RAIRO-Oper. Res. 56 (2022) 3219–3244
https://doi.org/10.1051/ro/2022128

RAIRO Operations Research
www.rairo-ro.org

SELECTION OF FINANCING STRATEGIES AND BUSINESS MODES FOR A CAPITAL-CONSTRAINED MANUFACTURER

Yi Gao and Lei Fang*

Abstract. E-commerce platforms adopt both reseller and agency business modes to achieve better performance, and also provide financing services for qualified manufacturers to alleviate their financial difficulties. This paper analyzes financing strategy (bank financing or platform financing) and business mode selection (reseller mode, agency mode or both of them) for a capital-constrained manufacturer. We find that no matter which business mode is adopted, the platform always provides lower interest rates than bank, which in turn makes retail prices lower. Meanwhile, the manufacturer and the platform can become more profitable under platform financing. In addition, compared with the manufacturer adopting bank financing, the manufacturer has different business mode preferences when adopting platform financing. We put forward business mode recommendations for the manufacturer under different financing strategies.

Mathematics Subject Classification. 90B50, 91B24, 91B28.

Received August 25, 2021. Accepted July 22, 2022.

1. Introduction

With the vigorous development of e-commerce, many B2C platforms have added agency business mode, allowing third-party sellers or manufacturers to settle in. For example, in the early days of JD.com, it operated the platform through a reseller mode. It purchased products from manufacturers at wholesale prices and sold them to customers at retail prices. At the end of 2010, JD.com added an agency mode in which third-party manufacturers directly sold products to customers on the platform and the platform took a commission on each transaction. The presence of third-party manufacturers greatly enriches the product categories of the platform and attracts more customers. At the same time, allowing third-party manufacturers to sell products directly saves the platform's fixed costs such as inventory costs. Through the investigation, scholars find that platforms with two business modes tend to choose high demand products to sell through reseller mode [12]. However, we observe on JD.com that not all high demand products are sold through reseller mode. For example, Saturnbird, Hello MyDeer and UCC are three types of coffee with high sales volume on JD.com. Saturnbird adopts reseller mode, Hello My Deer adopts agency mode and UCC adopts both reseller and agency modes. This shows that even if the platform is willing to resell the manufacturer's products, the manufacturer does not necessarily adopt

Keywords. E-commerce, finance, supply chain.

Business School, Nankai University, Tianjin 300071, P.R. China.
*Corresponding author: fanglei@nankai.edu.cn

or only adopt reseller mode. When the platform provides two business modes for manufacturers, choosing an optimal business mode is a crucial issue for manufacturers.

Due to the price competition of homogeneous products and the slow return of funds of the platform, manufacturers on platform are likely to face a shortage of funds [5]. Banks, with their strong capital and perfect financing system, have solved the financial difficulties of many manufacturers. However, the funds shortage of manufacturers not only affects their own profits, but also affects the revenue of the platform. Therefore, many platforms have also launched financing services for their cooperative manufacturers. For example, in 2013, JD.com launched the financing product Jingbaobei for its manufacturers of reseller mode, and launched Jingxiaodai for third-party manufacturers of agency mode in 2014. For manufacturers, the platform's financing services have the characteristics of short review period and fast lending. Therefore, when the platform is willing to provide loans to qualified manufacturers, choosing bank financing or platform financing is another important decision faced by manufacturers.

In the current studies, Wang *et al.* [33] and Zhen *et al.* [47] compare the impact of bank financing and platform financing on manufacturer's decision-making and profits. However, only the agency mode of the platform is considered in their research. In fact, platforms like JD and Amazon provide manufacturers with two business modes, agency and reseller. Different from the agency mode where the manufacturer bears the demand risk, the reseller mode is where the platform bears the demand risk. The manufacturer's financing behavior may have different effects on the equilibrium decision-making and profit under the platform's reseller mode, which is worthy of further exploration. In addition, Tian *et al.* [30]'s study has proved that manufacturer's business mode preference on the platform is affected by cost. Coincidentally, financing behavior affects the manufacturer's cost. Therefore, financing behavior is likely to affect manufacturer's business mode preference.

Based on the motivations above, we study the interaction between financing strategy and business mode selection of a manufacturer. We consider a supply chain which consists of an e-commerce platform and a capital-constrained manufacturer. The platform provides reseller mode and agency mode to the manufacturer. Meanwhile, the platform provides financing service if the manufacturer's qualifications meet the requirements. The manufacturer decides whether to finance from a bank or the platform and which kind of business mode to adopt: reseller mode (mode R), agency mode (mode A) or both of them (mode RA). We try to solve the following problems:

(1) Under different financing strategies, what are the equilibrium decisions of the manufacturer and the platform?
(2) In each mode, which financing strategy does the manufacturer prefer?
(3) How does the financing strategy affect the manufacturer's business mode preference?

First, we derive equilibrium solutions of the manufacturer and the platform under different financing strategies in each business mode, and analyze how the optimal decisions are affected by the relevant parameters. Then, in each business mode, we compare the manufacturer's profits when financing from the bank and when financing from the platform, and analyze the optimal financing strategy. Finally, we compare the differences of the manufacturer's business mode preferences between bank financing and platform financing, and analyze the impact of financing strategy on the manufacturer's business mode preferences.

The main contributions of this paper are as follows. First, the research on platform financing is separately considered under agency mode [33, 47] or reseller mode [41]. Our research considers that the platform provides these two alternative business modes when financing the manufacturer. Through comparison, we find that the interest rate decision of the platform under reseller mode is different from that under the agency mode. Under reseller mode, the platform is willing to provide interest-free loans when the manufacturer has no risk of external default. Differences in platform's interest rate decisions affect manufacturer's preference for platform business modes. Second, different from Wei *et al.* [35]'s results, our research proves that when considering a manufacturer with capital constraint, the reseller mode or both two mode is better than only agency mode under certain conditions. What's more, the manufacturer's business mode preferences when finances from a bank are different from those when finances from the platform. Our research provides a reference for capital-constrained manufacturers when choosing the platform's business mode under different financing strategies. Through the main conclusions drawn in this study, we suggest that platforms should provide manufacturers with lower interest rates than bank. Manufacturers should adjust their business mode choices based on financing decisions. If possible, manufacturers should try their best to seek financial support from the platform.

The following sections are arranged as follows. Section 2 reviews relevant literature about this study. Section 3 describes the model and notations. Section 4, Sections 5 and 6 discuss the financing equilibrium in mode R, mode A and mode RA, respectively. Section 7 shows the optimal business mode strategies through numerical experiments. Section 8 discusses the results obtained by models analysis and numerical experiments, and summarizes the management implications of this study. Section 9 concludes this study and proposes future research directions.

2. Literature review

Literature related to this study can be classified into two streams: supply chain finance and e-commerce platform's business mode.

2.1. Supply chain finance

The first stream of literature is supply chain finance. Our study mainly focuses on related research of bank financing and platform financing. In the research of bank financing, Yan *et al.* [39], Li *et al.* [17] and Lu *et al.* [21] study the bank's partial credit guarantee financing. Jin *et al.* [13] expand three financing strategies in which bank participate. Huang *et al.* [10] discuss optimal financing decisions of the retailer and the bank under three types of contracts. Yan and Ye [38] study whether upstream supplier should add direct channel when the retailer uses bank financing and equity financing to ease funding constraints. In addition, more and more scholars are paying attention to the financial performance of the green supply chain. Many enterprises have increased their investment in environmental protection in order to obtain economic and environmental returns [37]. Sachin and Rajesh [27] explore the impact of sustainability indicators, including the environment, on enterprises' financial performance. Huang *et al.* [11] study the impact of government subsidies for green products on the profits of a capital-constrained supply chain. In the research of platform financing, Chen *et al.* [5]'s case study shows how supply chain finance helps e-commerce platforms gain competitive advantages. Wang *et al.* [33] and Gong *et al.* [7] investigate the optimal financing strategies of the retailer and the platform and show how platform financing benefits supply chain members. In addition, manufacturers always face different forms of competition. Dong *et al.* [6] investigate how the platform provides financing to two competing manufacturers. Zhen *et al.* [47] and Yan *et al.* [41,42] study how platform financing affects the profitability of supply chain members when there is channel competition. Qin *et al.* [25] study a manufacturer who is regulated by a cap-and-trade mechanism, it sells products on an e-commerce platform. The manufacturer can use platform financing, upstream trade credit financing or a combination of both financing. The authors analyze the effects of each financing method on carbon emission reduction and order decisions. In the current research on platform financing, scholars only pay attention to agency mode of the platform, or only consider the reseller mode. Our study fills this gap by considering both of these two modes when comparing bank financing with platform financing.

2.2. E-commerce platform's business mode

Another stream of literature is e-commerce platform's business mode. A variety of business modes can ensure the flexibility of supply chains, which is vital to the development of supply chains [26]. The main business modes of e-commerce platforms include reseller mode and agency mode. From the perspective of the platform, the choice of reseller mode, agency mode or hybrid mode affects the platform's revenue and development. Hagiu and Wright [8] consider that the choice between reseller mode or agency mode depends on who has the most important information, the supplier or the platform. Abhishek *et al.* [1] further find that the influence of online channels on traditional channels should be taken into account when deciding whether to choose reseller mode or agency mode. According to the attribute of platform internal competition, Tian *et al.* [30] consider the impact of

TABLE 1. Location of this study.

Literature	Supply chain structure	Platform's business mode	Capital constraint
Wang *et al.* [33]	One platform, one retailer	Agency	√
Gong *et al.* [7]	One platform, one retailer	Agency	√
Dong *et al.* [6]	One platform, one/two retailer	Agency	√
Zhen *et al.* [47]	One platform, one manufacturer, one retailer	Agency	√
Yan *et al.* [41]	One platform, one supplier	Reseller	√
Yan *et al.* [42]	One platform, one supplier, one retailer	Agency	√
Wei *et al.* [35]	One platform, two manufacturers	Agency and reseller	–
Zennyo [43]	One platform, two suppliers	Agency and reseller	–
Zhao and Hou [46]	One intermediary, one supplier	Agency and reseller	–
This study	One platform, one manufacturer	Agency and reseller	√

the intensity of competition between upstream products on the choice of sales mode. Some other studies discuss the optimal operation decisions of the platform when it has two business modes at the same time. Jiang *et al.* [12] study an interesting problem, that is, the platform tends to resell high-demand products and consign long-tail products, which makes high-demand sellers attempt to hide high demand to retain the right to sell products. The game between the platform and sellers affects their profits. Zhang and Zhang [44] study the influence of the platform's demand information sharing strategy on the supplier's offline expansion strategy under the reseller mode and the agency mode, respectively. From the perspective of manufacturers, when platforms provide two alternative business modes, different choices have different effects on the profit of manufacturers. Wei *et al.* [35] and Zennyo [43] consider how manufacturers choose the business mode of the platform when two manufacturers compete with each other. Zhao and Hou [46] study whether a manufacturer under the platform reseller mode should introduce agency channel. Our research is also from the perspective of the manufacturer to analyze how the manufacturer should choose the business mode when the platform provides two business modes. Different from the existing research, we consider the manufacturer's capital constraints and financing strategies, which have an impact on the manufacturer's business modes selection.

In this study, we focus on how the capital-constrained manufacturer chooses financing strategy and platform business modes. In the studies of platform financing [7, 33], they assume that the platform only provides the agency mode. In our research, the platform provides both an agency mode and a reseller mode, which expands existing research. In addition, the capital constraint of the manufacturer has been ignored in previous studies about selection of business modes [35, 43]. Our study fills the research gap by discussing the impact of financing strategies on the manufacturer's business mode choices. The location of this study is shown in Table 1.

3. Model description

We consider a supply chain which consists of an e-commerce platform (referred to as "he") and a capital-constrained manufacturer (referred to as "she"). The platform has two business modes: reseller mode and agency mode, and provides financing service to the manufacturer if her qualifications meet the requirements. The manufacturer can sell her products through only reseller mode (mode R), only agency mode (mode A), or both two modes (mode RA). Meanwhile, she can complete production by financing from a bank or the platform.

The notations are summarized in Table 2. We use the superscript "k" to denote the business mode the manufacturer chooses, where $k = \mathrm{R}, \mathrm{A}$ or RA. The subscript "$i = 1$" denotes the case when the manufacturer finances from a bank and "$i = 2$" denotes finances from the platform. In addition, the subscript "$j = m, e, b$" denote the manufacturer, the e-commerce platform and the bank.

In accordance with the literature related to our study [35, 41, 47], we use a linear price-dependent demand function to represent actual demand. a represents initial demand of the market. ε represents stochastic demand

TABLE 2. Notations.

