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How a platform's private label interacts with a manufacturer's financing strategy

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ABSTRACT

Recently, major e-commerce retailers like Amazon and Alibaba have started providing working capital loans to capital-constrained manufacturers selling through their marketplaces. Additionally, these platforms often introduce private labels (PLs), such as Amazon Basics, that compete with manufacturers' brands. This leads to a coopetative partnership between platforms and these small and medium enterprises, such as LonoLife, which compete with the platforms' PLs and also avail loans from them. Using game-theoretic analyses, we investigate the following question: *How does the platform's PL introduction strategy impact a capital-constrained manufacturer's financing decision*? The manufacturer manages the operational risk in its manufacturing process while selecting the optimal financing strategy, with or without the platform's PL. Intuitively, if the platform introduces the PL, as a strategic response, the manufacturer should consider opting for bank financing. However, the manufacturer does the opposite by switching to platform financing when the values of the production cost are within the intermediate range and the perceived quality of PL is low. Interestingly, the platform might adopt a cooperative strategy by not introducing the PL if the manufacturer decides to use platform financing. We recommend that the platform can utilise its PL effectively to mitigate operational risk in the upstream production process.

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Supply chain management; supply chain finance; platform financing; private label; operational risk

1. Introduction

Insufficient working capital remains a major obstacle to the growth potential of small and medium-sized enterprises (SMEs). Despite the fact that over 50% of these businesses globally rely on short-term loans to cover their working capital needs; in 2021, only 28.4% of them have secured loans from traditional institutions like banks (World Bank 2021). SMEs often have difficulty obtaining bank loans since they do not have enough assets to use as collateral or a long enough credit history. Alternatively, e-commerce marketplaces like Amazon, Alibaba, and Shopify now offer loans to SMEs that operate as third-party sellers on their platforms.

In addition to providing financial services, platforms like Amazon and JD.com sell their own private labels (PLs, or equivalently store brands) and compete with third-party sellers on their marketplaces (Zhang and Hou 2022). For example, Amazon has launched more than 23,000 products under more than 400 distinct brand names (i.e. AmazonBasics and Amazon Essentials products) (Marketplace Pulse 2022). Keeping intermediary platforms' PLs in mind, capital-constrained SME sellers are concerned about their strategic financing choices: bank financing vs. platform financing. In this study, we explore these competitive and cooperative synergies between an SME manufacturer and an online e-commerce platform in which the platform acts both as a loan provider and as a competitor. The influence of platform-provided lending on manufacturers' financing decisions remains underexplored in the existing literature. Our paper aims to close this gap and provides theoretical contributions and managerial insights.

1.1. Motivation

Online retailers have grown significantly as a result of the accessibility, reach, and resources offered by platforms like Amazon and Alibaba. These platforms have transformed the retail landscape and created new opportunities for businesses of all sizes to thrive in the digital age. In 2021, the leading online marketplaces facilitated the sale of goods worth $3.25 trillion, showcasing unparalleled growth in their business (Freedman 2023).

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The size of a retail platform and the number of third-party sellers it can support determine how successful it is. SMEs constitute a major portion of these third-party sellers. Over 60% of all units sold on the Amazon marketplace come from SMEs (Mehta 2024). The convenience, credibility, and increased market reach offered by these platforms can lead to an average of 20–23% growth in net sales for SMEs within the first year of their product offering (e-tailize 2023). However, SME sellers often face challenges in obtaining the necessary funding to support their growth and expansion. Historically, SMEs have relied on bank financing to meet their funding needs. However, because of their small size, dearth of assets, and lack of an established credit history, they usually have difficulties obtaining bank loans. Furthermore, since the 2008 credit crisis, numerous small enterprises have found themselves paying a premium for bank funding. The lack of affordable financing can significantly impact the daily operations of these SMEs, preventing platforms from unleashing their true growth potential.

In order to address the funding needs of small and medium-sized businesses (SMEs), retail platforms have recently devised creative financing mechanisms under 'platform financing' (PF). Under PF, e-commerce giants like Amazon, Alibaba, and Shopify have begun offering non-collateralised financing to SMEs that sell products on their platforms. For instance, in the USA, Amazon has been providing loans through the Amazon Lending program since 2011. Moreover, Amazon has extended this service to sellers in other geographies, such as the United Kingdom, Canada, France, India, and China. Recently, Amazon has acquired a fintech company Axio to facilitate direct lending to its online sellers (Amazon 2025).

Similarly, Alibaba and JD.com offer their PF schemes, known as 'Pay Later' and 'Jing Xiao Dai', respectively. The sellers on the Walmart marketplace in the US can get a loan directly from Walmart through the 'Capital by Walmart' program (Walmart 2025). Some other examples, from all over the world, are Shopify Capital (Shopify 2025), Mercado Libre Credit (Mercado Crédito 2024), Allegro Merchant Finance (Allegro 2025), Rakuten Super Business Loan (Rakuten 2013), Coupang seller loan (Choi Si-young 2022), etc. Online SMEs have immensely benefited from these platform financing schemes. Numerous SMEs (such as Lonolife, Buttonsmith, and Tower) have expressed their appreciation for Amazon Lending in their testimonials, highlighting how it enabled them to overcome working capital shortages and foster business growth. Armando Colimodio, a co-owner of Colsen (an e-commerce business), states,

> By working with Amazon Community Lending, we've been able to invest in our business and expand our great product selection through the program's simple and quick loan acceptance process. We expect to double our sales this year and remain committed to growing our product portfolio.

Table 1. Illustrations of platform's private label and SME products competition.

Product category	SME's brand	Platform's private label
Chicken Broth	LonoLife[a]	Happy Belly[b] (Amazon)
Electronics	Power Practical[c]	Amazon Basics[d]
Organic product	SVA organics	365 Everyday value (Amazon)
Home Textile	Urban Villa	Solimo (Amazon)

[a]https://www.amazon.com/LonoLife-Chicken-Broth-Snack-Container/dp/B07MBR1QB5
[b]https://www.amazon.com/Happy-Belly-Broth-Chicken-Ounce/dp/B07VH118NP
[c]https://www.amazon.com/Power-Practical-Luminoodle-Basecamp-Waterproof/dp/B01G7SU4MM
[d]https://www.amazon.com/AmazonBasics-420-Rope-Light-40-Foot/dp/B07TV74YYJ

Retail platforms have recognised that PF can serve a dual purpose. First, this grants them an additional revenue stream through interest payments on loans. Additionally, it boosts their referral fee income since SMEs can expand their operations by accessing necessary working capital. Therefore, PF serves as an important instrument for retail platforms to enhance their revenue streams directly through interest income and indirectly through increased sales volumes, thanks to the enhanced stability of their marketplace business.

In recent times, platforms have witnessed the emergence of a third revenue stream: their own private label (PL) brands. Major e-commerce giants sell their own PL products on their respective platforms. For instance, Amazon has private labels such as AmazonBasics, Solimo, and Happy Belly. Similarly, JD.com sells its private label products under brands such as Best Home, Made by JD, and Jingmeng. Table 1 outlines an overview of selected Amazon's PLs and corresponding SMEs' products across different product categories. In 2017, Amazon had 30 private labels, and by 2022, this number had surpassed 100 (Chizhevskiy 2024). According to a study by KPMG India, private labels on online platforms are expected to expand at a rate 1.6 times faster than external brands while delivering twice the profit margins (Sharma 2020).

The interplay between PLs and financing mechanisms provided by platforms creates a compelling dynamic within the e-commerce ecosystem. On the one hand, a platform's PL competes directly with the products of an SME on the online marketplace. On the other hand, through its financing services, the platform offers a cooperative hand to the cash-constrained SME to grow its business. SMEs such as LonoLife and Power Practical, which compete with platforms' PLs, often avail loans from their respective platforms. This leads to an intriguing dilemma of a *co-opetitive relationship* between a retail platform and an SME, which we explore in our paper.

1.2. Research questions and key contributions

The emergence of PLs and financing mechanisms provided by platforms has sparked a debate on whether conventional financial institutions like banks or supply chain partners like retail platforms are better positioned to provide financing services to SME manufacturers. For example, prior studies demonstrate that when referral fees are low, an online seller may choose bank financing (Rath et al. 2021; Wang, Fan, and Yin 2019; Zhen et al. 2020). However, when operational risk is absent, platform financing is always chosen by sellers in a competitive market (Mandal et al. 2024). Nevertheless, existing literature is yet to examine the influence of a platform's private label (PL) on the financing strategy of a capital-constrained seller (or manufacturer). The platform anticipates the manufacturer's financing choice and decides whether to introduce a PL or not. Our research contributes to the body of knowledge on supply chain financing and private label strategies by exploring how a platform's private label offerings influence a manufacturer's financial decision-making. In summary, we aim to address the following research questions:

(1) In what way does the platform's choice to launch a private label influence the interest rates determined by both the bank and the platform?
(2) In what way does the platform's introduction of a private label impact the financing strategy of a manufacturer facing financial constraints?
(3) In the case of a capital-constrained manufacturer, does the platform benefit from launching its private label?

To examine these issues, we formulate a game-theoretic model where a manufacturer with limited funds distributes its product (manufacturer's brand or ML) to the downstream market via an intermediary platform and secures financing from either a bank or the platform. The platform might enter the market with its own private label, competing with the manufacturer's brand. Hence, the platform serves a dual role: it assists the cash-constrained manufacturer while simultaneously competing with the manufacturer through its PL, creating a coopetitive framework.

Our analysis generates several noteworthy results. Conventional reasoning suggests that a platform introducing a PL would raise the manufacturer's interest rate to deter ML sales. In contrast, we find that the platform offers a lower interest rate with the PL than without it, particularly when production costs are high. This strategy incentivizes the manufacturer to expand ML production, thereby helping to offset the higher costs created by the PL. We investigate how the PL strategy influences the interest rate structures of both the bank and the platform. When production costs are low, banks offer lower rates, and when costs are high, platforms undercut the bank by offering more favourable terms. We also find that under platform financing, the manufacturer chooses lower sales volumes when the PL is present compared to bank financing. Nevertheless, even in such cases, the manufacturer continues to prefer platform financing, while in the absence of a PL, the manufacturer opts for higher volumes through bank financing. Finally, we show that the platform does not always introduce a PL. When PL quality is lower than that of the ML and referral fees are small, the platform adopts a cooperative stance by not launching the PL.

Together, these results advance theory by revealing how private label competition and supply chain financing interact. They challenge the view that financing and product strategies are independent, showing instead that interest rate adjustments can turn PL competition into a complementary relationship. The findings also show how lender competitiveness shifts with production costs, extending prior models by identifying when platforms or banks lead in financing. We further examine various model extensions, such as (i) the platform's premium private label, (ii) the manufacturer's initial working capital, (iii) the platform operating in reseller mode, and (iv) the private label's quality improvement.

From a managerial perspective, the results offer practical guidance to platforms, banks, and manufacturers. Platforms should view financing policies not just as a revenue source but as a strategic lever to influence manufacturer behaviour and to balance competitive pressures from PLs. Banks must adapt their lending policies to remain competitive, particularly when production costs are high and platforms use financing to gain an advantage. For manufacturers, the study highlights that platform financing can remain beneficial even in the presence of PL competition, depending on cost and quality conditions. Finally, the finding that platforms may refrain from launching a PL under certain conditions underscores the value of cooperative strategies, suggesting that aligning financing and product policies can generate mutually beneficial outcomes.

The remainder of the paper is arranged as follows. In Section 2, we review the existing literature. In Section 3, we discuss the model formulation, and in Section 4, we derive equilibrium outcomes under different lending modes. In Sections 5 and 6, we present the main insights and key takeaways of this study. In Section 7, we present model extensions. Lastly, we offer important managerial insights and closing thoughts in Section 8. In the Appendix below, we provide proof of the main analytical results.

2. Literature review

2.1. Private labels

This stream of literature investigates a retailer's private label (or store brand) introduction decision and its implications on the upstream national brand manufacturer. The introduction of private label reduces the adverse effect of 'double marginalisation' and surprisingly, it can benefit the manufacturer (Ru, Shi, and Zhang 2015). Existing literature on private label studies private label management in different contexts, including wholesale price commitment (Groznik and Heese 2010), contract design (Cao et al. 2023), dual channel (Chai et al. 2021; Wang, Chen, and Song 2021), price leadership (Liao, Yano, and Trivedi 2020), quality differentiation (Li, Cai, and Chen 2022), etc. Liao, Yano, and Trivedi (2020) examine a seller's choice of private label quality in light of various price leadership and procurement strategies. Zheng, Jang, and Pan (2022) find that a retailer may carry an unpopular private label with negligible sales to intensify upstream competition between manufacturers. Li, Cai, and Chen (2022) reveal that the only private label product that increases overall supply chain profit and customer surplus is a premium one. Chakraborty, Chauhan, and Huang (2022) focus on the quality management of the private label and national brand manufacturers and find that, unlike the conventional notion, the PL's quality level can be more than that of ML. Extending the study to dual-channel decisions, Wang, Chen, and Song (2021) show that the manufacturer should go for direct selling of the ML product under low online shopping hassle cost and high transportation cost if his retailer introduces PL. Approaching from a new direction, Liu, Wang, and Xiao (2025) develop the manufacturer's follow-on product introduction strategy in the presence of his customer (i.e. the platform) for different product categories. Using the hotelling model, Chai et al. (2021) advocate that the brick-and-mortar retailers should introduce PL (even premium ones) to counter the showrooming in the presence of ML product mismatch. Recent research has examined the decision of online retailers like Amazon and Alibaba to introduce private labels in light of the growth of e-commerce (Li et al. 2023; Zhang and Hou 2022). Zhang and Hou (2022) show that, for a manufacturer, agency selling works best when the platform offers a private label and charges a modest referral fee. Li et al. (2023) examine an e-commerce platform's private label procurement options and find that it offers the highest service level and charges the highest possible agency costs when buying from an upstream manufacturer providing a national brand. Our paper differs from prior work in several key ways. We study how a capital-constrained manufacturer strategically selects financing options while accounting for the platform's private label. We also analyze how the manufacturer's financial constraints and operational risk influence the platform's decision to launch a private brand.

2.2. Supply chain finance

The work in this area covers recent developments around financing choices of supply chain agents. For an excellent review on supply chain finance, readers are referred to Li, He, and Wang (2022). Multiple studies have examined the financial implications of operational decisions (Liu, Li, and Jiang 2023; Qin et al. 2025; Shang, Bai, and Sun 2024; Zhao and Huchzermeier 2015). Prior research has extensively analysed a cash-constrained firm's financing alternatives; see, for example, bank financing (BF) (Buzacott and Zhang 2004; Jing, Chen, and Cai 2012), buyer financing (Deng et al. 2018; Gupta and Chen 2020; Kouvelis and Xu 2021; Tang, Yang, and Wu 2018; Tunca and Zhu 2018), and trade credit financing (Du, Yan, and Qin 2023; Wu, Muthuraman, and Seshadri 2019), etc. Deng et al. (2018) show that the manufacturer may prefer buyer financing to bank financing. Kouvelis and Xu (2021) examine how factoring and reverse factoring affect supply chain effectiveness when BF is present. In a recent study, Du, Yan, and Qin (2023) find that, under co-opetition, the retailer could prefer bank financing when sales costs are low, but the manufacturer prefers trade credit. Shang, Bai, and Sun (2024) investigated the asset financing role of carbon emission quota and demonstrated that a manufacturer should consider bank carbon financing if the carbon trade price is fixed. Ma et al. (2025) suggest that a platform can not use green equity financing as a tool to prevent the seller's encroachment. On the other hand, it may help the seller in taking a competitive stance in this co-opetitive setup. Qin et al. (2025) show how blockchain can help banks in devising smart contracts to link interest rates to the emission reduction performance of a capital-constrained manufacturer.

As platform financing (PF) becomes increasingly popular among online retailers, researchers have started to explore the impact of PF on channel members' operational and financing decisions. Existing research on PF compares it with traditional bank financing (Gong et al. 2020; Wang, Fan, and Yin 2019; Yan et al. 2020), or buyer financing (Zhen et al. 2020). One of the early papers on PF is Wang, Fan, and Yin (2019), which concludes that a retailer prefers PF under high initial working capital, and PF can provide supply chain coordination. Gong et al. (2020) derive the benefits of PF and Yan et al. (2020) show that PF benefits all supply chain players, even when the supplier has an offline channel. In contrast, Zhen et al. (2020) report that the manufacturer benefits from retailer financing[1] compared to PF under high channel competition and when the manufacturing cost is low. Rath et al. (2021) demonstrate that with operational risk and high cost of goodwill, the manufacturer chooses BF over PF. Some recent articles have explored the impact of PF with different channel contracts (Chang et al. 2022) and order fulfillment schemes (Liu, Yang, and Yu 2021). Bi, Liu, and Wang (2024) jointly analyze the online platform's financing and advertising service strategy for the capital-constrained seller and demonstrate how they interact with each other and can lead to a beneficial situation for both. Liu, Lu, and Yan (2024) compare the efficacy of the agency selling and reselling modes in the presence of platform financing. Similarly, Xu et al. (2024) develop an optimal platform financing strategy when the retailer is going for different green production systems. Lu et al. (2024) conduct the analysis of a platform's joint digital empowerment and financial empowerment strategy for a small farmer selling agricultural products online.

There is not much research on how supply-side risk affects financing strategies like PF. In these financing schemes, the lender (buyer or platform) shares the downside risk associated with order fulfillment. Tunca and Zhu (2018) argue that by using indirect finance methods, the risks in a supply chain may be controlled and overall channel profit can be increased. Tang, Yang, and Wu (2018) compare the buyer direct financing (BDF) strategy to the purchase order financing (POF) strategy. They show that if the supplier's fixed asset level is high enough and the manufacturer has better insight into the performance risk of the upstream supplier, the manufacturer will choose POF over BDF. We contribute to the literature by examining manufacturers' financing choices within the broader framework of platform lending and private-label strategies. Prior work on private labels has examined a retailer's (Li, Cai, and Chen 2022; Ru, Shi, and Zhang 2015) or a platform's (Li et al. 2023; Zhang and Hou 2022) PL introduction decision under various business scenarios. We extend this research by analyzing the platform's private label decision when the manufacturer is cash-constrained and how the manufacturer's operational risk influences both financing and PL adoption. Our study thus explores a coopetitive relationship where the platform acts as both lender and competitor.

3. Model

We examine an e-commerce supply chain consisting of a small and medium-sized enterprise (SME) manufacturer (referred to as 'he'), an intermediary e-tailing platform (referred to as 'she'), and a bank (referred to as 'it'). The manufacturer (e.g. Lonolife or Power Practical) produces and sells his products (manufacturer's label/brand or ML) on the e-tailing platform (e.g. Amazon or JD.com). The manufacturer faces a lack of working capital and obtains the required capital from either the bank or the platform. Further, the platform may also introduce her private label (PL) product (e.g. Amazon Basics) and sell it in the end market. In that case, the PL competes with the manufacturer's brand. For the rest of the study, we use the subscripts 'm', 'e', and 'b' to denote the manufacturer, the intermediary platform, and the bank, respectively.

