Sourcing from supplier in the presence of financial service providers’ information asymmetry and quit probabilities

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Abstract
Purpose – Considering the financial service providers’ (FSPs) information asymmetry in evaluating the supplier and their distinct quit probabilities, we want to examine the supplier’s preference of the financing schemes if both the bank and the online platform exist and how the buyer sets the contract terms in the two financing schemes.
Design/methodology/approach – We establish a Stackelberg game model to capture the interactions among three parties, i.e. a supplier, a capital-sufficient buyer and an FSP (either a bank or an online platform), within a first-time contract.
Findings – In the non-FSPs’ quit case, the buyer’s profit is higher under the bank loan scenario, while the supplier’s profit performs adversely. The supply chain’s profit is heavily dependent on the buyer’s profit difference between the two financing schemes. Moreover, we find that the supplier borrows the money to exactly cover the production cost. The equilibrium solutions of the FSPs’ quit case and of the capital-sufficient supplier’s case are also derived.
Originality/value – First, we assign different risk profiles to different FSPs in our setting so that modeling a previously ignored but practically significant problem. Second, we innovatively take the FSP’s quit probability into account in our model. Third, we elucidate how these factors can influence the relative efficiency of the two types of financing schemes and the settings of the contract, which further complements and extends the current SCF research.
Keywords Supply chain finance, Financial service provider, Bank loan financing, Online platform financing, Risk attitude, Quit probability
Paper type Research paper

1. Introduction
It is a common phenomenon that traditional financial institutions such as banks have been subject to more rigorous regulations and limited lines of credit in providing loans since the
last economic crisis in 2008 (Chen et al., 2020). Hence, these institutions behave more conservatively when financing customers, especially for small and medium-sized enterprises (SMEs) (Yuan et al., 2022; Tseng et al., 2021). As the main pillars and driving forces of economic growth, SMEs play a significant role in both developed and developing countries (Keskünn et al., 2010). Nevertheless, they often encounter great difficulties in accessing financing from banks due to their poor credit level and fewer collaterals (Ma et al., 2022; Huang et al., 2021; Yi et al., 2021; Zhao and Wang, 2021). For instance, according to the European Central Bank (2021), the SMEs signaled a decline in the availability of bank loans since mid-2015 and over two-thirds of SMEs in Europe complained that the unsatisfied financing needs from banks may result in their bankruptcies ultimately. With the ever-evolving nature of business (Siqin et al., 2022), online platform financing has gradually drawn increasing attention. In order to fulfill SMEs’ increasing and urgent financing needs, these online financing platforms start to play a pivotal role in the financing market (Gopal and Schnabl, 2020). Besides, to facilitate economic development, today, more and more governments around the world have launched new policies to support SME’s business (Pu et al., 2021). One direction is to support the bank to lend to SMEs in a more user-friendly way instead of continuing the stubborn lending procedures. This means a low-credit SME will have opportunities to access financing from a bank. Alternatively, the other direction is to encourage online platforms to play a role in the lending market, as discussed above.

However, since online platforms perform as newcomers in the finance industry and they always confront risky customers in terms of credit level, the potential risks related to the online platforms’ businesses may be underestimated by themselves. For instance, Greensill Capital, a large and influential online platform based in the UK and Australia, filed for insolvency protection on 8 March 2021, after being founded in 2011. Greensill’s main business is providing supply chain finance (SCF) services to help its customers obtain financing in order to cover the production cost and optimize the working capital flow. The dominant reason for Greensill’s failure is its risk-seeking attitude toward the customers (Reuters, 2021). From this story, we can see how a risk profile could seriously impact a firm’s survival, albeit Greensill was regarded as a promising and leading company in the UK. Also, we consulted many online platforms that provide SCF services and extracted the apparent differences between these two types of FSPs, as presented in Table 1. It is interesting to discover that the differences in risk profiles between these two types of FSPs are significant.

As a result of the different risk attitudes of these two FSPs, the obtained information in evaluations may be multi-levels in practice, i.e. banks collect more information than online platforms. This assumption is supported by the bankruptcy of the Greensill case as well as several papers in the finance field (see, e.g. Thakor, 2020; Erel and Liebersohn, 2020). The information asymmetry is thus raised. We capture the information difference between the

<table>
<thead>
<tr>
<th>Feature</th>
<th>Bank</th>
<th>Non-bank FSP</th>
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<tbody>
<tr>
<td>Regulation</td>
<td>Strict</td>
<td>Loose</td>
</tr>
<tr>
<td>Scrutiny level</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Credit level of borrower</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Loan limit</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Collateral</td>
<td>Must have</td>
<td>Not required</td>
</tr>
<tr>
<td>Efficiency</td>
<td>Low, stubborn, slower</td>
<td>High, agile, faster</td>
</tr>
<tr>
<td>Interest rate</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Revenue</td>
<td>Interest</td>
<td>Service fee (including interest)</td>
</tr>
<tr>
<td>Risk attitude</td>
<td>Risk averse</td>
<td>Risk seeking</td>
</tr>
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</table>

Table 1. Differences between non-bank FSPs and bank

Source(s): Author’s own work
bank and the online platform in this paper and recognize the bank’s information advantage over the online platform due to its risk-averse attitude in evaluating borrowers.

In addition to the various risk attitudes, we observe that on the one hand, there still exists the possibility that the online platform quits financing after assessing the customers. This partially results from its lax evaluation technologies (e.g. the online platform cannot accurately estimate the customers’ credit level so it will mistakenly refuse to lend) (Choi et al., 2021). On the other hand, as a traditional bank, it is common sense that a bank may stop financing the customers as well due to the unstable business environment after stringent evaluations. For example, according to REUTERS, in 2014, Citigroup announced it would exit 11 countries where it was experiencing lower market returns amid a soft global economy (Henry and D’Silva, 2014). Recently, Russia’s top bank Sberbank has been enduring Western sanctions and is quitting almost all European countries due to the war between Russia and Ukraine (Reuters, 2022). Therefore, we thereby consider that the quit probability of either a bank or an online platform is dependent on their evaluations of the customers’ credit levels. Because of the different risk attitudes, the information collected from the customers is different in evaluations. This induces a bank’s and an online platform’s heterogeneous quit probabilities toward customers. This is also consistent with the classical economic theorem that there might be socioeconomic influences on the probability of loan approval (Siles et al., 1994).

Now, one may imagine that in the context of a supply chain with a capital-constrained raw material supplier, who is an SME and is involved in a contract with a capital-sufficient buyer for the first time, needs extra capital resources for production, then the choice of FSPs becomes a critical issue for him/her. The interest rate the bank charges is relatively low since it lies in a competitive financing market. Under the online platform-induced financing scheme, usually named factoring, the supplier sells the invoices to the platform at a discount rate in exchange for early payment to meet the immediate cash requirements. From the supplier’s perspective, the financing cost from the bank is lower. However, the efficiency of online financing is usually higher. For example, a loan from a bank usually takes 1 month to obtain while it can easily receive the money within 48 h from an online platform. The faster speed of cash collection can help the supplier start to produce more quickly and demonstrate a strong financial status to the buyer the first time. This helps the supplier gain the buyer’s trust via a positive impression and facilitates further collaborations in the future. Thus, the supplier has an incentive to bear a higher financing cost through borrowing from an online platform. Otherwise, due to the long-lasting time of collecting the money from a bank for production, the lead time of goods delivery is thus extended, and a bad first impression is made. As it is a first-time contract, the buyer may lack confidence in collaborating with the supplier next time because of the latter’s poor financial performance. Hence, it could cause an opportunity cost loss for the supplier, i.e. the revenue generated from the buyer’s orders in the next production period. From the buyer’s perspective, the different FSPs’ involvements can lead to distinguished operations. Because the buyer does not know the supplier’s historical behavior, the buyer can only acquire indirect information via the FSPs. That is, a bank’s involvement ensures the bank’s excellent understanding of the supplier so that the buyer may take actions more confidently; yet an online platform’s involvement is nonsense because of its loose and unstable evaluations, so the buyer will perform carefully in transactions [2].

The existing literature within the SCF field, however, neglects the study of the aforementioned questions and seldom investigates the online platform’s role as an independent FSP. Only a few exceptions exist but are of certain limitations, i.e. these studies always consider a risk-neutral FSP in transactions and ignore the fact that the FSP may probably quit (see, e.g. Ma et al., 2020; Song et al., 2018). However, as we mentioned earlier, these two factors play a significant role in comparing the efficiency of the two financing schemes for different supply chain players. Therefore, motivated by these
limitations, we attempt to shed light on studying the relative efficiency of bank loan financing and online platform financing, in the presence of the FSPs’ information asymmetry and their quit probabilities. Specifically, we raise the following research questions:

(1) The supplier needs to consider which type of FSP is preferred if both bank and online platforms exist.

(2) As a profit maximizer, what is the buyer’s profitability under these two financing schemes and how can the buyer set the contract terms via utilizing the lending message transmitted from the various FSPs?