Parameters	
B	: Manufacturer's initial capital
c	: Manufacturer's unit production cost
a	: The initial demand of the market
ε	: The stochastic demand of the market
β	: The probability that the stochastic demand is high
b	: Demand sensitivity to own price
d	: The coefficient of cross-price sensitivity
θ	: Reseller channel demand ratio in mode RA, $\theta \in [0,1]$
λ	: Platform's commission ratio, $\lambda \in [0,1]$
Π_{ij}^k	: Profit functions
Decision variables	
p_{ij}^k	: Retail price for consumers
w_i^k	: Manufacturer's wholesale price to the platform, $k = \mathrm{R}, \mathrm{RA}$
r_j^k	: Loan interest rate, $j = e, b$, $r_j^k \in [0,1]$

of the market, it represents the volatility of demand. In this study, we assume that stochastic demand follows a binomial distribution, which has been used in many studies [18,19,23,47]. ε_H represents high demand and the probability of high demand is β. Correspondingly, ε_L represents low demand and the probability is $1-\beta$. We assume that low demand is low enough. When a capital-constrained manufacturer assumes the risk of stochastic demand, no matter in mode A or mode RA, the occurrence of low demand will cause the manufacturer to go bankrupt [19,23]. In mode R, the platform bears the risk of stochastic demand. Since the platform is well-funded and there is no risk of bankruptcy, we assume that the platform will place orders with the expected value of stochastic demand $\mu = \beta\varepsilon_H + (1-\beta)\varepsilon_L$, which is very common in the real industry [47]. Then, the demand function can be expressed as $q^{\mathrm{R}} = a - bp_{ie}^{\mathrm{R}} + \mu$. In mode A, the manufacturer assumes the risk of stochastic demand and will go bankrupt when low demand occurs. Due to the limited liability, no matter how many products the manufacturer orders, her profit is zero when bankruptcy occurs. So the manufacturer always tends to place orders in accordance with high demand to ensure maximum profit [23]. The demand function can be expressed as $q^{\mathrm{A}} = a - bp_{im}^{\mathrm{A}} + \varepsilon_H$. In mode RA, the demand function of the platform's reseller channel can be expressed as $q_e^{\mathrm{RA}} = \theta(a+\mu) - bp_{ie}^{\mathrm{RA}} + dp_{im}^{\mathrm{RA}}$, the agency channel can be expressed as $q_m^{\mathrm{RA}} = (1-\theta)(a+\varepsilon_H) - bp_{im}^{\mathrm{RA}} + dp_{ie}^{\mathrm{RA}}$. We assume that $0 < d < b$ which represents that market demand decreases with their own channel's price but increases with the other channel's price. Consumers are more sensitive to price in their own channel than in other channel. Without loss of generality, we have the following assumptions that $q^k > 0$, $c\big(1 + r_j^k\big) < w_i^k < p_{ij}^k$, $c\big(1 + r_j^k\big) < (1-\lambda)p_{ij}^k$.

4. The mode R

In this section, we discuss the optimal operational and financial decisions of the manufacturer when she chooses the reseller mode of the platform.

4.1. Finance from a bank

When the manufacturer decides to finance from a bank, the subsequent of the events are as follows. First, the bank decides the interest rate r_b^{R}. Then, the manufacturer decides the wholesale price w_1^{R} according to the interest rate. Finally, the platform decides his retail price p_{1e}^{R}. We solve this Stackelberg game in reverse order.

At the end of the selling season, the platform's profit can be expressed as

$$\Pi_{1e}^{\mathrm{R}} = \beta p_{1e}^{\mathrm{R}} q^{\mathrm{R}} + (1-\beta) p_{1e}^{\mathrm{R}} \big(a - b p_{1e}^{\mathrm{R}} + \varepsilon_L\big) - w_1^{\mathrm{R}} q^{\mathrm{R}}. \tag{4.1}$$

So we can conclude in Proposition 4.1:

Proposition 4.1. *In mode R, when the manufacturer finance from a bank, the optimal retail price of the platform is*

$$p_{1e}^{\mathrm{R}^*} = \frac{a + w_1^{\mathrm{R}} b + \beta^2(\varepsilon_H - \varepsilon_L) + \varepsilon_L}{2b}. \tag{4.2}$$

Proposition 4.1 indicates that the retail price increases with w_1^{R}. When the wholesale price increases, the increased cost of platform will be transferred to consumers, resulting in the increase of retail price. For a given w_1^{R}, the retail price increases with a and β but decreases with b. The increase of a and β will increase the total demand of the market. As has been observed in practice, an increase in demand leads to an increase in price. However, when consumers become more sensitive to price, the market demand will decrease, and the platform has to lower the retail price to increase market demand.

For the manufacturer, she borrows $\big(cq^{\mathrm{R}} - B\big)$ from the bank to produce products. Then she acquire $w_1^{\mathrm{R}} q^{\mathrm{R}}$ from the platform. Finally she pays back to the bank $\big(cq^{\mathrm{R}} - B\big)\big(1 + r_b^{\mathrm{R}}\big)$. The manufacturer's profit can be expressed as

$$\Pi_{1m}^{\mathrm{R}} = w_1^{\mathrm{R}} q^{\mathrm{R}} - \big(cq^{\mathrm{R}} - B\big)\big(1 + r_b^{\mathrm{R}}\big) - B. \tag{4.3}$$

Proposition 4.2. *In mode R, when the manufacturer finance from a bank, the optimal wholesale price of the manufacturer is*

$$w_1^{\mathrm{R}^*} = \frac{a + bc\big(1 + r_b^{\mathrm{R}}\big) + (2-\beta)\beta\varepsilon_H + (1-\beta)^2 \varepsilon_L}{2b}. \tag{4.4}$$

Proposition 4.2 indicates that the wholesale price increases with r_b^{R} and it is not difficult to conclude that the retail price will also increase with r_b^{R}. The increase in financing cost leads to the wholesale price and retail price increase simultaneously. For a given r_b^{R}, the wholesale price increases with a, β, c but decreases with b which is the same with retail price.

For the bank, its profit function can be expressed as

$$\Pi_b^{\mathrm{R}} = \big(cq^{\mathrm{R}} - B\big) r_b^{\mathrm{R}}. \tag{4.5}$$

Proposition 4.3. *In mode R, when the manufacturer finance from a bank, the optimal interest rate of the bank is*

$$r_b^{\mathrm{R}^*} = \frac{ac - bc^2 - 4B + c[(2-\beta)\beta\varepsilon_H + (1-\beta)^2\varepsilon_L]}{2bc^2}. \tag{4.6}$$

According to Proposition 4.3, we can acquire that the interest rate decreases with B. When the initial capital of the manufacturer increases, the manufacturer will borrow less. To increase the amount of money the manufacturer borrow and thus increase the bank's revenue, the bank will lower interest rate to further lower retail price, which leads to an increase of the market demand.

4.2. Finance from the platform

When the manufacturer decides to finance from the platform, the subsequent of the events are as follows. First, the platform decides the interest rate r_e^{R}. Then, the manufacturer decides the wholesale price w_2^{R}. Finally, the platform decides his retail price p_{2e}^{R}. We solve this Stackelberg game in reverse order.

The platform's profit can be expressed as

$$\Pi_{2e}^{\mathrm{R}} = \beta p_{2e}^{\mathrm{R}} q^{\mathrm{R}} + (1-\beta) p_{2e}^{\mathrm{R}} (a - b p_{2e}^{\mathrm{R}} + \varepsilon_L) - w_2^{\mathrm{R}} q^{\mathrm{R}} + \left(c q^{\mathrm{R}} - B\right) r_e^{\mathrm{R}}. \tag{4.7}$$

The first three part of the function is the sales profit and the forth part is the financing revenue. From the above expression, we can get the optimal retail price.

Proposition 4.4. *In mode R, when the manufacturer finance from the platform, the optimal retail price of the platform is*

$$p_{2e}^{\mathrm{R}^*} = \frac{a + w_2^{\mathrm{R}} b - c b r_e^{\mathrm{R}} + \beta^2 (\varepsilon_H - \varepsilon_L) + \varepsilon_L}{2b}. \tag{4.8}$$

The effect of parameters on p_{2e}^{R} is similar to that of p_{1e}^{R}.

The manufacturer's profit can be expressed as

$$\Pi_{2m}^{\mathrm{R}} = w_2^{\mathrm{R}} q^{\mathrm{R}} - \left(c q^{\mathrm{R}} - B\right)\left(1 + r_e^{\mathrm{R}}\right) - B. \tag{4.9}$$

Proposition 4.5. *In mode R, when the manufacturer finance from the platform, the optimal wholesale price of the manufacturer is*

$$w_2^{\mathrm{R}^*} = \frac{a + bc\left(1 + r_e^{\mathrm{R}}\right) + (2-\beta)\beta\varepsilon_H + (1-\beta)^2 \varepsilon_L}{2b}. \tag{4.10}$$

Proposition 4.5 indicates that the only difference between $w_2^{\mathrm{R}^*}$ and $w_1^{\mathrm{R}^*}$ is the interest rates. Substitute the equations (4.8), (4.10) into the profit function of the platform, we can get the optimal interest rate of the platform.

Proposition 4.6. *In mode R, when the manufacturer finance from the platform, the optimal interest rate of the platform is*

$$r_e^{\mathrm{R}^*} = 0. \tag{4.11}$$

In our study, we assume that the manufacturer has no outside default risk. In mode R, when the manufacturer completes the delivery and receives the payment from the platform, she can always cover her loan. In other words, the platform does not have any financing risks, and a positive interest rate will inevitably make the platform profitable. However, the increase in interest rate also leads to an increase in wholesale and retail prices, which increases the ordering cost of the platform and reduces market demand. This is not cost-effective for the platform. Therefore, the platform is willing to give up the financing income and only maintain a state of no loss in exchange for lower cost and higher demand to maximize the overall income. This conclusion is similar to Murali *et al.* [24]'s research, that is, when an enterprise has two related businesses, in some cases, the enterprise is willing to abandon one of them to better achieve the other.

By comparing different financing strategies of the manufacturer in mode R, we obtain Corollary 4.7.

Corollary 4.7. *In mode R, by comparing the optimal decisions of the manufacturer and the platform, we have*

(1) $r_b^{\mathrm{R}^*} > r_e^{\mathrm{R}^*}$, $w_1^{\mathrm{R}^*} > w_2^{\mathrm{R}^*}$, $p_{1e}^{\mathrm{R}^*} > p_{2e}^{\mathrm{R}^*}$;
(2) $\Pi_{1m}^{\mathrm{R}^*} < \Pi_{2m}^{\mathrm{R}^*}$, $\Pi_{1e}^{\mathrm{R}^*} < \Pi_{2e}^{\mathrm{R}^*}$.

Corollary 4.7 indicates that in mode R, when the manufacturer finances from a bank, the interest rate, wholesale price and retail price are always higher than when it finances from the platform. As we summarized in Proposition 4.6, the platform is willing to provide interest-free loans to the manufacturer, which reduces the cost of the manufacturer. Therefore, the manufacturer is willing to provide a lower wholesale price, which in turn allows the platform to set a lower retail price. These further lead to a reduction in the cost of the manufacturer and the platform, and increase the market demand. Both the manufacturer and the platform can benefit from finance service of the platform.

5. The mode A

In this section, we discuss the optimal operational and financial decisions of the manufacturer when she chooses the agency mode of the platform.

5.1. Finance from a bank

When the manufacturer decides to finance from a bank, the sequence of events are as follows. First, the bank decides the interest rate r_b^{A}. Then, according to the interest rate, the manufacturer decides the retail price p_{1m}^{A}. We solve this Stackelberg game in reverse order.

The manufacturer's profit can be expressed as

$$\Pi_{1m}^{\mathrm{A}} = \beta\big[(1-\lambda)p_{1m}^{\mathrm{A}}q^{\mathrm{A}} - \big(cq^{\mathrm{A}} - B\big)\big(1 + r_b^{\mathrm{A}}\big)\big] - B. \tag{5.1}$$

So we can conclude in Proposition 5.1:

Proposition 5.1. *In mode A, when the manufacturer finance from a bank, the optimal retail price of the manufacturer is*

$$p_{1m}^{\mathrm{A}^*} = \frac{(1-\lambda)a + bc(1+r_b^{\mathrm{A}}) + (1-\lambda)\varepsilon_H}{2b(1-\lambda)}. \tag{5.2}$$

Proposition 5.1 indicates that given the interest rate, $p_{1m}^{\mathrm{A}^*}$ increases with a, ε_H, c, λ but decreases with b. Because a and ε_H increase the market demand, c and λ increase the costs of the manufacturer, all these will increase the retail price. Similarly, increased price sensitivity will still lower the retail price.