3.1. Lending configurations

Based on the manufacturer's financing strategy and the platform's PL introduction decision, we have four potential lending configurations. When the platform chooses to introduce the PL, we have two lending configurations: (i) **BS**: in this case, the manufacturer chooses bank financing and competes directly with the platform's private label, (ii) **PS**: in this case, the manufacturer opts for platform financing even though the platform has a competing PL product. Similarly, we also consider two benchmark configurations in which the platform does not introduce the PL, and the manufacturer chooses either the bank financing (BN) or the platform financing strategy (PN). Let index j stand for lending configuration $j \in \{BS, PS, BN, PN\}$.

The bank, in our model, works in a perfectly competitive market and sets the interest rate at which its expected profit is zero (Mandal et al. 2024; Rath et al. 2021). For the rest of our analysis, we use the superscripts BS, PS, BN, and PN to represent the manufacturer's lending configurations, indicating selling quantities, market prices, interest rates, firm profits, and equilibrium outcomes. Figure 1 highlights how the bank, the manufacturer, the internet platform, and the customers interact strategically.

3.2. Manufacturer

We assume that the SME manufacturer produces a single product (i.e. the ML) by incurring a unit production cost c ($c > 0$). For each configuration $j \in \{BS, PS\}$, he produces q_m^j and sells those quantities to end customers at a unit price p_m^j. The manufacturer, as previously indicated, is cash-constrained and requires a loan to provide the necessary working capital. cq_m^j. First, we assume

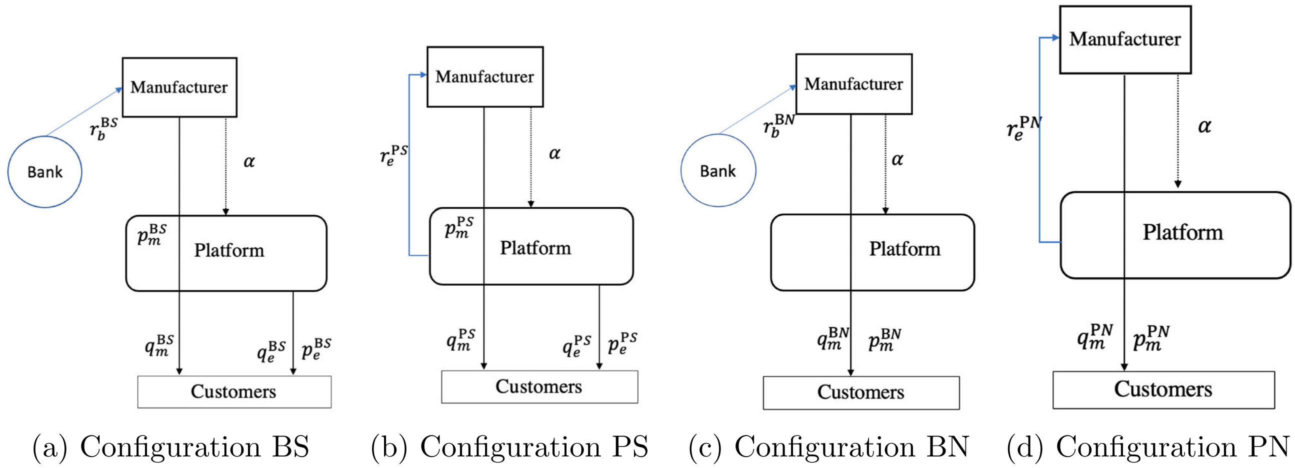


Figure 1. Lending configurations.

that the manufacturer has no working capital (Mandal et al. 2024). In Section 7.2, we relax this assumption and explore the scenario where the manufacturer has some initial working capital, which is denoted by w ($w > 0$), and analyze its impact on the manufacturer's financing and the platform's PL introduction decisions. The manufacturer has two strategic financing choices: collateralised bank financing (BF) and non-collateralised platform financing (PF). We assume that the manufacturer is granted sufficient loans by either lender, allowing them to produce the required sales quantities q_m^j, $j \in \{\mathrm{BS}, \mathrm{PS}, \mathrm{BN}, \mathrm{PN}\}$ (Wang, Fan, and Yin 2019).

We also consider the presence of operational risk for the manufacturer, which could potentially result in his inability to fulfill customer orders. The origin of operational risk can encompass technological, logistics and processing risks, all of which can lead to product delivery failure (Dhingra and Krishnan 2021; Markou and Corsten 2021). Let λ be the probability with which the manufacturer fails to fulfill customer demand, and as a result, he receives no income and is unable to pay back the debt. In this case, typically, the manufacturer files for bankruptcy (Chang et al. 2022; Wang, Fan, and Yin 2019). Conversely, with probability $1 - \lambda$ the manufacturer delivers the product successfully and is able to repay the loan amount. Additionally, we assume that the risk-free rate is zero and that the duration of the credit period is equal to the duration of the selling season (Kouvelis and Zhao 2018).

3.3. Bank

Before the selling season begins, the manufacturer obtains a collateralised loan from the bank. Let r_b^{BS} ($r_b^{\mathrm{BS}} \geq 0$) be the loan interest rate that the bank charges to the manufacturer. At the end of the selling season, with probability $1 - \lambda$, the manufacturer pays back the repayment amount $cq_m^{\mathrm{BS}}(1 + r_b^{\mathrm{BS}})$. If the manufacturer defaults on the loan, the bank liquidates the manufacturer's fixed assets, such as plants and equipment that were used as collateral (Mandal et al. 2024). Let β ($0 < \beta < 1$) be the fraction of the loan amount that the bank keeps as collateral. Thus, the bank can only recover βcq_m^{BS} amount from the manufacturer if he fails to repay the bank's loan amount.

3.4. Platform

In our supply chain settings, the platform plays distinct roles and generates her revenue from multiple sources. First, it serves as an online marketplace where the manufacturer sells his products directly to end customers. In Section 7.3, we relax this assumption and consider a scenario in which the platform operates as a reseller. Once orders are fulfilled successfully, the manufacturer pays the platform a referral fee/commission rate (represented as α) for each unit of product sold through her. Following existing business practice, we assume that α ($0 < \alpha < 1$) is an exogenous parameter that represents a fixed percentage of the manufacturer's revenue (Wang, Fan, and Yin 2019; Yan et al. 2020). Secondly, under PF, the platform provides non-collateralised loans to the manufacturer (Chang et al. 2022; Wang, Fan, and Yin 2019). Let r_e^{PS} ($r_e^{\mathrm{PS}} \geq 0$) represent the loan interest rate that the platform charges to the manufacturer. At the end of the selling season, with probability $1 - \lambda$, the manufacturer pays back the repayment amount $cq_m^{\mathrm{PS}}(1 + r_e^{\mathrm{PS}})$. Since PF is an unsecured loan, there is a probability of λ that the manufacturer will default on the loan, resulting in the platform earning zero profit. Moreover, there is a unit goodwill cost of $k > 0$ incurred by the platform as a result of non-fulfillment of customer orders (Cho et al. 2019).

So, for each configuration $j \in \{\text{BS}, \text{PS}, \text{BN}, \text{PN}\}$, the platform bears a total goodwill cost of kq_m^j. Third, when the platform sells her own PL on the marketplace, it directly competes with the manufacturer's product. For each configuration, $j \in \{\text{BS}, \text{PS}\}$, the platform sells q_e^j units in the downstream market at a unit price of p_e^j. Let δc, where $0 < \delta < 1$, be the unit production cost of the PL. This implies that the unit production cost of ML is higher than that of the PL (Liao, Yano, and Trivedi 2020; L. Wang, Chen, and Song 2021). Alternatively, δ can also be interpreted as the effect of the cost-effectiveness of PL relative to ML (Karray and Martín-Herrán 2019). We also analyze the case in which $\delta > 1$ (Zhang et al. 2025; Zheng, Jang, and Pan 2022). For more details, the readers are referred to Appendix A5 (see Online Supplement).

3.5. Customers' purchase decisions and demand functions

The downstream market comprises a continuum of customers with a unit mass. Customers are heterogeneous in their willingness to pay (or valuation) for one unit of quality, represented by θ. In line with existing literature on private labels, we assume that θ follows a uniform distribution between 0 and 1 (Groznik and Heese 2010; Li et al. 2023). The firms (the manufacturer and the platform) do not know the specific value of θ for any given customer, but they are familiar with the distribution of θ. It is assumed that each customer purchases only one unit of either product. In a configuration $j \in \{\text{BS}, \text{PS}, \text{BN}, \text{PN}\}$, a customer with a valuation θ obtains utility $\mathcal{U}_i^j(\theta) = \theta s_i - p_i^j$ by purchasing one unit of product from firm $i \in \{m, e\}$. If the customer buys nothing, it gets utility as zero. Without loss of generality, the quality of ML, s_m is normalised to 1. Let the quality of PL, $s_e = \gamma$. Alternatively, γ can be interpreted as the perceived quality of the PL in comparison to that of the ML. In addition, we assume that $0 < \gamma < 1$ to ensure that all customers prefer ML over PL when both brands are available at the same market price (Ru, Shi, and Zhang 2015; Zheng, Jang, and Pan 2022). However, in Section 7.1, we relax this assumption and analyze a scenario in which the perceived quality of the PL is higher than that of the ML, i.e. $\gamma > 1$.

A customer purchases the product that provides the highest nonnegative utility. In the absence of the PL (i.e. for the benchmark configurations: BN and PN), a customer with valuation θ purchases the ML if $\mathcal{U}_m^j(\theta) = \theta - p_m^j \geq 0$, i.e. $\theta \geq p_m^j$, $j \in \{\text{BN}, \text{PN}\}$. Therefore, in benchmark configurations, the inverse demand function for ML, $p_m^j(q_m^j) = 1 - q_m^j$, $j \in \{\text{BN}, \text{PN}\}$. In contrast, in the presence of PL, a customer with valuation θ purchases ML if $\mathcal{U}_m^j(\theta) \geq \max\{\mathcal{U}_e^j(\theta), 0\}$, i.e. $\theta - p_m^j \geq \max\{\theta\gamma - p_e^j, 0\}$, $j \in \{\text{BS}, \text{PS}\}$. Similarly, the same customer purchases the PL if $\theta\gamma - p_e^j \geq \max\{\theta - p_m^j, 0\}$. With simple algebraic manipulations, we can arrive at the following inverse demand functions for ML and PL: $p_m^j(q_m^j, q_e^j) = 1 - q_m^j - \gamma q_e^j$ and $p_e^j(q_m^j, q_e^j) = \gamma(1 - q_m^j - q_e^j)$, $j \in \{\text{BS}, \text{PS}\}$.

Table 2. Key model parameters and variables.

	Description
Lending configurations	
BS (PS) :	Scenario in which the manufacturer chooses bank financing (platform financing) and the platform has a competing PL
BN (PN) :	Scenario in which the manufacturer chooses bank financing (platform financing) and the platform does not introduce the PL
Subscripts and superscripts	
j:	Superscript used to denote the lending configurations $j \in \{\text{BS}, \text{PS}, \text{BN}, \text{PN}\}$
i:	Subscript used to denote player $i \in \{m, e\}$, m for the manufacturer, and e for the platform
l:	Subscript used to denote lender $l \in \{b, e\}$, b for the bank and e for the online platform
Parameters for base model	
α :	Referral fee rate/commission rate charged by the platform, $0 < \alpha < 1$
γ :	Perceived quality of the PL relative to that of the ML, $\gamma > 0$
λ :	Probability with which the manufacturer fails to fulfill customer demand (operational risk), $0 < \lambda < 1$
k :	Unit cost of goodwill loss for the platform in case the manufacturer is unable to repay the loan, $k > 0$
β :	Unit collateral value of the manufacturer's asset expressed as a percentage of the total loan, $0 < \beta < 1$
c_i :	Unit production cost to from player i, $c_i > 0$; where $c_i = c$ if $i = m$ and $c_i = \delta c$ if $i = e$, $\delta > 0$
w :	Initial working capital of the manufacturer
Decision variables	
q_i^j:	Selling quantities for player i under lending configuration j
p_i^j:	Product price for player i under lending configuration j
r_l^j:	Interest rate charged by the lender l under lending configuration j
Profit functions	
Π_j^i:	Profit of player i under lending configuration j

3.6. Sequence of events

We investigate how the platform's private label influences the manufacturer's financing strategy. Figure 2 presents the sequence of events modelled in this study (with or without the private label). We provide a summary of key model parameters and variables in Table 2.

4. Model analysis

4.1. BS configuration

Under this lending framework, the bank takes the lead by establishing the interest rate (r_b^{BS}). Subsequently, the

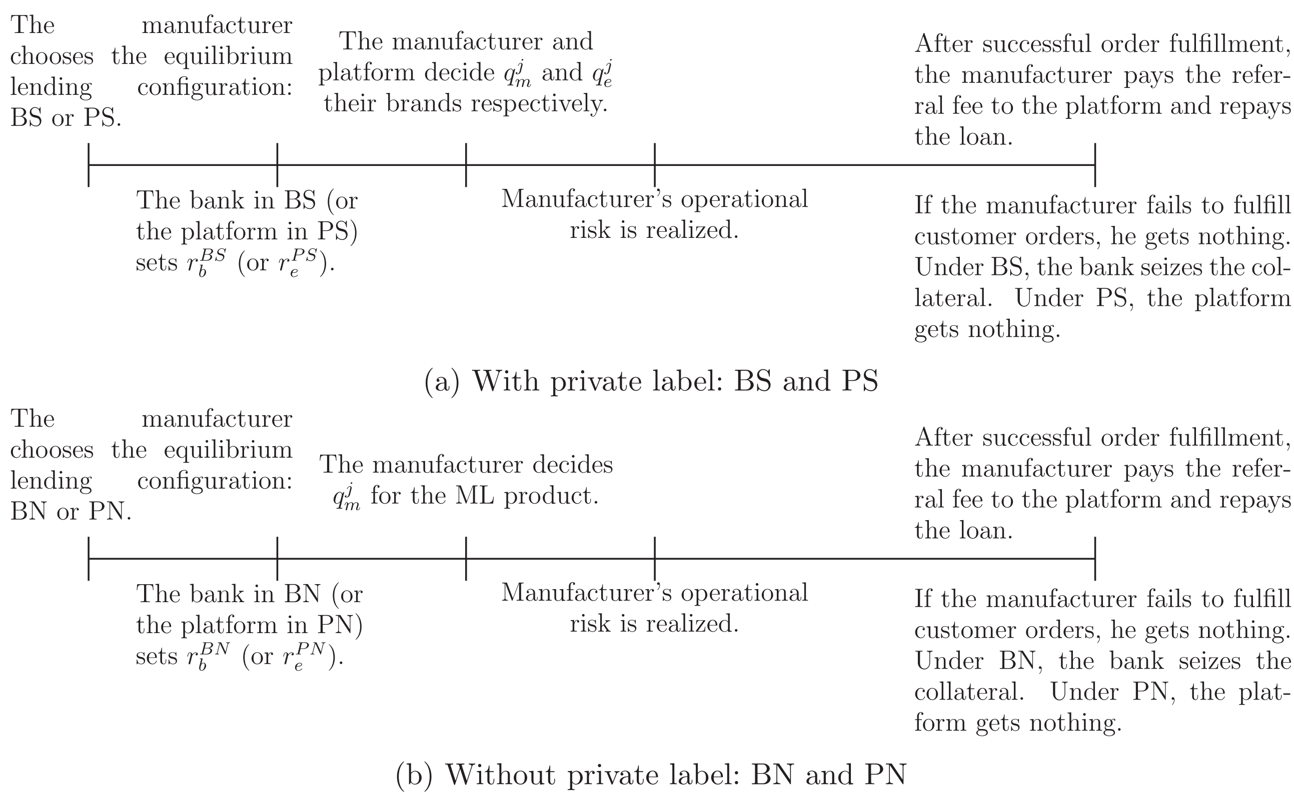


Figure 2. Timing of the games with or without the private label (PL).

manufacturer and the platform strategically and simultaneously determine their sales quantities, $q_i^{\text{BS}}, i \in \{m, e\}$. We use backward induction to solve this two-stage subgame. First, for a given bank interest rate, r_b^{BS}, we determine the optimal selling quantities $q_m^{\text{BS}^*}$ and $q_e^{\text{BS}^*}$ that maximise $\Pi_m^{\text{BS}}(q_m^{\text{BS}}, q_e^{\text{BS}}, r_b^{\text{BS}})$ and $\Pi_e^{\text{BS}}(q_m^{\text{BS}}, q_e^{\text{BS}}, r_b^{\text{BS}})$, respectively. The manufacturer and the platform are risk-neutral profit maximisers and solve the following optimisation problems.

$$\begin{aligned}
&\max_{q_m^{\text{BS}}}\{\Pi_m^{\text{BS}}(q_m^{\text{BS}}, q_e^{\text{BS}}, r_b^{\text{BS}}) = (1-\lambda)((1-\alpha)p_m^{\text{BS}} q_m^{\text{BS}} \\
&\quad - c q_m^{\text{BS}}(1 + r_b^{\text{BS}})) - \lambda\beta c q_m^{\text{BS}}\},\\
&\max_{q_e^{\text{BS}}}\{\Pi_e^{\text{BS}}(q_m^{\text{BS}}, q_e^{\text{BS}}, r_b^{\text{BS}}) = (1-\lambda)\alpha p_m^{\text{BS}} q_m^{\text{BS}} \\
&\quad + (p_e^{\text{BS}} - \delta c) q_e^{\text{BS}} - \lambda k q_m^{\text{BS}}\}.
\end{aligned}$$

Then, we substitute $q_m^{BS^*}$ and $q_e^{BS^*}$ in the bank's profit function, $\Pi_b^{BS}(q_m^{BS}, q_e^{BS}, r_l^{BS}))$. The bank sets the financing condition (i.e. the interest rate) based on the manufacturer's operational risk, which leads to loan default. The bank solves the following optimisation problem while determining its interest rate $r_b^{\text{BS}^*}$: $r_b^{\text{BS}^*} = \{r^{\text{BS}} | \Pi_b^{\text{BS}}(q_m^{\text{BS}}, q_e^{\text{BS}}, r_b^{\text{BS}}) = 0\}$, where $\Pi_b^{\text{BS}}(q_m^{\text{BS}}, q_e^{\text{BS}}, r_b^{\text{BS}}) = (1-\lambda) c q_m^{\text{BS}}(1 + r_b^{\text{BS}}) + \lambda\beta c q_m^{\text{BS}} - c q_m^{\text{BS}}$. The following lemma presents the equilibrium results in BS configuration.

