Third-Party Logistics Financing and Logistics Service Decision-Making Under Supplier Competition: Postprint

Authors: Ma Zhonghua, Xu Xueqin

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Abstract

This study examines the financing strategy selection problem for third-party logistics (3PL) enterprises when suppliers in competitive relationships face capital constraints. We consider a two-echelon supply chain comprising two competing suppliers and one retailer, where the 3PL enterprise provides procurement agency, logistics, and financing services to the supply chain. Specifically, we analyze the 3PL' s financing willingness decision—whether to provide financing to suppliers or not—under two scenarios: (1) when providing financing through procurement agency can secure price discounts, and (2) when additional capital costs are considered in the procurement agency process. We establish profit models for the 3PL, suppliers, and retailers under different scenarios, derive optimal pricing strategies for suppliers and retailers, and determine the optimal logistics service fee decision for the 3PL. By comparing each enterprise' s profits before and after financing, we analyze the positive effects of 3PL participation in supply chain financing. The findings reveal that 3PL financing to capital-constrained suppliers in a competitive environment can enhance the profits of the 3PL, the retailer, and the overall supply chain. Furthermore, the 3PL demonstrates greater willingness to provide financing to suppliers when accounting for its own capital costs, and the benefits to both the 3PL and retailer increase as competition among suppliers intensifies.

Full Text

Third Party Logistics Financing and Logistics Service Decision-Making Under Supplier Competition

Ma Zhonghua, Xu Xueqin
(School of Economics & Management, Shanghai Maritime University, Shanghai 201306, China)

Abstract: This paper examines the financing strategy choices of third-party logistics enterprises (3PL) when suppliers in competitive relationships face financial constraints. We consider a two-echelon supply chain composed of two competing suppliers and one retailer, where the 3PL provides procurement, logistics, and financing services for the supply chain. We analyze the 3PL' s financing willingness under two scenarios: obtaining price discounts when providing financing during procurement, and considering additional capital costs during procurement. The 3PL decides whether to provide financing to suppliers. We establish profit models for the 3PL, suppliers, and retailer under different circumstances, derive optimal pricing for suppliers and the retailer, and determine the 3PL' s optimal logistics service fee decision. By comparing enterprise profits before and after financing, we analyze the positive role of 3PL participation in supply chain financing. The research shows that providing financing to capital-constrained suppliers in competitive environments can increase the revenues of the 3PL, retailer, and overall supply chain. Moreover, 3PLs are more willing to provide financing when considering their own capital costs, and the more intense the competition between suppliers, the greater the benefits for the 3PL and retailer.

Keywords: competing suppliers; third-party logistics; supply chain financing; supply chain management

0 Introduction

Third-party logistics enterprises (3PL) have evolved from providing traditional logistics services such as warehousing and transportation to offering high-end logistics services including transaction management, settlement, sales management, and information management. Yianxunda has effectively connected transaction processes between upstream and downstream enterprises by establishing an entire supply chain ecosystem, creating dynamic enterprise alliances and increasing overall supply chain benefits. Meanwhile, capital flow issues in supply chains have attracted attention from both industry and academia. Enterprise capital shortages not only affect their own production and operations but also impact upstream and downstream enterprises, thereby influencing overall supply chain revenues. Leveraging their advantage of controlling all logistics activities, 3PLs provide strong financial support through financial services such as financing warehouses and warehouse receipt pledge, with main operational modes including: 3PL acting as an agent supervisor under bank leadership to provide financing, integrating logistics and financial services through financing warehouse models, and other models such as agency settlement, pledge loans, and unified credit authorization.

With competition among supply chains becoming the norm, financing decisions involving 3PLs have greater practical significance when considering enterprise competition. This paper examines how 3PL participation in supply chain financing affects retailer pricing decisions and contributes to increasing overall supply chain benefits when suppliers are in competitive relationships.