The bank's profit function can be expressed as

$$\Pi_b^{\mathrm{A}} = \beta\big(cq^{\mathrm{A}} - B\big)\big(1 + r_b^{\mathrm{A}}\big) + (1-\beta)(1-\lambda)p_{1m}^{\mathrm{A}}\big(a - bp_{1m}^{\mathrm{A}} + \varepsilon_L\big) - \big(cq^{\mathrm{A}} - B\big). \tag{5.3}$$

Then we can acquire Proposition 5.2:

Proposition 5.2. *In mode A, when the manufacturer finance from a bank, the optimal interest rate of the bank is*

$$r_b^{\mathrm{A}^*} = \frac{(1-\lambda)ac\beta - bc^2\beta - 2(1-\lambda)B\beta + c(1-\lambda)[(2\beta-1)\varepsilon_H + (1-\beta)\varepsilon_L]}{(1+\beta)bc^2}. \tag{5.4}$$

Because the manufacturer has a risk of bankruptcy, when he borrows a larger amount from the bank (a larger a), the bank prefers a higher interest rate to balance the risk. When he borrows a smaller amount from the bank (a larger B or b), the bank will use a lower interest rate. When considering β, an increase in β will simultaneously increase the amount of borrowing and reduce the risk of bankruptcy, which will have two opposite effects on interest rates. Specifically, when B is relatively low $\left(B < \frac{ac(1-\lambda) - bc^2 + c(1-\lambda)(3\varepsilon_H - 2\varepsilon_L)}{2(1-\lambda)}\right)$, the increase in β mainly increases the amount of borrowing, which leads to a larger interest rate. When B is relatively high $\left(B > \frac{ac(1-\lambda) - bc^2 + c(1-\lambda)(3\varepsilon_H - 2\varepsilon_L)}{2(1-\lambda)}\right)$, the increase in β mainly reduces the risk of bankruptcy, which leads to a smaller interest rate.

In this model, the platform does not make any decisions. The platform's profit can be expressed as

$$\Pi_{1e}^{\mathrm{A}} = \lambda p_{1m}^{\mathrm{A}^*}\Big(a - bp_{1m}^{\mathrm{A}^*} + \mu\Big). \tag{5.5}$$

5.2. Finance from the platform

When the manufacturer decides to finance from the platform, the platform decides the interest rate r_e^{A}, then, the manufacturer decides the retail price p_{2m}^{A}.

The manufacturer's profit can be expressed as

$$\Pi_{2m}^{\mathrm{A}} = \beta\big[(1-\lambda)p_{2m}^{\mathrm{A}}q^{\mathrm{A}} - \big(cq^{\mathrm{A}} - B\big)\big(1+r_e^{\mathrm{A}}\big)\big] - B. \tag{5.6}$$

So we can conclude in Proposition 5.3:

Proposition 5.3. *In mode A, when the manufacturer finance from the platform, the optimal retail price of the manufacturer is*

$$p_{2m}^{\mathrm{A}^*} = \frac{(1-\lambda)a + bc\big(1+r_e^{\mathrm{A}}\big) + (1-\lambda)\varepsilon_H}{2b(1-\lambda)}. \tag{5.7}$$

Proposition 5.3 indicates that the only difference between $p_{1m}^{\mathrm{A}^*}$ and $p_{2m}^{\mathrm{A}^*}$ is the interest rate. Therefore, we next focus on the optimal interest rate decision.

The platform's profit function can be expressed as

$$\Pi_{2e}^{\mathrm{A}} = \lambda p_{2m}^{\mathrm{A}^*}\Big(a - bp_{2m}^{\mathrm{A}^*} + \mu\Big) + \beta\big(cq^{\mathrm{A}} - B\big)\big(1+r_e^{\mathrm{A}}\big) + (1-\beta)(1-\lambda)p_{2m}^{\mathrm{A}}\big(a - bp_{2m}^{\mathrm{A}} + \varepsilon_L\big) - \big(cq^{\mathrm{A}} - B\big). \tag{5.8}$$

Then we can acquire Proposition 5.4:

Proposition 5.4. *In mode A, when the manufacturer finance from the platform, the optimal interest rate of the platform is*

$$r_e^{\mathrm{A}^*} = \frac{(1-\lambda)^2 ac\beta - bc^2(\beta - \lambda\beta + \lambda) - 2(1-\lambda)^2 B\beta + c(1-\lambda)[(2\beta - \lambda\beta - 1)\varepsilon_H + (1-\beta)\varepsilon_L]}{[1+\beta(1-\lambda)]bc^2}. \tag{5.9}$$

$r_e^{\mathrm{A}^*}$ has similar properties to $r_b^{\mathrm{A}^*}$, which has been explained under Proposition 5.2. Next, we compare the optimal decisions and optimal profits under the two financing options.

Corollary 5.5. *In mode A, by comparing the equilibrium solutions of the manufacturer and the platform, we can conclude that*

(1) $r_b^{\mathrm{A}^*} > r_e^{\mathrm{A}^*}$, $p_{1m}^{\mathrm{A}^*} > p_{2m}^{\mathrm{A}^*}$;
(2) $\Pi_{1m}^{\mathrm{A}^*} < \Pi_{2m}^{\mathrm{A}^*}$, $\Pi_{1e}^{\mathrm{A}^*} < \Pi_{2e}^{\mathrm{A}^*}$.

Compared with the bank who purely rely on financing to make a profit, the platform can also benefit from sales. When the platform provides financing service to the manufacturer, higher interest rate can obtain more financing revenue. But due to the increase in price and the decrease in demand, the sales revenue of the platform will be damaged. Therefore, the platform is willing to provide a lower interest rate. Even though this will reduce financing revenue, it effectively increases market demand and sales revenue. In this way, the manufacturer can benefit from lower interest rate and higher market demand, and the platform can obtain additional financing revenue, thus increasing their profits.

6. The mode RA

In this section, we discuss the optimal operational and financial decisions of the manufacturer when she chooses both the reseller and agency modes of the platform.

6.1. Finance from a bank

When the manufacturer decides to finance from a bank, the sequence of events are as follows. First, the bank decides the interest rate r_b^{RA}. Then, the manufacturer decides both the wholesale price w_1^{RA} and retail price of the agency mode p_{1m}^{RA}. Finally, the platform decides his retail price of reseller mode p_{1e}^{RA}.

At the end of the selling season, the platform's profit can be expressed as

$$\begin{aligned}\Pi_{1e}^{\mathrm{RA}} = {} & \beta p_{1e}^{\mathrm{RA}} q_e^{\mathrm{RA}} + (1-\beta)p_{1e}^{\mathrm{RA}}\left[\theta(a+\varepsilon_L) - bp_{1e}^{\mathrm{RA}} + dp_{1m}^{\mathrm{RA}}\right] - w_1^{\mathrm{RA}} q_e^{\mathrm{RA}} \\ & + \lambda p_{1m}^{\mathrm{RA}}\left\{\beta q_m^{\mathrm{RA}} + (1-\beta)\left[(1-\theta)(a+\varepsilon_L) - bp_{1m}^{\mathrm{RA}} + dp_{1e}^{\mathrm{RA}}\right]\right\}. \end{aligned} \tag{6.1}$$

In mode RA, the profit of the platform includes the reseller channel's profit (the first three parts) and the agency channel's profit (the forth part). The platform's optimal retail price decision can be summarized as follows:

Proposition 6.1. *In mode RA, when the manufacturer finance from a bank, the optimal retail price of reseller mode is*

$$p_{1e}^{\mathrm{RA}^*} = \frac{\theta a + w_1^{\mathrm{RA}} b + (1+\lambda)dp_{1m}^{\mathrm{RA}} + \theta\left[\beta^2(\varepsilon_H - \varepsilon_L) + \varepsilon_L\right]}{2b}. \tag{6.2}$$

Proposition 6.1 indicates that the platform's retail price increases with p_{1m}^{RA}. Due to price competition, when agency channel increases the price, the price of the reseller channel will also increase. At the same time, the increase in w_1^{RA} increases the cost of the platform, so he increases the retail price to keep profitability. In addition, for the given p_{1m}^{RA} and w_1^{RA}, the increases of θ and d increase the market demand which lead to a higher retail price of the platform.

The manufacturer's profit can be expressed as

$$\Pi_{1m}^{\mathrm{RA}} = \beta\left\{w_1^{\mathrm{RA}} q_e^{\mathrm{RA}} + (1-\lambda)p_{1m}^{\mathrm{RA}} q_m^{\mathrm{RA}} - \left[c\left(q_e^{\mathrm{RA}} + q_m^{\mathrm{RA}}\right) - B\right]\left(1 + r_b^{\mathrm{RA}}\right)\right\} - B. \tag{6.3}$$

Proposition 6.2. *In mode RA, when the manufacturer finance from a bank, the optimal retail price and wholesale price of the manufacturer are*

$$p_{1m}^{\mathrm{RA}^*} = \frac{(1-\lambda)aX_1 - c\left(1+r_b^{\mathrm{RA}}\right)\left(d^2-b^2\right) + (1-\lambda)X_2}{2(1-\lambda)(b^2-d^2)} \tag{6.4}$$

$$w_1^{\mathrm{RA}^*} = \frac{abY_1 + bc\left(1+r_b^{\mathrm{RA}}\right)\left(b^2-d^2\right) + \varepsilon_H Y_2 + \varepsilon_L Y_3}{2b(b^2-d^2)} \tag{6.5}$$

where $X_1 = b(1-\theta) + d\theta$, $X_2 = [b(1-\theta) + d\beta\theta]\varepsilon_H + d(1-\beta)\theta\varepsilon_L$, $Y_1 = (\theta - \lambda + \lambda\theta)b + (1-\theta-\lambda\theta)d$, $Y_2 = \beta\theta\left[(2-\beta)b^2 - (1-\beta+\lambda)d^2\right] + bd(1-\lambda)(1-\theta)$, $Y_3 = (1-\beta)\theta[(1-\beta)b^2 - (\lambda-\beta)d^2]$.

Proposition 6.2 indicates that given a r_b^{RA}, an increase in demand (a, β, ε_H, ε_L, $(1-\theta)$) or cost (c, λ) can lead to an increase in the retail price of the manufacturer. When r_b^{RA} increases, the wholesale price and the retail price of the manufacturer increases which leads to the increase of platform's retail price.

For the bank, its profit function can be expressed as

$$\begin{aligned}\Pi_b^{\mathrm{RA}} = {} & \beta\left[c\left(q_e^{\mathrm{RA}} + q_m^{\mathrm{RA}}\right) - B\right]\left(1 + r_b^{\mathrm{RA}}\right) + (1-\beta)\left\{w_1^{\mathrm{RA}} q_e^{\mathrm{RA}} + (1-\lambda)p_{1m}^{\mathrm{RA}}\left[(1-\theta)(a+\varepsilon_L) - bp_{1m}^{\mathrm{RA}} + dp_{1e}^{\mathrm{RA}}\right]\right\} \\ & - \left[c\left(q_e^{\mathrm{RA}} + q_m^{\mathrm{RA}}\right) - B\right]. \end{aligned} \tag{6.6}$$

$r_b^{\mathrm{RA}^*}$ is the interest rate that maximizes equation (6.6). Because the form is too complicated, we will not discuss it in detail.

6.2. Finance from the platform

When the manufacturer decides to finance from the platform, the sequence of events are as follows. First, the platform decides the interest rate r_e^{RA}. Then, the manufacturer decides both the wholesale price w_2^{RA} and retail price of the agency mode p_{2m}^{RA}. Finally, the platform decides his retail price of reseller mode p_{2e}^{RA}. We solve this Stackelberg game in reverse order.