Lemma 4.1: *For the BS configuration, there exists a unique equilibrium, and the equilibrium interest rate and sales quantities are given by:*

$$\begin{aligned}
r_e^{\text{BS}^*} &= \frac{(1-\beta)\lambda}{1-\lambda},\\
q_m^{\text{BS}^*} &= \frac{\begin{array}{c}(1-\alpha)(2-\gamma)(1-\lambda)\\ -c(2-\delta(1-\alpha)(1-\lambda))\end{array}}{(1-\alpha)(4-\gamma(1+\alpha(1-\lambda)))(1-\lambda)},\\
q_e^{\text{BS}^*} &= \frac{\begin{array}{c}\gamma(1-\alpha)(1-\alpha(1-\lambda))(1-\lambda)\\ +c\gamma(1+\alpha-\alpha\lambda) - 2c\delta(1-\alpha)(1-\lambda)\end{array}}{(1-\alpha)\gamma(4-\gamma(1+\alpha(1-\lambda)))(1-\lambda)}.
\end{aligned}$$

The corresponding profits of the manufacturer and the platform are expressed as follows:

$$\Pi_m^{\text{BS}^*} = \frac{\begin{array}{c}((1-\alpha)(2-\gamma)(1-\lambda)\\ -c(2-\delta(1-\alpha)(1-\lambda)))^2\end{array}}{(1-\alpha)(4-\gamma(1+\alpha(1-\lambda)))^2(1-\lambda)} \quad \text{and}$$

$$\Pi_e^{BS^*} = \frac{\begin{array}{c}((\gamma(c+(1-\alpha)(1+\alpha(1-\lambda))(1-\lambda)\\ -c\alpha(1-\delta(1-\alpha)(1-\lambda))(1-\lambda))\\ -\alpha\gamma^2(1-\alpha)(1-\lambda)^2-2c\delta(1-\alpha)(1-\lambda))\\ (\gamma(1-\alpha)(1-\alpha(1-\lambda))(1-\lambda)\\ +c\gamma(1+\alpha-\alpha\lambda)-2c\delta(1-\alpha)(1-\lambda)))\end{array}}{\gamma(1-\alpha)^2(4-\gamma(1+\alpha(1-\lambda)))^2(1-\lambda)^2} - \frac{\begin{array}{c}(\alpha(c(2-\gamma(1+\alpha(1-\lambda))\\ +\delta(1-\alpha)(1-\lambda))\\ +(1-\alpha)(2-\gamma)(1-\lambda))\\ ((1-\alpha)(2-\gamma)(1-\lambda)\\ -c(2-\delta(1-\alpha)(1-\lambda))))\end{array}}{(1-\alpha)^2(4-\gamma(1+\alpha(1-\lambda)))^2(1-\lambda)} + \frac{\begin{array}{c}k\lambda((1-\alpha)(2-\gamma)(1-\lambda)\\ -c(2-\delta(1-\alpha)(1-\lambda)))\end{array}}{(1-\alpha)(4-\gamma(1+\alpha(1-\lambda)))(1-\lambda)},$$

respectively.

4.2. PS configuration

Within this framework, the platform initiates the process by defining the lending rate, r_e^{PS}. Following that, both the manufacturer and the platform simultaneously decide their sales quantities q_m^{PS} and q_e^{PS}, respectively. Once again, we apply the backward induction method to solve this subgame. For a specific platform interest rate r_e^{PS}, we begin by solving the manufacturer's and the platform's profit maximisation problems to derive their respective sales quantities. q_m^{PS*} and q_e^{PS*}:

$$\max_{q_m^{PS}}\{\Pi_m^{PS}(q_m^{PS}, q_e^{PS}, r_e^{PS}) = (1-\lambda)((1-\alpha)p_m^{PS}q_m^{PS} - cq_m^{PS}(1+r_e^{PS}))\},$$

$$\max_{q_e^{PS}, r_e^{PS}}\{\Pi_e^{PS}(q_m^{PS}, q_e^{PS}, r_e^{PS}) = (1-\lambda)(\alpha p_m^{PS}q_m^{PS} + cq_m^{PS}(1+r_e^{PS})) + (p_e^{PS}-\delta c)q_e^{PS} - (c+\lambda k)q_m^{PS}\}.$$

At the final stage of the process, the platform optimises its profit, thereby influencing the resulting interest rate. $r_e^{PS^*}$. Lemma 4.2 describes the outcomes at the equilibrium condition for the PS lending configuration.

Lemma 4.2: *For the PS configuration, there exists a unique equilibrium, and the equilibrium interest rate and sales quantities are given by:*

$$r_e^{PS^*} = \frac{\begin{array}{c}(1-\alpha)(8-4\gamma+\gamma^2+\gamma\alpha^2(2-\gamma)(1-\lambda)^2-\lambda(4-\gamma)\\ (2-2k-\gamma)-\alpha(1-\lambda)(8-2\gamma-\gamma\lambda(2-2k-\gamma))\\ -c(8+4\alpha\delta(1-\alpha)-16\lambda+4\lambda(2\alpha+\delta(1-\alpha)^2)\\ -\gamma(1+\alpha(1-\lambda))(4-\delta(1-\alpha)^2(1-\lambda)-2\lambda(2-\alpha))))\end{array}}{2c(8-3\gamma-2\alpha(2+\gamma(1-\lambda))(1-\lambda)+\alpha^2\gamma(1-\lambda)^2-2\lambda(4-\gamma))},$$

$$q_m^{PS^*} = \frac{2-c(2-\delta(2-\lambda))-\gamma(2-\lambda)-2\lambda(1+k)}{8-3\gamma-2\alpha(2+\gamma(1-\lambda))(1-\lambda)+\alpha^2\gamma(1-\lambda)^2-2\lambda(4-\gamma)},$$

$$q_e^{PS^*} = \frac{\gamma(6+c(1+\alpha(1-\lambda))(2+\delta(1-\alpha)(1-\lambda))-2(3-k)\lambda-2\alpha(1-\lambda)(3-\lambda-k\lambda))}{2\gamma(8-3\gamma-2\alpha(2+\gamma(1-\lambda))(1-\lambda)+\alpha^2\gamma(1-\lambda)^2-2\lambda(4-\gamma))},$$
$$- \frac{4c\delta(2-\alpha)(1-\lambda)-\gamma^2(1-\alpha)(1+\alpha(1-\lambda))(1-\lambda)}{2\gamma(8-3\gamma-2\alpha(2+\gamma(1-\lambda))(1-\lambda)+\alpha^2\gamma(1-\lambda)^2-2\lambda(4-\gamma))}.$$

The corresponding profits of the manufacturer and the platform are expressed as follows:

$$\Pi_m^{PS^*} = \frac{(1-\alpha)(1-\lambda)(c(2-\delta(2-\lambda))+\gamma(2-\lambda)-2(1-\lambda-k\lambda))^2}{(8-3\gamma-2\alpha(2+\gamma(1-\lambda))(1-\lambda)+\alpha^2\gamma(1-\lambda)^2-2\lambda(4-\gamma))^2} \quad \text{and}$$

$$\Pi_e^{PS^*} = \frac{\begin{array}{c}4c^2\delta^2(2-\alpha)(1-\lambda)+\gamma^3(1-\alpha)^2(1-\lambda)^2-2\gamma^2(2\alpha-2c(2-\lambda)\\ +c\delta(1-\alpha)^2(1-\lambda)^2-2\alpha\lambda-2\lambda(1+k(2-\lambda)-\lambda))\\ +\gamma(c^2(4-4\delta(2-\lambda)+\delta^2(1-\alpha)^2(1-\lambda)^2)+4(1-\lambda-k\lambda)^2)\\ -4c\gamma(2(1-\lambda-k\lambda)+\delta(2-2\alpha(1-\lambda)-\lambda(1-k(2-\lambda)+\lambda)))\end{array}}{4\gamma(8-3\gamma-2\alpha(2+\gamma(1-\lambda))(1-\lambda)+\alpha^2\gamma(1-\lambda)^2-2\lambda(4-\gamma))}$$

4.3. BN configuration

Under BN, the bank first decides the interest rate (r_b^{BN}). Next, the manufacturer determines the selling quantity, q_m^{BN}. The profit functions for the manufacturer, platform, and bank are given by:

$$\Pi_m^{BS}(q_m^{BN}, r_b^{BN}) = (1-\lambda)((1-\alpha)p_m^{BN}(q_m^{BN})q_m^{BN} - cq_m^{BN}(1+r_b^{BN})) - \lambda\beta c q_m^{BN},$$

$$\Pi_e^{BN}(q_m^{BN}, r_b^{BN}) = (1-\lambda)\alpha p_m^{BN}(q_m^{BN})q_m^{BN} - \lambda k q_m^{BN},$$

$$\Pi_b^{BN}(q_m^{BN}, r_b^{BN}) = (1-\lambda)cq_m^{BN}(1+r_b^{BN}) + \lambda\beta c q_m^{BN} - cq_m^{BN}.$$

Lemma 4.3 describes the outcomes at the equilibrium condition for the BN lending configuration.

Lemma 4.3: *For the BN configuration, there exists a unique equilibrium, and the equilibrium interest rate and the manufacturer's sales quantity are given by:* $r_b^{BN^*} = \frac{(1-\beta)\lambda}{1-\lambda}$, $q_m^{BN^*} = \frac{1}{2} - \frac{c}{2(1-\alpha)(1-\lambda)}$. *The corresponding profits of the manufacturer and the platform are expressed as follows:* $\Pi_m^{BN^*} = \frac{(1-c-\alpha-\lambda+\alpha\lambda)^2}{4(1-\alpha)(1-\lambda)}$ *and* $\Pi_e^{BN^*} = \frac{(1-c-\alpha-\lambda+\alpha\lambda)((1+c-\alpha)\alpha-(1-\alpha)(2k+\alpha)\lambda)}{4(1-\alpha)^2(1-\lambda)}$.

4.4. PN configuration

In this setting, first, the platform determines the interest rate, r_e^{PN}, which maximises her profit function, Π_e^{PN}. Next, the manufacturer decides the selling quantity, q_m^{PN}, for which his profit is maximised. The profit functions for the manufacturer and the platform are given below:

$$\Pi_m^{PN}(q_m^{PN}, r_e^{PN}) = (1-\lambda)((1-\alpha)p_m^{PN}(q_m^{PN})q_m^{PN} - cq_m^{PN}(1+r_e^{PN})),$$

$$\Pi_e^{PN}(q_m^{PN}, r_e^{PN}) = (1-\lambda)(\alpha p_m^{PN}(q_m^{PN})q_m^{PN} + cq_m^{PN}(1+r_e^{PN})) - \lambda k q_m^{PN} - cq_m^{PN}.$$

Lemma 4.4 describes the outcomes at the equilibrium condition for the PN lending configuration.

Lemma 4.4: *For the PN configuration, there exists a unique equilibrium, and the equilibrium interest rate and the manufacturer's sales quantity are given by:* $r_e^{PN^*} = \frac{c(2-\alpha)\lambda+(1-\alpha)(1-\alpha-(1-k-\alpha)\lambda)-c}{c(2-\alpha)(1-\lambda)}$, $q_m^{PN^*} = \frac{1-c-\lambda-k\lambda}{2(2-\alpha)(1-\lambda)}$. *The corresponding profits of the manufacturer and the platform are expressed as follows:* $\Pi_m^{PN^*} = \frac{(1-\alpha)(1-c-\lambda-k\lambda)^2}{4(2-\alpha)^2(1-\lambda)}$ *and* $\Pi_e^{PN^*} = \frac{(1-c-\lambda-k\lambda)^2}{4(2-\alpha)(1-\lambda)}$.

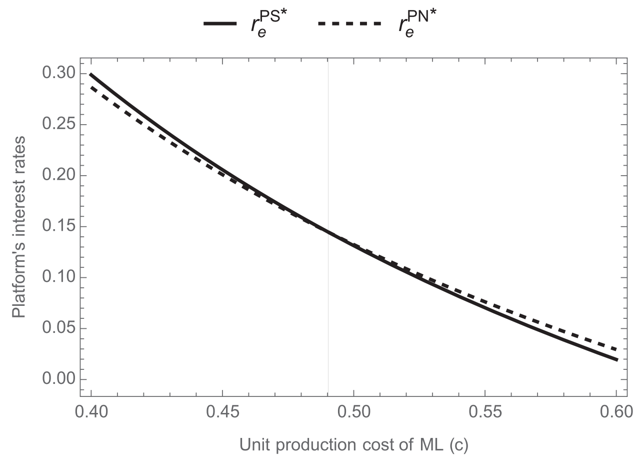


Figure 3. Comparison of platform interest rates under PS and PN. Parametric values: $\lambda = 0.2, \delta = 0.7, \alpha = 0.3, k = 0.2$.

5. Results

In this section, we compare the lenders' interest rates, firms' selling quantities, and firms' profits under bank and platform financing (with or without PL). For our analyses, we only consider the feasible region for which the interest rates, selling quantities, market prices, and firm profits are non-negative. Throughout our analyses, we have extensively explored a wide range of parameter values (i.e. varying $\lambda, \delta, \alpha, \beta, k, c$ and γ). For example, in Figure 3, we have used the following parametric values for demonstration purposes: $\lambda = 0.2, \delta = 0.7, \alpha = 0.3, \beta = 0.2, k = 0.2, c,$ and $\gamma \in \{0.3, 0.5\}$. The referral fee rate (α) for Amazon.com ranges from 2% to 45%.[2] Hence, we consider the referral fee (α) to be 0.3, which has also been used in Huang (2022). Similarly, around 20% of all e-commerce shipments and 30% of cash-on-delivery shipments face delivery issues and return to origin. Hence, we consider the fulfillment risk to be 0.2. Private label reports indicate that the manufacturing cost of PL varies between 50%[3] and 85%[4] of the ML product's manufacturing cost. Hence, we consider that the unit production cost of PL is 70% of ML's production cost. Further, all the parametric values also have support from the existing literature (see Lu et al. 2024; Mandal et al. 2024; Rath et al. 2021; Wang, Fan, and Yin 2019; Zhen et al. 2020 for further details). The Appendix below contains all of the proofs for this section.

5.1. Bank and platform interest rates

Given the manufacturer's financing choice, we first compare the lender's interest rate. Without the PL, the platform's only sources of income are referral fees and the manufacturer's loan repayment when the manufacturer opts for platform financing. By selling the PL, she secures an additional source of revenue. Intuitively, under the PS configuration, the platform should consider offering the manufacturer a higher interest rate than in the PN configuration. This would compel the manufacturer to lower ML sales quantities, thereby enhancing the sales of PL. In contrast, our findings indicate that the platform could charge a reduced interest rate with the PL compared to the scenario without the PL. We present this result in Proposition 5.1.

Proposition 5.1: ***(Impact of private label on the lender's interest rate):***

(a) *When the manufacturer chooses platform financing, then* $r_e^{\mathrm{PN}^*} \geq r_e^{\mathrm{PS}^*}$ *if* $c \geq c_{rP}^{SN}$. *Otherwise, if* $c < c_{rP}^{SN}$, *then* $r_e^{\mathrm{PN}^*} < r_e^{\mathrm{PS}^*}$.
(b) *When the manufacturer chooses bank financing, then* $r_b^{\mathrm{BS}^*} = r_b^{\mathrm{BN}^*}$.

Contrary to conventional wisdom, Proposition 5.1(a) shows that the interest rate is not always raised by the platform while launching her PL. Instead, in Figure 3, we observe that she reduces the interest rate upon introduction of the PL if the unit ML production cost, c, is high. This can be explained as follows. Without the PL, the platform generates revenue through two sources: (a) referral fees and (b) the total interest earned on the amount borrowed by the manufacturer. When the platform launches the PL, she secures an additional revenue stream by selling its own brand. Under low unit production cost, c, the platform lowers the interest rate in the absence of the PL, allowing the manufacturer to increase ML production. In contrast, in the presence of PL, the platform aims to promote her own brand and may, therefore, increase the interest rate charged to the manufacturer. Consequently, the platform earns higher profits from selling the PL, leading to an increased interest rate in the presence of the PL. (i.e. $r_e^{\mathrm{PN}^*} \geq r_e^{\mathrm{PS}^*}$). However, when the unit production cost, c, is high, the platform does not generate sufficient profits from selling the PLs due to the increased PL costs. Thus, the presence of the PL may incentivize the platform to reduce her interest rate. This is because the platform also benefits from the interest paid by the manufacturer on the borrowed amount. Consequently, the platform may lower its interest rate, encouraging the manufacturer to increase production. Thus, the platform lowers her interest rate when PL is present (i.e. $r_e^{\mathrm{PN}^*} < r_e^{\mathrm{PS}^*}$) and the unit ML production cost is high.

In Proposition 5.1(b), we find that the introduction of the PL does not affect the bank's interest rate. It is important to note that the bank operates outside the e-commerce supply chain and functions within a perfectly competitive market, setting the interest rate such that its marginal revenue equals the marginal cost of lending. Consequently, the introduction of PL does not affect the bank interest rate. Thus, the interest rate set by the bank remains unchanged with the introduction of a private label. Next, in Proposition 5.2, we compare the interest rates offered by the bank and the platform under different lending configurations: BS, PS, BN, and PN.

Proposition 5.2 (Comparison of bank and platform interest rates): *Comparing the equilibrium bank and platform interest rates under different lending configurations, we obtain:*

(a) $r_b^{\mathrm{BN}^*} < r_e^{\mathrm{PN}^*}$ *and* $r_b^{\mathrm{BS}^*} < r_e^{\mathrm{PS}^*}$, *if* $c < \min\{c_{rN}^{BP}, c_{rS}^{BP}\}$.[5]
(b) $r_b^{\mathrm{BN}^*} \geq r_e^{\mathrm{PN}^*}$ *and* $r_b^{\mathrm{BS}^*} \geq r_e^{\mathrm{PS}^*}$, *if* $c \geq \max\{c_{rN}^{BP}, c_{rS}^{BP}\}$.
(c) $r_b^{\mathrm{BN}^*} < r_e^{\mathrm{PN}^*}$ *and* $r_b^{\mathrm{BS}^*} \geq r_e^{\mathrm{PS}^*}$, *if* $\gamma < \gamma_{rSN}^{BP}$[6] *and* $c_{rS}^{BP} \leq c < c_{rN}^{BP}$.
(d) $r_b^{\mathrm{BN}^*} \geq r_e^{\mathrm{PN}^*}$ *and* $r_b^{\mathrm{BS}^*} < r_e^{\mathrm{PS}^*}$, *if* $\gamma \geq \gamma_{rSN}^{BP}$ *and* $c_{rN}^{BP} \leq c < c_{rS}^{BP}$.