Theoretical research on 3PL participation in supply chain financing has attracted widespread scholarly attention. Various financing modes exist in practice, and the value of 3PLs differs when they assume different roles. Chen Xiangfeng and Zhu Daoli compared the different values of 3PLs in traditional, agency, and control roles. Lu Qihui et al. used an EOQ model to study and compare member benefits in supply chains under entrusted supervision, logistics bank, and unified credit financing modes, providing decisions on pledge rates and financing interest rates when manufacturers and logistics enterprises participate in pledge financing simultaneously. As 3PL business scope expands from traditional logistics to supply chain financing, its impact on enterprise revenues and decisions cannot be ignored: Meng Weidong and Wang Wenqian established optimal loan pricing models for banks and storage pricing models for 3PLs, providing optimal pledge financing quantity decisions for enterprises under 3PL participation, and analyzed the impact of financing on enterprise and overall supply chain revenues. Chen and Cai analyzed and compared financing channels for capital-constrained retailers from banks or 3PLs, concluding that 3PL participation yields higher benefits for enterprises and the overall supply chain through retailer ordering quantity models. In 3PL participation in supply chain financing, financing decisions not only affect overall supply chain revenues but also influence enterprise operational decisions. Sun Ximei et al. studied the relationship between pledge quantity, pledge rate, and loan interest rate, providing supplier pricing models and analyzing conditions for financing participation. Kong Wei and Ma Zhonghua introduced inventory pledge financing into supply chain trade credit financing, analyzing retailer optimal ordering decisions under 3PL participation in inventory pledge financing. Existing theoretical research on 3PL participation in supply chain financing has detailed operational modes and their impact on overall supply chain revenues and enterprise operational decisions, but all under monopolistic supply chain contexts without considering competition between enterprises or supply chains. In reality, competition is an important factor affecting enterprise decisions. This paper considers financing and logistics service decisions by 3PLs and operational decisions by retailers under supplier competition.

Another relevant research direction concerns competitive supply chains, including downstream retailer competition and upstream supplier/manufacturer competition. Research on supply chain coordination and enterprise operational decisions under competition is abundant. Zhang et al. studied supply chain coordination under demand disruptions with competing retailers. Sinha and Sarmah examined price competition and channel coordination when competing suppliers sell non-homogeneous products to a common retailer. Scholars have also noted differences between competitive and non-competitive environments: Cachon et al. studied contract selection when retailers order from competing manufacturers, showing that contracts differ from single-manufacturer scenarios. Shilei Yang et al. considered channel structure equilibrium for manufacturers selling asymmetric competing products, comparing retailer pricing decisions under three competition modes. Wang Yong et al. examined opti-

mal pricing models and profit impacts in a three-echelon supply chain with competing manufacturers under asymmetric information games. These studies considered competition's impact on enterprise decisions and overall supply chain benefits. Jiang et al. further examined decision-making in competitive supply chains with 3PL participation but did not address 3PLs providing financing to capital-constrained enterprises while participating in supply chain logistics, which is the focus of this paper.

Is 3PL financing beneficial for the enterprise and others? Furthermore, considering 3PL financing with capital gains (price discounts) and additional capital costs (interest rates), how do logistics service fee decisions change? Are capital gains or capital costs beneficial for 3PLs and other enterprises? When supply chain enterprises are in competitive relationships, how do decisions on whether 3PLs participate in financing, enterprise pricing decisions, and overall supply chain benefit optimization become affected? These are the key questions this paper addresses. This paper combines supplier competition factors with 3PL participation factors to discuss 3PL financing and logistics service fee decisions and retailer pricing decisions. Compared with existing research, innovations include: (1) considering 3PL enterprises directly participating in supply chain financing, using their capital advantages to provide financing to capital-constrained enterprises, providing procurement services for retailers, directly conducting capital transactions with suppliers and charging corresponding fees, and then making financing decisions; (2) considering competition between suppliers and examining retailer operational decisions under the combined influence of competition and capital constraints.