At the end of the selling season, the platform's profit can be expressed as

$$\begin{aligned}\Pi_{2e}^{\mathrm{RA}} = {} & \beta p_{2e}^{\mathrm{RA}} q_e^{\mathrm{RA}} + (1-\beta) p_{2e}^{\mathrm{RA}}\left[\theta(a+\varepsilon_L) - b p_{2e}^{\mathrm{RA}} + d p_{2m}^{\mathrm{RA}}\right] - w_2^{\mathrm{RA}} q_e^{\mathrm{RA}} \\ & + \lambda p_{2m}^{\mathrm{RA}}\left\{\beta q_m^{\mathrm{RA}} + (1-\beta)\left[(1-\theta)(a+\varepsilon_L) - b p_{2m}^{\mathrm{RA}} + d p_{2e}^{\mathrm{RA}}\right]\right\} \\ & + \beta\left[c(q_e^{\mathrm{RA}} + q_m^{\mathrm{RA}}) - B\right]\left(1 + r_e^{\mathrm{RA}}\right) + (1-\beta)\left\{w_2^{\mathrm{RA}} q_e^{\mathrm{RA}}\right. \\ & \left. + (1-\lambda) p_{2m}^{\mathrm{RA}}\left[(1-\theta)(a+\varepsilon_L) - b p_{2m}^{\mathrm{RA}} + d p_{2e}^{\mathrm{RA}}\right]\right\} - \left[c\left(q_e^{\mathrm{RA}} + q_m^{\mathrm{RA}}\right) - B\right]. \end{aligned} \tag{6.7}$$

So we can conclude in Proposition 6.3:

Proposition 6.3. *In mode RA, when the manufacturer finance from the platform, the optimal retail price of reseller mode is*

$$p_{2e}^{\mathrm{RA}^*} = \frac{\theta a + w_2^{\mathrm{RA}} b\beta + (2-\beta+\beta\lambda) d p_{2m}^{\mathrm{RA}} + c(b-d)\left[1 - \beta\left(1 + r_e^{\mathrm{RA}}\right)\right] + \theta\left[\beta^2(\varepsilon_H - \varepsilon_L) + \varepsilon_L\right]}{2b}. \tag{6.8}$$

We further analyze the manufacturer's decisions. The manufacturer's profit can be expressed as

$$\Pi_{2m}^{\mathrm{RA}} = \beta\left\{w_2^{\mathrm{RA}} q_e^{\mathrm{RA}} + (1-\lambda) p_{2m}^{\mathrm{RA}} q_m^{\mathrm{RA}} - [c(q_e^{\mathrm{RA}} + q_m^{\mathrm{RA}}) - B](1 + r_e^{\mathrm{RA}})\right\} - B. \tag{6.9}$$

Then we can come to Proposition 6.4:

Proposition 6.4. *In mode RA, when the manufacturer finance from the platform, the optimal retail price and wholesale price of the manufacturer are*

$$p_{2m}^{\mathrm{RA}^*} = \frac{(1-\lambda) a X_1 - c(1 + r_e^{\mathrm{RA}})(d^2 - b^2) + (1-\lambda) X_2}{2(1-\lambda)(b^2 - d^2)} \tag{6.10}$$

$$w_2^{\mathrm{RA}^*} = \frac{a Z_1 + c(b^2 - d^2) Z_2 + \beta\varepsilon_H Z_3 + (1-\beta)\theta\varepsilon_L Z_4}{2b(b^2 - d^2)\beta} \tag{6.11}$$

where $X_1 = b(1-\theta) + d\theta$, $X_2 = [b(1-\theta) + d\beta\theta]\varepsilon_H + d(1-\beta)\theta\varepsilon_L$, $Z_1 = b^2\theta + bd\beta(1-\theta)(1-\lambda) - d^2\theta(1-\beta+\beta\lambda)$, $Z_2 = d - b + \beta(2b-d)(1 + r_e^{\mathrm{RA}})$, $Z_3 = \theta(2-\beta)b^2 - \theta(2+\lambda\beta-2\beta)d^2 + bd(1-\theta)(1-\lambda)$, $Z_4 = (1-\beta)b^2 - (1+\lambda\beta-2\beta)d^2$.

Substitute the equations (6.8), (6.10), (6.11) into the profit function of the platform, we can sort out the platform's profit as a function of r_e^{RA}. $r_e^{\mathrm{RA}^*}$ is the interest rate that maximizes the platform's profit.

Due to the complexity of calculation, we will use numerical experiments to assist in comparing the decisions and profits of the manufacturer and the platform under these two financing modes. According to the realistic data of the commission rate of JD and Amazon, we set $\lambda = 0.15$. In addition, because under the mode RA, customers buy the same product on the same platform whether it is in the reseller channel or the agency channel, we assume that all customers are distributed on the two channels with equal probability, *i.e.*, $\theta = 0.5$ [35, 42]. According to the constraints $b > d$, $\varepsilon_H > \varepsilon_L$, we refer to the existing literature [47] to set $b = 1$, $d = 0.5$, $\varepsilon_H = 1.5$ and $\varepsilon_L = 0$. Other parameters are set as: $a = 1$, $\beta = 0.9$ and $B = 0.1$ [41, 47]. We show how the optimal interest rates of mode RA are affected by c in Figure 1.

Figure 1 shows that the optimal interest rates in mode RA first increase and then decrease with c. When c is relatively low, the increase in c increases the total amount of borrowings, and the increase in financing risk leads to an increase in interest rate. When c continues to increase, the retail price also continue to increase,

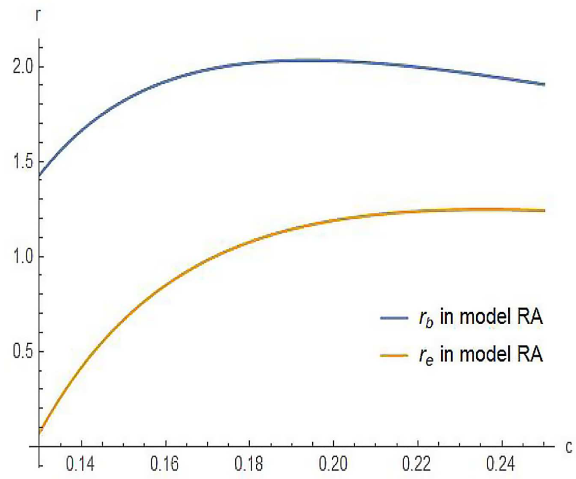

FIGURE 1. The optimal interest rates under different c.

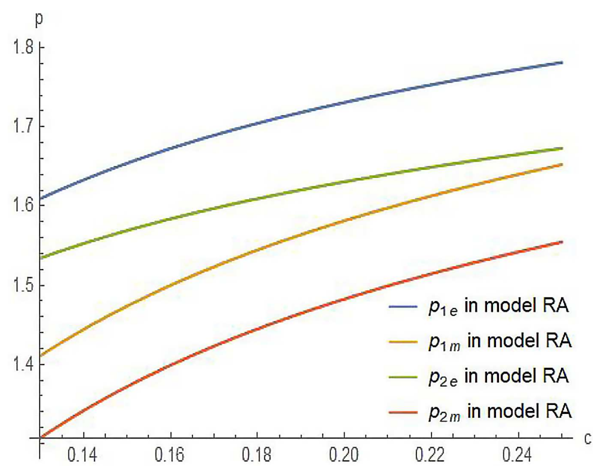

FIGURE 2. The optimal retail prices under different c.

and the decrease in demand reduces the total amount of borrowings. At this time, the financing risk decreases and the interest rate also decreases. Figure 1 also shows that the interest rate of the platform is always lower than that of the bank, because the platform has an incentive to exchange lower interest rate for lower retail prices, thereby increasing total demand. This is determined by the dual roles of the platform (loan provider and transaction participant).

Then, we show the optimal retail prices under these two financing modes.

Figure 2 shows that retail prices increase with c. In addition, whether it is the retail price of the platform or the retail price of the manufacturer, the retail prices are always lower when financing from the platform because of the lower interest rate of the platform. In the same financing mode, the price of the platform is always higher than the price of the manufacturer. This is due to the double marginal effect of the platform's reseller mode.

Figure 3 shows that wholesale prices increase with c. We also find that when c is relatively low, the wholesale price of financing from the bank is higher, but when c is relatively high, the wholesale price of financing from

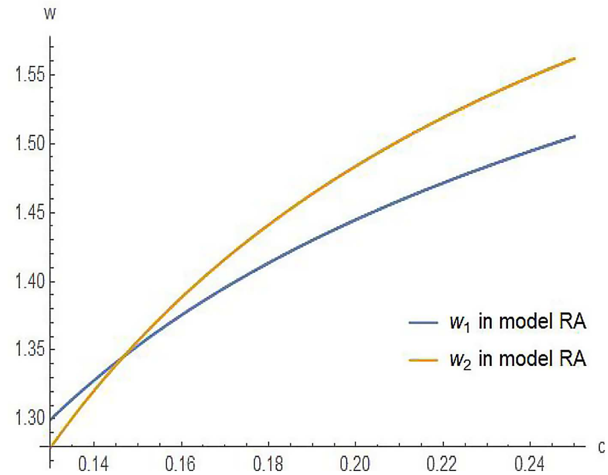

FIGURE 3. The optimal wholesale prices under different c.

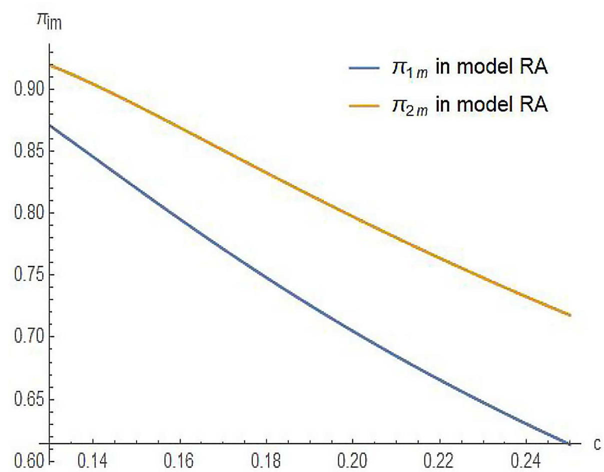

FIGURE 4. The manufacturer's profits under different c.

the platform is higher. Since when financing the platform, the manufacturer's retail price is always lower, and the marginal profit of agency channel is also lower. As c increases, the manufacturer will increase the wholesale price more to increase profit of the reseller channel.

Figures 4 and 5 show the profits of the manufacturer and the platform under different financing modes. For the manufacturer, her profit always decreases as c increases, which is consistent with intuition. Financing from the platform always enables her to obtain higher profit due to the lower interest rate. For the platform, when the manufacturer financing from the bank, the profit of the platform decreases with c. This is because the increase in price reduces the demand. But when the manufacturer financing from the platform, the profit of the platform increases with c when c is high. This is because the high c leads to a high financing revenue of platform. It is not difficult to find that the platform can always benefit from providing financing because he can obtain additional financing income.

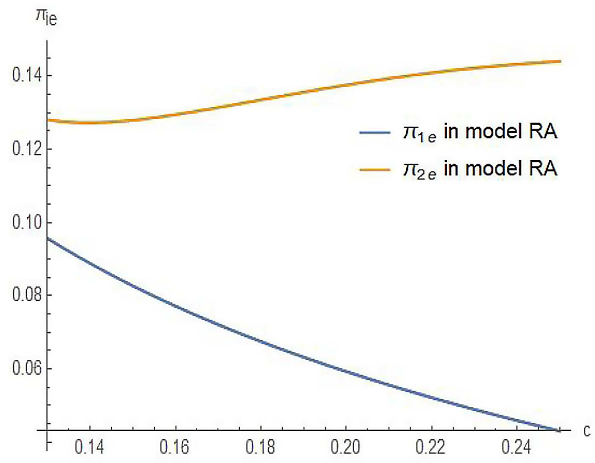

FIGURE 5. The platform's profits under different c.

So far, we have found that whether it is mode R, mode A or mode RA, the manufacturer is always more willing to finance from the platform. However, due to a series of requirements such as qualification review for financing, not all manufacturers can obtain financing provided by the platform. Under different financing modes, will the manufacturer's preference for business modes be affected? We will solve this question in the next section.

7. Manufacturer's business mode preference analysis

In this section, we analyze how financing decision affects the manufacturer's business mode preference. We use numerical experiments to show how the manufacturer's business mode preference is affected by c, b and B when financing from a bank or the platform.

7.1. The influence of c

We first show how the retail prices and the manufacturer's profits are affected by c when the manufacturer finances from the bank.

Figure 6 shows that when the manufacturer finances from the bank, the retail prices increase with c. The price under mode R is the highest, followed by the average price under mode RA, and the lowest is the price under mode A. The prices of the reseller channel are always higher than those of the agency channel, which is due to the double marginalization effect. For the manufacturer, she is always willing to choose mode A, as shown in Figure 7, because low price brings more demand. Under the three business modes, the profits of the manufacturer decrease with cost under both mode A and mode RA, because the increase of retail prices leads to a decrease in demands. But under mode R, the manufacturer's profit first increases and then decreases, because the manufacturer obtains wholesale revenue, and the marginal profit is small under mode R. When the cost is relatively low, the increase in the wholesale price increases the manufacturer's marginal profit, so the total profit will increase slightly. But when the cost is relatively high, the increase in cost will greatly reduce the demand, resulting in a decline in total profit.

