambda_1$), we know that the e-tailer generates higher customer demand under LF than under PF due to lower retail price (Proposition 1). Hence, the 3PL firm earns a higher overall shipping fee revenue under LF as the order quantity under LF is higher than that under PF. Moreover, its expected revenue from the credit business remains high in this case because the likelihood of an e-tailer's default is low due to the low risk. Hence, with higher revenue from core business (revenue from overall shipping fee) and significant support from credit business (revenue from loan interests), the 3PL firm earns more revenue under LF when the e-tailer has low operational risk ($\lambda \leq \lambda_2$). However, with the increase in operational risk, the chance of the e-tailer's default goes up, increasing the loss of capital for the 3PL firm under LF. Moreover, the risk effect comes into play, and the order quantity decreases faster under LF with operational risk, reducing the revenue gap between LF and PF. Therefore, when the operational risk is higher than the threshold ($\lambda > \lambda_2$), the 3PL firm obtains lower profit under LF than PF because of lower order quantity and higher loss from the e-tailer's default. Hence, the 3PL firm is better off under platform financing for higher risk.

Next, in Proposition 4, we explore the scenarios in which the platform benefits from PF and LF, respectively. For expositional simplicity, we characterise different levels of e-tailer's operational risk in the subsequent analyses: very low ($\lambda \leq \lambda_3$), low ($\lambda_3 < \lambda < \lambda_2$), moderate ($\lambda_2 < \lambda < \lambda_1$), high ($\lambda_1 < \lambda < \lambda_4$), and very high ($\lambda \geq \lambda_4$).

Proposition 4. The platform's profit under PF is higher than that under LF ($\pi_P^{PF^*} \geq \pi_P^{LF^*}$) when the e-tailer's operational risk is very low[16] ($\lambda \leq \lambda_3$) or very high[17] ($\lambda \geq \lambda_4$). Otherwise, when $\lambda_3 < \lambda < \lambda_4$, then $\pi_P^{PF^*} < \pi_P^{LF^*}$.

Proposition 4 states that the platform obtains more profit under PF for very low or very high operational risk. For intermediary values of the risk, his profit is more under LF. Under PF, the platform has two sources of revenue: the referral fee and the interest rate. Meanwhile, under LF, his only revenue source is the referral fee. Proposition 2 states that the e-tailer's revenue is lower under PF under the low-risk scenario ($\lambda < \lambda_2$). Therefore, the platform's referral fee revenue under PF is less than that under LF. However, under very low operational risk ($\lambda < \lambda_3$), the likelihood of the e-tailer's default is very low. This leads to substantial revenues for the platform from his lending business. Due to this additional revenue stream under PF, the platform obtains more profit under PF than LF when the operational risk is very low. With the increase in operational risk, the e-tailer's default rate goes up (i.e., $\lambda_3 < \lambda < \lambda_4$), decreasing the expected revenue from the lending business. The reduced revenue becomes insufficient to offset the revenue gap between LF and PF from referral fee under moderate-risk conditions. With a further increase in risk, the e-tailer's default rate becomes very high, due to which the platform expects a loss from the lending business (as the e-tailer can fail to repay the loan), which makes his expected profit in PF less than that under LF. Therefore when $\lambda_3 < \lambda < \lambda_4$. The platform is better off under LF.

However, under very high risk ($\lambda > \lambda_4$), the platform expects to earn a higher profit under PF than under LF. In this scenario, the e-tailer obtains lower revenue under LF due to the high retail price (Proposition 2). Thus, the platform loses a significant amount of referral fee under LF. Whereas, under PF, the platform can suitably set the interest rate to improve the referral fee revenue compared to LF. Moreover, this also compensates for the possible loss from the lending business. Hence, he earns more profit under PF with very high operational risk. Previous studies (Rath et al., 2021; Wang et al., 2019a) conclude that the platform is better off with platform financing as compared to bank financing. We contribute to these studies by identifying the market scenarios in which the platform can benefit under each mode of financing.

[15] It can easily be proven that $\lambda_2 = 1 - ((1-\alpha)^2 + \sqrt{(2-\alpha)(1-\alpha)}\alpha)(c_l + c_p)/(1-\alpha)(1-(3-\alpha)\alpha) < \lambda_1$.

[16] It can easily be proven that $\lambda_3 = 1 - \left(1 - (3-\alpha)\alpha + \sqrt{(2-\alpha)(4-\alpha)}\,\alpha\right)(c_l + c_p)/((1-\alpha)(1-3(2-\alpha)\alpha)) < \lambda_2$.

[17] We can easily prove that $\lambda_4 = 1 - \left(1 - (3-\alpha)\alpha - \sqrt{(2-\alpha)(4-\alpha)}\,\alpha\right)(c_l + c_p)/((1-\alpha)(1-3(2-\alpha)\alpha)) > \lambda_1$.

After analysing individual preferences under various market conditions, we now focus on the convergence of the optimal financing mode of the supply chain players in Propositions 5 and 6. Next, Proposition 5 discusses the market scenario in which LF is the best financing mode for all the parties involved.

Proposition 5. The e-tailer, the platform, and the 3PL firm are better off under LF when the operational risk of the e-tailer is low $(\lambda_3 < \lambda < \lambda_2)$.

According to Proposition 5, LF leads to a win-win-win outcome for all the players when the e-tailer's operational risk is low. From Proposition 3, we know that the 3PL firm obtains a higher profit when the risk is very low $(0 < \lambda < \lambda_3)$ or low $(\lambda_3 < \lambda < \lambda_2)$. Similarly, we also find that the e-tailer chooses LF over PF for these values of operational risk (Proposition 2). Hence, we can state that 3PL is a better option for the e-tailer and the 3PL firm when the risk is low or very low. However, the platform is better off under PF when the operational risk is very low $(0 < \lambda < \lambda_3)$ (Proposition 4). He prefers LF to PF under the low-risk condition $(\lambda_3 < \lambda < \lambda_2)$. Therefore, we conclude that when the operational risk is low $(\lambda_3 < \lambda < \lambda_2)$, all the three supply chain partners are better off under LF. Thus, 3PL financing achieves a win-win-win outcome when $\lambda_3 < \lambda < \lambda_2$. In a different supply chain setting (in the absence of an e-commerce platform), some existing SCF studies (Chen et al., 2018; Hua et al., 2021) find that 3PL financing can improve the profit of all the supply chain players. In contrast, we consider an e-commerce supply chain and show that 3PL financing can achieve a win-win-win outcome only when the e-tailer's operational risk is very low. Next, we determine the market condition under which all the supply chain members prefer PF to LF and present the result in Proposition 6.

Proposition 6. All the supply chain members (the e-tailer, the platform, and the 3PL) prefer PF to LF when the operational risk of the e-tailer is very high $(\lambda > \lambda_4)$.

Proposition 6 states that PF can achieve a win-win-win outcome when the operational risk is very high. Proposition 2 states that the e-tailer prefers PF to LF when her operational risk is high or very high $(\lambda > \lambda_1)$. Similarly, from Proposition 3, we find that the 3PL firm is also better off under PF in this market condition. Therefore, PF is the optimal preference of the e-tailer and the 3PL firm when the risk is high or very high. However, the platform is better off under PF only under very high operational risk $(\lambda > \lambda_4)$. Therefore, we can say that when the operational risk is very high $(\lambda > \lambda_4)$, the platform, the e-tailer, and the 3PL firm prefer PF to LF. Hence, PF achieves a win-win-win situation in this market scenario. It may be noted that Rath et al. (2021) reported that under low production costs and low goodwill costs, PF improves the total supply chain profit of a two-tier supply chain. However, we consider a three-tier supply chain and show that PF leads to a win-win-win outcome for all the supply chain players when the e-tailer's operational risk is very high.