1 Parameters and Basic Assumptions

We consider a two-echelon supply chain comprising two competing suppliers and one retailer. Supplier 1 supplies product 1, and supplier 2 supplies product 2. The two products are partially substitutable, so when one product is insufficiently supplied, its supply portion enters the market to satisfy some consumer demand, though the other product cannot completely substitute for it. Logistics between suppliers and the retailer are handled by a third-party logistics enterprise (3PL). The 3PL purchases products from suppliers and pays for them; when products are delivered to the retailer, the 3PL collects payment and logistics service fees from the retailer. The supply chain transaction structure is shown in [Figure 1: see original paper]. Two suppliers determine wholesale prices for their products, the 3PL purchases both products from suppliers 1 and 2 and transports them to the retailer, and the retailer determines retail prices for both products to sell to the market. Product market demand is price-related and affected by both the product' s own retail price and the substitute product' s retail price.

Notation is defined as follows:

1) Decision variables

p_i: Retail price per unit of product i (retailer)
d_i: Demand quantity of product i (retailer)
w_i: Wholesale price per unit of product i (supplier)
m: Logistics service fee per unit charged by 3PL (3PL)
q: Financing amount provided by 3PL to capital-constrained supplier (3PL)

2) Auxiliary variables
c_i: Unit production cost of supplier i
c_L: Unit logistics service operating cost of 3PL
B_0: Own capital quantity of capital-constrained supplier ($B_0 \geq 0$)
q_0: Production quantity of capital-constrained supplier without financing source
α_1: Price discount ratio given by capital-constrained supplier to 3PL ($\alpha_1 > 0$)
r: Capital interest rate for 3PL financing ($0 < r < 1$)

Subscripts $k = R, S_1, S_2, L$ represent retailer, supplier 1, supplier 2, and 3PL respectively.

Based on practical relationships, we assume $w_i > c_i + m$ and $p_i > w_i + m$ hold. Demand functions for both products are continuous, and we assume market consumers are price-sensitive, meaning demand for product i decreases with its own price and increases with the substitute product' s price. For analytical convenience, we adopt inverse demand functions:

$$p_i = \theta_i - \beta d_i - \gamma d_j, \quad i = 1, 2, j \neq i$$

where θ_i represents the inherent price of product i, indicating that a product' s price is more affected by its own demand than by substitute demand. β indicates the degree to which retail price is affected by the product' s own quantity, and γ indicates the substitutability between the two products. The closer γ is to β, the greater the substitutability.

The decision sequence for relevant enterprises is as follows: First, given wholesale prices and logistics service prices for both products, the retailer determines sales prices and calculates respective demand quantities for procurement; second, the 3PL determines its optimal logistics service price to maximize profit given product wholesale prices; finally, the two suppliers determine their optimal wholesale prices, as shown in [Figure 1: see original paper]. Additionally, this paper assumes complete information symmetry between suppliers, between suppliers and the retailer, and between suppliers and the 3PL.

2 Model Establishment and Analysis

The 3PL provides procurement and logistics services for the retailer in the supply chain, charging logistics service fees. Suppliers sell different products through a

common retailer and are in competitive relationships. If one supplier has insufficient capital, insufficient product supply will affect the retailer' s revenue and pricing decisions, as well as the 3PL' s logistics service revenue. To analyze the impact of capital constraints on retailer decisions and 3PL revenue, as well as the role of 3PL participation in supply chain financing, this paper uses enterprise profits when suppliers have sufficient capital as a benchmark, comparing corresponding profits under capital constraints and 3PL financing scenarios to provide relevant enterprise decisions.