But when the manufacturer finances from the platform, the results are different. Figure 8 shows that when the manufacturer finances from the platform, the retail prices also increase with c. But the lowest price is the average price of mode RA. Considering the conclusions we have drawn before, when a manufacturer finances from the platform, the prices are lower than when she finances from the bank. At this time, if the manufacturer chooses the lowest price mode, even if more demand is obtained, it is difficult to guarantee profit because the price is too low. Therefore, as shown in Figure 9, when c is low, the manufacturer chooses a slightly higher price

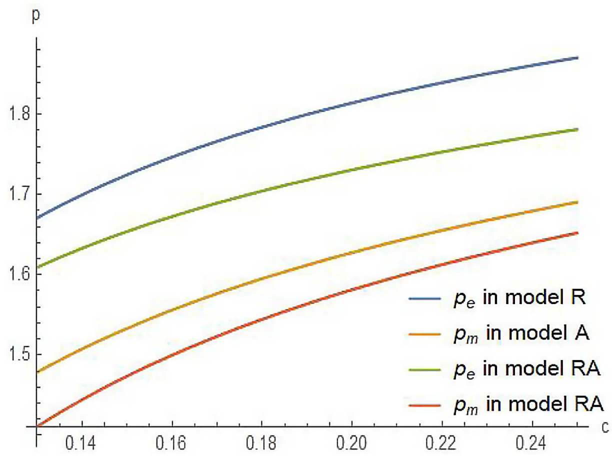

FIGURE 6. Retail prices under different c when finances from a bank.

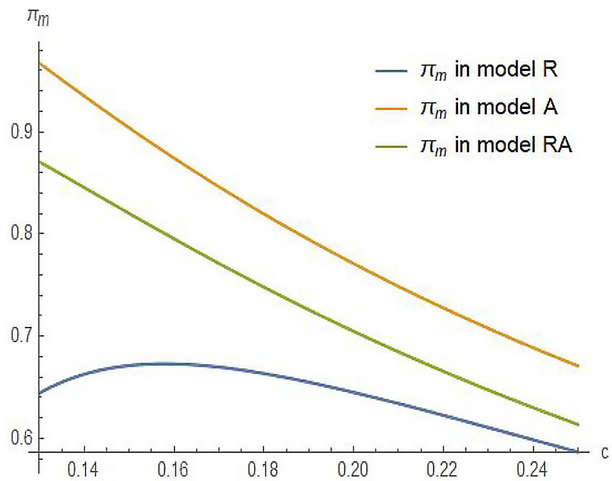

FIGURE 7. The manufacturer's profits under different c when finances from a bank.

mode, mode A, to ensure marginal profit. With the increase of c, the prices gradually rising, the manufacturer chooses the lowest price mode, model RA, to ensure sufficient demand. Different from Figure 7, in Figure 9, the manufacturer's profit in mode R decreases with the cost. The reason is that when the manufacturer finances from the platform, the platform is willing to provide interest-free interest rates under mode R. At this time, the increase in cost has little effect on wholesale price, and cannot significantly increase the marginal revenue. Therefore, the reduced demand decreases the manufacturer's profit.

7.2. The influence of b

In this section, we discuss how b affects prices and the mode preferences of the manufacturer.

Figures 10 and 11 show that as b increases, retail prices decrease with b. We have explained this result in the previous propositions. When consumers' sensitivity to prices increases, market demand will decrease accordingly. Therefore, decision makers need to lower prices to increase demand. Figures 12 and 13 show the manufacturer's

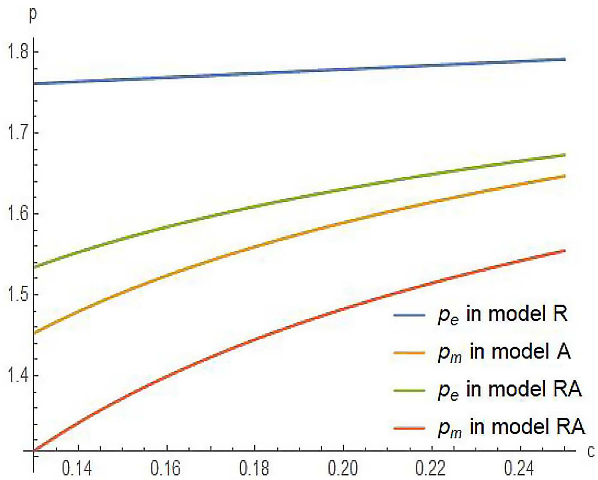

FIGURE 8. Retail prices under different c when finances from the platform.

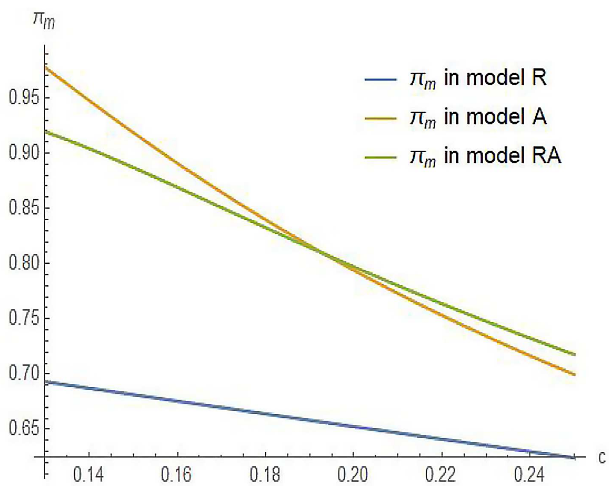

FIGURE 9. The manufacturer's profits under different c when finances from the platform.

mode preference under different b. The increase in b leads to the decrease in retail prices, so the profits of the manufacturer decrease accordingly. For the manufacturer, when b is relatively low, she can choose a mode with a high price which can ensure marginal profit. But when b is relatively high, she has to choose a mode with a low price to ensure demand. As shown in Figures 12 and 13, whether it is financing from a bank or the platform, the manufacturer always prefers the mode RA when b is relatively low, and prefers the mode A when b is relatively high. But when b is at an intermediate level, financing decision will affect the manufacturer's business mode preference. Specifically, if the manufacturer finances from the bank, she will prefer mode A, and if she finances from the platform, she will prefer mode RA. As we mentioned before, when a manufacturer finances from a bank, the retail prices will be higher. At this time, as b increases, her demand will decrease faster, so she earlier chooses a mode with more demand to ensure profit.

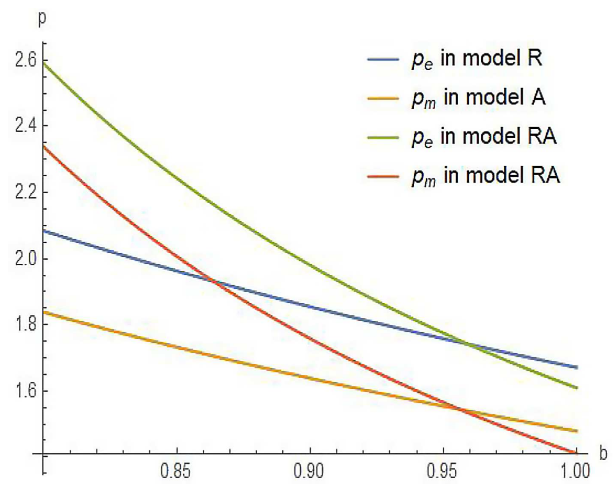

FIGURE 10. Retail prices under different b when finances from a bank.

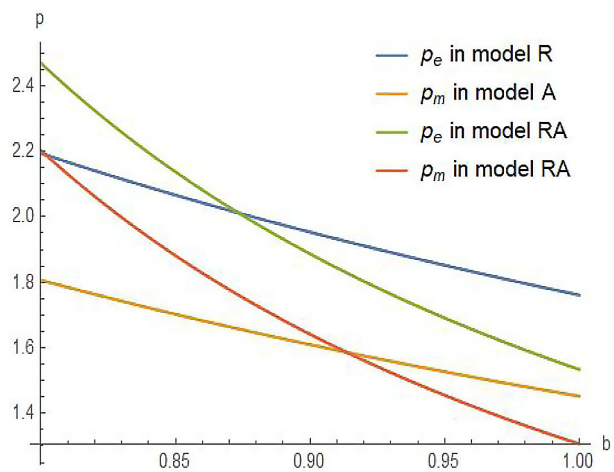

FIGURE 11. Retail prices under different b when finances from the platform.

7.3. The influence of B

In this section, we discuss how the initial capital affects prices and the mode preferences of the manufacturer.

When the manufacturer finances from a bank, Figure 14 shows that retail prices decrease with B. With the increase of B, the manufacturer's loan amount decreases, and the financing cost also decreases, resulting in a decrease in prices. Similarly, due to the double marginalization effect, the retail prices of the reseller channel are higher. Figure 15 shows that the manufacturer's profits first increase and then decrease with B which is caused by the decrease in prices. When the prices gradually decrease at a high level, the manufacturer's demands increase, leading to an increase in profits. As the prices drop further, the profits margin decrease, leading to lower profits for the manufacturer. By comparison, the manufacturer has the highest profit in mode A when finances from a bank, because the lower price in mode A brings more demand.

When the manufacturer finances from the platform, the price in mode R is not affected by B, as is shown in Figure 16. This is because in mode R, the platform is willing to provide interest-free loans, which is equivalent to

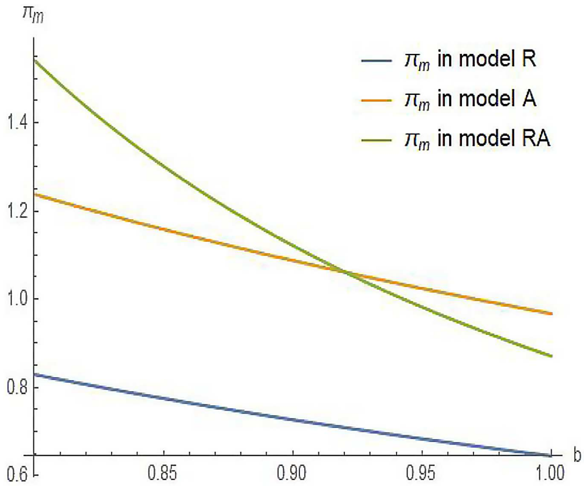

FIGURE 12. The manufacturer's profits under different b when finances from a bank.

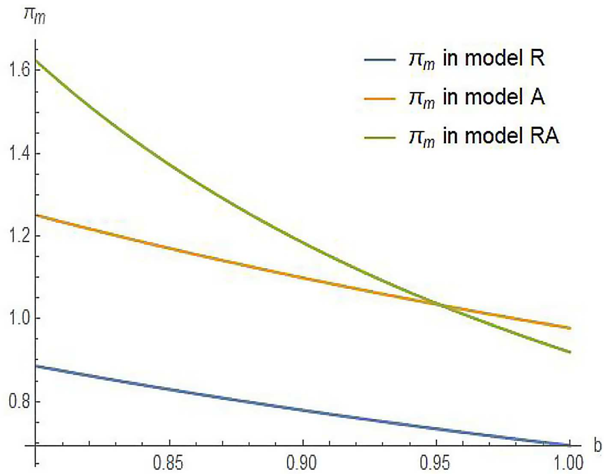

FIGURE 13. The manufacturer's profits under different b when finances from the platform.

the situation that the manufacturer has sufficient funds. Therefore, in Figure 17, the profit of the manufacturer in mode R is also not affected by B. When B is low, due to the change in interest rate, the manufacturer will be more profitable in mode RA. When B is high, the price of mode A and mode RA are both low, but the price of mode R is high, which can ensure that the manufacturer has sufficient marginal profit, so the manufacturer will choose mode R.

Through comparative analysis, we find that when the manufacturer finances from a bank, if b is relatively small, the manufacturer prefers mode RA, otherwise, mode A is her best choice. But when the manufacturer finances from the platform, she prefers mode RA when c is relatively high, b is relatively low or B is low enough, and prefers mode R when B is high enough. Otherwise, she prefers mode A. These results indicate that different financing strategies affect the manufacturer's business mode preferences. We also find that due to the double marginalization effect, the reseller channel of the platform, no matter under mode R or mode RA, usually has

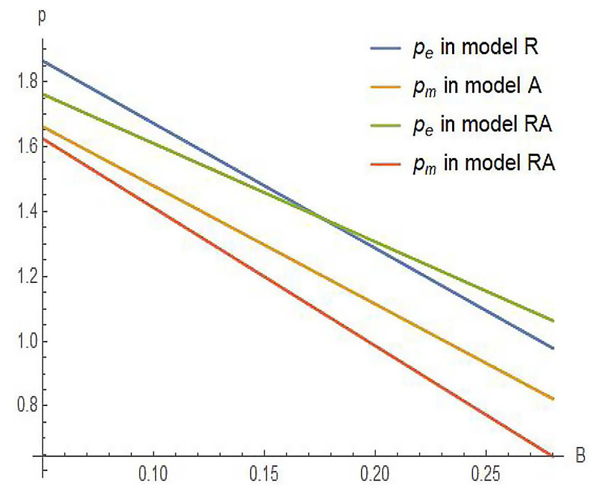

FIGURE 14. Retail prices under different B when finances from a bank.