Proposition 5.2(a) demonstrates that when c is low (i.e. $c < \min\{c_{rN}^{BP}, c_{rS}^{BP}\}$), the bank sets a lower interest rate compared to the platform. Conversely, Proposition 5.2(b) indicates that a high c (i.e. $c \geq \max\{c_{rN}^{BP}, c_{rS}^{BP}\}$) leads the bank to impose a higher interest rate than that of the platform. The following is an explanation for these findings. When the cost of production c is low, the collateral requirement specified by the bank accounts for a considerable proportion of the overall value of the loan, given the loan amount itself is modest. This lowers the risk of default for the bank, allowing the manufacturer to secure the necessary funds at a reduced interest rate. In contrast, the platform provides unsecured loans to the manufacturer and bears the entire risk of potential nonpayment of the loan amount. Hence, the interest rate under the PF configuration remains higher than that under the BF. On the contrary, when ML production costs rise, the ML sales quantities decline. Under PF (in both scenarios, with and without PL), the platform earns revenue from various sources: referral fees and interest on the amount borrowed by the manufacturer. A decline in ML sales reduces the earnings from referral fees. To counteract this, the platform lowers the interest rate, thereby boosting the manufacturer's sales quantities. Despite a decrease in interest fee revenue, the platform compensates for this with a surge in referral fee revenue driven by increased ML sales. Consequently, the platform can generate a higher overall revenue by offering a lower interest rate to the manufacturer.

Furthermore, in Proposition 5.2(c,d), we present threshold policies by comparing the bank and platform

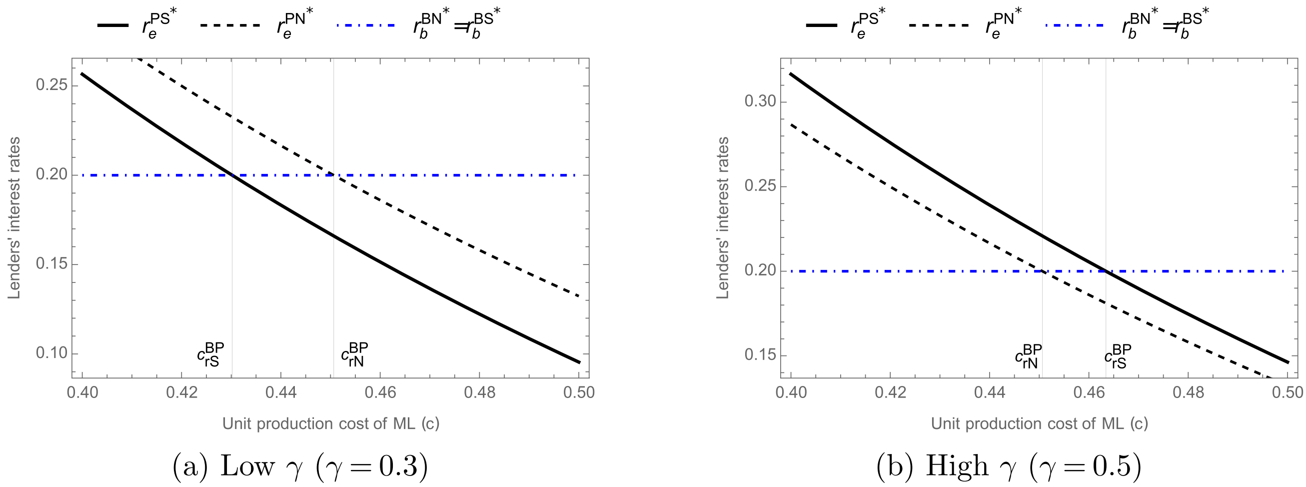


Figure 4. Comparison of bank and platform interest rates under different lending configurations. Parametric values: $\lambda = 0.2$, $\delta = 0.7$, $\alpha = 0.3$, $\beta = 0.2$, $k = 0.2$.

interest rates for intermediate values of ML unit production costs (i.e. $\max\{c_{rN}^{BP}, c_{rS}^{BP}\} \le c < \min\{c_{rN}^{BP}, c_{rS}^{BP}\}$). For intermediate values of the production cost and in the presence of the PL, when the perceived quality of PL (i.e. γ) is low (high), the interest rate charged by the platform is lower (higher) than that of the bank. Figure 4(a,b) illustrate the same phenomenon. As the perceived quality of the PL (γ) increases, the competition intensity of the PL also increases. When the value of γ is low, the profitability of the platform from PL sales decreases. As a result, she lowers her interest rate to offset the profit losses incurred from PL sales. On the contrary, when γ is high, there is an increase in the platform's revenue from PL sales. The platform increases its interest rate to promote PL sales.

Research on supply chain finance (SCF) suggests that, unlike traditional lenders such as banks, the platform may offer interest rates that can be either lower or higher. For instance, Chang et al. (2022) demonstrate that if the seller has a higher working capital, the platform offers a lower interest rate than the bank. Rath et al. (2021) indicate that the platform provides an interest rate that exceeds the bank's rate for lower production cost values. Otherwise, the interest rate charged by the bank is higher than that of the platform. In a market with an intermediary platform's PL, we find a similar insight. In a market configuration with a dual-channel manufacturer, Zhen et al. (2020) illustrate that the bank's interest rate may surpass the platform's interest rate when there is a high referral fee or fierce competition between online and offline channels. This study contributes to the existing literature by investigating the impact of the platform's private label (PL) on the interest rates set by both the bank and the platform. Although conventional thinking suggests that launching a PL would push the platform to impose higher rates than banks, our analysis demonstrates that the platform may instead reduce interest rates, even while maintaining its private label.

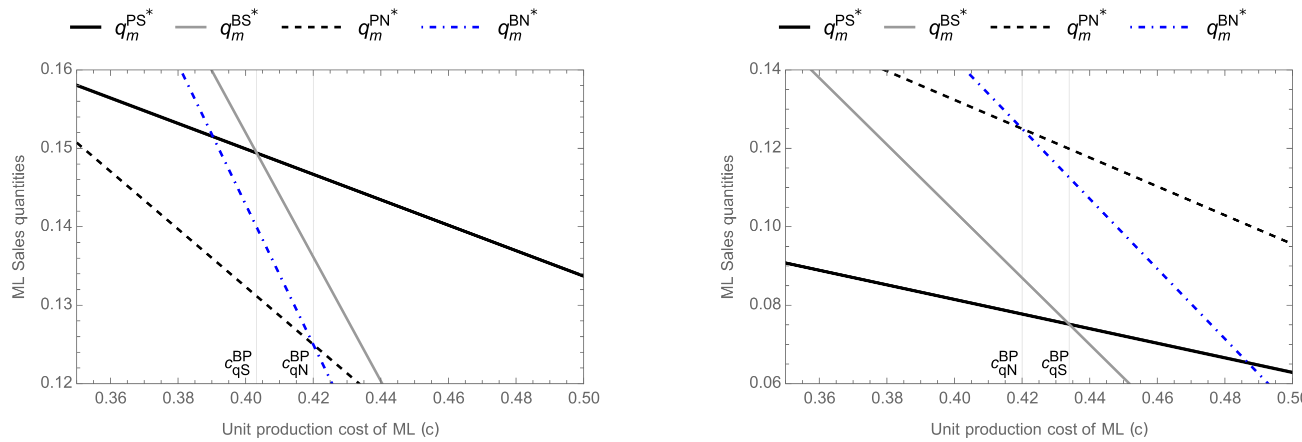
5.2. Sales quantities of the manufacturer

Next, we focus on comparing the manufacturer's sales quantities under different lending configurations: BS, PS, BN, and PN. In Proposition 5.3, examine how the introduction of the private label affects the manufacturer's sales quantities across various lending configurations.

Proposition 5.3 (Comparison of ML sales qunatitites): *Comparing the equilibrium ML sales quantities under different lending configurations, we obtain:*

(a) $q_m^{BN^*} > q_m^{PN^*}$ *and* $q_m^{BS^*} > q_m^{PS^*}$, *if* $c < \min\{c_{qN}^{BP}, c_{qS}^{BP}\}$.[7]
(b) $q_m^{BN^*} \le q_m^{PN^*}$ *and* $q_m^{BS^*} \le q_m^{PS^*}$, *if* $c \ge \max\{c_{qN}^{BP}, c_{qS}^{BP}\}$.
(c) $q_m^{BN^*} > q_m^{PN^*}$ *and* $q_m^{BS^*} \le q_m^{PS^*}$, *if* $\gamma < \gamma_{qSN}^{BP}$[8] *and* $c_{qS}^{BP} \le c < c_{qN}^{BP}$.
(d) $q_m^{BN^*} \le q_m^{PN^*}$ *and* $q_m^{BS^*} > q_m^{PS^*}$, *if* $\gamma \ge \gamma_{qSN}^{BP}$ *and* $c_{qN}^{BP} \le c < c_{qS}^{BP}$.

Proposition 5.3(a) states that when c is low (i.e. $c < \min\{c_{qN}^{BP}, c_{qS}^{BP}\}$), the manufacturer's sales quantities are always higher under the BN (BS) configuration than the PN (PS) configuration. Whereas Proposition 5.3(b) indicates that when the unit production cost is high (i.e. $c \ge \max\{c_{qN}^{BP}, c_{qS}^{BP}\}$), the manufacturer's sales quantities are greater with platform financing than with bank financing. This result is influenced by the fact that the bank's interest rate is lower (higher) than the platform's interest rate when c is low (high). As a result, the sales quantities for ML under the bank financing remain consistently higher (lower) than those under platform



(a) Low γ ($\gamma = 0.3$) (b) High γ ($\gamma = 0.5$)

Figure 5. Comparison of interest rates under different lending configurations. Parametric values: $\lambda = 0.2$, $\delta = 0.7$, $\alpha = 0.3$, $\beta = 0.2$, $k = 0.2$.

financing for low (high) production cost values, irrespective of the platform's decision to introduce a private label.

Next, in Proposition 5.3(c,d), we demonstrate threshold policies for ML quantities when c is moderate (i.e. $\max\{c_{qN}^{BP}, c_{qS}^{BP}\} \leq c < \min\{c_{qN}^{BP}, c_{qS}^{BP}\}$). For a moderate production cost and a perceived low (high) quality of PL, in the presence of PL, the manufacturer opts for higher (lower) ML sales quantities under the platform financing strategy compared to bank financing (see Figure 5(a,b)). As the quality of the PL increases, the competition intensity of the PL increases, leading more customers to choose the PL over the ML. Thus, for a moderate value of production cost and a low-quality (high-quality) PL, the bank charges a higher (lower) interest rate compared to the platform (see Proposition 5.2(c,d)). Hence, under low (high) perceived quality of the PL, the sales quantities for ML are greater (lower) under platform financing compared to bank financing.

Our findings are consistent with previous research, suggesting that the manufacturer's sales quantities (and, similarly, product prices) under platform financing can be lower/higher than those under bank financing (Rath et al. 2021; Yan et al. 2020; Zhen et al. 2020). We contribute to this stream of literature by investigating the impact of the platform's PL on ML sales quantities. The prevailing notion is that when the platform introduces a private label, the manufacturer should set lower sales quantities under platform financing compared to bank financing. On the contrary, the manufacturer may increase his sales quantities under platform financing in comparison to bank financing, even when the PL is present, while he would set larger sales quantities under bank financing in the absence of the PL.

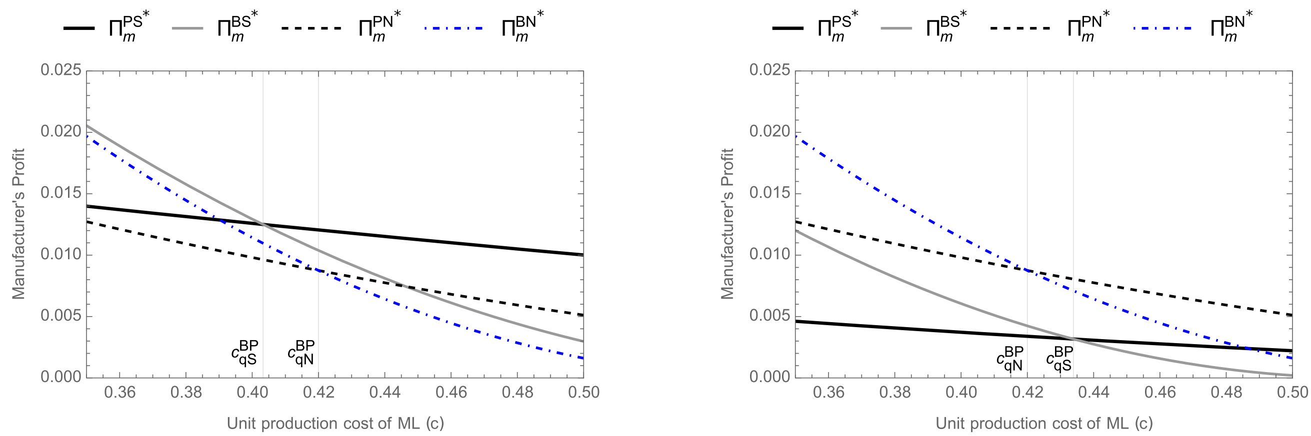
5.3. Manufacturer's profit and equilibrium financing choice

In this section, we examine how the presence of the platform's PL impacts the manufacturer's profits under various lending configurations. The prevailing wisdom is that upon the introduction of the PL, the manufacturer primarily benefits from bank financing. In contrast to this line of thinking, Proposition 5.4 demonstrates that the manufacturer may benefit from platform financing even with the presence of the private label (PL), whereas she would generally prefer bank financing without the PL.

Proposition 5.4: ***Comparison of manufacturer's profit:*** *Comparing the equilibrium manufacturer's profit under different lending configurations, we obtain:*

(a) $\Pi_m^{BN^*} > \Pi_m^{PN^*}$ *and* $\Pi_m^{BS^*} > \Pi_m^{PS^*}$, *if* $c < \min\{c_{qN}^{BP}, c_{qS}^{BP}\}$.
(b) $\Pi_m^{BN^*} \leq \Pi_m^{PN^*}$ *and* $\Pi_m^{BS^*} \leq \Pi_m^{PS^*}$, *if* $c \geq \max\{c_{qN}^{BP}, c_{qS}^{BP}\}$.
(c) $\Pi_m^{BN^*} > \Pi_m^{PN^*}$ *and* $\Pi_m^{BS^*} \leq \Pi_m^{PS^*}$, *if* $\gamma < \gamma_{qSN}^{BP}$ *and* $c_{qS}^{BP} \leq c < c_{qN}^{BP}$.
(d) $\Pi_m^{BN^*} \leq \Pi_m^{PN^*}$ *and* $\Pi_m^{BS*} > \Pi_m^{PS^*}$, *if* $\gamma \geq \gamma_{qSN}^{BP}$ *and* $c_{qN}^{BP} \leq c < c_{qS}^{BP}$.

Proposition 5.4(a) states that when c is low (i.e. $c < \min\{c_{qN}^{BP}, c_{qS}^{BP}\}$), the manufacturer attains higher profits with bank financing compared to platform financing. Whereas Proposition 5.4(b) states that for higher unit production costs (i.e. $c \geq \max c_{qN}^{BP}, c_{qS}^{BP}$), the manufacturer's profit is greater with platform financing than with



(a) Low γ ($\gamma = 0.3$) (b) High γ ($\gamma = 0.5$)

Figure 6. Comparison of the manufacturer's profit under different lending configurations. Parametric values: $\lambda = 0.2, \delta = 0.7, \alpha = 0.3, \beta = 0.2, k = 0.2$.

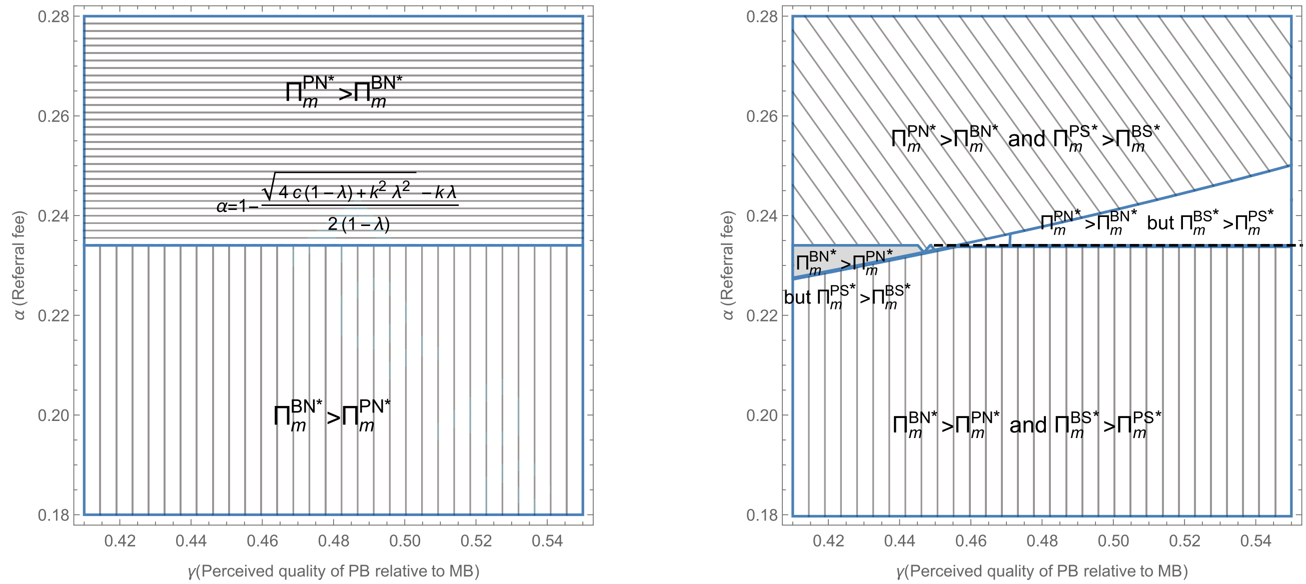
bank financing. This occurs because, when the unit production cost c is low, the manufacturer sets higher sales quantities (and consequently lower market prices) under the bank financing strategy than the platform financing. Nevertheless, the increase in ML sales quantities under bank financing is sufficient to compensate for the reduction in market prices, resulting in the manufacturer earning higher profits with the BN (BS) configuration than with the PN (PS) configuration. Thus, the manufacturer chooses bank financing (platform financing) when the unit production cost is low (high), regardless of the platform's decision to introduce the PL.

However, the findings above change considerably for moderate values of production costs (that is, $\max\{c_{qN}^{BP}, c_{qS}^{BP}\} \le c < \min\{c_{qN}^{BP}, c_{qS}^{BP}\}$). Conventional wisdom posits that if the platform introduces a private label, the manufacturer should, as a counterstrategy, opt for bank financing. Surprisingly, Proposition 5.4(c) demonstrates that the manufacturer does the opposite by switching to platform financing when the production cost values are moderate and the perceived quality of the PL is low (i.e. $\gamma < \gamma_{qSN}^{BP}$). With the introduction of the PL, the manufacturer gains greater profits from platform financing, while, in the absence of PL, the manufacturer would have earned greater profits through bank financing (see Figure 6(a)). This can be explained as follows: for intermediate levels of production costs and a low-quality private label, the interest rate offered by the platform is lower than the bank's interest rate (see Proposition 5.2(c)). Consequently, when the perceived quality of PL is low, the ML sales quantities are higher under platform financing than under bank financing.