2.1 Suppliers with Sufficient Capital

When both suppliers have sufficient capital, they determine wholesale prices that maximize their profits by predicting each other' s prices, so both wholesale prices reach Nash equilibrium in competition. At this time, the 3PL only plays a logistics service role in the supply chain, purchasing products from suppliers and delivering them to the retailer. The profits of the retailer, 3PL, and two suppliers are respectively:

$$\pi_R = (p_1 - w_1 - m)d_1 + (p_2 - w_2 - m)d_2$$

$$\pi_L = (m - c_L)(d_1 + d_2)$$

$$\pi_{S_1} = (w_1 - c_1)d_1$$

$$\pi_{S_2} = (w_2 - c_2)d_2$$

Given wholesale prices and logistics fees determined by the two suppliers and 3PL, the retailer determines order quantities for each product that maximize its profit. Substituting the inverse demand functions (1) into the retailer profit function (2) and taking first-order derivatives with respect to product demand quantities and setting them to zero yields:

$$d_1^* = \frac{2\beta(\theta_1 - w_1 - m) - \gamma(\theta_2 - w_2 - m)}{4\beta^2 - \gamma^2}$$

$$d_2^* = \frac{2\beta(\theta_2 - w_2 - m) - \gamma(\theta_1 - w_1 - m)}{4\beta^2 - \gamma^2}$$

Given wholesale prices, the 3PL determines its optimal unit logistics fee to maximize profit based on the retailer' s response function (6). Taking the first-order derivative of its profit function with respect to logistics fee m and setting it to zero yields the optimal unit logistics service fee:

$$m^* = \frac{1}{2\beta}\left[c_L + \frac{\beta(\theta_1+\theta_2) - \beta(w_1+w_2) - \gamma(\theta_1+\theta_2-w_1-w_2)}{2\beta-\gamma}\right]$$

Based on the response functions of the retailer and 3PL (equations 6 and 7) and anticipating competitors' wholesale price decisions, the two suppliers determine wholesale prices that maximize their profits, forming a Nash equilibrium. Setting $\partial\pi_{S_1}/\partial w_1 = 0$ and $\partial\pi_{S_2}/\partial w_2 = 0$ simultaneously yields the optimal wholesale prices:

$$w_1^* = \frac{2\beta(\theta_1+c_1+c_L) - \gamma(\theta_2+c_2+c_L)}{4\beta-\gamma}$$

$$w_2^* = \frac{2\beta(\theta_2+c_2+c_L) - \gamma(\theta_1+c_1+c_L)}{4\beta-\gamma}$$

Substituting (8) into (6) and (7) yields the optimal solutions:

Proposition 1. When two competing suppliers have sufficient capital, they reach Nash equilibrium. The optimal wholesale prices are given by (8), the logistics service fee charged by the 3PL is given by (9), and the retailer' s optimal order quantities are given by (10).

2.2 Capital-Constrained Supplier 1

Consider supplier 1' s own capital quantity B_0, and assume this capital quantity cannot satisfy normal market demand, i.e., $B_0 < w_1 d_1^*$. At this time, supplier 1 faces capital constraints without financing support, denoted as scenario N. Supplier 1's production quantity in this situation is $q_0 = B_0/w_1$. Since products 1 and 2 are partially substitutable, when product 1' s output cannot satisfy market demand, the price-demand functions for both products become:

$$p_1 = \theta_1 - \beta q_0 - \gamma d_2$$

$$p_2 = \theta_2 - \beta d_2 - \gamma q_0$$

The profit functions for the retailer, 3PL, and two suppliers are:

$$\pi_R^N = (p_1 - w_1 - m)q_0 + (p_2 - w_2 - m)d_2$$

$$\pi_L^N = (m - c_L)(q_0 + d_2)$$

$$\pi_{S_1}^N = (w_1 - c_1)q_0$$

$$\pi_{S_2}^N = (w_2 - c_2)d_2$$

Similar to the previous solution process, we obtain the response functions for the 3PL and retailer, and the optimal wholesale prices satisfy:

$$\frac{\partial \pi_{S_1}^N}{\partial w_1} = 0, \quad \frac{\partial \pi_{S_2}^N}{\partial w_2} = 0$$