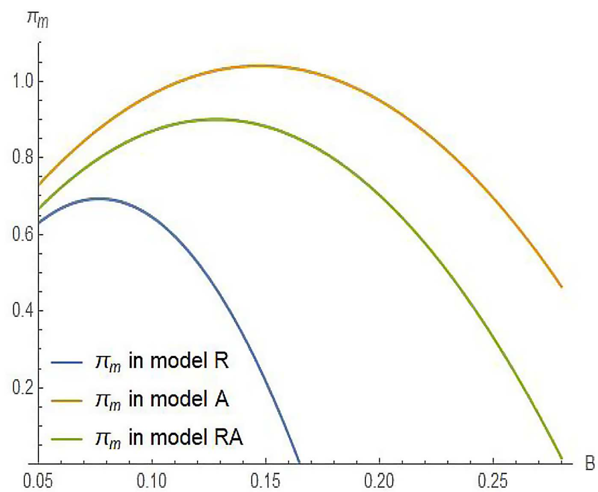

FIGURE 15. The manufacturer's profits under different B when finances from a bank.

higher retail prices than that of mode A or mode RA's agency channel, which makes the two channels have different advantages. That is, high prices can ensure sufficient marginal revenue, and low prices can ensure sufficient market demand. Although there will be competition if two channels are selected at the same time, it can also neutralize the advantages and disadvantages of price and market demand. The manufacturer needs to weigh the marginal revenue and market demand to make the best business mode choice.

8. DISCUSSIONS AND IMPLICATIONS

8.1. Discussions

In this section, we discuss the results obtained by models analysis and numerical experiments of this study.

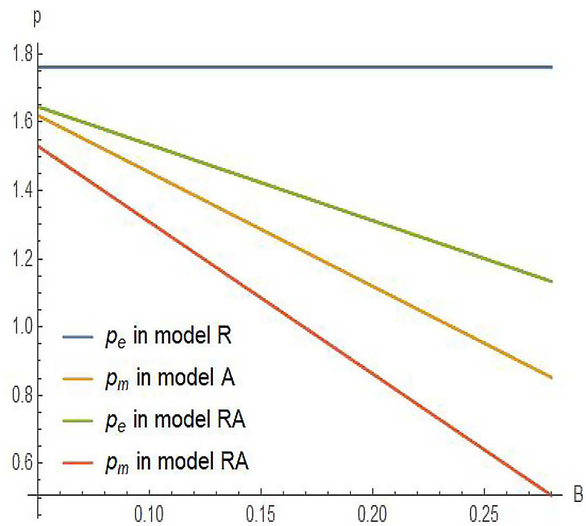

FIGURE 16. Retail prices under different B when finances from the platform.

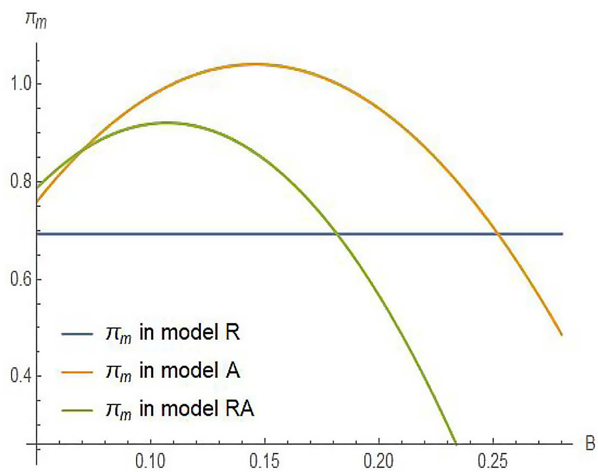

FIGURE 17. The manufacturer's profits under different B when finances from the platform.

Firstly, when considering financing decision, the platform always provides a lower interest rate. The purpose of platform providing financing service is different from that of a bank. A bank providing financing service to manufacturers is to earn interest revenue, while platform's revenue comes from two parts, including interest revenue and sales revenue. Although a higher interest rate will increase the platform's financing revenue, it also leads to higher prices and lower demand which damages sales revenue. In order to balance the two parts of the revenue, the platform can sacrifice a part of the financing revenue to increase the sales revenue, thereby promoting the increase of the overall profit. Due to the low interest, the retail prices of products are always lower under platform financing. Platform financing is a better choice for the manufacturer and the platform, because low interest saves cost for the manufacturer and low price brings more demand.The result is similar to Zhen *et al.* [47] that platform financing is a better choice for the manufacturer than bank financing. However, we find other different and interesting results when extending Zhen *et al.* [47]'s pure agency mode to both agency and reseller modes. Specifically, under the reseller mode, the platform is even willing to provide interest free loans to manufacturers without risk of external default. This makes the reseller mode potentially more advantageous than the agency mode. We further prove that if the platform has two business modes, the capital-constrained manufacturer will not always prefer the agency mode, and her preference for the business mode will be influenced by parameters such as demand sensitivity to price, production cost and initial capital.

Secondly, when considering business mode decision, the reseller channel of the platform, no matter under mode R or mode RA, usually has higher retail prices than that of mode A or mode RA's agency channel, which is due to the double marginal effect. When considering the choice of business modes, the manufacturer needs to make a trade-off between high (low) prices and low (high) demands. At the same time, different financing strategies also affect the manufacturer's business mode preference. Specifically, if the manufacturer finances from the bank, she prefers mode RA when the price is not sensitive to demand, otherwise, she prefers mode A. If the manufacturer finances from the platform, she prefers mode RA when production cost is relatively high, the price is not sensitive to demand or initial capital is low enough, and prefers mode R when initial capital is high enough. Otherwise, she prefers mode A. Based on the above results, we find that retail prices are affected by both financing decisions and business mode decisions, and further affect market demand. Changes in prices and demands will affect the profits of the manufacturer and the platform. In Wei *et al.* [35]'s study, they verified that manufacturers without capital constraints always prefer the agency mode than reseller mode. Our research shows that if the manufacturer incurs the challenge of capital constraints, the reseller mode or the mixed mode of two roles may be a better choice than the agency mode based on demand sensitivity to price, production cost and initial capital, and different financing strategies will also affect the manufacturer's mode preference.

8.2. Implications

Based on the above discussions, we put forward management implications of this study.

For a manufacturer, her profit is affected by both financing decision and business mode decision, we suggest that the manufacturer should adjust the most favorable business mode based on financing strategy. In addition, it is always advantageous for manufacturers to finance from the platform, because the platform can always provide lower financing interest rates. However, not all manufacturers can obtain financing provided by the platform. We suggest that manufacturers should try their best to obtain the qualifications to finance from the platform, such as better sales performance and higher credit levels, etc..

For a platform, we suggest that the platform should provide lower financing interest rate than a bank, and maximizing financing revenue should not be the sole goal of platform's financing decision. In addition, when the manufacturer chooses platform financing, the platform will become more profitable. Therefore, the platform should actively provide manufacturers with comprehensive financing services to attract more manufacturers to choose platform financing. At the same time, the platform should also help manufacturers who cannot obtain platform financing qualifications to meet financing requirements as soon as possible. Besides, from the results of numerical experiments, we can conclude that the diversified business modes of the platform are suitable for manufacturers with different conditions. Therefore, the platform should actively provide flexible business modes to attract more manufacturers to cooperate with the platform.

9. Conclusions

In practice, many e-commerce platforms provide reseller business mode and agency business mode for manufacturers. In addition, platforms also provide financing services for capital-constrained manufacturers. Bank financing and platform financing are both commonly used for manufacturers on the platform. In this study, we analyze a capital-constrained manufacturer's optimal financing decision (bank financing or platform financing) and business mode choice (only reseller mode, only agency mode or both of them), and analyze the interaction between financing decisions and business mode choice.

We draw the following main conclusions. Firstly, no matter in mode R, mode A or mode RA, the platform can always provide lower financing interest rate than bank, resulting in lower retail prices. Especially in the absence of other default risks of the manufacturer, the platform is willing to provide interest-free loans in mode R. Secondly, different financing strategies affect the manufacturer's business mode preference. If the manufacturer finances from the bank, she prefers mode RA when the price is not sensitive to demand, otherwise, she prefers mode A. If the manufacturer finances from the platform, she prefers mode RA when production cost is relatively high, the price is not sensitive to demand or initial capital is low enough, and prefers mode R when initial capital is high enough. Otherwise, she prefers mode A. Thirdly, although bank financing can solve the financial constraint for the manufacturer, financing from the platform always makes the manufacturer and the platform more profitable. Therefore, both the platform and the manufacturer should try their best to facilitate financing cooperation between them.

The theoretical and practical significance of this research are summarized as follows. The theoretical significance of this study is to explore how financing decisions affect the business mode choices of manufacturers on the platform, and fill the gaps in previous studies that only focused on one business mode of the platform or did not consider the impact of the manufacturer's financial constraints on business mode preference. The practical significance of this research is to provide guidance on how platforms provide financing services and how manufacturers choose the most suitable business mode based on different financing methods.

There are still some limitations in this study. First, this study assumes that the e-commerce platform provides generous financing strategy. In future research, we will further consider the situation where the platform has a loan limit for the manufacturer. Second, we only consider the decision of one manufacturer and ignore the competition among manufacturers. Therefore, we will further consider the financing and business mode decisions of manufacturers where multiple manufacturers are competing.

Appendix A.

Proof of Proposition 4.1. Taking the derivative of function (4.1) with respect to p_{1e}^{R}, we have $\frac{\mathrm{d}\Pi_{1e}^{\mathrm{R}}}{\mathrm{d}p_{1e}^{\mathrm{R}}} = -2bp_{1e}^{\mathrm{R}} + a + w_1^{\mathrm{R}}b + \beta\mu + (1-\beta)\varepsilon_L$, because $\frac{\mathrm{d}^2\Pi_{1e}^{\mathrm{R}}}{\mathrm{d}p_{1e}^{R2}} = -2b < 0$, the optimal p_{1e}^{R} satisfies $\frac{\mathrm{d}\Pi_{1e}^{\mathrm{R}}}{\mathrm{d}p_{1e}^{\mathrm{R}}} = 0$, then we have $p_{1e}^{\mathrm{R}^*} = \frac{a+w_1^{\mathrm{R}}b+\beta\mu+(1-\beta)\varepsilon_L}{2b}$. □

Proof of Proposition 4.2. Taking the derivative of function (4.3) with respect to w_1^{R}, we have $\frac{\mathrm{d}\Pi_{1m}^{\mathrm{R}}}{\mathrm{d}w_1^{\mathrm{R}}} = \left(a - bp_{1e}^{\mathrm{R}^*}\right) + \mu - \frac{w_1^{\mathrm{R}}b}{2} + \frac{bc\left(1+r_b^{\mathrm{R}}\right)}{2}$, because $\frac{\mathrm{d}^2\Pi_{1m}^{\mathrm{R}}}{\mathrm{d}w_1^{R2}} = -b < 0$, the optimal w_1^{R} satisfies $\frac{\mathrm{d}\Pi_{1m}^{\mathrm{R}}}{\mathrm{d}w_1^{\mathrm{R}}} = 0$, then we have $w_1^{\mathrm{R}^*} = \frac{a+bc\left(1+r_b^{\mathrm{R}}\right)+(2-\beta)\beta\varepsilon_H+(1-\beta)^2\varepsilon_L}{2b}$. □

Proof of Proposition 4.3. Taking the derivative of function (4.5) with respect to r_b^{R}, we have $\frac{\mathrm{d}\Pi_b^{\mathrm{R}}}{\mathrm{d}r_b^{\mathrm{R}}} = c\left(a - bp_{1e}^{\mathrm{R}^*} + \mu\right) - B - \frac{bc^2r_b^{\mathrm{R}}}{4}$, because $\frac{\mathrm{d}^2\Pi_b^{\mathrm{R}}}{\mathrm{d}r_b^{R2}} = -\frac{bc^2}{2} < 0$, the optimal r_b^{R} satisfies $\frac{\mathrm{d}\Pi_b^{\mathrm{R}}}{\mathrm{d}r_b^{\mathrm{R}}} = 0$, then we have $r_b^{\mathrm{R}^*} = \frac{ac-bc^2-4B+c\left[(2-\beta)\beta\varepsilon_H+(1-\beta)^2\varepsilon_L\right]}{2bc^2}$. □