We establish a Stackelberg game model to capture the interactions among three parties, i.e. a supplier, a capital-sufficient buyer and an FSP (either a bank or an online financing platform), within a first-time contract. The equilibrium results for each party are derived. Regarding the research gap, we contribute to the current SCF literature in the following aspects. First, we assign different risk profiles to different FSPs in our setting so that modeling a previously ignored but practically significant problem, i.e. the information asymmetry between the bank and the online platform. Second, we take the FSP’s different quit probability into account in our model to reflect practice. Third, we elucidate how these factors can influence the relative efficiency of the two types of financing schemes and the settings of the optimal contract structure, which can further complement and extend the current SCF research.

The rest of the paper is structured as follows. In Section 2, a comprehensive literature review is presented. In Section 3, the model details are illustrated. In Section 4, the optimal solutions under different financing schemes and their comparisons are given. In Section 5, the managerial insights are provided. Section 6 concludes the full paper.

2. Literature review

This study lies in the interface of operations and finance discipline, investigating the two financing schemes led by the two FSPs in a supply chain considering the FSPs’ various risk attitudes and their quit probabilities. As such, it is mainly related to bank loan literature and factoring literature in the SCF domain. In addition, this paper focuses on characterizing the pivotal role of the FSP in lending business, thus it is also relevant to the study of the financial institutions in an SCF process.

Bank loan financing is a common operation and draws extensive attention in the SCF literature, examining a wide range of issues including the comparisons between a bank loan and other financing schemes (e.g. Deng et al., 2018; Tang et al., 2018), the bank’s external role in financing SMEs (e.g. Van der Vliet et al., 2015; Kouvelis and Zhao, 2018), SCF contract design under bank loan (e.g. Kouvelis and Zhao, 2016; Yang and Birge, 2018). Specifically, Deng et al. (2018) theoretically analyze and compare the performance of bank finance and buyer finance in a supply chain. They study the optimal contract terms under bank finance and derive the supplier’s optimal order decision \( q \) and the assembler’s optimal wholesale pricing decision \( w \), respectively. They find that based on a wholesale price contract (i.e. given the retailer’s order quantity, the supplier decides the wholesale price), the decision variables of \( q \) and \( w \) are dependent. The same setting applies to Chen et al. (2020). However, we discuss and compare the performance of bank finance and online platform’s factoring scheme in a capital-constrained supply chain. Based on the buyer’s pair contract (a buyer who is in a dominant position, can decide both the order quantity and the wholesale price simultaneously in practice. An example of JD.com can be found in Tunca and Zhu (2018)), our results show that \( q \) and \( w \) are independent and we focus on illustrating how the buyer’s (or the online platform) decisions on \( q \) and \( w \) are affected by the supplier’s initial capital level \( A_0 \). In addition, we consider the supplier’s opportunity cost loss under the bank loan scenario and show how
the opportunity cost loss will impact the buyer’s decision on the contract term. Tang et al. (2018) examine the relative efficiency of purchase order financing and buyer direct financing by classifying the asset regions. Van der Vliet et al. (2015) investigate to what extent the payment delay will impact the supplier’s profitability in a bank-led reverse factoring contract. Next, compared with Kouvelis and Zhao (2018)’s work studying the supplier’s financing solutions (bank loan vs. retailer’s early payment) and the retailer’s financing solutions (bank loan vs. trade credit), they derive the optimal solutions on q and w under the combined effects of the players’ credit ratings and the financing rates, which is clearly deviated from our research focus. In addition, we consider the supplier’s credit level in our model to reflect the various risk attitudes of the bank and the online platform in operations, i.e. their distinct quit probabilities. In another paper, Kouvelis and Zhao (2016) study the optimal contract terms settings in different types of contracts, e.g. revenue-sharing, buyback and quantity discount. They develop the optimal decisions on q and w by considering the players’ default costs in loans and a revenue-sharing-induced transfer payment between the supplier and the retailer. Again, to focus on the financial service providers’ information asymmetry and quit probabilities, we solely consider the case of a pair contract, and the default risk is included in our model as well. Yang and Birge (2018) examine the risk-sharing role of trade credit by including the bank loan as a complementary financing solution. Hence, they try to answer the questions of when one should use trade credit alone and when one should use trade credit and bank loan jointly. Their results of q and w are thus subject to the trade credit terms. We instead want to answer a question of the preference of the two financing schemes for different supply chain participants (including the supply chain), so the optimal decisions of q and w are derived individually. Recently, due to technology improvement and business environment changes, new operations have been adopted in bank loans. For example, Lee et al. (2023) investigate an innovative bank-intermediated trade finance contract, dynamic trade finance (DTF), under which banks dynamically adjust loan interest rates as an order passes through different steps in the trade process. Therefore, their results more focused on the multiple thresholds of the interest rate in determining the optimal contract terms in DTF. We alternatively explore the operational decisions of the order quantity and the wholesale price in a traditional bank loan scenario and an online platform’s factoring scenario. Wang and Cai (2023) investigate the joint value of bank loans and loan insurance and reveal that both supplier and buyer enjoy the combination of bank loan and loan insurance in a cooperative environment. They derive the optimal solutions of q and w based on the range of the fixed insurance premium and the insured loan limit through a third-party insurer. This setting is thoroughly different from our model; thus the results are different either. Additionally, these previous works tend to assume that bank has weak information about the borrowers’ operational efficiency. Nonetheless, we assume the bank has better information compared with an online platform because of its risk-averse attitude in evaluations. Moreover, to the best knowledge, we are the first to contain the FSPs’ quit cases and non-quit cases in one paper. Previous literature tend to assume the FSPs would not quit with probability 1 once they are involved in SCF transactions. However, we consider this point since we observe that the real-life cases of FSPs quit emerge largely as we discussed in the introduction section. All these points are reflected in our model to differentiate our work from others as well as to be closer to reality.

Another stream of research is associated with the online platform-induced factoring literature. Chen et al. (2020) mainly study the decision of positive interest rate in an in-house factoring scheme. As for the order decision q and the wholesale pricing decision w, they follow the same way to find the optimal solutions in a wholesale price contract. Nevertheless, it is worth noting that we model the operations of the online platform based on the practice of an authentic online platform operating in the UK (Stenn, 2024), so the solutions are valid and can be directly applied to practice when borrowing from an online platform. Kouvelis and Xu
(2021) study optimal solutions of $q$ and $w$ under the forms of recourse factoring and non-recourse factoring (where the bank bears the most of the default risk because the bank does not have recourse against the supplier if default occurs) and consider the impact of players’ credit ratings. Similarly, Wang and Xu (2023) investigate the value of smart contracts and derive the optimal decisions of $q$ and $w$ in the presence of the supplier’s liquidity risk. As explained above, we consider the supplier’s credit risk, and these settings are obviously different from ours so the results are different as well. Narayanan et al. (2022) suggest a way of expediting factoring by leveraging smart contracts on a blockchain network to estimate the invoice amount at various milestone events as the freight transport from supplier to shipper. Besides, differing from the existing literature, we regard the online platform as an independent FSP that has a risk-seeking attitude and also has the probability to quit the market because of evaluation failures.

The last stream is about the characteristics of FSPs in financing SMEs. The existing literature in the SCF sector ignores the examination of FSPs’ various risk attitudes and hardly ever carefully investigates the function of the online platform. There are only a few exceptions, but they have certain restrictions, such as the fact that these studies always assume a risk-neutral FSP in transactions and overlook the possibility that the FSP may quit due to unanticipated reasons. For example, Martin and Hofmann (2017) explain the significance of the FSP’s operating role in SCF activities, while they ignore the impact of risk attitudes on the FSP’s operations. Song et al. (2018) compare SCF solutions provided by commercial banks and the third-party FSPs that help SMEs access financing. Similarly, they assume the bank and the FSPs have the same type of risk attitudes, i.e. risk-neutral. Chen et al. (2019) investigate the third-party logistics financing role in optimizing supply chain cash flow. They admit that considering the complexity of heterogeneous risk profiles of various firms may generate more intriguing results. The same limitations apply to Huang et al. (2022) and Ma et al. (2020). Moreover, as various risk attitudes induce information asymmetry between different FSPs as we mentioned earlier, we thus also examine the current operations management literature studying this issue. Schmidt et al. (2015) concentrate on the phenomena where companies signal to their suppliers when they have information advantages over them regarding future demands by announcing substantial procurement orders. In the context of investors having incomplete knowledge about the firm’s demand uncertainty, Lai and Xiao (2018) investigate the impact that management short-term market value can have on a firm’s inventory. According to recent publications like Beer et al. (2018), Zhang et al. (2020) and Chod et al. (2020), the payoffs of the relevant parties can be influenced by signaling the critical aspects that occur within the transactions under information asymmetry. Nonetheless, the information asymmetry in this paper results from the difference of the two FSPs’ collected information in evaluations. In addition, all mentioned works do not consider the FSPs’ quit probabilities. In contrast, we consider both the FSPs’ various risk attitudes and their quit probabilities in our model settings so that we can authentically reflect reality and further complement the application scenarios in SCF research (See Table 2).