Solving these yields:

$$w_1^{N*} = \frac{(2\beta - \gamma)(\theta_1 + c_1 + c_L) - \gamma(\theta_2 + c_2 + c_L)}{4\beta - 2\gamma}$$

$$w_2^{N*} = \frac{2\beta(\theta_2 + c_2 + c_L) - \gamma(\theta_1 + c_1 + c_L)}{4\beta - \gamma}$$

Proposition 2. When one of two competing suppliers faces capital constraints, supplier 1' s optimal wholesale price is given by (19), supplier 2' s optimal wholesale price is given by (19), the 3PL' s logistics service fee is obtained by substituting (19) into (18), and the retailer' s optimal order quantities are given by (17).

Proposition 3. From $\partial d_2^*/\partial B_0 < 0$, $\partial w_2^{N*}/\partial B_0 < 0$, and $\partial m^{N*}/\partial B_0 > 0$ (when B_0 satisfies $B_0 < w_1 d_1^*$), we know that as supplier 1' s own capital quantity increases within the constraint range, supplier 2' s profit increases.

When supplier 1 faces capital shortage without financing, both suppliers' wholesale prices are relatively higher compared to the sufficient capital case, but product sales volumes are lower. For supplier 1, when its own capital quantity is small, lack of financing prevents sufficient production, resulting in low profits; when its own capital is larger, since all produced products are sold to the retailer who is in a disadvantaged negotiating position, supplier 1 sets a higher wholesale price and thus obtains greater profits than in the sufficient capital case. For supplier 2, its wholesale price increases. When supplier 1' s capital is insufficient and without financing, supplier 2' s profit is higher than when financing is provided; when supplier 1' s capital is larger and 接近 sufficient for production, supplier 2' s profit is higher in the sufficient capital case. The 3PL charges relatively lower logistics fees, and due to reduced supply of product 1, the 3PL' s profit decreases significantly. The retailer' s profit from selling product 1 is zero as all revenue is used for procurement and logistics fees, while product 2' s demand is lower and wholesale price higher, so the retailer' s overall profit also decreases substantially.

Proposition 4. When one supplier faces capital constraints without financing, both the 3PL' s and retailer' s profits decrease significantly compared to the

sufficient capital case. Since the retailer's loss outweighs the two suppliers' gains, overall supply chain efficiency decreases when suppliers face capital constraints.

2.3 3PL Provides Financing

The above analysis shows that capital shortages harm 3PL and supply chain interests. We now examine 3PL financing decisions and corresponding enterprise profits. When upstream enterprises face capital constraints, they seek financing or loans to alleviate the problem. Bank loans typically require sufficient creditworthiness and charge high interest, prompting enterprises to seek financing from downstream supply chain enterprises or third parties. To attract financing, they offer price discounts. When 3PLs accept discount contracts, logistics service prices are inevitably affected. Therefore, 3PLs helping capital-constrained suppliers face decisions on whether to accept price discount contracts. Additionally, when 3PLs provide capital to constrained enterprises, they bear capital costs. When 3PL capital turnover is high, lower capital costs are almost negligible. Thus, this paper primarily examines three scenarios: no discount and no interest rate, discount without interest rate, and no discount with interest rate, comparing enterprise profits to determine optimal logistics service pricing and discount contract acceptance decisions. The case with both discount and interest rate is similar to the no-discount-no-interest case and is omitted for brevity.

Supplier 1' s own capital quantity is B_0, and as previously assumed, B_0 satisfies $0 < B_0 < w_1 d_1^*$. First, consider the scenario where the 3PL helps supplier 1 with financing without additional capital gains or costs. The 3PL provides capital assistance based on retailer procurement demand and supplier 1' s existing capital, i.e., financing quantity $q = d_1^* - B_0/w_1$. At this time, each enterprise' s profits are the same as when both suppliers have sufficient capital. Thus, financing enables supplier 1 to supply the quantity retailers need to purchase, with sufficient production, allowing the 3PL and retailer to obtain more profit from product 1 procurement and sales, thereby solving the profit loss problem caused by supplier capital shortages.