In the theoretical analysis section, we find that LF is the preferred financing mode of all the supply chain players when the operational risk is low. Similarly, when the operational risk is very high, the e-tailer, the platform, and the 3PL firm are better off under PF simultaneously. Most of the prior SCF papers have concluded their analysis at this step (i.e., finding the equilibrium choices of the supply chain players). According to a Forbes report[18] and Amazon's mission statement,[19] it is evident that online marketplaces need to have a customer-centric policy to become the market leader. In this era of growing pro-consumer e-commerce regulation worldwide, online platforms and e-tailers should consider consumer welfare while formulating any new operational or financial strategy. However, existing studies in online retailing (Gao et al., 2023; Guo et al., 2022) and supply chain finance (An et al., 2021; Geng et al., 2023; Mandal et al., 2023) suggest that firms' operational and financial strategies do not always align with consumer welfare. Therefore, we also examine the consumer surplus from a social responsibility perspective. For two-sided marketplaces (i.e., the platform), the consumer side is as important as the e-tailer side. Hence, we compare consumer surplus under different financing modes and find out how the financing decisions of the supply chain players affect consumers. A consumer gains a surplus of $u - p^{j*}$ from the consumption of one unit of the product, where u is the intrinsic value associated with the product and uniformly distributed between 0 and 1. To calculate the aggregate surplus, we take the summation of all the consumers' non-negative utility surplus in the market. We derive the consumer surplus (CS^j) from the utility model as follows (Gur et al., 2023; Jin et al., 2023):

$$CS^j = \int_{p^{j*}}^{1} {}^{1}\left(u - p^{j*}\right) du$$

$$CS^{LF*} = \frac{1}{2}\left(\frac{(1-\alpha)(1-\lambda) - c_l - c_p}{4(1-\alpha)(1-\lambda)}\right)^2$$

$$CS^{PF*} = \frac{1}{2}\left(\frac{1-\lambda-c_l-c_p}{4(2-\alpha)(1-\lambda)}\right)^2$$

We present the findings from the comparative analysis of consumer surplus in Proposition 7.

Proposition 7. The consumer surplus under 3PL financing is lower than that under platform financing $\left(CS^{LF*} \leq CS^{PF*}\right)$ in case of high

[18] https://www.forbes.com/sites/forbestechcouncil/2022/12/30/why-a-customer-centric-approach-is-key-to-e-commerce-at-scale/?sh=6444615a293f.

[19] https://aws.amazon.com/executive-insights/content/the-imperatives-of-customer-centric-innovation/.

operational risk (i.e., $\lambda \geq \lambda_1$). Otherwise, if $\lambda < \lambda_1$, then $CS^{LF*} > CS^{PF*}$.

From Proposition 1, we know that the final retail price is lower under LF than PF when the operational risk is low. Thus, a consumer obtains a higher utility surplus $(u - p^{l*})$ under LF. It may be noted that the demand is high under LF in this case due to the low retail price. Hence, in the case of low operational risk, the consumer surplus is more under LF owing to higher demand and utility surplus. However, when the operational risk increases, the demand and utility surplus are more under PF, leading to a higher consumer surplus. Next, we conduct numerical experiments to derive additional findings and managerial insights.

5. Numerical analyses

In this section, we conduct several numerical experiments and analyse the e-tailer's optimal choice of financing mode (either LF or PF) to derive critical managerial insights. We especially focus on identifying the market conditions under which the optimal financing mode becomes profitable for each supply chain player. Using a set of numerical experiments, we study the impact of various model parameters on each player's profit. We also determine the market scenarios under which LF and PF achieve a win-win-win outcome. The setup used for numerical analyses is explained below. We consider the following set of parametric values throughout the paper: $c_p = 0.3, c_l = 0.2, \gamma = 0.2$. This numerical setup derives support from existing SCF literature (Chen et al., 2018; Huang et al., 2019; Rath et al., 2021). We conducted a robustness check by considering various combinations of the parametric values and found similar results in all the numerical setups.

5.1. Impact of the platform's referral fee rate and the e-tailer's operational risk

E-commerce platforms typically set their referral fee rates based on the category of products, independent of the lending business. For example, Amazon charges 3–45 % as a referral fee for different product categories.[20] For small jewellery and watches, it charges a very low referral fee of 5 % and 3 %, respectively. Similarly, the referral fee for the fine art and collectable coins category is as low as 10 %. Moreover, products such as clothing (17 %) and electronic accessories (15 %) are in the moderate referral fee category. Few product categories (e.g., gift cards, entertainment collectables) come in the range of high referral fee. Apart from this, Amazon charges a very high referral fee for Amazon explore (30 %) and Amazon device accessories (45 %). Similarly, the referral fee varies from 3 % to 20 % on the Walmart marketplace.[21] Therefore, we first explore how the impact of referral fee on the total revenue of the supply chain members varies under different financing modes.

We begin our numerical examination by investigating the impact of referral fee and operational risk on the retail price. Fig. 3 shows that the retail price under 3PL financing (LF) for high referral fee products is higher than that under platform financing (PF). This can be explained as follows. Under PF, the platform has dual revenue sources: referral fee and interest amount. Under PF, the platform can strategically charge a lower interest rate to reduce the total payable amount for the e-tailer. While this strategy reduces his income from interest fee, it improves his total revenue by increasing the referral fee owing to higher demand under PF. This is called the referral fee effect. Under a high referral fee scenario, the referral fee effect is high. This is because the platform charges a low interest rate under PF, which eventually increases customer demand and referral fee revenue. Due to the low interest rate under PF, the e-tailer's payable amount due to lending becomes less under PF than under LF. Further, the e-tailer does not incur any additional cost due to bankruptcy, leading to a lower cost under PF than LF. Hence, she sets a lower retail price under PF under high referral fee conditions. In contrast, for lower values of referral fee, the retail price is higher (lower) under LF under high (low) risk. Under these scenarios, the platform charges a high interest rate to compensate for the low referral fee income. Therefore, the interest cost for the e-tailer becomes higher under PF than under LF. Under LF, the e-tailer has an additional cost of bankruptcy that increases with the likelihood of default. Thus, the e-tailer incurs a lower financing cost under LF, leading to lower retail price when both referral fee and operational risk are low. On the other hand, at a higher level of risk and a lower value of referral fee, the cost of bankruptcy under LF surpasses the cost incurred due to lending under PF, leading to a higher financing cost under LF. Hence, she charges a higher retail price under LF for lower values of referral fee and high operational risk.

Next, we focus on how the referral fee affects an e-tailer's profitability at different levels of operational risk. Fig. 4 shows that the e-tailer's profit is higher for products with a high referral fee. However, for product with a lower referral fee, the e-tailer with a low (high) operational risk earns more profit under LF (PF). The e-tailer gets more demand under PF for high referral fee products due to the low price. Hence, her revenue, as well as profit, is higher under PF. However, under a lower referral fee, she obtains more demand under LF (PF) when the risk is low (high), leading to higher revenue and higher profit under LF (PF).

Next, we discuss the impact of problem parameters (i.e., referral fee and operational risk) on the 3PL firm's profit. We find that when the referral fee is low, the 3PL firm's profit is higher under LF (PF) at a lower (high) value of operational risk (see Fig. 5). This is because when the referral fee is low, the e-tailer sets a lower retail price, leading to high market demand. Thus, the 3PL firm generates more revenue under LF from the logistics business due to higher demand. Moreover, the 3PL firm's revenue from the lending business is also significant under low risk because the e-tailer's likelihood of bankruptcy is low. Hence, the 3PL firm earns a higher profit under this scenario when risk is low. In contrast, the 3PL firm obtains higher profit under PF for larger values of the referral fee. In this case, the 3PL firm's loss due to the e-tailer's bankruptcy becomes high. Hence, the 3PL firm is better off under PF than LF.

[20] https://sellercentral.amazon.com/gp/help/external/GTG4BAWSY39Z98Z3.
[21] https://sellerhelp.walmart.com/seller/s/guide?article=000006011.

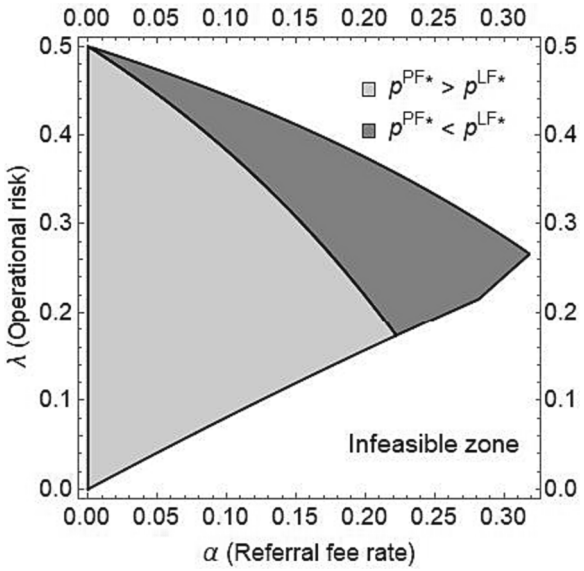


Fig. 3. Comparison of Retail Price.