3. Model
We start with the basic model description then the introduction of the two financing models follows.

3.1 Initial settings
Assume a two-layer supply chain with a capital-sufficient downstream buyer and an upstream supplier, who supplies a product to the buyer [3]. Both parties meet each other for
<table>
<thead>
<tr>
<th>Typical papers</th>
<th>Main attributes</th>
<th>Our attributes</th>
<th>Our contributions</th>
</tr>
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<tbody>
<tr>
<td>Bank loan financing</td>
<td>Bank finance vs. buyer finance</td>
<td>Bank finance vs. the online platform’s factoring scheme</td>
<td>First, we assign different risk profiles to different FSPs in our setting so that modeling a previously ignored but practically significant problem, i.e., the information asymmetry between the bank and the online platform. Second, we take the FSP’s different quit probability into account in our model to reflect practice. Third, we elucidate how these factors can influence the relative efficiency of two types of financing schemes and the settings of the optimal contract structure, which can further complement and extend the current SCF research</td>
</tr>
</tbody>
</table>
| Deng et al. (2018), Chen et al. (2020) | A wholesale price contract  
q and w are independent  
The supplier’s initial capital level  
The supplier’s credit risk  
The supplier’s default risk on bank loans  
The supplier’s opportunity cost loss  
The financial service providers’ distinct risk attitudes and quit probabilities  
The information asymmetry between the two FSPs  
Model the operations of the online platform based on the practice of an authentic online platform | | |
| Tang et al. (2018)                  | Purchase order financing vs. buyer direct financing  
Payment delay  
Reverse factoring contract | | |
| Van der Vliet et al. (2015)        | | | |
| Kouvelis and Zhao (2018)           | Bank loan vs. retailer’s early payment (supplier’s financing solution)  
Bank loan vs. trade credit (retailer’s financing solution) | | |
| Kouvelis and Zhao (2016)           | Revenue-sharing contract  
Buyback contract  
Quantity discount contract  
Default costs in loans  
A revenue-sharing-induced transfer payment | | |
| Yang and Birge (2016)              | Trade credit vs. bank loans  
q and w are subject to the trade credit terms | | |
| Lee et al. (2023)                  | Dynamic trade finance  
The setting of interest rate | | |
| Wang and Cai (2023)                | Bank loans plus loan insurance  
Both supplier and buyer benefit in a cooperative environment | | |
| Online platform financing          | In-house factoring scheme  
The setting of interest rate  
A wholesale price contract | | |
| Chen et al. (2020)                 | | | |
| Kouvelis and Xu (2021)             | Recourse factoring vs. non-recourse factoring  
Credit ratings | | |
| Wang and Xu (2023)                 | Smart contracts  
The supplier’s liquidity risk | | |
| Narayananam et al. (2022)          | Smart contracts  
Blockchain network | | |

Table 2. The summary of literature review
the first time. The supplier’s financing needs (if any) can be achieved either from a traditional bank or an online platform. The buyer’s capital resource is always strong, she can pay back the loan (if any) she is obliged to pay [4]. Before the contracting stage that our study focuses on, both FSPs evaluate the supplier’s credit level when lending happens. There are two common time epochs in the model, indexed as $t = 0$ and $t = 2$. At time $t = 0$, the buyer, acting as a leader in the supply chain, provides the supplier with a pair contract $(w, q)$, where $w$ is the unit wholesale price, $q$ is the order quantity. This is a common practice for larger buyers who have stronger bargaining power compared with SMEs (Tunca and Zhu, 2018). The supplier’s unit production cost is denoted by $c_p$ ($c_p < w$). If the supplier’s budget at $t = 0$, denoted as $A_0$, is insufficient to produce the ordered products, i.e. $A_0 < c_p q$, the supplier will find a financing solution to finish the production. We assume that the production duration and the delivery duration are normalized to zero. At $t = 2$, the demand of the end market is realized as $d$ with a cumulative distribution function (c.d.f.) $F(\cdot)$ and a probability density function (p.d.f.) $f(\cdot)$.

The supplier gets paid by the buyer. The buyer sells the products to the end customers and receives an immediate cash return with a unit price $p$. For each unit of missing demand, the buyer incurs a goodwill loss cost of $c_g$. Moreover, we assume that the salvage value for any leftover is zero. Finally, they buyer sends all unsold products to the supplier for a full refund, $w$ per unit. This is again a common return policy in practice (Chen and Grewal, 2013).

In particular, at time $t = 0$, there are probabilities that the FSPs may quit the market. Specifically, if there are evaluation failures or unstable transaction factors, either the online platform or the bank would not continuously provide financing to the supplier, then the inability to renew financing may ultimately lead to supply chain disruptions. Nature determines the two types of suppliers in terms of their credit levels, i.e. the low credit level with a proportion of $\xi_l \in (0, 1)$ and the high credit level with a proportion of $1 - \xi_l$. If facing a high-credit supplier, the FSPs’ quit probability is $\beta_l \in (0, 1)$; otherwise, its quit probability is $\beta_h$. Define $\theta$ as the prior knowledge of the FSPs’ expected quit probability, i.e. $\theta = \xi_l \beta_l + (1 - \xi_l) \beta_h$. Compared with the risk-averse bank, the online platform always puts less effort into knowing its customers based on our observations. Therefore, by virtue of the information advantage formed in the scrutinized evaluation process, the bank has a more accurate prior knowledge in terms of the supplier’s credit level. Hence, we can draw a safe assumption that the online platform does not know the exact type of the supplier (this also

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<td>Ignore the FSP’s risk attitude</td>
<td>Risk profiles of various firms</td>
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<tr>
<td>Song et al. (2018)</td>
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<tr>
<td>Chen et al. (2019), Huang et al. (2022), and Ma et al. (2020)</td>
<td>Information advantages regarding future demands</td>
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<tr>
<td>Schmidt et al. (2015)</td>
<td>Management of short-term market value with incomplete knowledge about the firm’s demand uncertainty</td>
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<tr>
<td>Lai and Xiao (2018)</td>
<td>Signaling the critical aspects of information asymmetry</td>
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<td>Beer et al. (2018), Zhang et al. (2020), and Chod et al. (2020)</td>
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Table 2. Source(s): Author’s own work
explains why the online platform’s mistaken lending occurs), while the traditional bank, on the other hand, knows the supplier’s true type after rigorous evaluations.

### 3.2 Two FSP-involved financing schemes

We next present the details of the two FSPs’ operations. For simplicity, when the traditional bank is the FSP, we focus on the case where the supplier is a high credit-level type (i.e. the quit probability for the bank is \( \beta_t \)); when the online platform is the FSP, the supplier’s credit level is unknown owing to the insufficient evaluation (i.e. the quit probability for the online platform is \( \theta \)) [5].

#### 3.2.1 When the FSP is the traditional bank.

We start with the case where the supplier may secure financing from a bank. We denote this scenario as \( bk \). The timeline follows the general sequence: At \( t = 0 \), the buyer first provides the contract \((w, q)\) to the supplier. If the supplier’s initial capital \( A_0 \) cannot cover the production cost, he borrows a loan \( l \) from the bank. Then, the bank decides to provide the amount \( l \) with a probability \( 1 - \beta_t \), and the finished goods will be delivered to the buyer. If the bank borrows, the interest rate for the bank loan is competitively determined, i.e. the bank’s expected payoff equals investing the loan amount in a risk-free market. We denote the risk-free rate by \( r_f \) and the bank’s interest rate by \( r_b \). At \( t = 1 \), the supplier receives the bank loans. The duration of money collection from the bank induces an opportunity cost loss, \( c_o (> 0) \), for the supplier in this production cycle, because of the bank’s inefficiency in handling the lending process as we illustrated in the introduction. At \( t = 2 \), the market demand and the buyer’s revenue materialize. We assume there is no defective product. The supplier will get paid fully and pay back the loan amount plus the interest to the extent possible depending on his cash level.