2.3.1 No Discount, No Interest Rate When supplier 1 is capital-constrained, to obtain 3PL financial support, it is willing to offer a price discount α_1 ($\alpha_1 > 0$) on the financed portion, meaning the wholesale price for financed products is $(1 - \alpha_1)w_1$. Similarly, to satisfy retailer procurement and market demand, the 3PL helps supplier 1 with financing quantity $q = d_1 - B_0/w_1$, denoted as scenario F. The profits of each enterprise are:

$$\pi_R^F = (p_1 - w_1 - m)d_1 + (p_2 - w_2 - m)d_2$$

$$\pi_L^F = (m - c_L)(d_1 + d_2) + \alpha_1 w_1 (d_1 - B_0/w_1)$$

$$\pi_{S_1}^F = (w_1 - c_1)d_1 - \alpha_1 w_1(d_1 - B_0/w_1)$$

$$\pi_{S_2}^F = (w_2 - c_2)d_2$$

Following the same decision sequence and considering profit maximization for each enterprise, the decision results are:

Proposition 5. When one supplier faces capital constraints and the 3PL provides financing with discount but no interest rate, the financing quantity is $q = d_1 - B_0/w_1$, suppliers' optimal wholesale prices are given by (26), the 3PL' s logistics service fee is given by (25), and the retailer' s optimal order quantities are given by (24).

Proposition 6. When the 3PL finances with discount but no interest rate, for both suppliers, since $\partial w_1^{F*}/\partial B_0 > 0$ and $\partial w_2^{F*}/\partial B_0 > 0$, wholesale prices increase with own capital quantity. From $\partial m^{F*}/\partial B_0 < 0$, the unit logistics price decreases as own capital quantity increases.

Proposition 7. Under discount-without-interest-rate financing, different price discounts have different impacts on enterprise profits. For the 3PL, there exists a critical value α_0 (α_0 satisfies $\pi_L^F = \pi_L^N$) where financing profit exceeds no-financing profit when $\alpha_1 > \alpha_0$, and is lower when $\alpha_1 < \alpha_0$. Comparing retailer profits shows that for any $\alpha_1 > 0$, financing yields greater retailer profit. For supplier 1 (supplier 2), there exists a critical value α_1^* (α_2^*) where financing profit is lower than no-financing profit when $\alpha_1 < \alpha_1^*$ ($\alpha_1 < \alpha_2^*$), and greater when $\alpha_1 > \alpha_1^*$ ($\alpha_1 > \alpha_2^*$). Thus, larger discounts make financing beneficial for suppliers 1 and 2. Comparing overall supply chain profits shows that for any $\alpha_1 > 0$, financing improves overall supply chain efficiency.

2.3.3 No Discount, With Interest Rate When supplier 1 is capital-constrained, if the 3PL helps with financing, it incurs capital costs. The financing amount is $q = d_1 - B_0/w_1$, with capital interest rate r, while supplier 1 does not offer price discounts for financing. This scenario is denoted as F_r, with enterprise profits:

$$\pi_R^{F_r} = (p_1 - w_1 - m)d_1 + (p_2 - w_2 - m)d_2$$

$$\pi_L^{F_r} = (m - c_L)(d_1 + d_2) - rw_1(d_1 - B_0/w_1)$$

$$\pi_{S_1}^{F_r} = (w_1 - c_1)d_1$$

$$\pi_{S_2}^{F_r} = (w_2 - c_2)d_2$$

The decision results are:

Proposition 8. When one supplier faces capital constraints and the 3PL provides financing without discount but with interest rate, the financing quantity is $q = d_1 - B_0/w_1$, suppliers' optimal wholesale prices are given by (29), the 3PL' s logistics service fee is given by (28), and the retailer' s optimal order quantities are given by (27).