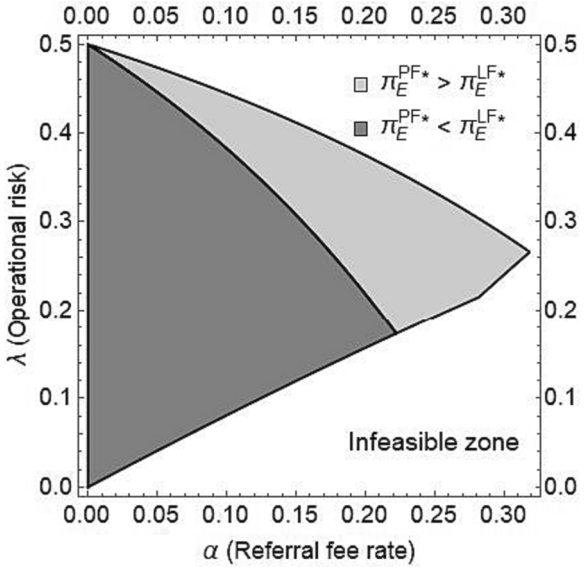


Fig. 4. Profit comparison of the e-tailer.

Next, Fig. 6 shows that the platform's profit is more under PF when the referral fee is very high. As discussed, the platform has two revenue sources in PF: interest income and referral fee income. In contrast, he has only referral fee revenue under LF. We know the demand is higher under PF when the referral fee is very high. Therefore, he earns more referral fee revenue under PF, leading to higher profit. Similarly, when the referral fee is very low, the platform is better off under PF under low risk. The platform charges a high interest rate under PF for very low referral fee products to compensate for the lower referral fee income. Furthermore, he obtains significant revenue from lending under low risk due to the low likelihood of default. Due to this additional revenue source, the total profit of the platform under PF is more than that under LF. However, under high risk, the e-tailer's default rate is high. Hence, the revenue from the lending business is low, leading to less profit under PF. Additionally, we find that the platform prefers PF to LF under high-risk scenarios for other intermediate values of the referral fee. In such cases, he loses a significant amount of referral fee revenue under LF due to lower demand. On the other hand, he can improve his profit under PF by judiciously deciding the interest rate vis-à-vis the referral fee.

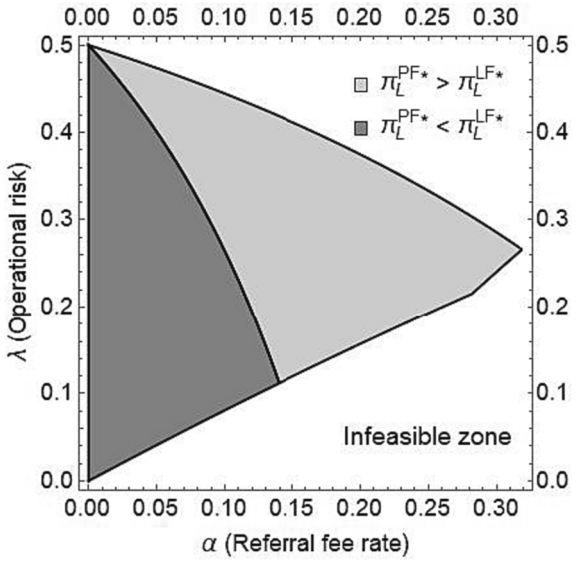


Fig. 5. Profit comparison of the 3PL firm.

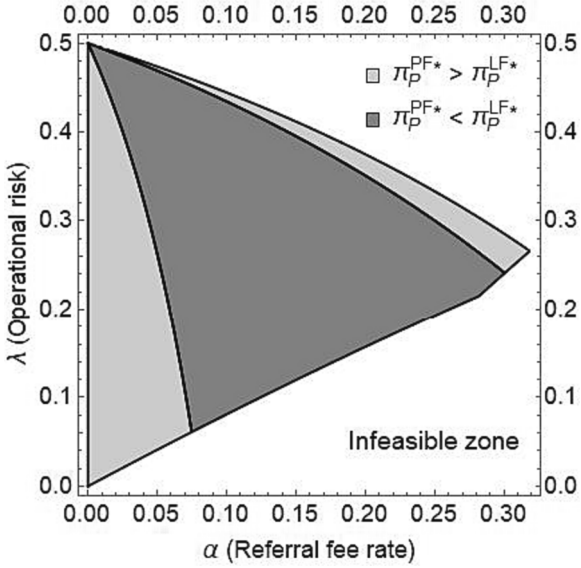


Fig. 6. Profit comparison of the platform.

5.2. *E-tailer's product-based strategy and Win-win-win scenario*

From the analysis presented in Section 5.1, we find that the preferences of each supply chain player (the e-tailer, the 3PL firm, and the platform) do not always align with each other. This section tries to find a product-based strategy for the e-tailer and a win-win-win situation under both financing modes. For ease of comparison, we divide the feasible region into five zones (see Fig. 7): very low referral fee, low referral fee, moderate referral fee, high referral fee, and very high referral fee. From Section 5.1, we derive product-based financing strategies for the e-tailer at various levels of operational risk. For products with a high referral fee (e.g., gift cards and entertainment collectables) and very high referral fee (e.g., Amazon devices and Amazon experiences), the e-tailer should choose PF. Similarly, she is better off under LF for products with a very low referral fee (e.g., small jewellery and watches). On the other hand, for products such as fine art (low referral fee) and clothing (moderate referral fee), the optimal financing choice is risk-dependent. Under low (high) risk, she prefers LF (PF). Thus, we present a decision-support framework based on the interplay of the e-tailer's operational risk and product-based referral fee in Table 4.

Now, we discuss the market scenarios under which PF and LF achieve a win-win-win outcome. From Section 5.1, we know that for products with a low referral fee, the 3PL firm prefers LF to PF when the e-tailer has low operational risk. Moreover, the e-tailer and the

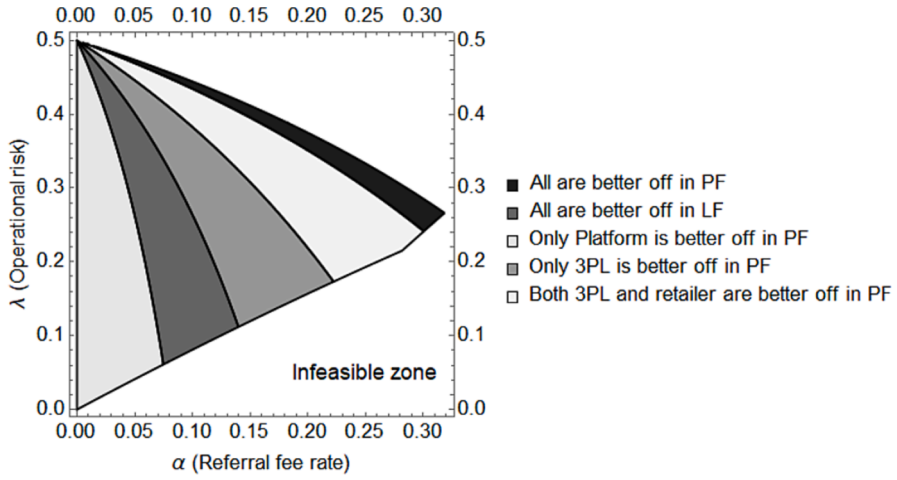


Fig. 7. Win-win–win condition under different market conditions.

platform earn higher profits under LF in these cases. Hence, when the referral fee is low, all the supply chain players prefer LF to PF under low risk. Therefore, LF achieves a win-win-win scenario in this case. Similarly, when the referral fee is very high, the platform prefers PF to LF, and the e-tailer and the 3PL firm are also better off under PF. Hence, in this region, PF achieves a win-win-win outcome naturally. We also find that when the referral fee is high or moderate, PF achieves a win-win-win outcome only when the e-tailer's operational risk is high. This is because the platform, the e-tailer, and the 3PL firm earn more under PF if the risk is high. If the product has a very low referral fee, neither LF nor PF achieves a win-win-win solution due to the misalignment of preferences.

5.3. Effect of initial working capital

One of the key assumptions in the base model is that the e-tailer has no initial working capital to carry out business operations. However, in reality, she can have some working capital. In this analysis, we relax this assumption and study a capital-constrained supply chain where the e-tailer has 'z' working capital, which does not cover the total procurement cost. She takes a loan from the 3PL partner or online platform for the remaining amount $(d^j w^j - z)$. The profit functions under LF and PF are provided below.