Therefore, the supplier’s expected cash position at \( t = 2 \) before repaying the loan can be written as

\[
A_1 = \begin{cases} 
(A_0 + l - c_o q)(1 + r_f) + \min\{q, d\} - c_o & \text{if the bank does not quit} \\
(A_0 - c_o q + \min\{A_0/c_o, q, d\}) & \text{if the bank does quit}
\end{cases}
\]  

(1)

Denote the supplier’s expected profit \( \Pi_{bk}^s \) as a function of \( q, w, l \) under the bank-involved financing scheme. If the bank provides financing to the supplier, at the due time, the supplier will make a payment of \( \min\{l(1 + r_b), A_1\} \), thus the ending capital level will be \( A_1 - \min\{l(1 + r_b), A_1\} = (A_1 - l(1 + r_b))^+ \). If the bank does not provide financing, then the supplier’s profits remain at \( A_1 \). Therefore, by (1) we have

\[
\Pi_{bk}^s(q, w, l) = (1 - \beta_t)E[(A_1 - l(1 + r_b))^+] + \beta_t A_1
\]

\[
= (1 - \beta_t)E[((A_0 + l - c_o q)(1 + r_f) + \min\{q, d\} - c_o - l(1 + r_b))^+] + \beta_t E[(A_0 - c_o q + \min\{A_0/c_o, q, d\})]
\]  

(2)

In addition, two constraints should be satisfied. The first is the bank’s loan amount should at least cover the supplier’s production cost when the bank does provide loans. The second is the bank’s payoff should be the same as the profit generated from investing the loan amount in a risk-free market. Hence, given the contract offer \((w, q)\), the supplier’s problem when accepting the offer can be written as
We define the buyer’s expected profit as a function of $q$ and $w$ for the bank-loan scenario as $\Pi_{bk}^{b}(q, w)$. The buyer collects the revenues (i.e. $p (p > w)$ per unit sold) at $t = 2$ and pays $w$ to the supplier per unit sold, and may incur a goodwill loss of $c_{g}$ per unit of unmet demand [6]. Hence, we have

$$\Pi_{bk}^{b}(q, w) = E\left[ (1 - \beta_{l})(p - w)\min\{q, d\} + \beta_{l}(p - w)\min\left\{\frac{A_{0}}{c_{p}}, q, d\right\}\right]$$

$$- c_{g}E\left[ (1 - \beta_{l})(d - q)^{+} + \beta_{l}\left( d - \min\left\{\frac{A_{0}}{c_{p}}, q\right\}\right)^{+}\right]$$

(4)

The buyer must ensure the supplier’s participation through the contract, i.e. the supplier’s expected end profit in this contract will exceed or at least equal to his alternative option, i.e. what he would otherwise obtain by investing his money in a risk-free market (individual rationality (IR)). We denote this constraint as IR. Besides, the supplier chooses the optimal loan amount $l_{bk}^{*}$ he is willing to borrow, given the contract (incentive compatibility (IC)). We denote this constraint as IC. Hence, the buyer’s problem under the bank-loan scenario can be written as

$$\max_{q, w \geq 0} \Pi_{bk}^{b}(q, w)$$

s.t. $\Pi_{bk}^{b}(q, w, l_{bk}^{*}) \geq A_{0}(1 + r_{f})$

(5)

where $l_{bk}^{*}$ is the supplier’s optimal option for $(q, w)$ as given in (3)

3.2.2 When the FSP is the online platform. Compared with the traditional bank, the online platform behaves more aggressively in order to attract more customers. In factoring, a supplier can easily be financed by selling the account receivables or invoices that are unpaid by the buyer to the online platform to obtain an immediate loan, then the buyer later remits the loan amount to the online platform directly and pays the rest of the invoices to the supplier at the invoice due date. Hence, with the help of factoring, the capital-limited supplier can satisfy his financing needs promptly instead of waiting a long period to receive a loan from the bank which may incur an opportunity cost. The online platform can earn profits by charging service fees. Based on the practice of a real online platform operating in the UK, we establish the model as follows.

We denote the online platform-involved scenario as $op$. At $t = 0$, the buyer provides the supplier with a pair contract $(w, q)$. The supplier finds an online platform to meet his capital needs $l$. To hedge the potential default risk, the online platform usually provides the loans separately twice. That is, if the online platform does not quit the market with probability $1 - \theta$, the supplier receives an immediate loan with a certain proportion $\lambda$, $\lambda \in (0, 1)$, to fulfill the order. This is called the first payment. $\lambda$ is exogenously and competitively determined by the market. The supplier then produces and delivers the goods and the unmet orders are lost. At $t = 2$, the demand is realized. At $t = \tau$, i.e. the contracted payment term between the buyer
and the supplier \(0 \leq \tau \leq 365\), the online platform receives the repayment of the loan from the buyer, the suppliers receives \(\text{wmin}\{q, d\} - l(\geq 0)\) from the buyer, and the online platform pays the remaining loans to the supplier and deducts the service fee \(\text{lr}_f/365\), where \(r_f\) is a fixed annum interest rate. \(\text{lr}_f/365\) is thus viewed as the online platform’s service rate. Usually, \(r_f\) is greater than \(r_b\) to hedge the higher default risk of the customers. Some comments are needed here. In general, \(l\lambda\) is already satisfied for the supplier to start production. Hence, it seems like the second part of loan \(l\) is redundant for him. With the online platform’s involvement, however, it needs to first ensure that the nominal payoffs between the supplier and the buyer stay unchanged as in the bank loan case, i.e. the buyer’s payment to the supplier is still \(\text{wmin}\{q, d\}\). Note that if no second payment exists, the actual payment the supplier receives from the buyer becomes \(\text{wmin}\{q, d\} - l\), which is less than his nominal payoff. So, there is a portion of the supplier’s profit contained in the second payment stage. Hence, the online platform’s twice payment method meets this requirement and makes these two financing schemes comparable. Second, the online platform needs to hedge the potential default risk from the buyer. Suppose a buyer defaults on the loan at the due date, it will be a huge loss for the online platform if it gives the entire loan to the supplier initially. By withholding the second part of the loan, the damages could be smaller if the buyer defaults. Third, the online platform will charge the service fee in the second payment as we mentioned above. These are the reasons for this two-stage payment approach exists. If the online platform does quit the market with probability \(\theta\), then the supplier ending cash remains 
\[
(A_0 - c_p q)^+ (1 + r_f) + \text{wmin}\left\{\frac{A_0}{c_p}, q, d\right\}
\]
as given in (1).

Different from the bank loan case, with loose regulations, the supplier can lend more than needed in the online platform. If the supplier borrows more than needed to cover the production costs, i.e. \(l > (c_p q - A_0)^+\), then he may invest the extra money in a risk-free market to obtain more profits, without adding any value to the buyer’s operation and thus increasing the loan amount the buyer should pay unnecessarily (Tunca and Zhu, 2018). Hence, to avert such exploitation of financing, the buyer must require the supplier and the online platform to ensure that \(l \leq (c_p q - A_0)^+\). In fact, the buyer will use the payment term \(\tau\) to limit the supplier’s overborrowing behavior (this will be illustrated in Section 4.3). As a first-time contract, the supplier obeys this rule.

We denote the supplier’s expected profit in this scenario \(\Pi_{\text{op}}^{\text{p}}\). Given the contract and loan parameters, \(q, w, \tau, \lambda\), the supplier maximizes \(\Pi_{\text{op}}^{\text{p}}\) and ensures that he has enough cash to cover production costs at the initial stage. Then, the supplier’s problem is

\[
\max_{0 \leq l \leq q \text{eq}} \Pi_{\text{op}}^{\text{p}}(q, w, \tau, \lambda, l)
\]

\[
= (1 - \theta)E[(A_0 + l\lambda - c_p q)(1 + r_f) + \text{wmin}\{q, d\} - l + l(1 - \lambda - \text{lr}_f/365)]
\]

\[
+ \theta E\left[ (A_0 - c_p q)^+ (1 + r_f) + \text{wmin}\left\{\frac{A_0}{c_p}, q, d\right\} \right]
\]

\[
s.t. A_0 + l\lambda - c_p q \geq 0
\]

\[
(\text{Supplier’s production budget constraint})
\]

The buyer’s payoff in the online platform-involved scenario is similar to the bank-involved scenario except for the prior knowledge of the supplier’s credit level. That is
The buyer again ensures the supplier’s IR constraint and IC constraint. We denote $l^*_{op}$ to solve the supplier’s optimization problem in (6), given $(q, w, \tau)$. Therefore, the buyer’s problem under online platform financing can be written as

$$\max_{q, w \geq 0, 0 \leq \tau \leq 365} \Pi_{op}^b(q, w)$$

subject to $\Pi_{op}^b(q, w, \tau, l^*_{op}) \geq A_0(1 + r_f)$ (IR)

$$l^*_{op} \leq (c_p q - A_0)^+$$ (The constraint to limit supplier overborrowing)

where $l^*_{op}$ is the supplier’s optimal option for $(q, w)$ as given in (6) (IC)

Figure 1 illustrates a comparison of these two financing schemes and shows how information asymmetry between the bank and the online platform can influence the relevant operations. The notations are given in Table 3.

4. Model analysis

In this section, we first derive the first-best solution in a centralized supply chain as our benchmark. Then, we conduct individual analyses for the two FSPs-induced financing schemes separately. The comparison of these two schemes is presented at the end of this section.

4.1 The first-best solution

In order to well compare the efficiency of these two financing schemes, we first demonstrate the outcome of the benchmark model, i.e. the first-best scenario, where the supply chain is centralized. As it is a centralized supply chain without capital constraint, neither the bank nor the online platform is involved, thus there is no consideration of both information asymmetry and quit probability. In this case, the supplier’s budget constraint, IR and IC constraints vanished. We denote this scenario by $f_b$, so the problem can be written as

$$\max_{q \geq 0} \Pi_{b}^f = E \left[ \min \{ p d, c_p (d - q)^+ + c_p q (1 + r_f) \} \right]$$

(9)

Solving (9), the optimal order quantity of this benchmark model is

$$q^*_b = F^{-1} \left( \frac{1 - c_p (1 + r_f)}{\bar{p} + c_p} \right)$$

(10)

4.2 Equilibrium analysis when the FSP is the bank

When the supplier proceeds financing from a traditional bank, we discuss the equilibrium solutions for each party under the conditions that the bank could quit or not quit respectively.