Proposition 9. When the 3PL finances without discount but with interest rate, wholesale prices for both products increase with own capital quantity. From $\partial m^{F_r*}/\partial r > 0$, the 3PL' s unit logistics service price increases as the interest rate increases.

Proposition 10. Comparing the 3PL's profit with and without financing under no-discount-with-interest-rate scenarios shows that for any realistic interest rate, financing yields higher profit. Comparing retailer profits shows financing also benefits retailers. For suppliers 1 and 2, conversely, profits are relatively lower after financing regardless of interest rate. Comparing overall supply chain profits reveals a critical interest rate value r_0 (where r_0 is large, beyond realistic ranges). When $r < r_0$, the supply chain benefits from financing; when $r > r_0$, the supply chain suffers from financing.

In summary, 3PL financing with capital gains has different impacts on enterprise profits. With different price discounts, post-financing profits for the 3PL, suppliers 1 and 2, and the overall supply chain may be higher or lower than without financing. Retailer profits benefit under all discount levels. 3PL financing with capital costs also differentially impacts enterprise profits. Under realistic conditions, for any interest rate, post-financing profits for the 3PL, retailer, and overall supply chain are higher than without financing, while the two suppliers' profits are relatively lower. Therefore, 3PL financing benefits most enterprises and the overall supply chain, but only by choosing appropriate price discounts or interest rates can the 3PL, individual enterprises, and the overall supply chain achieve optimal benefits.

3 Numerical Analysis

This section uses numerical analysis to examine the pros and cons of 3PL financing for itself and supply chain members, and discusses how supplier 1' s own capital quantity and competition intensity with supplier 2 affect financing strategies. Assuming complete information symmetry between suppliers, we set parameters as $\theta_1 = \theta_2 = 200$, $c_1 = c_2 = 25$, $c_L = 4$, $\beta = 4$, $\gamma = 2$.

When suppliers have sufficient capital, competition reaches Nash equilibrium, and the 3PL and retailer make profit-maximizing decisions. Optimal decisions and profits are: $p_1^* = p_2^* = 166.75$, $w_1^* = w_2^* = 63$, $m^* = 70.5$, $\pi_R^* = 368.521$, $\pi_L^* = 737.042$, $\pi_{S_1}^* = \pi_{S_2}^* = 210.583$.

When supplier 1' s capital is constrained, i.e., capital quantity B_0 satisfies $0 < B_0 < w_1 d_1^*$, we analyze under what conditions the 3PL is more willing

to finance. We consider three scenarios: supplier 1 constrained without financing (no financing), 3PL financing with discount only (a discount), and 3PL financing with interest rate only (an interest rate). We analyze how different B_0 values affect profits, as shown in [Figure 2: see original paper].

Analysis 1: Profit changes under different financing scenarios with varying capital quantities. When supplier 1' s own capital is small, the 3PL gains maximum benefit by providing financing with price discounts. When supplier 1' s own capital is larger, the 3PL benefits most by considering capital costs or providing financing without discounts. Supply chain enterprises show different results. When supplier 1' s capital is small, supplier 1 hopes to obtain 3PL financing without giving price discounts and refuses financing acceptance, while supplier 2 hopes supplier 1 gives discounts and obtains financing. The retailer is less sensitive to capital quantity but naturally prefers supplier 1 to give discounts and obtain financing. For the overall supply chain, maximum profit is achieved when the 3PL helps supplier 1 obtain financing with price discounts, and profits increase with more capital.