Under the platform financing (PF) mode:

$$\pi_E^{PF} = (1-\lambda)(1-\alpha)d^{PF}p^{PF} - (1-\lambda)\left(d^{PF}\left(w_s^{PF}+c_p\right)-z\right)\left(1+r^{PF}\right), \tag{18}$$

$$\pi_P^{PF} = (1-\lambda)\left(\alpha d^{PF}p^{PF} + \left(d^{PF}(w_s^{PF}+c_p)-z\right)\left(1+r^{PF}\right)\right) - \left(d^{PF}(w_s^{PF}+c_p)-z\right), \tag{19}$$

$$\pi_L^{PF} = d^{PF}w_s^{PF} - c_l d^{PF}. \tag{20}$$

Under the 3PL financing (LF) mode:

$$\pi_E^{LF} = (1-\lambda)(1-\alpha)d^{LF}p^{LF} - (1-\lambda)\left(d^{LF}(w_s^{LF}+c_p)-z\right)\left(1+r^{LF}\right) - \lambda\gamma\left(d^{LF}(w_s^{LF}+c_p)-z\right), \tag{21}$$

$$\pi_P^{LF} = (1-\lambda)\alpha\, d^{LF}p^{LF}, \tag{22}$$

$$\pi_L^{LF} = (1-\lambda)\left(d^{LF}(w_s^{LF}+c_p)-z\right)\left(1+r^{LF}\right) + \lambda\gamma\left(d^{LF}(w_s^{LF}+c_p)-z\right) - \left(\left(c_l+c_p\right)d^{LF}-z\right). \tag{23}$$

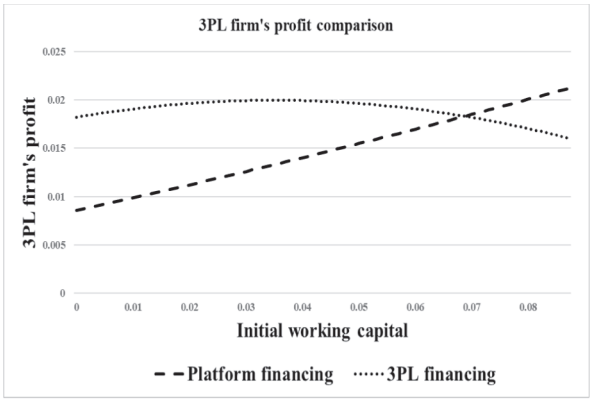
We conduct numerical experiments in this extension due to the mathematical complexity of the optimal profit expressions. To find the impact of initial working capital on the financing strategies of the supply chain players, we use different sets of parameter values: $c_p = 0.3, c_l = 0.2, \gamma = 0.2, \lambda = 0.1, \alpha = 0.05$; $c_p = 0.3, c_l = 0.2, \gamma = 0.2, \lambda = 0.3, \alpha = 0.05$; $c_p = 0.3, c_l = 0.2, \gamma = 0.2, \lambda = 0.3, \alpha = 0.15$; $c_p = 0.3, c_l = 0.2, \gamma = 0.2, \lambda = 0.3, \alpha = 0.25$. We find that in some cases, the base model results may change based on the retailer's initial working capital level. For illustration, we use the following parameter values in this extension: $c_p = 0.3, c_l = 0.2, \gamma = 0.2, \lambda = 0.1, \alpha = 0.05$.

We find that with an increase in the e-tailer's initial working capital, the 3PL firm's profit under 3PL financing first increases and then goes down. In contrast, its profit under platform financing increases (Fig. 8(a)). With an increase in the e-tailer's initial working capital, her loan requirement goes down, which reduces the interest rate, leading to a lower selling price and higher demand. Due to this, the 3PL firm's earnings from the logistics service increase with the e-tailer's initial working capital. Moreover, the 3PL firm's capital loss decreases due to reduced loan amounts. On the other hand, due to lower loan amounts and interest fee, 3PL firm's interest fee revenue decreases with the working capital. Therefore, in 3PL financing (LF), its total profit first increases due to higher shipping

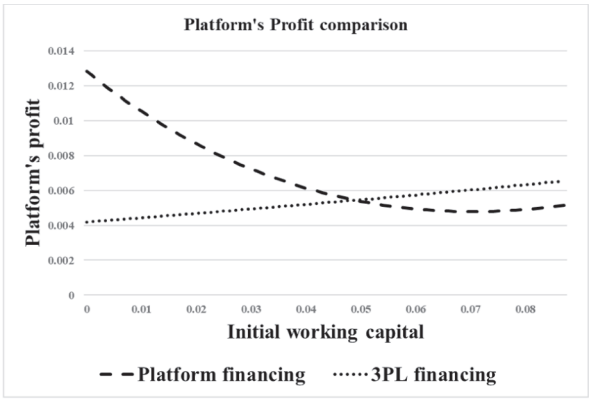
fee revenue and later decreases due to higher loss of interest fee revenue. Under platform financing, the 3PL firm's only source of revenue is the logistics business. Due to higher demand, the shipping fee revenue increases with working capital, leading to higher profits. Similarly, the platform's profit under platform financing (3PL financing) decreases (increases) with working capital (Fig. 8(b)), which can be explained with similar logic. In this case, the platform's profit goes down under PF because the increase in his referral fee revenue is low owing to the low referral fee rate, and the reduction in interest fee revenue is high due to a decrease in the loan amount and interest rate.

From the e-tailer's profit comparison (Fig. 8(c)), we find that when the working capital is low, the e-tailer is better off under 3PL financing, which aligns with the base case result. We also notice that with an increase in working capital, the platform saves more from a reduction in capital loss than the 3PL firm because LF is a secured loan. Hence, the platform reduces interest rates more under PF than the 3PL firm under LF, which decreases total procurement cost and selling price, leading to a higher increase in demand and revenue under PF. Therefore, the e-tailer's profit improves faster under platform financing than under 3PL financing owing to a higher reduction in interest rate. Eventually, the e-tailer earns higher profit under platform financing, unlike the base case. With a further increase in working capital, the e-tailer's profit under PCF starts decreasing due to an increase in the total cost of procurement owing to a higher logistics fee (See Appendix D). Therefore, when the working capital becomes high, the e-tailer earns more profit under 3PL financing.

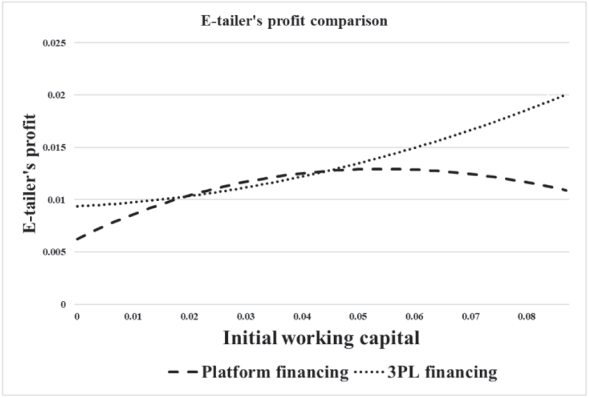
We also examined the effect of the e-tailer's operational risk on the impact of working capital. For this analysis, we consider the following parametric setup: $c_p = 0.3, c_l = 0.2, \gamma = 0.2, \lambda = 0.3(high), \alpha = 0.05$. We find that with an increase in working capital, 3PL firm's profit increases in PF and LF. Unlike the low-risk scenario, the 3PL firm's and the platform's capital loss due to the e-tailer's default reduces significantly with working capital as the probability of default is high due to high operational risk. In the case of a 3PL firm, the increment in shipping fee revenue and the reduction in capital loss dominates the reduction in interest fee revenue; hence, its profit always goes up under LF and remains higher than that under PF, like the base case (Fig. 9(a)). Similarly, from Fig. 9(b), we find that the platform's profit first goes down with working capital like low-risk case (Fig. 8(b)) due to a decrease in interest fee revenue; however, his profit increases for higher values of working capital owing to a higher reduction in capital loss. The e-tailer's profit comparison shows that when working capital is low, the result is the same as the base case. However, with increased working capital, her profit under LF goes down at first owing to increased capital loss. Later, when the working capital is high, while the e-tailer's



(a). 3PL firm's profit comparison



(b). Platform's profit comparison



(c). E-tailer's profit comparison

Fig. 8. Impact of initial working capital ($c_p = 0.3, c_l = 0.2, \gamma = 0.2, \lambda = 0.1, \alpha = 0.05$).