Proof of Proposition 4.4. Taking the derivative of function (4.7) with respect to p_{2e}^{R}, we have $\frac{\mathrm{d}\Pi_{2e}^{\mathrm{R}}}{\mathrm{d}p_{2e}^{\mathrm{R}}} = -2bp_{2e}^{\mathrm{R}} + a + w_2^{\mathrm{R}}b - bcr_e^{\mathrm{R}} + \beta^2(\varepsilon_H - \varepsilon_L) + \varepsilon_L$, because $\frac{\mathrm{d}^2\Pi_{2e}^{\mathrm{R}}}{\mathrm{d}p_{2e}^{R2}} = -2b < 0$, the optimal p_{2e}^{R} satisfies $\frac{\mathrm{d}\Pi_{2e}^{\mathrm{R}}}{\mathrm{d}p_{2e}^{\mathrm{R}}} = 0$, then we have $p_{2e}^{\mathrm{R}^*} = \frac{a+w_2^{\mathrm{R}}b-cbr_e^{\mathrm{R}}+\beta^2(\varepsilon_H-\varepsilon_L)+\varepsilon_L}{2b}$. □

Proof of Proposition 4.5. Taking the derivative of function (4.9) with respect to w_2^{R}, we have $\frac{\mathrm{d}\Pi_{2m}^{\mathrm{R}}}{\mathrm{d}w_2^{\mathrm{R}}} = \left(a - bp_{2e}^{\mathrm{R}^*} + \mu\right) - \frac{w_2^{\mathrm{R}}b}{2} + \frac{bc\left(1+r_e^{\mathrm{R}}\right)}{2}$, because $\frac{\mathrm{d}^2\Pi_{2m}^{\mathrm{R}}}{\mathrm{d}w_2^{R2}} = -b < 0$, the optimal w_2^{R} satisfies $\frac{\mathrm{d}\Pi_{2m}^{\mathrm{R}}}{\mathrm{d}w_2^{\mathrm{R}}} = 0$, then we have $w_2^{\mathrm{R}^*} = \frac{a+bc\left(1+r_e^{\mathrm{R}}\right)+(2-\beta)\beta\varepsilon_H+(1-\beta)^2\varepsilon_L}{2b}$. □

Proof of Proposition 4.6. Taking the derivative of function (4.7) with respect to r_e^{R}, we have $\frac{\mathrm{d}\Pi_{2e}^{\mathrm{R}}}{\mathrm{d}r_e^{\mathrm{R}}} = -B < 0$, then we have $r_e^{\mathrm{R}^*} = 0$. □

Proof of Corollary 4.7. Substitute equations (4.4), (4.6) into equation (4.2), substitute equations (4.10), (4.11) into equation (4.8), we have $r_b^{\mathrm{R}^*} > r_e^{\mathrm{R}^*}$, $w_1^{\mathrm{R}^*} > w_2^{\mathrm{R}^*}$, $p_{1e}^{\mathrm{R}^*} > p_{2e}^{\mathrm{R}^*}$. Let $D = a - bc + (2-\beta)\beta\varepsilon_H + (1-\beta)^2\varepsilon_L$, $\Pi_{1m}^{\mathrm{R}^*} = \frac{-48B^2+24BcD+c^2D^2}{32bc^2}$, $\Pi_{2m}^{\mathrm{R}^*} = \frac{D^2}{8b}$. $\Pi_{1m}^{\mathrm{R}^*}$ is a concave function of B. When $B = \frac{cD}{4}$, $\Pi_{1m}^{\mathrm{R}^*}$ is the maximum where $\Pi_{1m}^{\mathrm{R}^*} = \frac{D^2}{8b} = \Pi_{2m}^{\mathrm{R}^*}$. From the premise $cq^{\mathrm{R}^*} > B$, we have $B < \frac{cD}{4}$. So $\Pi_{1m}^{\mathrm{R}^*} < \Pi_{2m}^{\mathrm{R}^*}$. Next we compare the profit of the platform. Because $r_e^{\mathrm{R}^*} = 0$, given a w, we have $p_{1e}^{\mathrm{R}^*} = p_{2e}^{\mathrm{R}^*}$, $\Pi_{1e}^{\mathrm{R}} = \Pi_{2e}^{\mathrm{R}} = \frac{b}{2}w^2 - \frac{w}{2}[a + (2-\beta)\beta\varepsilon_H + (1-\beta)^2\varepsilon_L] + \frac{[a+\beta^2(\varepsilon_H-\varepsilon_L)+\varepsilon_L]^2}{4b}$. It is a convex function of w. When $w = \bar{w} = \frac{a+(2-\beta)\beta\varepsilon_H+(1-\beta)^2\varepsilon_L}{b}$, $\Pi_{ie}^{\mathrm{R}^*}$ is the minimum. Because $w_2^{\mathrm{R}^*} < w_1^{\mathrm{R}^*} < \bar{w}$, we have $\Pi_{1e}^{\mathrm{R}^*} < \Pi_{2e}^{\mathrm{R}^*}$. □

Proof of Proposition 5.1. Taking the derivative of function (5.1) with respect to p_{1m}^{A}, we have $\frac{\mathrm{d}\Pi_{1m}^{\mathrm{A}}}{\mathrm{d}p_{1m}^{\mathrm{A}}} = (1-\lambda)q^{\mathrm{A}} - (1-\lambda)bp_{1m}^{\mathrm{A}} + bc\left(1+r_b^{\mathrm{A}}\right)$, because $\frac{\mathrm{d}^2\Pi_{1m}^{\mathrm{A}}}{\mathrm{d}p_{1m}^{\mathrm{A}2}} = -2(1-\lambda)b < 0$, the optimal p_{1m}^{A} satisfies $\frac{\mathrm{d}\Pi_{1m}^{\mathrm{A}}}{\mathrm{d}p_{1m}^{\mathrm{A}}} = 0$, then we have $p_{1m}^{\mathrm{A}^*} = \frac{(1-\lambda)a+bc(1+r_b^{\mathrm{A}})+(1-\lambda)\varepsilon_H}{2b(1-\lambda)}$. □

Proof of Proposition 5.2. Taking the derivative of function (5.3) with respect to r_b^{A}, we have $r_b^{\mathrm{A}^*} = \frac{(1-\lambda)ac\beta-bc^2\beta-2(1-\lambda)B\beta+c(1-\lambda)[(2\beta-1)\varepsilon_H+(1-\beta)\varepsilon_L]}{(1+\beta)bc^2}$. □

Proof of Proposition 5.3. Taking the derivative of function (5.6) with respect to p_{2m}^{A}, we have $\frac{\mathrm{d}\Pi_{2m}^{\mathrm{A}}}{\mathrm{d}p_{2m}^{\mathrm{A}}} = (1-\lambda)q^{\mathrm{A}} - (1-\lambda)bp_{2m}^{\mathrm{A}} + bc\left(1+r_e^{\mathrm{A}}\right)$, because $\frac{\mathrm{d}^2\Pi_{2m}^{\mathrm{A}}}{\mathrm{d}p_{2m}^{\mathrm{A}2}} = -2(1-\lambda)b < 0$, the optimal p_{2m}^{A} satisfies $\frac{\mathrm{d}\Pi_{2m}^{\mathrm{A}}}{\mathrm{d}p_{2m}^{\mathrm{A}}} = 0$, then we have $p_{2m}^{\mathrm{A}^*} = \frac{(1-\lambda)a+bc\left(1+r_e^{\mathrm{A}}\right)+(1-\lambda)\varepsilon_H}{2b(1-\lambda)}$. □

Proof of Proposition 5.4. Taking the derivative of function (5.8) with respect to r_e^{A}, the optimal r_e^{A} satisfies $\frac{\mathrm{d}\Pi_{2e}^{\mathrm{A}}}{\mathrm{d}r_e^{\mathrm{A}}} = 0$, then we have $r_e^{\mathrm{A}^*} = \frac{(1-\lambda)^2ac\beta-bc^2(\beta-\lambda\beta+\lambda)-2(1-\lambda)^2B\beta+c(1-\lambda)[(2\beta-\lambda\beta-1)\varepsilon_H+(1-\beta)\varepsilon_L]}{[1+\beta(1-\lambda)]bc^2}$. □

Proof of Corollary 5.5. $r_e^{\mathrm{A}^*} - r_b^{\mathrm{A}^*} < 0$, we have $r_e^{\mathrm{A}^*} < r_b^{\mathrm{A}^*}$, $p_{2m}^{\mathrm{A}^*} < p_{1m}^{\mathrm{A}^*}$. Substitute the expression of $p_{im}^{\mathrm{A}^*}$ into the manufacturer's profit function, we have $\Pi_m^{\mathrm{A}} = -B + B\beta(1+r) + \frac{\beta[bc(1+r)-(a+\varepsilon_L)(1-\lambda)]^2}{4b(1-\lambda)}$. It is a convex function of r. When $r = \bar{r} = \frac{ac(1-\lambda)-bc^2-2B(1-\lambda)+c(1-\lambda)\varepsilon_H}{bc^2}$, Π_m^{A} is the minimum. Because $r_e^{\mathrm{A}} < r_b^{\mathrm{A}} < \bar{r}$, we have $\Pi_{1m}^{\mathrm{A}^*} < \Pi_{2m}^{\mathrm{A}^*}$. Π_{2e}^{A} is a concave function of r, when $r = r_e^{\mathrm{A}^*}$, $\Pi_m^{\mathrm{A}}\left(r_e^{\mathrm{A}^*}\right)$ is the maximum. Therefore, $\Pi_m^{\mathrm{A}}\left(r_b^{\mathrm{A}^*}\right) = \Pi_{1e}^{\mathrm{A}} + \beta(cq^{\mathrm{A}} - B)\left(1+r_b^{\mathrm{A}}\right) + (1-\beta)(1-\lambda)p_{2m}^{\mathrm{A}}\left(a - bp_{2m}^{\mathrm{A}} + \varepsilon_L\right) - \left(cq^{\mathrm{A}} - B\right) < \Pi_m^{\mathrm{A}}\left(r_e^{\mathrm{A}^*}\right) = \Pi_{2e}^{\mathrm{A}}$, that is, $\Pi_{1e}^{\mathrm{A}} < \Pi_{2e}^{\mathrm{A}}$. □

Proof of Proposition 6.1. Taking the derivative of function (6.1) with respect to p_{1e}^{RA}, we have $\frac{\mathrm{d}\Pi_{1e}^{\mathrm{RA}}}{\mathrm{d}p_{1e}^{\mathrm{RA}}} = \theta a + w_1^{\mathrm{RA}}b + (1+\lambda)\mathrm{d}p_{1m}^{\mathrm{RA}} + \theta\left[\beta^2(\varepsilon_H - \varepsilon_L) + \varepsilon_L\right] - 2bp_{1e}^{\mathrm{RA}}$, because $\frac{\mathrm{d}^2\Pi_{1e}^{\mathrm{RA}}}{\mathrm{d}p_{1e}^{\mathrm{RA}2}} = -2b < 0$, the optimal p_{1e}^{RA} satisfies $\frac{\mathrm{d}\Pi_{1e}^{\mathrm{RA}}}{\mathrm{d}p_{1e}^{\mathrm{RA}}} = 0$, then we have $p_{1e}^{\mathrm{RA}^*} = \frac{\theta a+w_1^{\mathrm{RA}}b+(1+\lambda)dp_{1m}^{\mathrm{RA}}+\theta\left[\beta^2(\varepsilon_H-\varepsilon_L)+\varepsilon_L\right]}{2b}$. □

Proof of Proposition 6.2. Taking the partial derivative of function (6.3) with respect to p_{1m}^{RA}, w_1^{RA}, the Hessian matrix is negative definite, then we have $p_{1m}^{\mathrm{RA}^*} = \frac{(1-\lambda)aX_1-c\left(1+r_b^{\mathrm{RA}}\right)\left(d^2-b^2\right)+(1-\lambda)X_2}{2(1-\lambda)(b^2-d^2)}$, $w_1^{\mathrm{RA}^*} = \frac{abY_1+bc\left(1+r_b^{\mathrm{RA}}\right)\left(b^2-d^2\right)+\varepsilon_HY_2+\varepsilon_LY_3}{2b(b^2-d^2)}$, where $X_1 = b(1-\theta) + d\theta$, $X_2 = [b(1-\theta) + d\beta\theta]\varepsilon_H + d(1-\beta)\theta\varepsilon_L$, $Y_1 = (\theta - \lambda + \lambda\theta)b + (1-\theta-\lambda\theta)d$, $Y_2 = \beta\theta\left[(2-\beta)b^2 - (1-\beta+\lambda)d^2\right] + bd(1-\lambda)(1-\theta)$, $Y_3 = (1-\beta)\theta$ $[(1-\beta)b^2 - (\lambda-\beta)d^2]$. □