4.2.1 When the bank quits the market. We start with the analysis of bank loan financing when the bank quits the market. Given the bank’s quitting, the supplier’s optimal decision on
1. The buyer provides the supplier with a pair contract \((w, q)\)

2. The supplier finds a financing solution to meet his capital needs \(f\)

3. The bank decides whether to finance or not with probability \(1 - \beta\)

4. The bank does not lend money to the supplier

5. The supplier produces and delivers the goods and the unmet orders are lost

6. The demand is realized

7. The buyer makes the payment to the supplier

8. The supplier repays the loan with interest to the bank if solvent

---

1. The buyer provides the supplier with a pair contract \((w, q)\)

2. The supplier finds a financing solution to meet his capital needs \(f\)

3. The online platform decides whether to provide finance or not with probability \(\theta\)

4. The online platform does not lend money to the supplier

5. The supplier produces and delivers the goods and the unmet orders are lost

6. The demand is realized

7. The buyer makes the balance payment to the supplier and repays the loan in full to the online platform

8. The online platform returns the balance loan (less service fee) to the supplier as the 2nd payment

---

**Figure 1. Comparison of the two financing schemes**

**Source(s):** Authors’ own work
the loan amount and the bank’s interest setting both vanish. Hence, we focus on the contract terms provided by the buyer.

**Proposition 1.** For bank loan financing, if \( \beta_l = 1 \)

\[
(1) \quad q_{lb}^* = \begin{cases} 
q_{fb}^*, & \text{if } A_0 \geq c_p q_{fb}^* \\
A_0/c_p, & \text{if } A_0 < c_p q_{fb}^* 
\end{cases}
\]

\[
(2) \quad w_{lb}^* = \begin{cases} 
E\left[\min\left(q_{fb}^*, d\right)\right], & \text{if } A_0 \geq c_p q_{fb}^* \\
A_0(1 + r_f), & \text{if } A_0 < c_p q_{fb}^* 
\end{cases}
\]

**Proposition 1** states the significance of the supplier’s initial capital level \( A_0 \). If the supplier has a sufficiently high initial capital level, i.e. \( A_0 \geq c_p q_{fb}^* \), he pays for operations with his own capital resources. Observing the supplier’s stable financial status, the buyer shows more confidence and she determines the optimal order quantity that achieves the first-best level to maximize the profit. Hence, in this situation, the equilibrium order quantity \( q_{lb}^* \) can coordinate the supply chain. When the supplier’s capital level cannot cover the buyer’s optimal order quantity, or even worse, the bank quits the market, the buyer only achieves the equilibrium...
order quantity at $\frac{\partial q^*}{\partial p}$. Regarding the wholesale price, from (12), we can see $A_0$ also plays a critical role in determining the optimal wholesale price when the bank quits the market.

4.2.2 When the bank does not quit the market. We next study when the bank does not quit the market, and how are the supplier’s and the buyer’s operational and financial equilibrium decisions, as well as the bank’s interest rate settings? If the bank does not quit, we assume that the supplier’s initial capital level must be less than the production cost for ease of exposition, i.e. $A_0 < c_p q^*_f$; otherwise, the bank’s involvement is meaningless.

**Proposition 2.** For bank loan financing, if $\beta_l = 0$,

$$q^*_{bk} = q^*_f$$

$$w^*_{bk} = \frac{c_o + c_p q^*_f (1 + r_f)}{E\left[\min\{q^*_f, d\}\right]}$$

$$l^*_{bk} = c_p q^*_f - A_0$$

As for the bank’s interest rate, there exists a unique $r^*_b$ ($r^*_b > r_f$) to solve equation

$$l^*_{bk} (1 + r_f) = E\left[\min\{l^*_{bk} (1 + r_b), c_p q^*_f (1 + r_f)\}\right]$$

**Proposition 2** shows that when the bank does not quit the market, considering the supplier’s participation constraint, the buyer performs slightly differently from the situation where facing a capital-sufficient supplier as presented in **Proposition 1**. In observing the bank’s involvement, the buyer considers that the supplier’s credit achieves a certain level. To offset the supplier’s financing cost, the buyer would like to raise the wholesale price by considering the supplier’s opportunity cost loss $c_o$, to help the supplier earn more profits. With respect to the supplier, as the loan amount is indifferent to his profit (See the Proof of **Proposition 1** in Supplementary_material_appendix_1), thus the supplier will borrow exactly up to that level. Further, given the supplier’s loan request, the bank sets a unique interest rate $r^*_b$ to mitigate its investment failure. From **Proposition 1** and **2**, therefore, we can conclude that as long as the bank does not quit, the supplier’s capital resource is always guaranteed to be adequate to achieve the equilibrium outcomes for all parties.

4.3 Equilibrium analysis when the FSP is the online platform

Next, we illustrate the equilibrium solutions of the online platform financing scheme. As we explained in the model description in Section 3.2, the online platform’s quit case is the same as the bank’s quit case. Therefore, we only consider the scenario where the online platform does not quit, and the supplier’s capital level is insufficient to cover the production costs [7].

**Proposition 3.** For online platform financing, if $A_0 < c_p q_{app}$, then in equilibrium, the supplier borrows up to the level to cover his production costs if the online platform does not quit the market, i.e. $\theta = 0$. Moreover,

$$q^*_{op} = F^{-1}\left(1 - \frac{c_p (1 + \tau r_f / 365\lambda)}{p + c_g}\right) \leq q^*_f$$

$$q^*_{op} = F^{-1}\left(1 - \frac{c_p (1 + \tau r_f / 365\lambda)}{p + c_g}\right) \leq q^*_f$$

Industrial Management & Data Systems
With the involvement of an online platform, Proposition 3 reveals the supply chain’s profitability is decreased as the optimal order quantity is smaller than the bank loan case. Compared with the traditional bank, the online platform’s participation cannot indirectly reflect the qualification of the supplier because of its casual evaluation process. Hence, the buyer is prudent in deciding the order quantity to avoid manufacturing failures. Moreover, there is a higher service fee charged by the online platform. These factors result in the reduction of the supply chain’s optimal order quantity in the online platform financing in the end. Additionally, since $r^*$ seriously hinges on the supplier’s profit, the buyer can utilize this variable to limit the supplier’s overborrowing behavior when necessary[8]. For the online platform, although it seems cannot decide any variables in this factoring contract (its revenue is $l r t / 365$, the loan amount $l$ and the agreed payment term are determined by the supplier and the buyer respectively, $r_i$ is a fixed annum interest rate), lending to such suppliers is always better than investing in a risk-free market since $r f / 365 \geq r_f$ (see the online Proof of Proposition 3 in Supplementary_material_appendix_1). This explains why online platforms have emerged in the financing market. Interestingly, we can also observe that the wholesale price under online platform financing is decreasing in $A_0$. This phenomenon can be intuitively explained as confronting a relevant rich supplier, a buyer lying in a dominant position will not give the supplier much more profit in the first collaboration. However, the supplier still earns more under online platform financing which will be exhibited below.

4.4 The comparisons between the two FSPs-Induced financing schemes

We now compare these two schemes. For ease of exposition, we only focus on the case where $l > 0$.

Proposition 4. (i) The online platform charges a higher service rate than the bank’s interest rate when the payment term is beyond a threshold, i.e. $r_b^* < \frac{r_f}{365} < r_i$ if $\tau \geq \frac{365 (c p q^*_b + A_0 - e_c)}{(c p q^*_b - A_0) r_i}$.

(ii) If the bank or the online platform does not quit the market, there exists a $\epsilon > 0$ such that for all $\text{Var} [d] < \epsilon$, $w^*_b \leq w^*_{op}$, $q^*_b \geq q^*_{op}$, $\prod_b^{bk} \geq \prod_b^{op}$. For the supply chain, $\prod_{sc}^{bk} \geq \prod_{sc}^{op}$, if $\prod_b^{bk} - \prod_b^{op} \geq I_{bk} (r_b^* - r_f)$, where $\prod_{sc} = \prod_i + \prod_b$, $i = bk, op$.