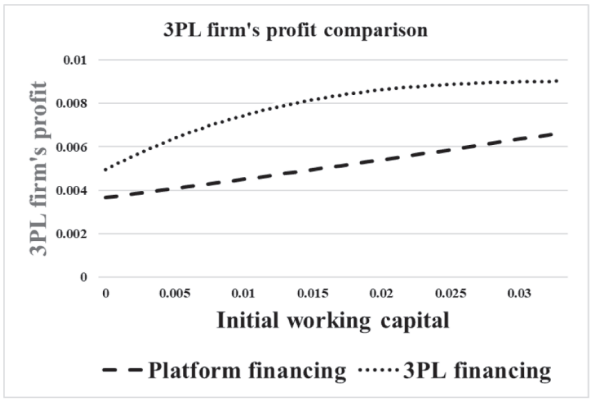
capital loss is very high, the 3PL firm's credit risk becomes very low due to collateral and low loan amounts, which leads to low interest costs and high demand. Therefore, the sales revenue increases sufficiently to offset the increment in capital loss, increasing the e-tailer's profit when working capital is high. The above analysis shows that the e-tailer's working capital significantly affects the financing strategies of the supply chain players.

5.4. Impact of the logistics cost and the product cost

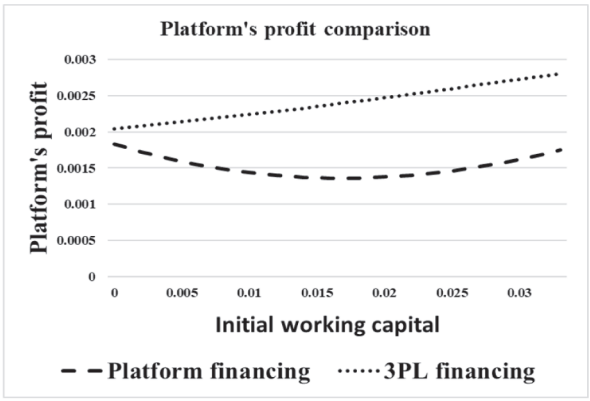
This section analyses how the supply chain players' financing decisions change with logistics and product costs. We consider different sets of parametric values for the analysis and find the results robust. We use the following set of parametric values for illustration: $\alpha = 0.15, \lambda = 0.3, \gamma = 0.2$. We present the findings below.

We find that when the unit logistics and product costs are low, the retail price under LF is lower than that under PF (Fig. 10 (a)). As the 3PL financing (LF) is a secured loan, the 3PL firm charges a lower interest rate than the platform in this scenario. Moreover, the loan amount is less when the logistics and product costs are low. In case of bankruptcy, the e-tailer loses lesser collateral to the 3PL firm. Hence, the total cost of the e-tailer is less under LF due to lower interest and bankruptcy costs. Thus, she sets a lower retail price under LF. However, the loan amount is also high when the logistics and product costs become high. In bankruptcy, the e-tailer loses a higher amount of collateral, leading to higher bankruptcy cost. Under high logistics and product costs, the bankruptcy cost outweighs the benefits of lower interest fee under LF. Hence, she sets higher retail price under LF. As the retail price in LF is low (high) under low (high) logistics cost and product cost, the demand under LF becomes high (low). Thus, she gets higher (lesser) revenue and profit under LF than PF when the logistics and product costs are low (high) (Fig. 10 (b)).

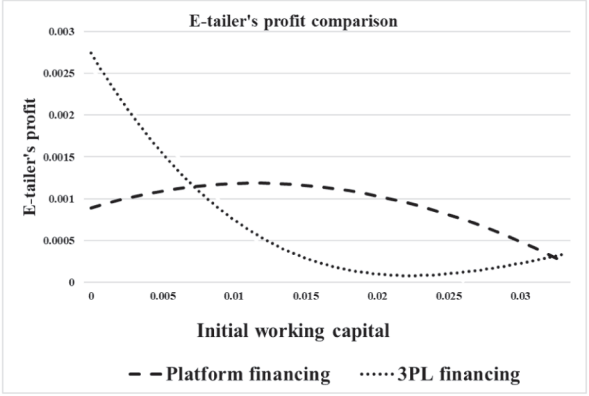
From Fig. 10 (c), we find that when the logistics and product costs are low (high), the 3PL firm is better off under LF (PF). The reason is that the demand is higher in LF under low logistics and product costs. Thus, the 3PL firm gets higher revenue from its shipping business. Moreover, the loss of capital due to the e-tailer's bankruptcy is also low as the loan amount is low. Hence, the 3PL firm gets more profit under LF. With the increase in logistics and product cost, the demand difference between the LF and PF decreases, leading to a lower difference in revenue from the shipping business. Furthermore, in case of the e-tailer's bankruptcy, the 3PL firm loses more capital under LF due to increased loan amount. Under PF, the 3PL firm loses no capital. This leads to a decrease in the 3PL firm's profit



(a). 3PL firm's profit comparison



(b). Platform's profit comparison



(c). E-tailer's profit comparison

Fig. 9. Impact of initial working capital ($c_p = 0.3, c_l = 0.2, \gamma = 0.2, \lambda = 0.3, \alpha = 0.05$).

difference between LF and PF. When the logistics and product costs become sufficiently high, the 3PL firm earns more under PF than LF.

Next, we analyse the platform's profit and find that when the costs are very low or very high, the platform is better off under PF; otherwise, he is better off under LF (Fig. 10 (d)). As mentioned earlier, the platform has two revenue sources: referral fee revenue and interest fee revenue. When the logistics and product costs are low, the platform earns more referral fee revenue under LF as the e-tailer's sales are more under LF. However, when the costs are very low, the platform earns sufficient interest fee under PF to offset the difference in referral fee revenue compared to LF. Moreover, the platform's loss of capital in case of the e-tailer's bankruptcy is also small, as the loan amount is very small. Hence, the platform's profit is higher under PF. With an increase in the costs, the loan amount goes up, and the platform's capital loss goes up. He earns more under LF. Similarly, when the costs are very high, the platform's referral fee revenue is more under PF due to higher sales. Additionally, he also earns the interest fee revenue. Combined, both take care of the capital loss due to the e-tailer's bankruptcy, leading to higher profit under PF. Hence, the platform is better off under PF when the logistics and product costs are very high. Combining all the findings above (like we did under Section 5.2), we find that when the referral fee is low (very high), all the supply chain players are better off under LF (PF) (Fig. 10 (e)). Thus, a win-win-win scenario can arise under both LF and PF.