In contrast, Proposition 5.4(d) states that when the production cost is at a moderate level and the perceived quality of PL is high, the PL introduction decision results in the manufacturer achieving a greater profit through bank financing compared to platform financing (see Figure 6(b)). To counteract the threat posed by the platform's PL, the manufacturer switches to bank financing following the introduction of the PL. When the perceived quality of the private label is high, the volumes of ML sales are greater with bank financing than with platform financing (see Proposition 5.3(d)). Hence, the manufacturer opts for the bank financing strategy in the presence of PL.

Another key parameter for e-commerce platforms is the referral fee (α), which denotes the commission rate that platforms, such as Amazon, JD.com, and Walmart, charge third-party manufacturers (Geng, Tan, and Wei 2018). Based on anecdotal data, the referral fee is observed to range from 8% – 45%. For example, Amazon.com charges a 17% referral fee for clothing and accessories, an 8% fee for consumer electronics, and a 15% fee for books and software from third-party sellers (Amazon 2024). Managers in small and medium enterprises are keen on understanding how they should devise their financing strategy corresponding to their specific product categories. Therefore, we pose the following question: *How does the referral fee impact the manufacturer's equilibrium financing strategy*? Nevertheless, due to computational intricacies, we numerically examine the effect of referral fee (α) and perceived quality of PL relative to ML (γ) on the manufacturer's strategic financing choice.

Figure 7(a)[9] shows that the manufacturer opts for bank financing when the referral fee is low and platform financing when the referral fee is high. It is worth noting that, under PN, the platform earns revenue from both the referral fee and the interest accrued on the loaned amount. On the other hand, in BN, the platform



(a) Without private label (b) With private label

Figure 7. Low δ: Manufacturer's financing choices based on the referral fee (α) and the relative quality of PL (γ). Parametric values: $c = 0.5$, $\beta = 0.2$, $\lambda = 0.2$, $\delta = 0.7$, $k = 0.2$. Please note that the grey-coloured area in (b) represents the region where $\Pi_m^{BN^*} > \Pi_m^{PN^*}$ but $\Pi_m^{BS^*} \leq \Pi_m^{PS^*}$.

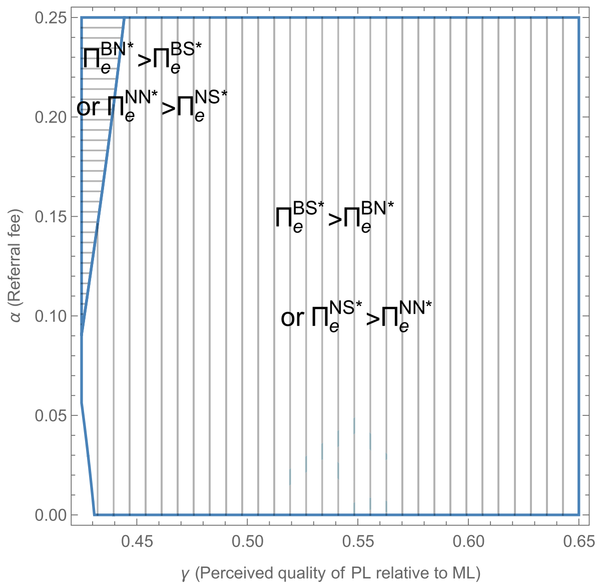
relies solely on referral fee revenue. For high referral fees, the platform reduces its interest rate, which stimulates greater ML demand and results in higher overall profits for the platform. In contrast, when referral fees are low, the platform increases the interest rate to optimise its profit from loan interest. Because bank financing provides a collateralised loan to the manufacturer, the bank's interest rate is lower than that of the platform. Therefore, for low (high) referral fees, the manufacturer's profit from bank financing is higher (lower) than that from platform financing.

Intuitively, the manufacturer should choose bank financing in response to the platform's PL introduction. Contrary to the conventional notion, we find that the manufacturer may still opt for platform financing despite the presence of the PL. Figure 7(b) illustrates that with the introduction of PL, the manufacturer achieves higher profits with platform financing for intermediate levels of referral fees and a low-quality private label. This occurs because the platform sets a reduced interest rate when the perceived quality of the PL is low (i.e. γ is low). As the platform achieves lower revenue from selling the PL (as γ is low), she reduces her interest rate to enhance greater demand for ML products and increase her profit. On the other hand, as the quality of the private label (γ) increases, its competition intensity also rises. To promote the PL, the platform raises her interest rate. In response to the decision to introduce the PL, the manufacturer switches to bank financing.

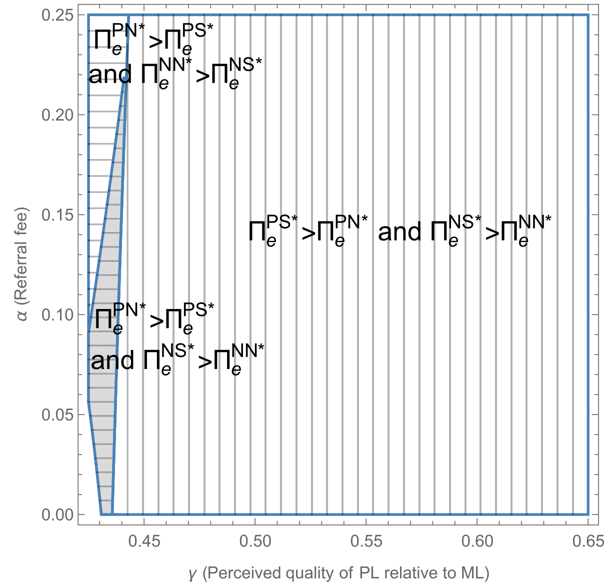
Previous literature has compared manufacturer profits under bank financing and platform financing and reports that the upstream manufacturer earns higher profits with platform financing when referral fees are high (Rath et al. 2021; C. Wang, Fan, and Yin 2019). In contrast, our study demonstrates that upon the introduction of PL, the manufacturer can secure a higher profit under platform financing than under bank financing; while in the absence of the private label, the manufacturer would have earned more with bank financing than with platform financing. Thus, the presence of PL may result in a competitive relationship between the manufacturer and the platform.

6. Impact of private label introduction

Existing literature on private labels examines the market conditions under which a downstream retailer (Li, Cai, and Chen 2022; Ru, Shi, and Zhang 2015) or platform (Li et al. 2023; Zhang and Hou 2022) introduces its own PL. In this study, we present the following question: *In case the upstream manufacturer is capital-constrained, under what market conditions would the platform decide to introduce her own private label?* The common intuition suggests that the platform should always introduce the PL while simultaneously extending working capital loans to the manufacturer. The rationale behind this is that the platform can generate revenue from both avenues: through the sale of PLs and the repayment of loans by



(a) No financing or Bank financing



(b) Platform financing

Figure 8. Platform's private label introduction decision based on the referral fee (α) and the relative quality of PL (γ). Parametric values: $c = 0.5$, $\beta = 0.2$, $\lambda = 0.2$, $\delta = 0.7$, $k = 0.2$. Please note that the grey-coloured area in (b) represents the region where $\Pi_e^{PN^*} > \Pi_e^{PS^*}$ but $\Pi_e^{NS^*} > \Pi_e^{NN^*}$.

the manufacturer. In contrast, our findings indicate that the platform refrains from introducing the PL when the perceived quality of PL, relative to ML, is significantly low.

From Figure 8(a), we obtain identical conditions for the platform's PL introduction decision under 'no financing' (in case the manufacturer is not capital-constrained) and bank financing scenarios. We can easily show that the manufacturer and platform generate identical profits under no financing[10] and bank financing scenarios. This is because the bank operates within a perfectly competitive market, establishing an interest rate at which its expected profit breaks even. In Figure 8(a), we observe that the platform does not always benefit from introducing the PL. In cases where the perceived quality of PL is significantly lower than that of the ML, she should refrain from introducing the PL. A low-quality PL leads to diminished revenue for the platform from PL sales. Furthermore, with the introduction of the PL, there is a decrease in ML sales due to the PL encroachment, resulting in a further reduction in the platform's profits derived from referral fees. Thus, her overall profit diminishes with the introduction of the PL when the perceived quality of the PL is low. This result is consistent with the prior literature on the private label (Ru, Shi, and Zhang 2015).

However, the platform's strategy of introducing the PL differs when the capital-constrained manufacturer chooses platform financing. In particular, in Figure 8(b), we observe a distinct grey region (indicated by low referral fees and a low-quality PL) where the platform opts not to introduce PL under the platform financing, while it would have been introduced under no financing or bank financing scenario. By offering loans, the platform guarantees income from loan repayments made by the manufacturer. Conversely, when the manufacturer chooses platform financing, she gains an additional revenue stream from PL sales. In the grey-shaded region (see Figure 8(b)), where the perceived quality of the PL is low, the revenue generated from PL sales is limited. Furthermore, to promote the PL, the platform raises her interest rate, leading to decreased ML sales and a decline in revenue from loan repayments and referral fees. The loss in profit due to the increased platform interest rate cannot offset the gains from PL sales, particularly when the quality of the PL is low. Conversely, without the PL, there is an increase in ML sales, resulting in higher revenues from loan repayments and referral fees. Hence, for low referral fees and a low-quality private label (PL), the platform adopts a cooperative strategy by choosing not to introduce the PL.

Previous literature has shown that a retailer introduces its own PL when the PL quality is high (Li, Cai, and Chen 2022; Ru, Shi, and Zhang 2015). Li et al. (2023) also find a similar market scenario in which a platform decides to introduce the PL. Compared to the studies mentioned above, we find that the insights from our study are consistent and robust. However, our research illustrates that when the capital-constrained manufacturer opts for platform financing, she can adopt a cooperative strategy by refraining from introducing the private label.

7. Model extensions

In this section, we explore several model extensions.

7.1. Premium private label

In the base case scenario, we assume that the perceived quality of the PL is lower than that of the ML. In this extension, we consider a scenario in which the platform's PL is a premium brand compared to the ML, i.e. $\gamma > 1$. For the benchmark configurations, the inverse demand functions for ML remain the same (i.e. $p_m^j(q_m^j) = 1 - q_m^j$, $j \in \{\text{BN}, \text{PN}\}$). Similar to Section 3.5, in the presence of PL, we derive the following inverse demand functions for ML and PL: $p_m^j(q_m^j, q_e^j) = 1 - q_m^j - q_e^j$ and $p_e^j(q_m^j, q_e^j) = \gamma - q_m^j - \gamma q_e^j$, $j \in \{\text{BS}, \text{PS}\}$.

Under BS configuration, the profit functions of the manufacturer and the platform are given by: $\Pi_m^{\text{BS}}(q_m^{\text{BS}}, q_e^{\text{BS}}, r_b^{\text{BS}}) = (1-\lambda)((1-\alpha)p_m^{\text{BS}}(q_m^{\text{BS}}, q_e^{\text{BS}})q_m^{\text{BS}} - cq_m^{\text{BS}}(1 + r_b^{\text{BS}})) - \lambda\beta cq_m^{\text{BS}}$, and $\Pi_e^{\text{BS}}(q_m^{\text{BS}}, q_e^{\text{BS}}, r_b^{\text{BS}}) = (1-\lambda)\alpha p_m^{\text{BS}}(q_m^{\text{BS}}, q_e^{\text{BS}})q_m^{\text{BS}} + (p_e^{\text{BS}}(q_m^{\text{BS}}, q_e^{\text{BS}}) - \delta c)q_e^{\text{BS}} - \lambda kq_m^{\text{BS}}$, respectively. The profit function of the bank is given by: $\Pi_b^{\text{BS}}(q_m^{\text{BS}}, q_e^{\text{BS}}, r_b^{\text{BS}}) = (1-\lambda)cq_m^{\text{BS}}(1 + r_b^{\text{BS}}) + \lambda\beta cq_m^{\text{BS}} - cq_m^{\text{BS}}$. Under PS configuration, the profit functions of the platform and the manufacturer are given by: $\Pi_e^{\text{PS}}(q_m^{\text{PS}}, q_e^{\text{PS}}, r_e^{\text{PS}}) = (1-\lambda)(\alpha p_m^{\text{PS}}(q_m^{\text{PS}}, q_e^{\text{PS}})q_m^{\text{PS}} + cq_m^{\text{PS}}(1 + r_e^{\text{PS}})) + (p_e^{\text{PS}}(q_m^{\text{PS}}, q_e^{\text{PS}}) - \delta c)q_e^{\text{PS}} - (c + \lambda k)q_m^{\text{PS}}$, and $\Pi_m^{\text{PS}}(q_m^{\text{PS}}, q_e^{\text{PS}}, r_e^{\text{PS}}) = (1-\lambda)((1-\alpha)p_m^{\text{PS}}(q_m^{\text{PS}}, q_e^{\text{PS}})q_m^{\text{PS}} - cq_m^{\text{PS}}(1 + r_e^{\text{PS}}))$, respectively. The resulting equilibrium expressions for BS and PS are available in Appendix A1 (see Online Supplement). We again observe that, in the presence of the PL, the manufacturer attains higher profits with bank financing than platform financing when $c < c_{qS1}^{BP}$ (see the Appendix below for the value of c_{qS1}^{BP}). Otherwise, the manufacturer prefers the platform financing. In Figure 9, we find that the manufacturer chooses the platform financing when the perceived quality of PL is not too high and referral fees are high. Further, Figure 9(b) reveals that with the introduction of PL, the manufacturer achieves higher profits with bank financing, thereby switching from platform financing (see Figure 9(a)) to bank financing for moderate levels of referral fees.

7.2. Impact of initial working capital

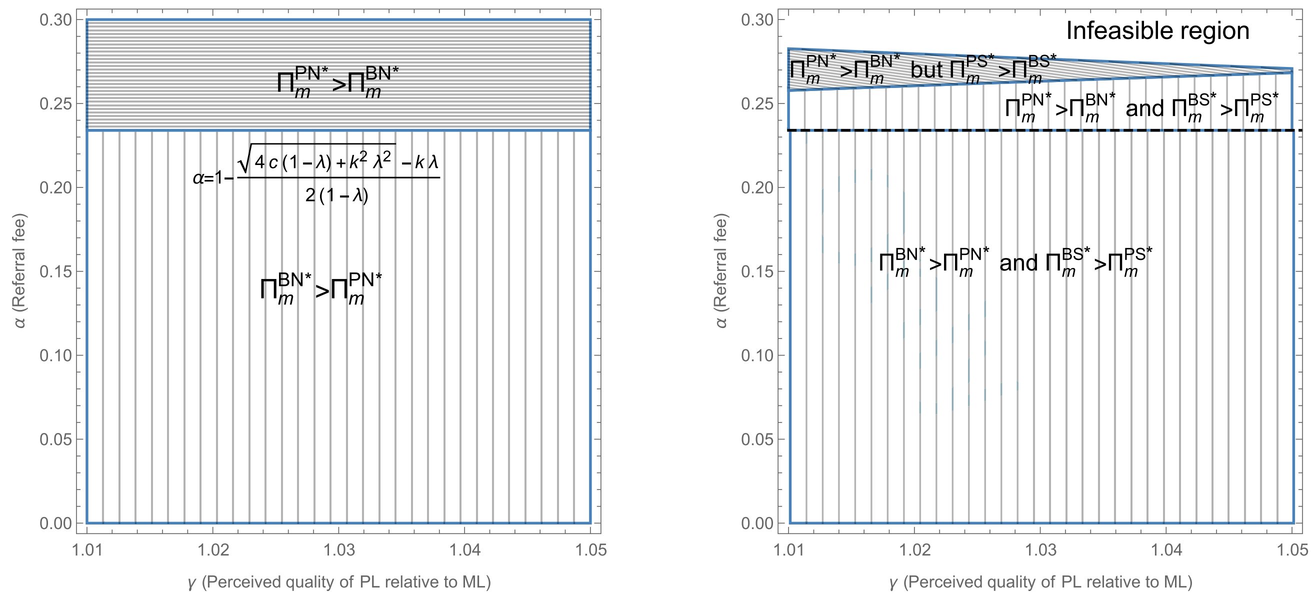
In this section, we assume that w $(w > 0)$ be the initial working capital of the manufacturer and he borrows the remaining amount, $(cq_m^j - w)$ from either the bank or the platform. We derive the equilibrium expressions under the lending configuration $j \in \{\text{BN}, \text{PN}, \text{BS}, \text{PS}\}$ in Appendix A2 (see Online Supplement). Due to the complexity of the equilibrium expressions, we numerically analyze the impact of the initial working capital on the manufacturer's financing choice.

From Figure 10(a,b), we find that as w increases, regardless of the presence of the PL, the manufacturer tends to switch from bank to platform financing. When w is low (i.e. $w < \min\{w_N^{BP}, w_S^{BP}\}$), the manufacturer opts for bank financing over platform financing. However, when w is high (i.e. $w \geq \max\{w_N^{BP}, w_S^{BP}\}$), the manufacturer chooses platform financing. With a high w, the manufacturer requires a smaller loan amount, thus reducing the risk of loss associated with potential manufacturer default. As w increases, the platform reduces her interest rate, incentivizing the manufacturer to opt for platform financing. We refer to this as the *wealth effect*. We find interesting results when the value of w is moderate ($\min\{w_N^{BP}, w_S^{BP}\} \leq w < \max\{w_N^{BP}, w_S^{BP}\}$). When w is moderate and γ is low, in the presence (absence) of the PL, the manufacturer opts for platform financing (bank financing).

7.3. Reseller mode

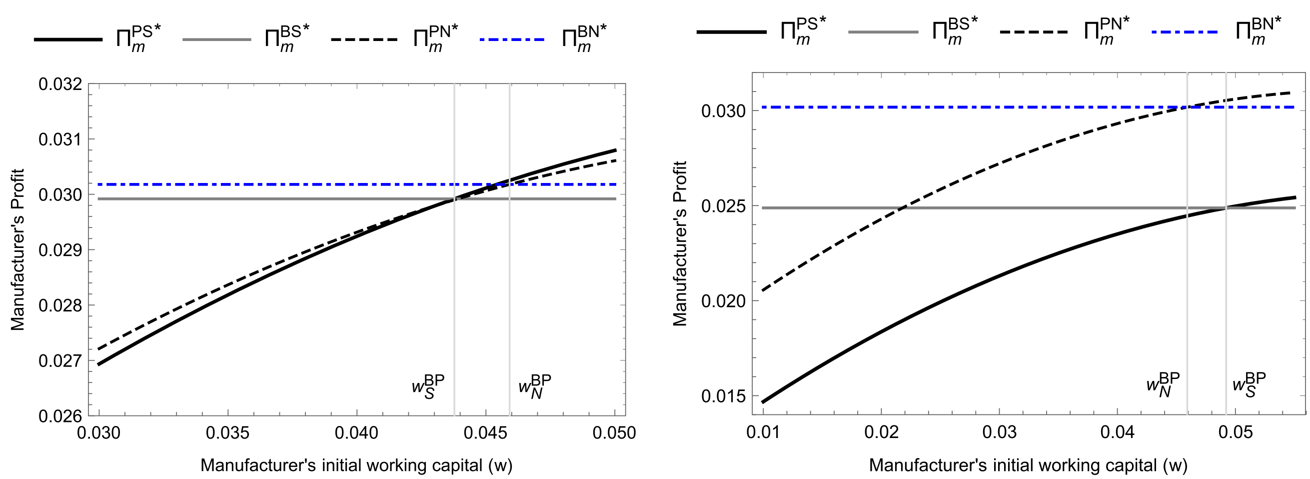
In addition to functioning as a marketplace, the platform can also operate as a reseller (Abhishek, Jerath, and Zhang 2016; Tian et al. 2018). In this mode, the platform purchases products from the manufacturer at a wholesale price z_i^j and resells them to the customers at retail price p_i^j, for $j \in \{\text{BS}, \text{PS}, \text{BN}, \text{PN}\}$.