Figure 2 demonstrates the comparison of the equilibrium results with different FSPs. As part (i) of Proposition 4 states, when the buyer’s payment delay is beyond a certain threshold, the online platform charges a higher service rate to hedge the default risk as the duration of the loan repayment is long (recall that the buyer repays the loan after $\tau$ periods). Put differently, the online platform increases the costliness of the loan via its service fee. As shown in panel (a) of Figure 2, both the bank’s interest rate $r_b^*$ and the online platform’s service rate $\frac{r_f}{365}$ decrease as the prior quit rate $\theta$ increases. The difference in order quantity in the two schemes is relatively small as shown in panel (b) of Figure 2, and they have similar trends to the interest rates. That is to say, the buyer is afraid of the FSPs’ quitting so that she will reduce the order quantity in case of production failure. The wholesale price under the online platform
financing scheme, nevertheless, is higher than the bank loan scenario. As demonstrated in panel (c) of Figure 2, when demand variability is high (i.e., when the variance for the exponential-distributed demand, $\sigma = 100$), for a low prior quit rate $\theta$, the buyer increases the wholesale price to ensure the supplier’s participation as the service fee is higher in the online financing scheme. Moreover, since $\theta > \beta_p$, the online platform’s quit probability is stochastically greater than that of the bank. Considering this, as long as the supplier obtains financing from the online platform, the buyer has the incentive to set a higher wholesale price to offset the higher borrowing cost so as to attract the supplier to involve in the contract within the latter’s IR constraint thus avoiding production failure. However, this action in turn hurts the buyer’s profitability. When $\theta$ continues to increase, both the online platform and the bank may quit, then the buyer would not trust the supplier and consider terminating the contract, so the wholesale price is reduced to zero. Therefore, the willingness of the FSPs’ involvement can affect the buyer’s pricing decisions. When the demand variability is low ($\sigma = 4$), it induces a lower order quantity as shown in panel (b). The lower orders result in lower wholesale prices according to Propositions 2 and 3.
Intriguingly, the supplier’s preference of FSP seems not to be strictly consistent with the buyer and the whole supply chain. As a Stackelberg follower, the supplier borrows the exact capital to cover the production cost and suffers a great opportunity cost loss under bank loan scenarios and hence prefers to select an online platform to meet the financing needs. This finding also supports the work done by Lu et al. (2020), who find that the SCF solution such as bank financing cannot considerably improve the SME’s SCF performance. However, the buyer who is eager to earn profits in the market wants the supplier to borrow to produce the ordered amount. As shown in panel (d) of Figure 2, the buyer’s profit decreases in the two financing schemes and is slightly sharper in the online platform financing as the prior quit rate increases. This is straightforward to understand that if both FSPs have a higher probability to quit, then the order quantity will be significantly reduced. Further, penalties emerge if the demands are backlogged, thus the buyer’s profit will be considerably reduced. In addition, contrasting with the online platform, the bank is more reliable in detecting the quality of the supplier. Hence, if the bank is involved in the game, with a higher-order quantity plus a lower wholesale price, the buyer benefits more than that under the online platform financing. Finally, it is interesting to find that if the buyer’s expected profit in the bank loan scenario is large enough and the profit difference between the two financing schemes is beyond a certain threshold, i.e. $l_b^*(r_b^* - r_f)$, from a supply chain’s perspective, the supplier’s profit loss caused by the opportunity cost in the bank loan scenario can be offset by the buyer’s profit. Therefore, under this condition, it is always better for a supply chain to finance from the bank with lower financing cost and stable operations.

5. Managerial insights
The derived major findings from this study can have a significant impact both on the industrial practitioner’s side and the academic researcher’s side. For a capital-constrained supplier who needs capital resources to continue operations, our results suggest that if both a bank and an online platform would like to lend, the latter is a better option for him. Based on this, our findings can give SMEs explicit guidance in obtaining financing from various FSPs. For a capital-sufficient buyer who meets her supplier for the first time, we help the buyer find the optimal contract terms regarding different FSPs with distinct quit probabilities. Besides, because of the FSPs’ risk attitudes, we shed light on how different FSPs’ involvement could influence the buyer’s contract decision in the presence of information asymmetry and the efficiency difference in loan provision between the bank and the online platform. Moreover, we prove that the buyer is always more beneficial under the bank’s involvement. This can be evidenced by real-life cases. For example, JD.com (one of the retailing giants in China), is willing to finance high-credit suppliers through collaborations with banks via loans to yield more revenues and save costs in case of supply failure from sourcing low-credit suppliers, who tend to get finance from a non-bank platform instead. Observing this, the governments and/or the policymakers can devise more efficient policies to support the bank’s lending business toward SMEs. For the two FSPs, we identify the optimal interest rate for the bank when lending and explain why the online platform’s service rate is higher than the bank’s interest rate. People who are interested can get to know the basic know-how of different lending procedures. Finally, from the supply chain’s perspective, the threshold of the buyer’s profit difference between the two financing schemes we identified can increase both the supplier’s and the buyer’s motivation in achieving the maximized profit for the whole supply chain.

From an academic point of view, we provide a modeling framework that reflects the FSP’s risk profiles and their quit probabilities in a supply chain. Note that these two parts are substantially ignored in the previous literature, thus we further complement the research of SCF. In addition, the comparisons between these two schemes plus the numerical illustration
generate a clear picture of how the efficiency of financing schemes can be comprehensively presented. Lastly, the theoretical results derived in this study can be a consolidated foundation for empirical verifications in the future when data are available.

6. Conclusions
In our model, we consider the two FSPs’ various risk attitudes and their quit probabilities in financing to simulate a scenario where a supplier (SME) may borrow money to cover production costs, given the buyer’s pair contract. Since this is a first-time contract, neither party knows the other’s historical performance. As a capital-constrained supplier, the supplier has the incentive to perform better in operations in order to win more contracts in the future. Based on the anecdotal evidence that the FSP may quit the market due to unpredictable reasons, and the fact that the online platform’s prior quit probability is very different from the bank’s assessment of that probability, the efficiencies of the two FSPs-induced financing schemes are compared.

Our findings first present the optimal contract structures under both financing schemes (in particular, the model of the online platform is based on the practice of an authentic online platform). We focus on illustrating how the buyer’s (or the online platform) decisions on \( q \) and \( w \) are affected by the supplier’s initial capital level \( A_0 \) and show how the supplier’s opportunity cost loss will impact the buyer’s decision on the contract term under bank loan scenario. Specifically, we show that in the non-FSPs’ quit case, to ensure that the supplier will not abuse of the system by borrowing more than needed, the capital-constrained supplier will only borrow the money up to the level of covering his production costs. Second, the buyer can effectively utilize the lending information carried out by the two FSPs to adjust the contract terms and maximize the profit. We prove that the buyer’s profit is higher under the bank loan scenario. This is because under the bank’s involvement, the buyer views the supplier’s qualification as excellent and takes the supplier’s financing cost plus the opportunity cost loss into consideration. Then, the buyer has more confidence in setting the first-best order quantity with a lower wholesale price. However, under online platform financing, such confidence disappears due to the loose evaluation of the supplier, so the buyer is more cautious in setting the contract terms. Hence, the order quantity is reduced to avoid production failure and the wholesale price is increased to offset the supplier’s higher financing cost. Third, we demonstrate that the supplier prefers to select an online platform as his FSP considering the opportunity cost loss when the FSP is the bank. Fourth, from the supply chain’s perspective, we identify a threshold related to the buyer’s profit difference between the two financing schemes. This threshold clarifies the efficiency of bank loan over online financing.

Our research provides theories on the efficiency of bank loan financing and online platform financing that are gaining increased use in supply chains, especially for SMEs who are eager to obtain financing to survive in the market. The insights concluded from our study contribute to the understanding of these meaningful operations and to their applications in practice. Future works can be expanded in four directions. First, we can focus on the FSPs’ risk attitudes and omit the main parties’ risk profiles, i.e. the supplier and buyer are assumed risk-neutral in this study. Modeling their various risk attitudes under different environment settings may generate other insights. In addition, some new technologies have been adopted by FSPs such as blockchain, cloud computing, etc. (Nath et al., 2022) Whether the adoption of these technologies can affect our results is worth testing. Third, as the various quit probability distributions can test the robustness of our theoretical results and may generate new findings, thus the study of the distributions of the quit probability can be extended as a promising future work. Last, exploring whether suppliers turn to online platforms for loans when banks quit is an interesting research direction in the future.
Notes
1. We browse the websites of some active online platforms across the globe, including Greensill, Stenn, Fund Park, MODIFI, Prime Revenue, PAISTONE CAPITAL, C2FO, Orbian, Kyriba, etc. They clearly stated their services, fees, interest rates, etc., therefore we can easily observe their operational behaviors and make a general comparison with a traditional bank.

2. Although the bank would like to relax the lending procedures in the new policy era, the evaluation process of the bank is still relatively rigorous compared with the online platform.

3. The multiproduct version of the model is a straightforward extension, and the results stay similar, thus we omit this setting in this paper.

4. Hereafter, for convenience in exposition, we refer to the buyer as “she,” the supplier as “he,” and the bank/online platform as “it.”

5. This setting implies the different risk profiles of the bank and the online platform in practice. The bank always adopts a risk-averse attitude when financing its customers, so the high-credit suppliers are always left for the bank to lend to after evaluations. Nevertheless, a risk-seeking online platform is indifferent to the credit types of its customers.

6. Note that the unmet demand can be either resulted from the low order quantity or the supplier’s late delivery due to its long money collection period under bank loan.