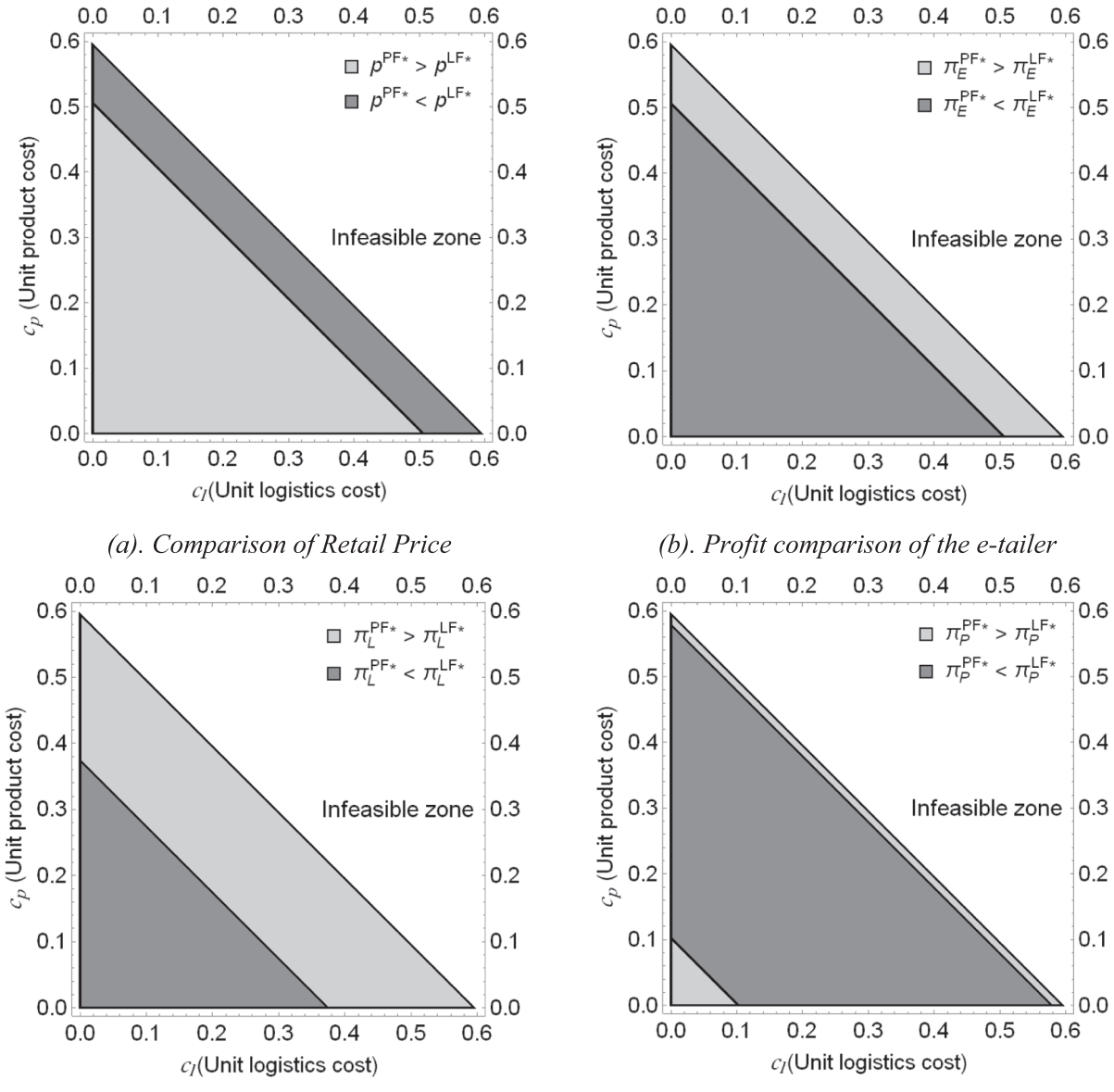
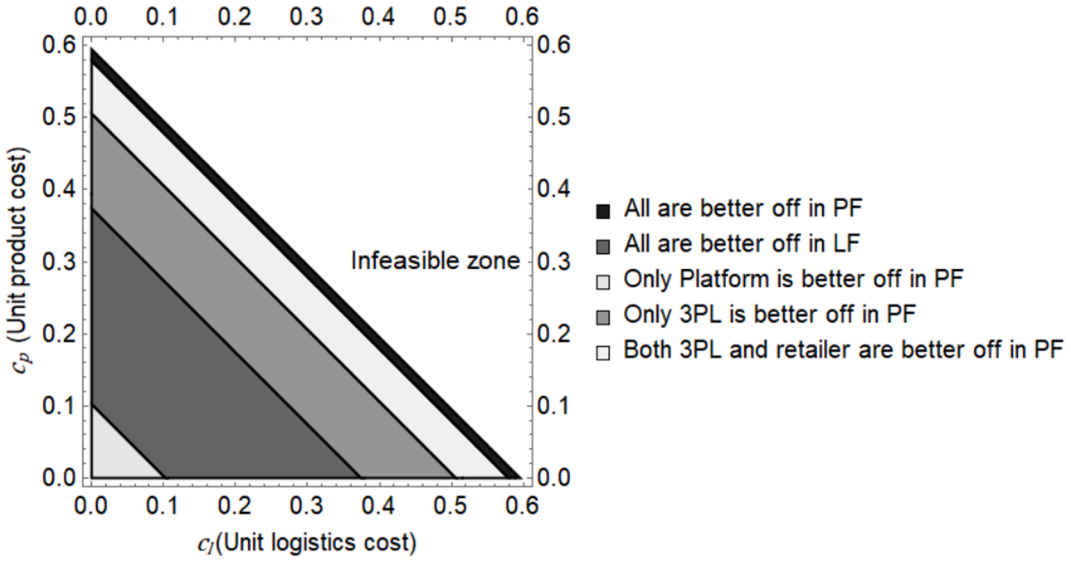


Fig. 10. Impact of logistics cost and product cost on the SCF scenario.



(e). Win-win-win condition under different market conditions

Fig. 10. (*continued*).

5.5. Impact of lender's loss aversion

Our base case considers the supply chain players to be risk neutral, in which they make the decisions by maximising their respective expected profits. For example, the e-tailer sets the retail price that maximises her expected profit. The lenders set the interest rate that gives them the maximum expected return. However, in practice, it has been observed that the supply chain players do not always make decisions as per the expected profit maximisation outcome (Wang and Webster, 2007). The reason is that expected measures only analyse the magnitude of unfavourable outcomes (Chiu and Choi, 2016). They fail to address the impact of uncertainty level on the decision-makers' choice. From the behavioural aspect, one decision-maker may be more averse to loss than another. Due to their attitude towards risk, they would have different strategies under the same market conditions. Thus, it is essential to incorporate the loss aversion nature of the lenders in the model to have a more realistic study.

In this extension, we consider the lenders (i.e., the 3PL firm in LF and the platform in PF) to be loss averse. They are more concerned about the expected losses than the profit. Following the existing research on loss aversion (Bai et al., 2019; Lee et al., 2015; Wang and Webster, 2007), we define the lenders' loss-aversion utility function to be piecewise linear as given below:

$$U(\pi_i^j) = \begin{cases} \pi_i^j, & \pi_i^j \geq 0 \\ \dfrac{\pi_i^j}{k_i}, & \pi_i^j < 0 \end{cases}$$

Where $k_i \leq 1$ describes the loss-averse nature of the 3PL firm ($i = L$) and platform ($i = P$) towards the e-tailer's operational risk. If $k_i = 1$, then the firm is risk neutral. The lower value of k_i indicates that the firm is more loss averse. We provide the loss aversion utility function under LF and PF below.

5.5.1. Platform Financing (PF)

Under PF, the platform gets positive profit (π_i^j) equal to $d^{PF}(\alpha p^{PF} + (w_s^{PF} + c_p)(1 + r^{PF})) - d^{PF}(w_s^{PF} + c_p)$ when the e-tailer fulfils the order successfully (i.e., the favourable outcome with probability $(1 - \lambda)$). If the e-tailer fails to fulfil the order, the platform loses the loaned amount equal to $d^{PF}(w_s^{PF} + c_p)$. Hence, his negative profit under unfavourable outcomes becomes $-d^{PF}(w_s^{PF} + c_p)$. Combining both the positive and negative outcomes, we get the following loss-aversion utility function for the platform:

$$U(\pi_P^{PF}) = (1 - \lambda)(d^{PF}(\alpha p^{PF} + (w_s^{PF} + c_p)(1 + r^{PF})) - d^{PF}(w_s^{PF} + c_p)) - \frac{\lambda d^{PF}(w_s^{PF} + c_p)}{k_P}$$

The profit expressions for the e-tailer and the 3PL firm remain the same as the base case. We follow the same methodology as the base case and obtain the equilibrium expressions under PF (please see online Appendix G).

5.5.2. 3PL Financing (LF)

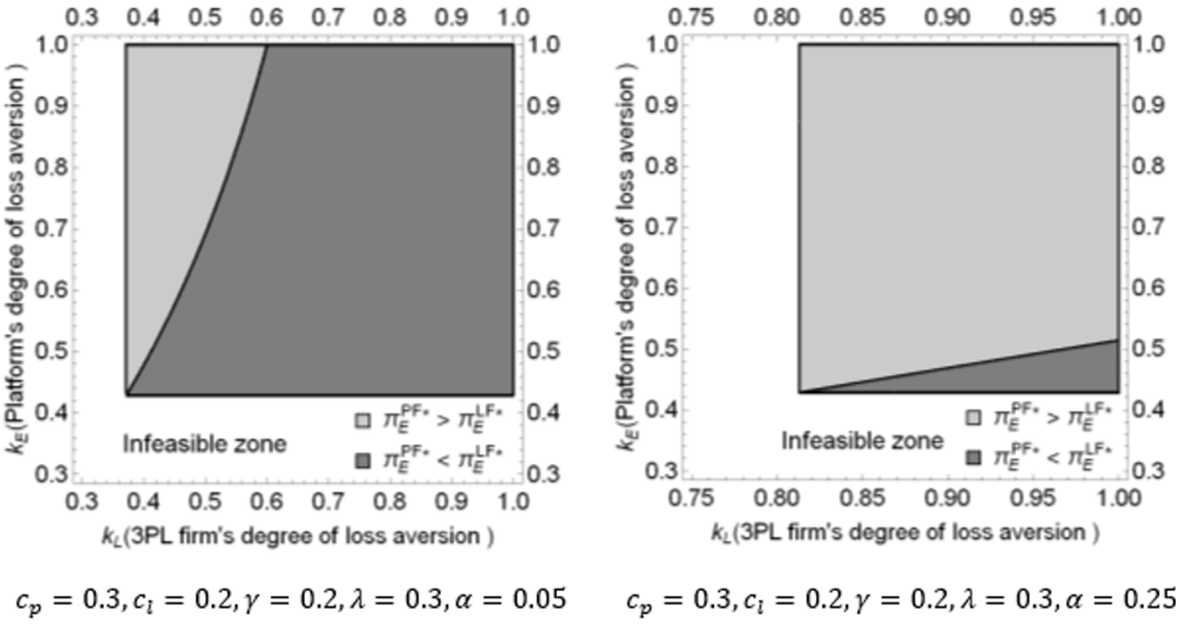
Under LF, the 3PL firm earns a positive profit equal to $d^{LF}(w_s^{LF} + c_p)(1 + r^{LF}) - (c_l + c_p)d^{LF}$ under favourable conditions. Its negative

profit under unfavourable market conditions is $\gamma d^{LF}(w_s^{LF} + c_p) - (c_l + c_p)d^{LF}$. Using this piecewise profit functions, we obtain the following loss-aversion utility function for the 3PL firm:

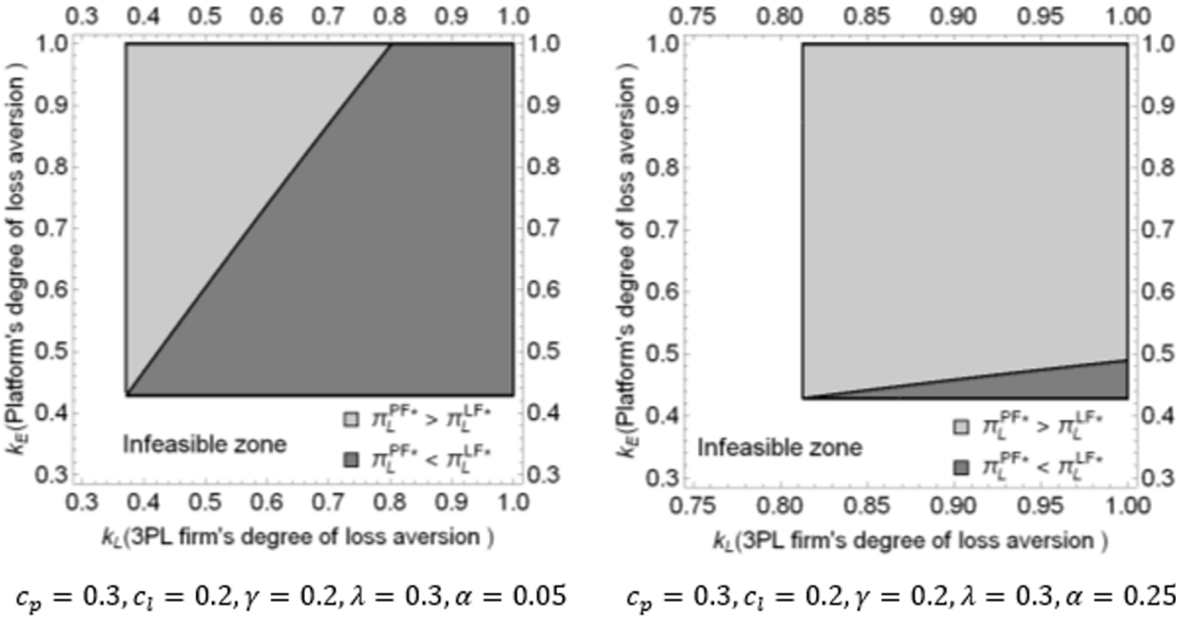
$$(\pi_L^{LF}) = (1-\lambda)(d^{LF}(w_s^{LF} + c_p)(1 + r^{LF}) - (c_l + c_p)d^{LF}) - \frac{\lambda((c_l + c_p)d^{LF} - \gamma d^{LF}(w_s^{LF} + c_p))}{k_L}$$

The profit functions of the platform and the e-tailer remain the same as the base case. The equilibrium expressions under LF are given in online Appendix G.

Due to the higher complexity of the equilibrium expressions, we conduct numerical analysis to show the impact of the lenders' loss aversion on the supply chain agents' equilibrium decisions. Fig. 11 (a) suggests that when the 3PL firm's (or platform's) loss aversion

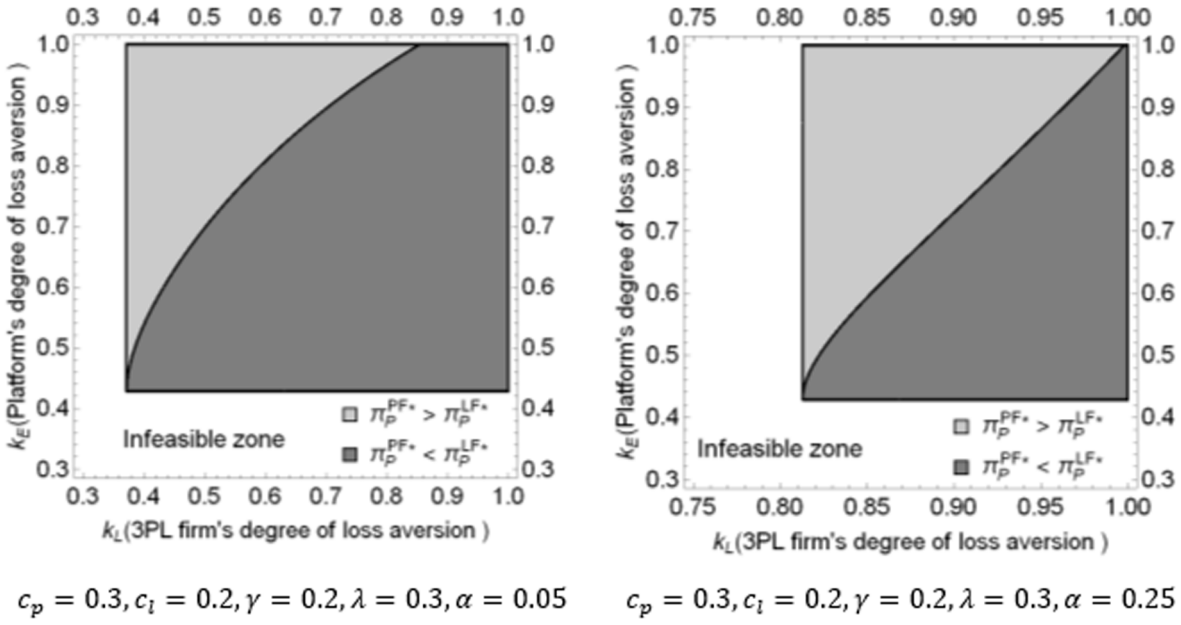


(a). Profit comparison of the e-tailer

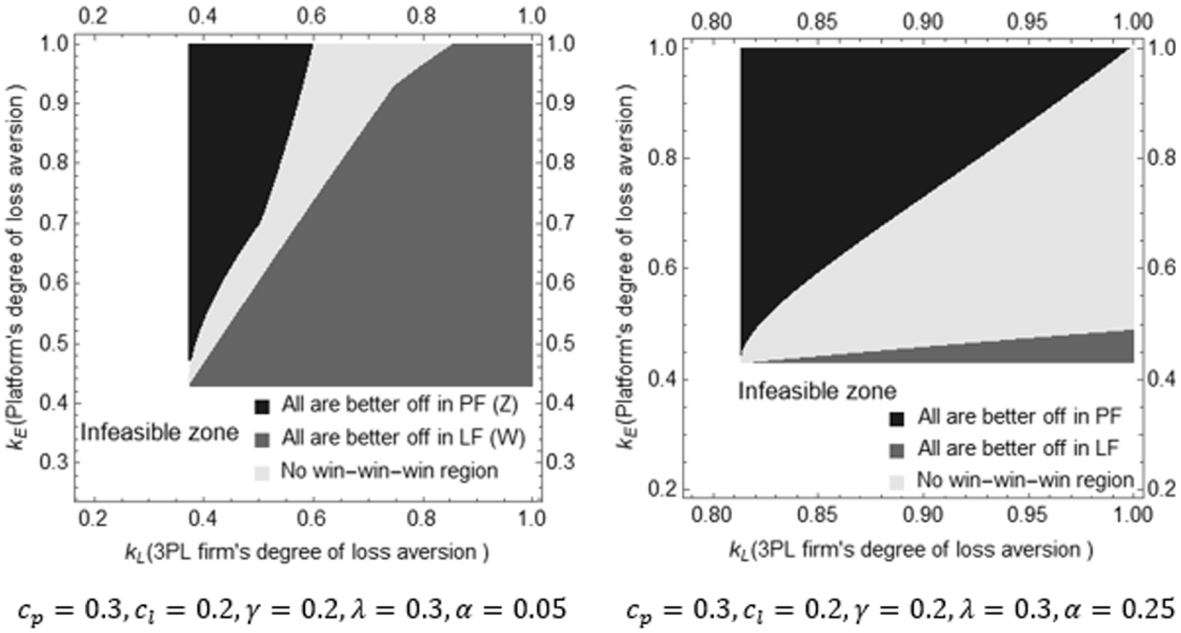


(b). Profit comparison of the 3PL firm

Fig. 11. Impact of the lender's loss-aversion.