Under BS configuration, the profit functions of the manufacturer and the platform are given by: $\Pi_m^{\text{BS}}(z_m^{\text{BS}}, q_m^{\text{BS}}, q_e^{\text{BS}}, r_b^{\text{BS}}) = (1-\lambda)(z_m^{\text{BS}}q_m^{\text{BS}} - (cq_m^{\text{BS}} - w)(1 + r_b^{\text{BS}})) - \lambda\beta(cq_m^{\text{BS}} - w) - w$, and $\Pi_e^{\text{BS}}(z_m^{\text{BS}}, q_m^{\text{BS}}, q_e^{\text{BS}}, r_b^{\text{BS}}) = (1-\lambda)(p_m^{\text{BS}}(q_m^{\text{BS}}, q_e^{\text{BS}}) - z_m^{\text{BS}})q_m^{\text{BS}} + (p_e^{\text{BS}}(q_m^{\text{BS}}, q_e^{\text{BS}}) - \delta c)q_e^{\text{BS}} - \lambda kq_m^{\text{BS}}$, respectively. The profit function of the bank is given by: $\Pi_b^{\text{BS}}(z_m^{\text{BS}}, q_m^{\text{BS}}, q_e^{\text{BS}}, r_b^{\text{BS}}) = (1-\lambda)(cq_m^{\text{BS}} - w)(1 + r_b^{\text{BS}}) + \lambda\beta(cq_m^{\text{BS}} - w) - (cq_m^{\text{BS}} - w)$. Under PS configuration, the profit functions of the platform and the manufacturer are given by: $\Pi_e^{\text{PS}}(z_m^{\text{PS}}, q_m^{\text{PS}}, q_e^{\text{PS}}, r_e^{\text{PS}}) = (1-\lambda)(p_m^{\text{PS}}(q_m^{\text{PS}}, q_e^{\text{PS}}) - z_m^{\text{PS}})q_m^{\text{PS}} + (cq_m^{\text{PS}} - w)(1 + r_e^{\text{PS}})) + (p_e^{\text{PS}}(q_m^{\text{PS}}, q_e^{\text{PS}}) - \delta c)q_e^{\text{PS}} - ((c + \lambda k)q_m^{\text{PS}} - w)$, and $\Pi_m^{\text{PS}}(z_m^{\text{PS}}, q_m^{\text{PS}}, q_e^{\text{PS}}, r_e^{\text{PS}}) = (1-\lambda)(z_m^{\text{PS}}q_m^{\text{PS}} - (cq_m^{\text{PS}} - w)(1 + r_e^{\text{PS}})) - w$. The profit functions for the manufacturer, platform, and bank under BN are given by: $\Pi_m^{\text{BS}}(z_m^{\text{BN}}, q_m^{\text{BN}}, r_b^{\text{BN}}) = (1-\lambda)(z_m^{\text{BN}}q_m^{\text{BN}} - (cq_m^{\text{BN}} - w)(1 + r_b^{\text{BN}})) - \lambda\beta(cq_m^{\text{BN}} - w) - w$, $\Pi_e^{\text{BN}}(z_m^{\text{BN}}, q_m^{\text{BN}}, r_b^{\text{BN}}) = (1-\lambda)(z_m^{\text{BN}} - p_m^{\text{BN}}(q_m^{\text{BN}}))q_m^{\text{BN}} - \lambda kq_m^{\text{BN}}$, and $\Pi_b^{\text{BN}}(z_m^{\text{BN}}, q_m^{\text{BN}}, r_b^{\text{BN}}) = (1-\lambda)(cq_m^{\text{BN}} - w)(1 + r_b^{\text{BN}}) + \lambda\beta(cq_m^{\text{BN}} -$



(a) Without private label (b) With private label

Figure 9. Manufacturer's financing choices when $\gamma > 1$. Parametric values: $c = 0.5$, $\beta = 0.2$, $\delta = 1.5$, $\lambda = 0.2$, $k = 0.2$.



(a) Low γ ($\gamma = 0.3$) (b) High γ ($\gamma = 0.4$)

Figure 10. Manufacturer's financing choices based on w. Parameter values: $\lambda = 0.2$, $\delta = 0.7$, $\alpha = 0.3$, $c = 0.3$, $\beta = 0.2$, $k = 0.2$.

$w) - (cq_m^{BN} - w)$, respectively. Under PN, the profit functions for the manufacturer and the platform are given as $\Pi_m^{PN}(z_m^{PN}, q_m^{PN}, r_e^{PN}) = (1-\lambda)(z_m^{BN}q_m^{PN} - (cq_m^{PN} - w)(1 + r_e^{PN})) - w$, and $\Pi_e^{PN}(z_m^{PN}, q_m^{PN}, r_e^{PN}) = (1-\lambda)((p_m^{PN}(q_m^{PN}) - z_m^{BN})q_m^{PN} + (cq_m^{PN} - w)(1 + r_e^{PN})) - \lambda k q_m^{PN} - (cq_m^{PN} - w)$.

In this scenario, the manufacturer decides the wholesale price, followed by the lender deciding the interest rate. The platform then decides the selling quantities of PL and ML products. In Appendix A3 (see Online Supplement), we provide the equilibrium outcomes for all four configurations: BS, PS, BN, and PN. In the following proposition, we analyze the manufacturer's strategic financing choice (with and without the PL).

Proposition 7.1 (Comparison of manufacturer's profit in reseller mode): *Comparing the equilibrium manufacturer's profit under different lending configurations in reseller mode, we obtain:* $\Pi_m^{BN*} > \Pi_m^{PN*}$ *and* $\Pi_m^{BS*} > \Pi_m^{PS*}$.

Proposition 7.1 suggests that the manufacturer always prefers bank financing under the reseller mode. The reason behind this is as follows. When the platform buys the product from the manufacturer and sells it to customers, the procurement cost of the ML remains more than the procurement cost of the PL, because the manufacturer's wholesale price is always more than the unit production cost of ML (i.e. c), which is more than that of PL (i.e.

δc, where $\delta < 1$). Due to this, the platform's profit margin becomes lower for ML products. In order to improve the profit margin, she charges the manufacturer a lower interest rate to nudge him to lower the wholesale price. However, the manufacturer gets a higher profit under BN/BS, even with a higher interest rate compared to the PN/PS configuration, as he is able to charge a higher wholesale price to the platform. Due to this, the manufacturer rejects the interest-free loan under PN/PS and opts for the bank financing (BN/BS). The higher wholesale revenue offsets the extra borrowing cost under BN/BS.

7.4. Impact of the platform's PL quality improvement

In this section, we extend our base model and analyze the impact of the platform's PL quality improvement on the manufacturer's financing strategy. We consider that the platform optimally enhances the PL quality by y_e^j by incurring a cost $\frac{gy_i^{j2}}{2}$ (Ru, Shi, and Zhang 2015). For the benchmark configurations, the inverse demand functions for ML remain the same (i.e. $p_m^j(q_m^j) = 1 - q_m^j, j \in \{\mathrm{BN}, \mathrm{PN}\}$). In the presence of PL, a customer with valuation θ purchases ML if $\mathcal{U}_m^j(\theta) \geq \max\{\mathcal{U}_e^j(\theta), 0\}$, i.e. $\theta - p_m^j \geq \max\{\theta(\gamma + y_e^j) - p_e^j, 0\}$, $j \in \{\mathrm{BS}, \mathrm{PS}\}$. Similarly, the same customer purchases the PL if $\theta(\gamma + y_e^j) - p_e^j \geq \max\{\theta - p_m^j, 0\}$. With simple algebraic manipulations, we can arrive at the following inverse demand functions for ML and PL: $p_m^j(q_m^j, q_e^j) = 1 - q_m^j - (\gamma + y_e^j)q_e^j$ and $p_e^j(q_m^j, q_e^j) = (\gamma + y_e^j)(1 - q_m^j - q_e^j)$, $j \in \{\mathrm{BS}, \mathrm{PS}\}$. Under BS configuration, the profit functions of the manufacturer and the platform are given by: $\Pi_m^{\mathrm{BS}}(q_m^{\mathrm{BS}}, q_e^{\mathrm{BS}}, r_b^{\mathrm{BS}}, y_e^{\mathrm{BS}}) = (1 - \lambda)((1 - \alpha)p_m^{\mathrm{BS}}(q_m^{\mathrm{BS}}, q_e^{\mathrm{BS}})q_m^{\mathrm{BS}} - cq_m^{\mathrm{BS}}(1 + r_b^{\mathrm{BS}})) - \lambda\beta cq_m^{\mathrm{BS}}$, and $\Pi_e^{\mathrm{BS}}(q_m^{\mathrm{BS}}, q_e^{\mathrm{BS}}, r_b^{\mathrm{BS}}, y_e^{\mathrm{BS}}) = (1 - \lambda)\alpha p_m^{\mathrm{BS}}(q_m^{\mathrm{BS}}, q_e^{\mathrm{BS}})q_m^{\mathrm{BS}} + (p_e^{\mathrm{BS}}(q_m^{\mathrm{BS}}, q_e^{\mathrm{BS}}) - \delta c)q_e^{\mathrm{BS}} - \lambda kq_m^{\mathrm{BS}} - .5g(y_e^{\mathrm{BS}})^2$, respectively. The profit function of the bank is given by: $\Pi_b^{\mathrm{BS}}(q_m^{\mathrm{BS}}, q_e^{\mathrm{BS}}, r_b^{\mathrm{BS}}, y_e^{\mathrm{BS}}) = (1 - \lambda)cq_m^{\mathrm{BS}}(1 + r_b^{\mathrm{BS}}) + \lambda\beta cq_m^{\mathrm{BS}} - cq_m^{\mathrm{BS}}$. Under PS configuration, the profit functions of the platform and the manufacturer are given by: $\Pi_e^{\mathrm{PS}}(q_m^{\mathrm{PS}}, q_e^{\mathrm{PS}}, r_e^{\mathrm{PS}}, y_e^{\mathrm{PS}}) = (1 - \lambda)(\alpha p_m^{\mathrm{PS}}(q_m^{\mathrm{PS}}, q_e^{\mathrm{PS}})q_m^{\mathrm{PS}} + c\, q_m^{\mathrm{PS}}(1 + r_e^{\mathrm{PS}})) + (p_e^{\mathrm{PS}}(q_m^{\mathrm{PS}}, q_e^{\mathrm{PS}}) - \delta c)q_e^{\mathrm{PS}} - (c + \lambda k)q_m^{\mathrm{PS}} - .5g(y_e^{\mathrm{BS}})^2$, and $\Pi_m^{\mathrm{PS}}(q_m^{\mathrm{PS}}, q_e^{\mathrm{PS}}, r_e^{\mathrm{PS}}, y_e^{\mathrm{PS}}) = (1 - \lambda)((1 - \alpha)p_m^{\mathrm{PS}}(q_m^{\mathrm{PS}}, q_e^{\mathrm{PS}})q_m^{\mathrm{PS}} - cq_m^{\mathrm{PS}}(1 + r_e^{\mathrm{PS}}))$, respectively.

The inclusion of additional parameters and optimisation makes the problem analytically intractable. Nonetheless, we conduct extensive numerical experiments and generate the following insights. We provide results from numerical analyses and equilibrium outcomes for all four configurations in Appendix A4 (see Online Supplement). The PL quality improvement is consistently higher under platform financing, which results in higher PL sales and lower ML sales under PS compared to BS. The platform earns more under PS, while the manufacturer earns more under BS. Regardless of the manufacturer's financing decision, the platform always benefits from introducing and optimising PL. Conversely, the manufacturer always gains more from bank financing. When the platform enhances PL quality, PL becomes more competitive. The manufacturer attempts to counter the improved PL quality by lowering its price. However, this strategy fails to recover sales and ultimately reduces the manufacturer's profit. The platform, in contrast, can charge a higher price for the improved product, attract more customers, and earn higher profits, even after accounting for the additional quality improvement cost. Overall, these results suggest that the platform should pursue quality improvement, though only up to an optimal extent.

8. Conclusion

Our paper examines a cooperative and competitive relationship between an online platform and an SME manufacturer. The platform competes with the cash-constrained manufacturer by offering her PL, while also offering finance services to him. We examine four distinct loan configurations: BN, PN, BS, and PS, depending on the manufacturer's financing strategy (bank or platform financing) and the platform's decision to introduce PL.

Our paper is one of the first attempts to analyze how a platform's private label (PL) affects a manufacturer's financing decisions. Specifically, we study the cooperative and competitive relationship between an online platform and an SME manufacturer, where the platform competes by offering its PL while simultaneously providing financing services to the manufacturer. Our work contributes to academic research and also provides actionable insights for managers.

Theoretical contributions

Our study contributes to the existing literature in several ways. The existing supply chain finance literature has examined the lending implications of different financing options (Zhen et al. 2020; Chang et al. 2022). We contribute to this research stream by analyzing how the presence of a platform's PL affects the interest rates charged by both the bank and the platform. We show that the platform strategically adjusts its lending rate when it introduces a PL and, in some cases, even charges a lower rate than the bank.

Prior studies have also highlighted the importance of referral fees in platform-based financing, demonstrating that higher referral charges can increase a manufacturer's profitability within this context (Chang et al. 2022; Wang, Fan, and Yin 2019). We extend this line of inquiry by showing that the manufacturer actually benefits more from bank financing when the platform has no PL than from platform financing when the PL is present. Finally, research by Ru, Shi, and Zhang (2015), Liao, Yano, and Trivedi (2020), and Li et al. (2022) has examined the conditions under which PL introduction is beneficial to the supply chain, with an emphasis on product quality. Our findings are consistent with this literature: we show that the platform introduces a PL only when its quality is sufficiently high. Moreover, we add a new dimension by demonstrating that if the manufacturer chooses platform financing, the platform may strategically decide not to launch its PL, effectively adopting a cooperative stance.

Managerial insights

Our results carry several concrete implications for managers at both large e-commerce platforms and SME manufacturers. Consider Amazon as an example: when Amazon introduces PLs such as Amazon Basics in electronics or Solimo in home textiles, it might be expected to raise lending rates to SME sellers like Power Practical or Urban Villa to push demand toward its own brands. However, our findings suggest the opposite may occur in certain cases – when production costs are high, Amazon could actually lower its lending rates relative to banks. By doing so, Amazon ensures that SMEs continue supplying manufacturer labels (MLs), thereby maintaining category depth while simultaneously growing its PL line. JD.com faces a similar trade-off in categories such as clothing and accessories, where the perceived quality of PLs is uneven and lowering lending rates can help balance competitive tension.

For SME manufacturers, the results suggest that financing choices must be carefully aligned with the competitive environment. When Amazon launches a PL with relatively low quality, SME firms may benefit from using Amazon's financing, as lower rates help sustain ML sales. However, when the PL is perceived to be of high quality – such as Amazon Basics in consumer electronics – bank financing becomes the safer strategy to shield profitability against stronger head-to-head competition. Referral fees further complicate this decision. In categories with low referral fees, such as groceries, bank financing remains advantageous, while in categories with moderate or high referral fees, like apparel or home goods, platform financing may prove more attractive even when a PL exists, provided its quality is not significantly superior.

From the platform's perspective, the interplay between PL introduction and financing choices implies that the two strategies should not be managed in isolation. Amazon, JD.com, and similar platforms can maximise long-term gains by coordinating their PL introduction with lending policies. For example, in low-referral-fee categories where PL quality may struggle to match branded products, such as fresh groceries, platforms may find it more profitable to adopt a cooperative stance and avoid introducing PLs if SMEs rely on their financing. In contrast, in categories where referral fees are higher and PLs enjoy strong consumer acceptance, such as home electronics or household essentials, the combination of PL introduction and lower lending rates can generate superior outcomes for both the platform and its ecosystem of sellers.

In short, our analysis suggests that platforms should view PL introduction, financing policies, and referral fees as integrated levers of strategy rather than independent decisions. Meanwhile, SME manufacturers should anticipate how platforms deploy these levers in their product categories and choose financing sources accordingly. The case of Amazon and JD.com illustrates that the right financing decision can make the difference between sustaining profitability and being crowded out by private labels.

Future research avenues

Our paper is one of the first attempts to analyze how a platform's PL affects a manufacturer's financing decisions. We can further extend this work in different directions. Prior research (e.g. X. Li, Cai, and Chen 2022) has looked at PLs that have a higher perceived quality than national brand products. Including this dimension of a private label in future research may lead to interesting insights. We may also study price competition between multiple manufacturers who sell their products on e-marketplaces and face competition from the platform's private label. Further research on supply chain finance may endeavor to undertake studies to empirically validate some of the analytical results.

Notes

1. Retailer financing is the loan provided by the offline retailer, through whom the manufacturer sells the goods in the offline channel.
2. https://sellercentral.amazon.com/help/hub/reference/external/G200336920#wjz_cjc_jcb.
3. https://www.loyal.guru/retail-trends/trends-private-label-growth/.
4. https://hbr.org/1996/01/brands-versus-private-labels-fighting-to-win.
5. The values of c_{rN}^{BP} and c_{rS}^{BP} are provided in the Appendix below.
6. We obtain the value of γ_{rSN}^{BP} by solving $c_{rN}^{BP} = c_{rS}^{BP}$. Due to high level of non-linearity, we do not obtain a closed-form solution to the above equation. It may be noted that $c_{rS}^{BP} < c_{rN}^{BP}$ iff $\gamma < \gamma_{rSN}^{BP}$.
7. The values of c_{qN}^{BP} and c_{qS}^{BP} are provided in the Appendix below.