7. The outcomes of the two financing schemes under the case where $A_0 \geq c_p q$ and the case where both FSPs quit are identical respectively. The equilibrium results are given in Proposition 1.

8. Usually, the payment delay $\tau^*$ is a fixed variable and is exogenous to the market. For instance, a delay like 60 or 120 days after goods delivery.

References


Proofs of Propositions

**Proof of Proposition 1.** In the bank-loan scenario, we first assume the bank is involved in the financing scheme to derive the general form of the solutions. The scenario of the bank’s quit can be easily derived based on the general solutions. By backward induction, we first find the bank’s equilibrium interest rate, given \( q, w, l > 0 \). Define

\[
G(l, r_b) = E[\min \{l(1+r_b), (A_0 + l - cpq)(1+r_f) + wmin\{q,d\} - c_o\} - l(1+r_f)]. \tag{A.1}
\]

By (3), the bank sets interest rate \( r_b^* \) by solving

\[
G(l, r_b) = 0 \tag{A.2}
\]

Notice that for any fixed \( l \geq 0 \), \( G(l, r_b) \) is strictly increasing in \( r_b \) for \( l(1+r_b) < (A_0 + l - cpq)(1+r_f) + wmin\{q,d\} - c_o \), and equals \( (A_0 - cpq)(1+r_f) + wE[\min\{q,d\}]-c_o \) for \( l(1+r_b) \geq (A_0 + l - cpq)(1+r_f) + wmin\{q,d\} - c_o \). We define \( wmin\{q,d\} \geq c_o \), otherwise, the supplier will never borrow from the bank.

When \( A_0 \geq cpq \), then \( l(1+r_f) \leq (A_0 + l - cpq)(1+r_f) \), and hence \( G(l, r_b) \bigg|_{r_b=r_f} = 0 \). Therefore, for any \( A_0 \geq cpq \), \( r_f = r_b \) is a solution to (A.2), and since \( l(1+r_f) < (A_0 + l - cpq)(1+r_f) + wmin\{q,d\} - c_o \), \( G(l, r_b) \) is strictly increasing in \( r_b \) at \( r_f = r_b \) and is non-decreasing elsewhere, so \( r_f \) is the unique solution for \( G(l, r_b) = 0 \). When \( A_0 < cpq \), plugging \( r_b = r_f \) into (A.1), we have

\[
G(l, r_f) = E[\min \{l(1+r_f), (A_0 + l - cpq)(1+r_f) + wmin\{q,d\} - c_o\} - l(1+r_f)] \\
\leq l(1+r_f) - l(1+r_f) = 0 \tag{A.3}
\]

Then it follows that since \( G(l, r_b) \) is strictly increasing in \( r_b \) for \( l(1+r_b) < (A_0 + l - cpq)(1+r_f) + wmin\{q,d\} - c_o \), when \( A_0 < cpq \), (A.2) will have a unique solution, \( r_b^* \) in \( (r_f; (A_0 - cpq)(1+r_f) + wE[\min\{q,d\}] - c_o) \), if and only if \( (A_0 - cpq)(1+r_f) + wE[\min\{q,d\}] - c_o > 0 \). Otherwise, if \( (A_0 - cpq)(1+r_f) + wE[\min\{q,d\}] - c_o = 0 \), then all \( r_b \geq (A_0 - cpq)(1+r_f) + wE[\min\{q,d\}] - c_o / q \) will be a solution, and if \( (A_0 - cpq)(1+r_f) + wE[\min\{q,d\}] - c_o < 0 \), then there will be no solution.

Thus, when \( (A_0 - cpq)(1+r_f) + wE[\min\{q,d\}] - c_o > 0 \), we have
Now, we solve the supplier’s problem. When \((A_0 - c_p q)(1 + r_f) + u \mathbb{E}[\min\{q, d\}] - c_o > 0\), \(G(l, r_b)\) has continuously differentiable partial derivatives in \(l\) and \(r_b\), which implies by the implicit function theorem that \(r^*_b(l)\) is continuously differentiable in \(l\). Therefore, in this region, taking the total derivative of the supplier’s objective function as given in (2),

\[
\frac{d \prod_s^{bk}(l, r^*_b(l))}{dl} = \frac{\partial \prod_s^{bk}(l, r^*_b(l))}{\partial l} + \frac{\partial \prod_s^{bk}(l, r^*_b(l))}{\partial r^*_b} \frac{dr^*_b}{dl}.
\]  

(A.5)

When \(A_0 \geq c_p q\), from (A.4) we have \(r^*_b(l) = r_f\). By (2), we can then see that \(\prod_s^{bk}(l, r^*_b(l))\) is independent of \(l\), and hence \(\frac{d \prod_s^{bk}}{dl} = 0\). When \(A_0 < c_p q\), define \(D^* = l(r_b - r_f) - (A_0 - c_p q)(1 + r_f)\),

and apply the implicit function theorem to (A.1) again, we then have

\[
\frac{dr^*_b}{dl} = -\frac{\frac{\partial G(l, r_b)}{\partial r_b}}{\frac{\partial G(l, r_b)}{\partial l}} \bigg|_{r_b=r^*_b(l)} = \frac{F(D^*)(r^*_b(l) - r_f)}{F(D^*)l} = \frac{(r_f - r^*_b(l))}{l}.
\]  

(A.7)

In addition, from (2), we have

\[
\frac{\partial \prod_s^{bk}(l, r^*_b(l))}{\partial l} = (1 - \beta_l)(r_f - r^*_b(l)) F(D^*), \quad \text{and} \quad \frac{\partial \prod_s^{bk}(l, r^*_b(l))}{\partial r_b} = -(1 - \beta_l)F(D^*). \]

(A.8)

By plugging (A.8) and (A.7) into (A.5), we have

\[
\frac{d \prod_s^{bk}(l, r^*_b(l))}{dl} = (1 - \beta_l)(r_f - r^*_b(l)) F(D^*) - (1 - \beta_l)lF(D^*) \frac{(r_f - r^*_b(l))}{l} = 0.
\]  

(A.9)

Hence, given the bank’s competitive interest rate, the supplier’s profit has no relationship with the loan amount he determines to borrow. In addition, the supplier also needs to satisfy the production budget constraint in (3), the loan he borrowed should be sufficient to cover the production cost, i.e. \(l \geq (c_p q - A_0)^+\). Nevertheless, the supplier may overborrow so as to invest the extra amount \(l - (c_p q - A_0)^+\) in the risk-free market without improving his profit, that is, the overborrowing will be a trivial action. Therefore, the supplier will only borrow \(l = (c_p q - A_0)^+\) amount to cover his production cost and avoid the trivial action.

Next, we solve the buyer’s problem. In (5), when \(A_0 \geq c_p q, l = 0\). Then the supplier’s IR constraint is

\[
(1 - \beta_l)((A_0 - c_p q)(1 + r_f) + u \min\{q, d\}) + \beta_l((A_0 - c_p q)(1 + r_f) + u \min\{q, d\}) \geq A_0(1 + r_f).
\]  

(A.10)

Note that the left hand side of (A.10) is increasing in \(u\), while from (5) we have
\[
\frac{\partial \prod_{b}^{\text{bk}}(q, w)}{\partial w} = -\min\{q, d\} < 0, \quad (A.11)
\]

which implies that the buyer’s profit is decreasing in \( w \). Hence, for any given \( q \geq 0 \), (A.10) must be binding. Therefore, solving for \( w \) and plugging in \( \prod_{b}^{\text{bk}}(q, w) \), the buyer’s profit function on \( A_{0} \geq c_{p}q \) is

\[
\prod_{b}^{1}(q) \triangleq p\mathbb{E}[\min\{q, d\}] - c_{p}q(1 + r_{f})(1 + r_{f}) - c_{g}\mathbb{E}[(d - q)^{+}], \quad (A.12)
\]

and \( w = c_{p}q(1 + r_{f})/\mathbb{E}[\min\{q, d\}] \). \( (A.13) \)

Also note that,

\[
\frac{d^{2}\prod_{b}^{1}(q)}{dq^{2}} = -(p + c_{g})f(q) < 0, \quad (A.14)
\]

therefore \( \prod_{b}^{1}(q) \) is concave and, based on the first order condition, is maximized at

\[
q_{bb} = R^{-1}\left(1 - \frac{c_{p}(1 + r_{f})}{p + c_{g}}\right) = q_{b}^{*} \quad (A.15)
\]

Next, suppose \( A_{0} < c_{p}q \), then the supplier will borrow \( c_{p}q - A_{0} \) and his participation constraint in (5) becomes

\[
(1 - \beta_{l})(w\mathbb{E}[\min\{q, d\}] - \mathbb{E}[\min\{l(1 + r_{b}), w\min\{q, d\} - c_{o}\}] - c_{o} + \beta_{l}\mathbb{E}\{\min\{\frac{A_{o}}{c_{p}}, d\}\}) \times \geq A_{0}(1 + r_{f}). \quad (A.16)
\]