(c). Profit comparison of the platform



(d). Win-win-win condition under different market conditions

Fig. 11. (*continued*).

increases, the e-tailer's preference changes from LF to PF (or PF to LF). With the increase in loss aversion, a lender's (suppose the 3PL firm) potential loss increases for the same magnitude of uncertainty, leading to a higher risk premium. Due to this, the borrowing cost of the e-tailer goes up, which increases the price and lowers the demand. The e-tailer earns less profit if she takes a loan from the 3PL firm. Thus, she takes a loan from the platform. A similar conclusion can be drawn for the platform's degree of risk aversion under PF.

Next, we observe that if the lender's loss aversion is low, it gets more profit under its financing mode. The additional revenue from the lending takes care of the potential loss. However, under high loss aversion, the lender's profit under its financing mode reduces due to high potential loss. Therefore, a high loss-averse lender obtains lower profit under its financing mode than the other lender's financing mode (Fig. 11(b) and 11(c)). Due to the changes in the supply chain player's preferences, the win-win-win scenario also changes with the degree of loss aversion of the lenders. When the 3PL firm's (or the platform's) degree of loss aversion becomes high,

PF (LF) achieves a win-win-win situation instead of LF (PF) (Fig. 11(d)). Thus, we conclude that loss aversion significantly impacts the financing strategy of the SCF instruments. This explains the difference between a supply chain agent's actual decision and profit-maximising outcome, as in Wang and Webster (2007) and Chiu and Choi (2016). Therefore, supply chain managers should consider both expected measures and risk measures during decision-making.

6. Managerial insights and concluding remarks

Third-party logistics (3PL) firms are becoming increasingly important for e-commerce supply chains. 3PL firms provide scalability, flexibility, and cost advantage in providing logistics services to e-tailer firms. Nowadays, deep-pocketed 3PL firms like S.F. Express and Eternal Asia have started financing capital-constrained e-tailers through a secured financing mode called 3PL financing (LF). This is because capital-constrained e-tailers do not easily obtain working capital loans from traditional lending institutions like banks due to a lack of credit history and business transparency. Similarly, online platforms such as Amazon and Alibaba also provide unsecured loans to the e-tailers selling on their platform, referred to as platform financing (PF). This research aims to devise an e-tailer's optimal borrowing strategy and analyse the effect of these financing modes on the operational decisions of supply chain members in the presence of operational risk. Thus, we develop a game-theoretic model for an e-commerce supply chain consisting of a capital-constrained e-tailer, an online platform, and a 3PL service provider. First, we compare the optimal retail price under LF and PF. The retail price is lower under PF when the e-tailer's operational risk is high; otherwise, it is lower under LF. Our findings contribute theoretically to the existing academic literature and provide managerial insights to practitioners.

We find that under high operational risk, the e-tailer gets more demand under PF than LF and earns higher profit. For low operational risk, she prefers LF to PF. The results suggest that the e-tailers such as Power Practical, Darlyng & Co., and Amaze Store should explore multiple financing modes instead of relying on a single financing mode (i.e., either PF or LF). Our study complements the existing literature on 3PL financing, which has focused on various parameters such as service level, initial working capital (Chen et al., 2011), channel leadership (Hua et al., 2021), demand uncertainty, risk preference (Wang et al., 2019b), competition and spillover effect (Wang et al., 2022b). Furthermore, the study reveals that the 3PL firm earns more profit under LF (PF) if the e-tailer's operational risk is low (high). This explains why 3PL firms like S.F. Express, Cainiao, and Eternal Asia are considering supply chain finance (SCF) as one of the major expansion areas. At the same time, Li and Chen (2019) have provided testimonials from Chinese 3PL firms about incurring huge losses due to bad debt. Therefore, the logistics and financial service integration should be done strategically, considering the default risk associated with lending. Next, we find that the platform is better off under PF when the operational risk is very low or very high; otherwise, he is better off under LF. Hence, online marketplaces like Amazon, JD.com, and Alibaba need not be antagonistic to 3PL firms providing integrated services and vice versa. We find some market conditions where the platform benefits from 3PL financing. In offline retailing, Chen and Xie (2009) and Chen et al. (2011) suggested that LF is always better for the individual players and the whole supply chain. Similarly, Wang et al. (2022b) reported that the 3PL firm always prefers to provide integrated service over bank financing. However, in the presence of PF, it is not always true. All supply chain players are better off under PF if the operational risk is high. Furthermore, our results show that a supply chain player's preference can change depending on the market parameters such as product cost, logistics cost, and product category.

We recommend a decision-support framework based on the interplay of the e-tailer's operational risk and product-based referral fee. PF obtains a win-win-win outcome under a very high referral fee. For products with a high or moderate referral fee, such as gift cards and entertainment collectables, PF is the win-win-win strategy under high risk. However, LF is the win-win-win strategy for low referral fee products (like laptops and fine arts) under a low-risk scenario. For products like clothing that have a low to moderate referral fee, LF (PF) is the optimal financing mode for the e-tailer with low (high) operational risk. From the consumer's perspective, the e-tailer's financing choices also maximise the consumer's welfare.

Further analysis reports that initial working capital can significantly alter the preference of the three players. Hua et al. (2021) showed that 3PL's profit is higher under LF if the initial working capital is high. In contrast, we prove that PF can generate more profit for the 3PL firm than the LF under high working capital. Additionally, we demonstrate the impact of the logistics and product costs on the SCF modes. We find that for products such as electronics and furniture (clothing and sunglasses) that have high (low) logistics and product costs, the e-tailer and the 3PL firm prefer PF (LF). However, the platform prefers PF under very high or very low logistics and product costs. Wang et al. (2022b) suggest that the retailer prefers LF to BF under high logistics costs in the presence of a spillover effect. In contrast, we find that if the spillover effect is not present, the retailer prefers LF to BF under low logistics costs. We also analyse the impact of the lender's loss aversion on the financing decisions of the supply chain players. Our paper also indicates that the lender's relative risk appetite can significantly alter the SCF strategies of the players in the capital-constrained online supply chain. With the increase in a lender's relative loss aversion, all the supply chain players may change their preferences from PF to LF or vice-versa.

Our study is one of the first to compare 3PL financing with platform financing in an e-commerce setup. We can extend this study in several directions. First, in this paper, we assume that the e-tailer does not fulfil any demand in case of failure. However, in practice, she might be able to fulfil a fraction of consumer demand. Second, the e-tailer can improve her efficiency with additional efforts (e.g., provisions for better quality checks at the time of product purchase and improvement of the product handling process) that reduce her operational risk. Hence, future studies may endogenise the operational risk and study its impact on the equilibrium decisions of the supply chain players. Currently, the platforms also provide logistics services to the e-tailers for an additional fee. Another interesting avenue of future research is including the logistics services provided by the platform in our model setup. In this paper, we consider only the inherent operational risk of the e-tailer in the analysis. Sometimes, the e-tailers may face multiple supply chain risks, such as operational risk and disruption risk jointly. Therefore, it would be intriguing to explore the joint impact of multiple risks on the

financing strategies of the online supply chain players.

CRediT authorship contribution statement

Sambit Brata Rath: Conceptualization, Formal analysis, Methodology, Writing – original draft, Writing – review & editing. **Preetam Basu:** Conceptualization, Formal analysis, Methodology, Writing – original draft, Writing – review & editing. **Kannan Govindan:** Conceptualization, Formal analysis, Methodology, Supervision, Writing – original draft, Writing – review & editing. **Prasenjit Mandal:** Conceptualization, Formal analysis, Methodology, Supervision, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.tre.2024.103459.

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