Proof of Proposition 6.3. Taking the derivative of function (6.7) with respect to p_{2e}^{RA}, we have $\frac{\mathrm{d}\Pi_{2e}^{\mathrm{RA}}}{\mathrm{d}p_{2e}^{\mathrm{RA}}} = \theta a + w_2^{\mathrm{RA}} b\beta + (2-\beta+\beta\lambda) dp_{2m}^{\mathrm{RA}} + c(b-d)[1-\beta(1+r_e^{\mathrm{RA}})] + \theta\left[\beta^2(\varepsilon_H - \varepsilon_L) + \varepsilon_L\right] - 2bp_{2e}^{\mathrm{RA}}$, because $\frac{\mathrm{d}^2\Pi_{2e}^{\mathrm{RA}}}{\mathrm{d}p_{2e}^{\mathrm{RA}2}} = -2b < 0$, the optimal p_{2e}^{RA} satisfies $\frac{\mathrm{d}\Pi_{2e}^{\mathrm{RA}}}{\mathrm{d}p_{2e}^{\mathrm{RA}}} = 0$, then we have $p_{2e}^{\mathrm{RA}^*} = \frac{\theta a + w_2^{\mathrm{RA}} b\beta + (2-\beta+\beta\lambda) dp_{2m}^{\mathrm{RA}} + c(b-d)[1-\beta(1+r_e^{\mathrm{RA}})] + \theta[\beta^2(\varepsilon_H-\varepsilon_L)+\varepsilon_L]}{2b}$. □

Proof of Proposition 6.4. Taking the partial derivative of function (6.9) with respect to p_{2m}^{RA}, w_2^{RA}, the Hessian matrix is negative definite, then we have $p_{2m}^{\mathrm{RA}^*} = \frac{(1-\lambda)aX_1 - c(1+r_e^{\mathrm{RA}})\left(d^2-b^2\right) + (1-\lambda)X_2}{2(1-\lambda)(b^2-d^2)}$, $w_2^{\mathrm{RA}^*} = \frac{aZ_1 + c(b^2-d^2)Z_2 + \beta\varepsilon_H Z_3 + (1-\beta)\theta\varepsilon_L Z_4}{2b(b^2-d^2)\beta}$, where $X_1 = b(1-\theta) + d\theta$, $X_2 = [b(1-\theta) + d\beta\theta]\varepsilon_H + d(1-\beta)\theta\varepsilon_L$, $Z_1 = b^2\theta + bd\beta(1-\theta)(1-\lambda) - d^2\theta(1-\beta+\beta\lambda)$, $Z_2 = d - b + \beta(2b-d)(1+r_e^{\mathrm{RA}})$, $Z_3 = \theta(2-\beta)b^2 - \theta(2+\lambda\beta-2\beta)d^2 + bd(1-\theta)(1-\lambda)$, $Z_4 = (1-\beta)b^2 - (1+\lambda\beta-2\beta)d^2$. □

Acknowledgements. This paper is supported by the Tianjin Philosophy and Social Science Planning Key Project (No. TJGL21-009) and National Natural Science Foundation of China (NSFC) (No.71671095). The authors would also like to express appreciation to the anonymous reviewers and editors for their very helpful comments that improved the paper.

References

[1] V. Abhishek, K. Jerath and Z.J. Zhang, Agency selling or reselling? Channel structures in electronic retailing. *Manage. Sci.* **62** (2016) 2259–2280.

[2] K. Cao, X. Xu, Y. Bian and Y. Sun, Optimal trade-in strategy of business-to-consumer platform with dual-format retailing model. *Omega* **82** (2019) 181–192.

[3] X. Chen, A model of trade credit in a capital-constrained distribution channel. *Int. J. Prod. Econ.* **159** (2015) 347–357.

[4] X. Chen and G. Cai, Joint logistics and financial services by a 3PL firm. *Eur. J. Oper. Res.* **214** (2011) 579–587.

[5] X. Chen, C. Liu and S. Li, The role of supply chain finance in improving the competitive advantage of online retailing enterprises. *Electron. Commer. Res. Appl.* **33** (2018) 100821.

[6] L. Dong, L. Ren and D. Zhang, Financing small and medium-size enterprises via retail platforms. *SSRN Electron. J.* (2018). DOI: 10.2139/ssrn.3257899.

[7] D. Gong, S. Liu, J. Liu and L. Ren, Who benefits from online financing? A sharing economy E-tailing platform perspective. *Int. J. Prod. Econ.* **222** (2020) 107490.

[8] A. Hagiu and J. Wright, Marketplace or reseller? *Manage. Sci.* **61** (2015) 184–203.

[9] S. Huang, Z.P. Fan and X. Wang, Optimal operational strategies of supply chain under financing service by a 3PL firm. *Int. J. Prod. Res.* **57** (2019) 3405–3420.

[10] J. Huang, W. Yang and Y. Tu, Financing mode decision in a supply chain with financial constraint. *Int. J. Prod. Econ.* **220** (2020) 107441.

[11] S. Huang, Z.P. Fan and N. Wang, Green subsidy modes and pricing strategy in a capital-constrained supply chain. *Transp. Res. Part E Logist. Transp. Rev.* **136** (2020) 101885.

[12] B. Jiang, K. Jerath and K. Srinivasan, Firm strategies in the "mid tail" of platform-based retailing. *Mark. Sci.* **30** (2011) 757–775.

[13] W. Jin, Q. Zhang and J. Luo, Non-collaborative and collaborative financing in a bilateral supply chain with capital constraints. *Omega* **88** (2019) 210–222.

[14] B. Jing, X. Chen and G.G. Cai, Equilibrium financing in a distribution channel with capital constraint. *Prod. Oper. Manag.* **21** (2012) 1090–1101.

[15] P. Kouvelis and W. Zhao, Financing the newsvendor: Supplier vs. bank, and the structure of optimal trade credit contracts. *Oper. Res.* **60** (2012) 566–580.

[16] P. Kouvelis and W. Zhao, Who should finance the supply chain? Impact of credit ratings on supply chain decisions. *Manuf. Serv. Oper. Manag.* **20** (2018) 19–35.

[17] B. Li, S.M. An and D.P. Song, Selection of financing strategies with a risk-averse supplier in a capital-constrained supply chain. *Transp. Res. Part E Logist. Transp. Rev.* **118** (2018) 163–183.

[18] Z. Li, S. Gilbert and G. Lai, Supplier encroachment under asymmetric information. *SSRN Electron. J.* (2012) 1–45.

[19] G. Liu, W. Zhao and X. Zhao, A new firm entry under capital constraint. *SSRN Electron. J.* (2019). DOI: 2139/ssrn.3324336.

[20] K.R. Lou and W.C. Wang, Optimal trade credit and order quantity when trade credit impacts on both demand rate and default risk. *J. Oper. Res. Soc.* **64** (2013) 1551–1556.

[21] Q. Lu, J. Gu and J. Huang, Supply chain finance with partial credit guarantee provided by a third-party or a supplier. *Comput. Ind. Eng.* **135** (2019) 440–455.

[22] B. Mantin, H. Krishnan and T. Dhar, The strategic role of third-party marketplaces in retailing. *Prod. Oper. Manag.* **23** (2014) 1937–1949.

[23] J. McAndrews and I. Nakamura, Entry-deterring debt. *J. Money Credit Banking* **24** (1992) 98–110.

[24] K. Murali, M.K. Lim and N.C. Petruzzi, The effects of ecolabels and environmental regulation on green product development. *Manuf. Serv. Oper. Manag.* **21** (2019) 519–535.

[25] J. Qin, H. Fu, Z. Wang and L. Xia, Financing and carbon emission reduction strategies of capital-constrained manufacturers in E-commerce supply chains. *Int. J. Prod. Econ.* **241** (2021) 108271.

[26] R. Rajesh, Flexible business strategies to enhance resilience in manufacturing supply chains: an empirical study. *J. Manuf. Syst.* **60** (2021) 903–919.

[27] N. Sachin and R. Rajesh, An empirical study of supply chain sustainability with financial performances of Indian firms. *Environ. Dev. Sustain.* **24** (2022) 6577–6601.

[28] Y. Shen, Platform retailing with slotting allowance and revenue sharing. *J. Oper. Res. Soc.* **69** (2018) 1033–1045.

[29] R. Tang and L. Yang, Financing strategy in fresh product supply chains under e-commerce environment. *Electron. Commer. Res. Appl.* **39** (2020) 100911.

[30] L. Tian, A.J. Vakharia, Y. Tan and Y. Xu, Marketplace, reseller, or hybrid: strategic analysis of an emerging e-commerce model. *Prod. Oper. Manag.* **27** (2018) 1595–1610.

[31] T.I. Tunca and W. Zhu, Buyer intermediation in supplier finance. *Manage. Sci.* **64** (2018) 5631–5650.

[32] C. Wang, M. Leng and L. Liang, Choosing an online retail channel for a manufacturer: direct sales or consignment? *Int. J. Prod. Econ.* **195** (2018) 338–358.

[33] C. Wang, X. Fan and Z. Yin, Financing online retailers: bank vs. electronic business platform, equilibrium, and coordinating strategy. *Eur. J. Oper. Res.* **276** (2019) 343–356.

[34] Y. Wang, Z. Yu and M. Jin, E-commerce supply chains under capital constraints. *Electron. Commer. Res. Appl.* **35** (2019) 100851.

[35] J. Wei, J. Lu and J. Zhao, Interactions of competing manufacturers' leader-follower relationship and sales format on online platforms. *Eur. J. Oper. Res.* **280** (2019) 508–522.

[36] Y. Xiao and J. Zhang, Preselling to a retailer with cash flow shortage on the manufacturer. *Omega* **80** (2018) 43–57.

[37] S. Xu, L. Fang and K. Govindan, Energy performance contracting in a supply chain with financially asymmetric manufacturers under carbon tax regulation for climate change mitigation. *Omega* **106** (2022) 102535.

[38] Q. Yan and F. Ye, Manufacturer's channel selection in a capital-constrained supply chain under bargaining game. *RAIRO: Oper. Res.* **55** (2021) S2161–S2179.

[39] N. Yan, B. Sun, H. Zhang and C. Liu, A partial credit guarantee contract in a capital-constrained supply chain: financing equilibrium and coordinating strategy. *Int. J. Prod. Econ.* **173** (2016) 122–133.

[40] Y. Yan, R. Zhao and Z. Liu, Strategic introduction of the marketplace channel under spillovers from online to offline sales. *Eur. J. Oper. Res.* **267** (2018) 65–77.

[41] N. Yan, Y. Liu, X. Xu and X. He, Strategic dual-channel pricing games with e-retailer finance. *Eur. J. Oper. Res.* **283** (2020) 138–151.

[42] N. Yan, Y. Zhang, X. Xu and Y. Gao, Online finance with dual channels and bidirectional free-riding effect. *Int. J. Prod. Econ.* **231** (2021) 107834.

[43] Y. Zennyo, Strategic contracting and hybrid use of agency and wholesale contracts in e-commerce platforms. *Eur. J. Oper. Res.* **281** (2020) 231–239.

[44] S. Zhang and J. Zhang, Agency selling or reselling: E-tailer information sharing with supplier offline entry. *Eur. J. Oper. Res.* **280** (2020) 134–151.

[45] C. Zhang, Y. Wang, Y. Liu and H. Wang, Coordination contracts for a dual-channel supply chain under capital constraints. *J. Ind. Manag. Optim.* **17** (2021) 1485–1504.

[46] Y. Zhao and R. Hou, Should a supplier engage in the marketplace? An equilibrium analysis in a hybrid-format supply chain. *RAIRO: Oper. Res.* **55** (2021) 2639–2655.

[47] X. Zhen, D. Shi, Y. Li and C. Zhang, Manufacturer's financing strategy in a dual-channel supply chain: third-party platform, bank, and retailer credit financing. *Transp. Res. Part E Logist. Transp. Rev.* **133** (2020) 101820.

[48] W. Zhuo, H. Yang, L.E. Céardenas-Barréon and H. Wan, Loss-averse supply chain decisions with a capital constrained retailer. *J. Ind. Manag. Optim.* **17** (2020) 711–732.