8. We obtain the value of γ^{BP}_{qSN} by solving $c^{BP}_{qN} = c^{BP}_{qS}$. Due to the high level of non-linearity, we do not obtain a closed-form solution to the above equation. It may be noted that $c^{BP}_{rS} \geq c^{BP}_{qN}$ iff $\gamma < \gamma^{BP}_{qSN}$.
9. In this scenario, we have considered that $0 < \delta < 1$. We also analyze a scenario in which $\delta > 1$. The results, presented in Appendix A5 in the Online Supplement, confirm the robustness of our base-case findings.
10. The resulting equilibrium expressions for the 'no financing' scenario are available in Appendix B (see Online Supplement).

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Appendix. Proofs of main results

The definitions of all parameters used in the manuscript are provided below:

- $c_{rP}^{SN} \stackrel{def}{=} \frac{\gamma^2(1-\alpha)(2-\alpha)(1-\lambda)^2(1+\alpha(1-\lambda))-\gamma\left(4\alpha^2(1-\lambda)^2+8\lambda^2-2\alpha(1-\lambda)(3-(5-k)\lambda)-2(k+5)\lambda+2\right)}{4\delta(2-\alpha)(1-\lambda)(\alpha(1-\lambda)+\lambda)-\gamma(1+\alpha(1-\lambda))\left(2-\delta(2-\alpha)(1-\alpha)(1-\lambda)^2\right)}$.
- $c_{rN}^{BP} \stackrel{def}{=} \frac{(1-\alpha)(1-\alpha-\lambda(1-\alpha-k))}{1-\beta\lambda(2-\alpha)}$.
- $c_{rS}^{BP} \stackrel{def}{=} \frac{(1-\alpha)(1-\lambda)\left(8+\alpha^2(2-\gamma)\gamma(1-\lambda)^2+\gamma^2+4\gamma-\alpha(1-\lambda)(8-2\gamma-\gamma\lambda(2(1-k)-\gamma))-(4-\gamma)\lambda(2(1-k)-\gamma)\right)}{4(1-\lambda)(2+\alpha\delta(1-\alpha)-\lambda((2-\alpha)(\alpha\delta+2\beta)-\delta))-\gamma(1+\alpha(1-\lambda))\left(4-2\lambda(1+\beta(3-\alpha-(2-\alpha)\lambda))-(1-\alpha)^2\delta(1-\lambda)^2\right)}$.
- We obtain the value of γ_{rSN}^{BP} by solving $c_{rN}^{BP}=c_{rS}^{BP}$, i.e. $\gamma_{rSN}^{BP} \stackrel{def}{=} \{\gamma \mid c_{rN}^{BP}=c_{rS}^{BP}\}$.
- $c_{qN}^{BP} \stackrel{def}{=} (1-\alpha)(1-\alpha-\lambda(1-\alpha-k))$.
- $c_{qS}^{BP} \stackrel{def}{=} \frac{(1-\alpha)(1-\lambda)\left(8+\alpha^2(2-\gamma)\gamma(1-\lambda)^2+\gamma^2+4\gamma-\alpha(1-\lambda)(8-2\gamma-\gamma\lambda(2(1-k)-\gamma))-(4-\gamma)\lambda(2(1-k)-\gamma)\right)}{\gamma(1-\alpha(1-\lambda))\left((1-\alpha)^2\delta(1-\lambda)^2-2(2-\lambda)\right)-4(1-\lambda)(2+(1-\alpha)\delta(\alpha(1-\lambda)+\lambda))}$.
- We obtain the value of γ_{qSN}^{BP} by solving $c_{qN}^{BP}=c_{qS}^{BP}$, i.e. $\gamma_{qSN}^{BP} \stackrel{def}{=} \{\gamma \mid c_{qN}^{BP}=c_{qS}^{BP}\}$.
- $c_{qS1}^{BP} \stackrel{def}{=} \frac{(1-\alpha)\gamma(1-\lambda)\left(\alpha^2(1-\lambda)^2-2\alpha(1-\lambda)(2\gamma-\lambda+1)+8\gamma(1-\lambda)+2\lambda-3+(2k+1)\lambda(4\gamma-\alpha(1-\lambda)-1)\right)}{2\gamma\left((1-\lambda)\left(\lambda\left(2(1-\alpha)^2\delta+\alpha\right)-2\alpha(1-(1-\alpha)\delta)\right)+\lambda-2\right)+(1-\alpha)^2\delta(1-\lambda)^2(1+\alpha(1-\lambda))+8\gamma^2(1-\lambda)}$

Proof of Lemma 4.1.: Under BS configuration, the profit functions of the manufacturer and the platform are given by: $\Pi_m^{BS}(q_m^{BS},q_e^{BS},r_b^{BS})=(1-\lambda)((1-\alpha)p_m^{BS}(q_m^{BS},q_e^{BS})q_m^{BS}-cq_m^{BS}(1+r_b^{BS}))-\lambda\beta cq_m^{BS}$, and $\Pi_e^{BS}(q_m^{BS},q_e^{BS},r_b^{BS})=(1-\lambda)\alpha p_m^{BS}(q_m^{BS},q_e^{BS})q_m^{BS}+(p_e^{BS}(q_m^{BS},q_e^{BS})-\delta c)q_e^{BS}-\lambda kq_m^{BS}$, respectively. The profit function of the bank is given by: $\Pi_b^{BS}(q_m^{BS},q_e^{BS},r_b^{BS})=(1-\lambda)cq_m^{BS}(1+r_b^{BS})+\lambda\beta cq_m^{BS}-cq_m^{BS}$. For any given r_b^{BS}, the manufacturer and the platform simultaneously solve the following optimisation problems: $\max_{q_m^{BS}}\{\Pi_m^{BS}(q_m^{BS},q_e^{BS},r_b^{BS})=(1-\lambda)((1-\alpha)p_m^{BS}(q_m^{BS},q_e^{BS})q_m^{BS}-cq_m^{BS}(1+r_b^{BS}))-\lambda\beta cq_m^{BS}\}$, and $\max_{q_e^{BS}}\{\Pi_e^{BS}(q_m^{BS},q_e^{BS},r_b^{BS})=(1-\lambda)\alpha p_m^{BS}(q_m^{BS},q_e^{BS})q_m^{BS}+(p_e^{BS}(q_m^{BS},q_e^{BS})-\delta c)q_e^{BS}-\lambda kq_m^{BS}\}$, respectively, where $p_m^{BS}(q_m^{BS},q_e^{BS})=1-q_m^{BS}-\gamma q_e^{BS}$ and $p_e^{BS}(q_m^{BS},q_e^{BS})=\gamma(1-q_m^{BS}-q_e^{BS})$.

$\Pi_m^{BS}(q_m^{BS},q_e^{BS},r_b^{BS})$ is concave in q_m^{BS} because $\frac{\partial^2\Pi_m^{BS}(q_m^{BS},q_e^{BS},r_b^{BS})}{\partial(q_m^{BS})^2}=-2(1-\alpha)(1-\lambda)<0\,\forall\alpha,\lambda\in(0,1)$. Similarly, $\Pi_e^{BS}(q_m^{BS},q_e^{BS},r_b^{BS})$ is concave in q_e^{BS}, because $\frac{\partial^2\Pi_e^{BS}(q_m^{BS},q_e^{BS},r_b^{BS})}{\partial(q_e^{BS})^2}=-2\gamma<0\;\forall\gamma\in(0,1)$. Solving the first order conditions, we get the values of $q_m^{BS}(r_b^{BS})=\frac{(1-\alpha)(2-\gamma)(1-\lambda)-c(2+2r_b^{BS}(1-\lambda)-\delta(1-\alpha)(1-\lambda)-2\lambda+2\beta\lambda)}{(1-\alpha)(4-\gamma(1+\alpha(1-\lambda)))(1-\lambda)}$ and $q_e^{BS}(r_b^{BS})=\frac{\gamma(1-\alpha(1-\lambda))(1-\alpha)(1-\lambda)-2c\delta(1-\alpha)(1-\lambda)+c\gamma(1+\alpha(1-\lambda))(1+r_b^{BS}(1-\lambda)-\lambda+\beta\lambda)}{\gamma(4-\gamma(1+\alpha(1-\lambda)))(1-\alpha)(1-\lambda)}$. Taking the values of $q_i^{BS}(r_b^{BS}),\,i\in\{m,e\}$ into account, the bank in a perfectly competitive market solves the following problem:

$$\Pi_b^{BS}(r_b^{BS})=\frac{(c(r_b^{BS}(1-\lambda)-\lambda+\beta\lambda)((1-\alpha)(2-\gamma)(1-\lambda)-c(2+2r_b^{BS}(1-\lambda)-\delta(1-\alpha)(1-\lambda)-2\lambda+2\beta\lambda)))}{(1-\alpha)(4-\gamma(1+\alpha(1-\lambda)))(1-\lambda)}=0$$

Solving the above equation, we find the break-even interest rate, $r_b^{BS^*}=\frac{(1-\beta)\lambda}{1-\lambda}$. Substituting the value of $r_b^{BS^*}$, we obtain the optimal outcomes: $q_m^{BS^*}$, $p_m^{BS^*}$, $p_e^{BS^*}$, $\Pi_m^{BS^*}$, and $\Pi_e^{BS^*}$. This establishes the proof of Lemma 4.1. ■

Proof of Lemma 4.2.: Under PS configuration, the profit functions of the platform and the manufacturer are given by: $\Pi_e^{PS}(q_m^{PS},q_e^{PS},r_e^{PS})=(1-\lambda)(\alpha p_m^{PS}(q_m^{PS},q_e^{PS})q_m^{PS}+cq_m^{PS}(1+r_e^{PS}))+(p_e^{PS}(q_m^{PS},q_e^{PS})-\delta c)q_e^{PS}-(c+\lambda k)q_m^{PS}$, and $\Pi_m^{PS}(q_m^{PS},q_e^{PS},r_e^{PS})=(1-\lambda)((1-\alpha)p_m^{PS}(q_m^{PS},q_e^{PS})q_m^{PS}-cq_m^{PS}(1+r_e^{PS}))$, respectively.

For any given q_m^{PS}, q_e^{PS} and r_e^{PS}, the platform and the manufacturer simultaneously solve the following optimisation problems: $\max_{q_e^{PS}}\{\Pi_e^{PS}(q_m^{PS},q_e^{PS},r_e^{PS})=(1-\lambda)(\alpha p_m^{PS}(q_m^{PS},q_e^{PS})q_m^{PS}+cq_m^{PS}(1+r_e^{PS}))+(p_e^{PS}(q_m^{PS},q_e^{PS})-\delta c)q_e^{PS}-(c+\lambda k)q_m^{PS}\}$ and $\max_{q_m^{PS}}\{\Pi_m^{PS}(q_m^{PS},q_e^{PS},r_e^{PS})=(1-\lambda)((1-\alpha)p_m^{PS}(q_m^{PS},q_e^{PS})q_m^{PS}-cq_m^{PS}(1+r_e^{PS}))\}$, where $p_m^{PS}(q_m^{PS},q_e^{PS})=1-q_m^{PS}-\gamma q_e^{PS}$, and $p_e^{PS}(q_m^{PS},q_e^{PS})=\gamma(1-q_m^{PS}-q_e^{PS})$, respectively.

The profit functions, $\Pi_m^{PS}(q_m^{PS},q_e^{PS},r_e^{PS})$ and $\Pi_e^{PS}(q_m^{PS},q_e^{PS},r_e^{PS})$ are concave in q_m^{PS} and q_e^{PS}, respectively, as $\frac{\partial^2\Pi_m^{PS}(q_m^{PS},q_e^{PS},r_e^{PS})}{\partial(q_m^{PS})^2}=-2(1-\alpha)(1-\lambda)<0\,\forall\alpha,\lambda\in(0,1)$ and $\frac{\partial^2\Pi_e^{PS}(q_m^{PS},q_e^{PS},r_e^{PS})}{\partial(q_e^{PS})^2}=-2\gamma<0\,\forall\gamma\in(0,1)$. By solving the first order conditions, we get the values of $q_m^{PS}(r_e^{PS})=\frac{(1-\alpha)(2-\gamma)(1-\lambda)-c(2+2r_e^{PS}(1-\lambda)-\delta(1-\alpha)(1-\lambda)-2\lambda+2\beta\lambda)}{(1-\alpha)(4-\gamma(1+\alpha(1-\lambda)))(1-\lambda)}$ and $q_e^{PS}(r_e^{PS})=\frac{\gamma(1-\alpha(1-\lambda))(1-\alpha)(1-\lambda)-2c\delta(1-\alpha)(1-\lambda)+c\gamma(1+\alpha(1-\lambda))(1+r_e^{PS}(1-\lambda)-\lambda+\beta\lambda)}{\gamma(4-\gamma(1+\alpha(1-\lambda)))(1-\alpha)(1-\lambda)}$. Taking the values of $q_i^{PS}(r_e^{PS}),\,i\in\{m,e\}$ into account, we maximise the platform's profit $\Pi_e^{PS}(r_e^{PS})$ and solve the following optimisation problem:

$\Pi_e^{PS}(r_e^{PS})=(1-\lambda)(\alpha p_m^{PS}(q_m^{PS}(r_e^{PS}),q_e^{PS}(r_e^{PS}))q_m^{PS}(r_e^{PS})+cq_m^{PS}(r_e^{PS})(1+r_e^{PS}))+(p_e^{PS}(q_m^{PS}(r_e^{PS}),q_e^{PS}(r_e^{PS}))-\delta c)q_e^{PS}(r_e^{PS})-(c+\lambda k)q_m^{PS}(r_e^{PS})$

Solving the first order condition, we obtain the optimal lending rate offered by the platform,

$$r_e^{PS^*}=\frac{\begin{array}{c}(1-\alpha)(8-4\gamma+\gamma^2+\gamma\alpha^2(2-\gamma)(1-\lambda)^2-\lambda(4-\gamma)(2-2k-\gamma)-\alpha(1-\lambda)(8-2\gamma-\gamma\lambda(2-2k-\gamma))\\ -c(8+4\alpha\delta(1-\alpha)-16\lambda+4\lambda(2\alpha+\delta(1-\alpha)^2)-\gamma(1+\alpha(1-\lambda))(4-\delta(1-\alpha)^2(1-\lambda)-2\lambda(2-\alpha))))\end{array}}{2c(8-3\gamma-2\alpha(2+\gamma(1-\lambda))(1-\lambda)+\alpha^2\gamma(1-\lambda)^2-2\lambda(4-\gamma))}.$$

Substituting the value of $r_e^{\text{PS}^*}$, we obtain the optimal outcomes: $q_m^{\text{PS}^*}$, $p_m^{\text{PS}^*}$, $p_e^{\text{PS}^*}$, $\Pi_m^{\text{PS}^*}$, and $\Pi_e^{\text{PS}^*}$. This establishes the proof of Lemma 4.2. ■

Proof of Lemma 4.3.: Under BN, the bank first decides the interest rate (r_b^{BN}). Next, the manufacturer determines the selling quantity, q_m^{BN}. The profit functions for the manufacturer, platform, and bank are given by: $\Pi_m^{\text{BS}}(q_m^{\text{BN}}, r_b^{\text{BN}}) = (1-\lambda)((1-\alpha)p_m^{\text{BN}}(q_m^{\text{BN}})q_m^{\text{BN}} - cq_m^{\text{BN}}(1+r_b^{\text{BN}})) - \lambda\beta cq_m^{\text{BN}}$, $\Pi_e^{\text{BN}}(q_m^{\text{BN}}, r_b^{\text{BN}}) = (1-\lambda)\alpha p_m^{\text{BN}}(q_m^{\text{BN}})q_m^{\text{BN}} - \lambda kq_m^{\text{BN}}$, $\Pi_b^{\text{BN}}(q_m^{\text{BN}}, r_b^{\text{BN}}) = (1-\lambda)cq_m^{\text{BN}}(1+r_b^{\text{BN}}) + \lambda\beta cq_m^{\text{BN}} - cq_m^{\text{BN}}$. We use the backward induction to solve this game. For any given r_b^{BN}, the manufacturer solves the following optimisation problem:

$$\max_{q_m^{\text{BN}}} \left\{\Pi_m^{\text{BN}}(q_m^{\text{BN}}, r_b^{\text{BN}}) = (1-\lambda)((1-\alpha)p_m^{\text{BN}}(q_m^{\text{BN}})q_m^{\text{BN}} - cq_m^{\text{BN}}(1+r_b^{\text{BN}})) - \lambda\beta cq_m^{\text{BN}}\right\},$$

where the inverse demand function for the manufacturer is given by: $p_m^{\text{BN}}(q_m^{\text{BN}}) = 1 - q_m^{\text{BN}}$. Now, $\Pi_m^{\text{BN}}(q_m^{\text{BN}}, r_b^{\text{BN}})$ is concave in q_m^{BN}, as $\frac{\partial^2 \Pi_m^{\text{BN}}(q_m^{\text{BN}}, r_b^{\text{BN}})}{\partial (q_m^{\text{BN}})^2} = -2(1-\alpha)(1-\lambda) < 0\ \forall \alpha, \lambda \in (0,1)$. By solving the first order condition, we get: $q_m^{\text{BN}}(r_b^{\text{BN}}) = \frac{1}{2} - \frac{c(1+r_b^{\text{BN}}(1-\lambda)-\lambda+\beta\lambda)}{2(1-\alpha)(1-\lambda)}$. Taking the value of q_m^{BN} into account, the bank solves the following problem:

$$\Pi_m^{\text{BN}}(r_b^{\text{BN}}) = \frac{c(r_b^{\text{BN}}(1-\lambda) - \lambda + \beta\lambda)((1-\alpha)(1-\lambda) - c(1 + r_b^{\text{BN}}(1-\lambda) - \lambda + \beta\lambda))}{2(1-\alpha)(1-\lambda)} = 0.$$

Solving the above equation, we find the break-even interest rate, $r_b^{\text{BN}^*} = \frac{(1-\beta)\lambda}{1-\lambda}$. Substituting the value of $r_b^{\text{BN}^*}$, we obtain the equilibrium sales quantity and market price: $q_m^{\text{BN}^*} = \frac{1}{2} - \frac{c}{2(1-\alpha)(1-\lambda)}$ and $p_m^{\text{BN}^*} = \frac{1}{2} + \frac{c}{2(1-\alpha)(1-\lambda)}$. The profits of the platform and manufacturer are given by: $\Pi_e^{\text{BN}^*} = \frac{(1-c-\alpha-\lambda+\alpha\lambda)((1+c-\alpha)\alpha-(1-\alpha)(2k+\alpha)\lambda)}{4(1-\alpha)^2(1-\lambda)}$, and $\Pi_m^{\text{BN}^*} = \frac{(1-c-\alpha-\lambda+\alpha\lambda)^2}{4(1-\alpha)(1-\lambda)}$, respectively. This establishes the proof of Lemma 4.3. ■