Analysis 2: Profit changes under different financing scenarios with varying competition intensity. When supplier 1 is capital-constrained, competition intensity with supplier 2 is affected, which influences enterprise profits. Under what competition intensity is 3PL financing more beneficial? We compare three scenarios (no financing, discount financing, interest rate financing) as γ varies from 0 to 3 (excluding 0), shown in [Figure 3: see original paper]. Then fixing $\gamma = 2$, we analyze profit changes as β varies from 3 to 8, shown in [Figure 4: see original paper]. These figures show that supplier competition affects all enterprises. When $\gamma \to \beta$, more intense competition reduces both suppliers' profits regardless of financing, increases retailer profits, decreases 3PL profits without financing, and increases 3PL profits with financing. For the 3PL, helping supplier 1 finance without price discounts yields higher profits when competition exists. For supplier 1, financing is preferred when competition is less intense, but not when competition is intense. For supplier 2, when competition is less intense, supplier 1 obtaining financing with price discounts yields greater profits, while when competition is intense, supplier 1 not obtaining financing yields greater profits. For the retailer, 3PL financing yields greater profits as long as supplier 1 obtains financing, with little difference between discount or interest rate scenarios. For the overall supply chain, 3PL financing with discounts yields the highest efficiency.

Analysis 3: Profit changes under different price discounts with 3PL financing. If supplier 1 hopes to attract 3PL financing through price discounts when capital-constrained, the discount ratio affects 3PL financing decisions. We compare no financing, discount financing, and interest rate financing scenarios. Assuming $B_0 = 75$, $\alpha_1 = 1.5$, $r = 0.05$, as shown in [Figure 5: see original paper]. Under discount financing, all supply chain enterprises' profits increase with larger discounts, while 3PL profits decrease. When discounts are large, supply chain enterprises and the overall chain achieve maximum profits, while

3PL profits are higher with interest rate financing. Therefore, regardless of discount size, the 3PL prefers to finance supplier 1 when considering capital costs, even though the supply chain and its members hope supplier 1 obtains financing with discounts.

Analysis 4: Profit changes under different interest rates with 3PL financing. Whether capital costs are considered affects 3PL financing decisions and service fee decisions. We analyze how different interest rates affect 3PL financing decisions and profits. Using the same curve representations as Analysis 3 and assuming $B_0 = 75$, as shown in [Figure 6: see original paper]. Supplier 1 achieves highest profits without financing, while supplier 2, the retailer, and the overall supply chain achieve highest profits when the 3PL finances supplier 1 with price discounts, and the 3PL achieves highest profits when financing with interest rates only. This result is basically consistent with previous analyses.

4 Conclusion

This paper studies a two-echelon supply chain with two competing suppliers and one retailer, where procurement and logistics services between suppliers and the retailer are provided by a 3PL. When competing suppliers face capital shortages, product supply shortage risks arise, reducing product sales and harming downstream retailer and 3PL profits. Therefore, downstream retailers hope suppliers maintain competition, and 3PLs hope both products meet market demand to obtain higher logistics revenues. For a supplier facing capital shortage, if the 3PL provides financing, different logistics service fees are charged depending on whether price discounts are obtained or capital costs are considered. This paper compares profits for the 3PL and supply chain enterprises under discount financing, capital cost financing, and no financing scenarios to analyze which financing option yields greater profits for the 3PL and overall supply chain.

Results show that when supplier 1' s own capital is small, the 3PL is willing to finance this supplier and prefers financing when considering capital costs. Supplier 1 also tends to accept financing when capital is small but refuses when capital is larger, as refusing yields greater profits. Supplier 2 shows different results from supplier 1, while the retailer expects the 3PL to help the capital-constrained supplier finance and prefers financing with supplier discounts to obtain higher profits. Overall, the two-supplier-one-retailer supply chain achieves maximum profit when the 3PL obtains price discounts while financing. Analysis also shows that more intense competition reduces suppliers' profits while increasing 3PL and retailer profits. Under any competition intensity, the 3PL will provide financing and prefers financing when considering capital costs.

This study has limitations. First, we assume complete information symmetry between enterprises, which may exist with long-term cooperation but should be relaxed in future research. Second, we assume linear demand-price relationships, while real demand is often uncertain. Future research could examine random demand scenarios and corresponding procurement and financing decisions. Addi-

tionally, both competing suppliers might face capital shortages simultaneously, raising questions about whether the 3PL would finance both, which warrants further investigation.

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Note: Figure translations are in progress. See original paper for figures.