Proof of Lemma 4.4.: Under PN, first, the platform determines the interest rate, r_e^{PN}, which maximises her profit function, Π_e^{PN}. Next, the manufacturer decides the selling quantity, q_m^{PN}, for which his profit is maximised. The profit functions for the manufacturer and the platform are given below: $\Pi_m^{\text{PN}}(q_m^{\text{PN}}, r_e^{\text{PN}}) = (1-\lambda)((1-\alpha)p_m^{\text{PN}}(q_m^{\text{PN}})q_m^{\text{PN}} - cq_m^{\text{PN}}(1+r_e^{\text{PN}}))$, $\Pi_e^{\text{PN}}(q_m^{\text{PN}}, r_e^{\text{PN}}) = (1-\lambda)(\alpha p_m^{\text{PN}}(q_m^{\text{PN}})q_m^{\text{PN}} + cq_m^{\text{PN}}(1+r_e^{\text{PN}})) - \lambda kq_m^{\text{PN}} - cq_m^{\text{PN}}$. For a given r_e^{PN}, the manufacturer solves the following optimisation problem:

$$\max_{q_m^{\text{PN}}} \left\{\Pi_m^{\text{PN}}(q_m^{\text{PN}}, r_e^{\text{PN}}) = (1-\lambda)((1-\alpha)p_m^{\text{PN}}(q_m^{\text{PN}})q_m^{\text{PN}} - cq_m^{\text{PN}}(1+r_e^{\text{PN}}))\right\},$$

where the inverse demand function for the manufacturer is given by: $p_m^{\text{PN}}(q_m^{\text{PN}}) = 1 - q_m^{\text{PN}}$. Now, $\Pi_m^{\text{PN}}(q_m^{\text{PN}}, r_e^{\text{PN}})$ is concave in q_m^{PN}, as $\frac{\partial^2 \Pi_m^{\text{PN}}(q_m^{\text{PN}}, r_e^{\text{PN}})}{\partial (q_m^{\text{PN}})^2} = -2(1-\alpha)(1-\lambda) < 0\ \forall \alpha, \lambda \in (0,1)$. By solving the first order condition, we get: $q_m^{\text{PN}}(r_e^{\text{PN}}) = \frac{1-c-cr_e^{\text{PN}}-\alpha}{2(1-\alpha)}$. Taking the value of q_m^{PN} into account, the platform solves the following optimisation problem:

$$\max_{r_e^{\text{PN}}} \left\{\Pi_e^{\text{PN}}(r_e^{\text{PN}}) = \frac{(1-c-cr_e^{\text{PN}}-\alpha)((1-\alpha)(\alpha(1-\lambda)-2k\lambda) + c(\alpha + r_e^{\text{PN}}(2-\alpha)(1-\lambda) - \lambda(2-\alpha)))}{4(1-\alpha)^2}\right\}.$$

Solving the first order condition, we obtain the equilibrium interest rate offered by the platform, $r_e^{\text{PN}^*} = \frac{c(2-\alpha)\lambda+(1-\alpha)(1-\alpha-(1-k-\alpha)\lambda)-c}{c(2-\alpha)(1-\lambda)}$. Substituting the value of $r_e^{\text{PN}^*}$, we obtain the equilibrium sales quantity and market price $q_m^{\text{PN}^*} = \frac{1-c-\lambda-k\lambda}{2(2-\alpha)(1-\lambda)}$ and $p_m^{\text{PN}^*} = \frac{3+c-2\alpha(1-\lambda)-\lambda(3-k)}{2(2-\alpha)(1-\lambda)}$. The equilibrium profits of the platform and manufacturer are given by: $\Pi_e^{\text{PN}^*} = \frac{(1-c-\lambda-k\lambda)^2}{4(2-\alpha)(1-\lambda)}$, and $\Pi_m^{\text{PN}^*} = \frac{(1-\alpha)(1-c-\lambda-k\lambda)^2}{4(2-\alpha)^2(1-\lambda)}$, respectively. This establishes the proof of Lemma 4.4. ■

Proof of Proposition 5.1.: (a) Comparing the equilibrium platform interest rate under PS and PN, we obtain: $r_e^{\text{PS}^*} - r_e^{\text{PN}^*} = \frac{\substack{(1-\alpha)(8-4\gamma+\gamma^2+\gamma\alpha^2(2-\gamma)(1-\lambda)^2-\lambda(4-\gamma)(2-2k-\gamma)-\alpha(1-\lambda)(8-2\gamma-\gamma\lambda(2-2k-\gamma)) \\ -c(8+4\alpha\delta(1-\alpha)-16\lambda+4\lambda(2\alpha+\delta(1-\alpha)^2)-\gamma(1+\alpha(1-\lambda))(4-\delta(1-\alpha)^2(1-\lambda)-2\lambda(2-\alpha))))}}{2c(8-3\gamma-2\alpha(2+\gamma(1-\lambda))(1-\lambda)+\alpha^2\gamma(1-\lambda)^2-2\lambda(4-\gamma))} - \frac{c(2-\alpha)\lambda+(1-\alpha)(1-\alpha-(1-k-\alpha)\lambda)-c}{c(2-\alpha)(1-\lambda)} > 0$, iff $\gamma^2(1-\alpha)(2-\alpha)(1-\lambda)^2(1+\alpha(1-\lambda)) - \gamma\left(4\alpha^2(1-\lambda)^2 + 8\lambda^2 - 2\alpha(1-\lambda)(3-(5-k)\lambda) - 2(k+5)\lambda + 2\right) - c(4\delta(2-\alpha)(1-\lambda)(\alpha(1-\lambda)+\lambda) - \gamma(1+\alpha(1-\lambda))\left(2-\delta(2-\alpha)(1-\alpha)(1-\lambda)^2\right)) > 0$. This implies when $c < c_{rP}^{SN} = \frac{\gamma^2(1-\alpha)(2-\alpha)(1-\lambda)^2(1+\alpha(1-\lambda))-\gamma\left(4\alpha^2(1-\lambda)^2+8\lambda^2-2\alpha(1-\lambda)(3-(5-k)\lambda)-2(k+5)\lambda+2\right)}{4\delta(2-\alpha)(1-\lambda)(\alpha(1-\lambda)+\lambda)-\gamma(1+\alpha(1-\lambda))\left(2-\delta(2-\alpha)(1-\alpha)(1-\lambda)^2\right)}$, $r_e^{\text{PS}^*} > r_e^{\text{PN}^*}$. Otherwise, $r_e^{\text{PN}^*} \geq r_e^{\text{PS}^*}$, when $c \geq c_{rP}^{SN}$. This establishes the proof of Proposition 5.1(a).

(b) Comparing the equilibrium bank interest rate under BS and BN, we obtain: $r_e^{\text{BS}^*} - r_e^{\text{BN}^*} = \frac{(1-\beta)\lambda}{1-\lambda} - \frac{(1-\beta)\lambda}{1-\lambda} = 0$. Thus, $r_e^{\text{BS}^*} = r_e^{\text{BN}^*}$. This establishes the proof of Proposition 5.1(b). ■

Proof of Proposition 5.2.: In Proposition 5.2, we know that $r_e^{\text{PN}^*} = r_b^{\text{BN}^*}$ iff $c = c_{rN}^{BP} = \frac{(1-\alpha)(1-\alpha-\lambda(1-\alpha-k))}{1-\beta\lambda(2-\alpha)}$. From the expression of $r_e^{\text{PN}^*} = \frac{c(2-\alpha)\lambda+(1-\alpha)(1-\alpha-(1-k-\alpha)\lambda)-c}{c(2-\alpha)(1-\lambda)}$ it is clear that $\lim_{c\to\infty} r_e^{\text{PN}^*} = +\infty$ as $(1-\alpha)(1-\alpha-\lambda(1-\alpha-k)) > 0$, whereas, $r_b^{\text{BN}^*} = \frac{(1-\beta)\lambda}{1-\lambda}$ remains as it is. Hence at $c = 0, r_e^{\text{PN}^*} > r_b^{\text{BN}^*}$, which means $r_e^{\text{PN}^*} > r_b^{\text{BN}^*}$ iff $c < c_{rN}^{BP}$. Similarly, $r_e^{\text{PS}^*} - r_b^{\text{BS}^*} =$

$$\frac{\begin{array}{c}(1-\alpha)(8-4\gamma+\gamma^2+\gamma\alpha^2(2-\gamma)(1-\lambda)^2-\lambda(4-\gamma)(2-2k-\gamma)-\alpha(1-\lambda)(8-2\gamma-\gamma\lambda(2-2k-\gamma))\\ -c(8+4\alpha\delta(1-\alpha)-16\lambda+4\lambda(2\alpha+\delta(1-\alpha)^2)-\gamma(1+\alpha(1-\lambda))(4-\delta(1-\alpha)^2(1-\lambda)-2\lambda(2-\alpha))))\end{array}}{2c(8-3\gamma-2\alpha(2+\gamma(1-\lambda))(1-\lambda)+\alpha^2\gamma(1-\lambda)^2-2\lambda(4-\gamma))} - \frac{(1-\beta)\lambda}{1-\lambda}$$

> 0, iff $c < c_{rS}^{BP}$. Moreover, from the definition of γ_{rSN}^{BP}, we obtain that $\gamma < \gamma_{rSN}^{BP}$ when $c_{rS}^{BP} < c_{rN}^{BP}$. Otherwise, for $\gamma \geq \gamma_{rSN}^{BP}$, we have $c_{rS}^{BP} \geq c_{rN}^{BP}$.

Therefore, $r_b^{\text{BN}^*} < r_e^{\text{PN}^*}$ and $r_b^{\text{BS}^*} < r_e^{\text{PS}^*}$, if $c < \min\{c_{rN}^{BP}, c_{rS}^{BP}\}$. Otherwise if $\gamma < \gamma_{rSN}^{BP}$ and $c_{rS}^{BP} \leq c < c_{rN}^{BP}$, then $r_b^{\text{BN}^*} < r_e^{\text{PN}^*}$ and $r_b^{\text{BS}^*} \geq r_e^{\text{PS}^*}$. When $\gamma \geq \gamma_{rSN}^{BP}$ and and $c_{rS}^{BP} \leq c < c_{rN}^{BP}$, then $r_b^{\text{BN}^*} \geq r_e^{\text{PN}^*}$ and $r_b^{\text{BS}^*} < r_e^{\text{PS}^*}$. Finally, $r_b^{\text{BN}^*} \geq r_e^{\text{PN}^*}$ and $r_b^{\text{BS}^*} \geq r_e^{\text{PS}^*}$, for $c \geq \max\{c_{rN}^{BP}, c_{rS}^{BP}\}$. This establishes the proof of Proposition 5.2(a), (b), (c), and (d). ■

Proof of Proposition 5.3.: We know that at $c = 0, q_m^{\text{PN}^*} - q_m^{\text{BN}^*} = \frac{1-\lambda-k\lambda}{2(2-\alpha)(1-\lambda)} - \frac{1}{2} = \frac{-(1-\lambda)(1-\alpha)-k\lambda}{2(2-\alpha)(1-\lambda)} < 0$, $q_m^{\text{PN}^*} = q_m^{\text{BN}^*}$ at $c = c_{qN}^{BP}$. Hence, $q_m^{\text{PN}^*} < q_m^{\text{BN}^*}$ iff $c < c_{qN}^{BP}$. Furthermore, $q_m^{\text{PS}^*} - q_m^{\text{BS}^*} = \frac{2-c(2-\delta(2-\lambda))-\gamma(2-\lambda)-2\lambda(1+k)}{8-3\gamma-2\alpha(2+\gamma(1-\lambda))(1-\lambda)+\alpha^2\gamma(1-\lambda)^2-2\lambda(4-\gamma)} - \frac{(1-\alpha)(2-\gamma)(1-\lambda)-c(2-\delta(1-\alpha)(1-\lambda))}{(1-\alpha)(4-\gamma(1+\alpha(1-\lambda)))(1-\lambda)} < 0$, iff $(2-c(2-\delta(2-\lambda))-\gamma(2-\lambda)-2\lambda(1+k))((1-\alpha)(4-\gamma(1+\alpha(1-\lambda)))(1-\lambda)) - (8-3\gamma-2\alpha(2+\gamma(1-\lambda))(1-\lambda)+\alpha^2\gamma(1-\lambda)^2-2\lambda(4-\gamma))((1-\alpha)(2-\gamma)(1-\lambda)-c(2-\delta(1-\alpha)(1-\lambda))) < 0$. By solving this, we get $q_m^{\text{PN}^*} < q_m^{\text{BN}^*}$ iff $c < c_{qS}^{BP}$. Moreover, from the definition of γ_{qSN}^{BP}, we obtain that $\gamma < \gamma_{qSN}^{BP}$ when $c_{qS}^{BP} < c_{rN}^{BP}$. Otherwise, for $\gamma \geq \gamma_{qSN}^{BP}$, we have $c_{qS}^{BP} \geq c_{qN}^{BP}$.

Therefore, $q_m^{\text{BN}^*} > q_m^{\text{PN}^*}$ and $q_m^{\text{BS}^*} > q_m^{\text{PS}^*}$, if $c < \min\{c_{qN}^{BP}, c_{rS}^{BP}\}$. Otherwise if $\gamma < \gamma_{qSN}^{BP}$ and $c_{qS}^{BP} \leq c < c_{qN}^{BP}$, then $q_m^{\text{BN}^*} > q_m^{\text{PN}^*}$ and $q_m^{\text{BS}^*} \leq q_m^{\text{PS}^*}$. When $\gamma \geq \gamma_{qSN}^{BP}$ and $c_{qS}^{BP} \leq c < c_{qN}^{BP}$, then $q_m^{\text{BN}^*} \leq q_m^{\text{PN}^*}$ and $q_m^{\text{BS}^*} > q_m^{\text{PS}^*}$. Finally, $q_m^{\text{BN}^*} \leq q_m^{\text{PN}^*}$ and $q_m^{\text{BS}^*} \leq q_m^{\text{PS}^*}$, for $c \geq \max\{c_{qN}^{BP}, c_{qS}^{BP}\}$. This establishes the proof of Proposition 5.3(a), (b), (c), and (d). ■

Proof of Proposition 5.4.: In this case, $\Pi_m^{\text{PN}^*} - \Pi_m^{\text{BN}^*} = \frac{(1-\alpha)(1-c-\lambda-k\lambda)^2}{4(2-\alpha)^2(1-\lambda)} - \frac{(1-c-\alpha-\lambda+\alpha\lambda)^2}{4(1-\alpha)(1-\lambda)} = (1-\alpha)(1-\lambda)(q_m^{\text{PN}^*} + q_m^{\text{BN}^*})(q_m^{\text{PN}^*} - q_m^{\text{BN}^*}) < 0$, iff $(q_m^{\text{PN}^*} - q_m^{\text{BN}^*}) < 0$ and we know that $(q_m^{\text{PN}^*} - q_m^{\text{BN}^*}) < 0$ iff $c < c_{qN}^{BP}$. Similarly, $\Pi_m^{\text{PS}^*} - \Pi_m^{\text{BS}^*} = \frac{(1-\alpha)(1-\lambda)(c(2-\delta(2-\lambda))+\gamma(2-\lambda)-2(1-\lambda-k\lambda))^2}{(8-3\gamma-2\alpha(2+\gamma(1-\lambda))(1-\lambda)+\alpha^2\gamma(1-\lambda)^2-2\lambda(4-\gamma))^2} - \frac{((1-\alpha)(2-\gamma)(1-\lambda)-c(2-\delta(1-\alpha)(1-\lambda)))^2}{(1-\alpha)(4-\gamma(1+\alpha(1-\lambda)))^2(1-\lambda)} = (1-\alpha)(1-\lambda)(q_m^{\text{PS}^*} + q_m^{\text{BS}^*})(q_m^{\text{PS}^*} - q_m^{\text{BS}^*}) < 0$, iff $c < c_{qS}^{BP}$. Moreover, from the definition of γ_{qSN}^{BP}, we obtain that $\gamma < \gamma_{qSN}^{BP}$ when $c_{qS}^{BP} < c_{rN}^{BP}$. Otherwise, for $\gamma \geq \gamma_{qSN}^{BP}$, we have $c_{qS}^{BP} \geq c_{qN}^{BP}$.

Therefore, $\Pi_m^{\text{BN}^*} > \Pi_m^{\text{PN}^*}$ and $\Pi_m^{\text{BS}^*} > \Pi_m^{\text{PS}^*}$, if $c < \min\{c_{qN}^{BP}, c_{rS}^{BP}\}$. Otherwise if $\gamma < \gamma_{qSN}^{BP}$ and $c_{qS}^{BP} \leq c < c_{qN}^{BP}$, then $\Pi_m^{\text{BN}^*} > \Pi_m^{\text{PN}^*}$ and $\Pi_m^{\text{BS}^*} \leq \Pi_m^{\text{PS}^*}$. When $\gamma \geq \gamma_{qSN}^{BP}$ and $c_{qS}^{BP} \leq c < c_{qN}^{BP}$, then $\Pi_m^{\text{BN}^*} \leq \Pi_m^{\text{PN}^*}$ and $\Pi_m^{\text{BS}^*} > \Pi_m^{\text{PS}^*}$. Finally, $\Pi_m^{\text{BN}^*} \leq \Pi_m^{\text{PN}^*}$ and $\Pi_m^{\text{BS}^*} \leq \Pi_m^{\text{PS}^*}$, for $c \geq \max\{c_{qN}^{BP}, c_{qS}^{BP}\}$. This establishes the proof of Proposition 5.4(a), (b), (c), and (d). ■

Proof of Proposition 7.1.: In this case, $\Pi_m^{\text{PN}^*} - \Pi_m^{\text{BN}^*} = \frac{c^2-2c(1-k\lambda-\lambda)+\lambda^2\left((k+1)^2+8w\right)-2\lambda(k+4w+1)+1}{8(1-\lambda)} - \frac{(1-c-k\lambda-\lambda)^2}{8(1-\lambda)} = -w\lambda < 0$, $\forall w, \lambda > 0$. Hence $\Pi_m^{\text{BN}^*} > \Pi_m^{\text{PN}^*}$ $\forall w, \lambda > 0$.

Similarly, $\Pi_m^{\text{PS}^*} - \Pi_m^{\text{BS}^*} =$

$$\frac{c^2(2-\delta(2-\lambda))^2+\gamma^2(2-\lambda)^2+2c(2-\delta(2-\lambda))(\gamma(2-\lambda)-2(-k\lambda-\lambda+1))+4\lambda^2\left(k^2+2k+8w+1\right)-4\gamma(2-\lambda)\left(-\lambda(k+4w+1)+2\lambda^2w+1\right)-8\lambda(k+4w+1)+4}{8\left(4(1-\lambda)-\gamma(\lambda-2)^2\right)} -$$

$\frac{(c(2-\delta(2-\lambda))+\gamma(2-\lambda)-2(-k\lambda-\lambda+1))^2}{8\left(4(1-\lambda)-\gamma(2-\lambda)^2\right)} = -w\lambda < 0, \forall w, \lambda > 0$. Hence $\Pi_m^{\text{BS}^*} > \Pi_m^{\text{PS}^*}$ $\forall w, \lambda > 0$ This establishes the proof of Proposition 7.1. ■