Further, from the bank’s interest rate setting equation, we have

\[
l(1 + r_{f}) = \mathbb{E}[\min\{l(1 + r_{b}), w\min\{q, d\} - c_{o}\}]. \quad (A.17)
\]

Recall that the buyer’s profit is decreasing in \( w \); hence (A.16) must be binding. Then, plugging (A.16) and (A.17) in \( \prod_{b}^{\text{bk}}(q, w) \), the buyer’s profit function on \( A_{0} < c_{p}q \) is

\[
\prod_{b}^{2}(q) \triangleq (p - w)\left((1 - \beta_{l})\min\{q, d\} + \beta_{l}\min\{\frac{A_{o}}{c_{p}}, d\}\right) - c_{g}\mathbb{E}\left[(1 - \beta_{l})(d - q)^{+}\right]
\]

\[
+ \beta_{l}\left(d - \frac{A_{o}}{c_{p}}\right)^{+}, \quad (A.18)
\]

and \( w = \frac{(1 - \beta_{l})c_{p}q + A_{o}\beta_{l}(1 + r_{f}) + c_{o}(1 - \beta_{l})}{(1 - \beta_{l})\min\{q, d\} + \beta_{l}\min\{\frac{A_{o}}{c_{p}}, d\}} \). \( (A.19) \)

Further, \( \frac{d^{2}\prod_{b}^{2}(q)}{dq^{2}} = -(1 - \beta_{l})(p + c_{g})f(q) < 0, \) \( (A.20) \)

therefore \( \prod_{b}^{2}(q) \) is also concave and, based on the first order condition, is maximized at
\[ q_{bh} = F^{-1}\left( 1 - \frac{c_p (1 + r_f)}{\bar{p} + c_g} \right) = q_{fb}^* \]  

(A.21)

From above analysis, to see part (i), we can conclude that

when \( \frac{A_0}{c_p} \geq q_{fb}^* \),

(A.22)

since \( \prod_q^i (q) \) is concave, the buyer’s profit is maximized at \( q_{fb}^* \), thus the buyer’s optimal order quantity is \( q_{fb}^* \) and the loan amount is zero. Furthermore, when \( \frac{A_0}{c_p} < q_{fb}^* \), since \( \prod_q^i (q) \) is also concave, the buyer’s profit is increasing in \( q \in \left[ 0, \frac{A_0}{c_p} \right] \), then the buyer’s profit is maximized at \( \frac{A_0}{c_p} \), thus the buyer’s optimal order quantity is \( \frac{A_0}{c_p} \) and the loan amount is zero if the bank quits. Then, plugging \( q_{fb}^* \) in (A.13) and (A.19) can derive part (ii) respectively. Q.E.D.

Proof of Proposition 2. Suppose the bank does not quit, i.e. \( \beta_i = 0 \). Using the notation of the proof of Proposition 1, since \( \prod_q^i (q) \) is concave and is maximized at \( q_{fb}^* \) as well, hence when \( A_0 < c_p q_{fb}^* \), the supplier will borrow up to that level to cover his production costs, given the bank’s willingness to provide financing. Therefore, \( q_{bh}^* = q_{fb}^* \). Then, plugging \( q_{fb}^* \) into the supplier’s binding participation constraint (A.16), we obtain

\[ w_{bh}^* = \frac{c_p q_{fb}^* (1 + r_f) + c_o}{E \left[ \min \left\{ q_{fb}^*, d \right\} \right]} \]  

(A.23)

Moreover, based on the supplier’s budget constraint, we illustrated in the proof of Proposition 1 that the loan amount \( l_{bh}^* = c_p q_{fb}^* - A_0 > 0 \). Finally, plugging \( l_{bh}^* \) in the bank’s interest rate setting equation (A.17), we have

\[ l_{bh}^* (1 + r_f) = E \left[ \min \left\{ l_{bh}^* (1 + r_f), \min \{ q, d \} - c_o \right\} \right]. \]  

(A.24)

Plugging (A.23) into (A.24), we then can obtain

\[ l_{bh}^* (1 + r_f) = E \left[ \min \left\{ l_{bh}^* (1 + r_f), c_p q_{fb}^* (1 + r_f) \right\} \right] \]  

(A.25)

By (A.4), we can have there exists a unique \( r_{bh}^* > r_f \) to solve equation (A.25). Q.E.D.

Proof of Proposition 3. For \( A_0 \geq c_p q \), no loan occurs, the buyer’s objective function is again \( \prod_q^i (q) \) as given in the proof of Proposition 1. The equilibrium solution of \( (q, w) \) is the same as in the Proposition 1. For \( A_0 < c_p q \), if the online platform does not quit the market, we start by examining the supplier’s borrowing behavior. Now, from (6), given the online platform’s first payment ratio \( \lambda \) and the fixed interest rate \( r_f \), we have

\[ \frac{\partial \prod_q^i (q, w, \tau, \lambda, l, r_f)}{\partial l} = \frac{(1 - \theta) \lambda (1 + r_f) - \lambda - \tau r_f}{365}, \]  

(A.26)

then the supplier’s profit is non-increasing in \( l \) if and only if
\[ \tau \geq \frac{365(1 - \theta)rf - \theta}{r_t}. \]  

(A.27)

For any \( \tau \geq 0 \) for which (A.27) is not satisfied, the supplier will borrow as much money as possible, while the buyer’s intention is to induce the supplier to borrow the exact amount needed to cover production, \((c_pq - A_0)\) as stated in (8). Therefore, the buyer sets \( \tau \geq \frac{365(1 - \theta)rf - \theta}{r_t} \) and the supplier will borrow \( l^* = (c_pq - A_0)^+ / \lambda \) amount to cover his production costs. Plugging into the supplier’s objective function in (6) and by the supplier’s IR constraint, we have

\[
(1 - \theta)E\left[w_{\min}\{q, d\} - \frac{(c_pq - A_0)}{\lambda} \left(\lambda + \frac{\tau r_t}{365}\right)\right] + \theta E\left[w_{\min}\left\{\frac{A_0}{c_p}, d\right\}\right] \geq A_0(1 + r_f). 
\]

(A.28)

Since the left hand side of (A.28) is decreasing in \( \tau \), although from (7), the buyer’s profit function has no relationship with \( \tau \), for the buyer’s cash to cash cycle, she always wants a longer payment term to improve her working capital level. Hence, the supplier’s participation constraint is binding to conclude the buyer’s optimal decision on the payment term \( \tau \), that is

\[
\tau^* = \frac{365\lambda (1 - \theta)E[w_{\min}\{q, d\} - (c_pq - A_0)] + \left(\theta E\left[w_{\min}\left\{\frac{A_0}{c_p}, d\right\}\right] - A_0(1 + r_f)\right]}{(1 - \theta)(c_pq - A_0) r_t}. 
\]

(A.29)

To verify the feasibility of \( \tau^* \), we need to prove that

\[
\tau^* > \frac{365\lambda (1 - \theta)rf - \theta}{r_t}, 
\]

(A.30)

then, it transforms to prove

\[
\frac{(1 - \theta)E[w_{\min}\{q, d\} - (c_pq - A_0)] + \left(\theta E\left[w_{\min}\left\{\frac{A_0}{c_p}, d\right\}\right] - A_0(1 + r_f)\right]}{(1 - \theta)(c_pq - A_0)} > (1 - \theta)rf - \theta, 
\]

(A.31)

for (A.31) holds, then we need to prove

\[
(1 - \theta)E[w_{\min}\{q, d\} - (c_pq - A_0)] + \left(\theta E\left[w_{\min}\left\{\frac{A_0}{c_p}, d\right\}\right] - A_0(1 + r_f)\right) \\
- (1 - \theta)^2 r_f (c_pq - A_0) \\
> 0, 
\]

(A.32)

since \((1 - \theta)^2 r_f < 1\), if

\[
(1 - \theta)E[w_{\min}\{q, d\} - (c_pq - A_0)] + \left(\theta E\left[w_{\min}\left\{\frac{A_0}{c_p}, d\right\}\right] - A_0(1 + r_f)\right) - (c_pq - A_0) \\
> 0, 
\]

(A.33)

then (A.32) > 0 holds.
Finally, by plugging (A.37) in the buyer to pay the supplier. Therefore, in the following proofs, we regard the payment term as a fixed parameter $\tau^*$. Now, plugging the above optimal solutions into the supplier’s IR constraint, we have

$$(1 - \theta)E\left[w_{\text{min}}(q, d) - \frac{(c_p q - A_0)}{\lambda} \left(\lambda + \frac{\tau^* r_f}{365}\right)\right] + \theta E\left[w_{\text{min}}\left\{\frac{A_0}{c_p}, d\right\}\right] \geq A_0(1 + r_f).$$

(A.36)

Since the left-hand side is increasing in $w$, while the buyer’s objective function in (7) is decreasing in $w$, thus (A.36) must be binding in equilibrium solutions. For any $A_0 < c_p q$, we obtain

$$w^*(q) = \frac{A_0(1 + r_f) + (1 - \theta)(c_p q - A_0) \left(1 + \frac{\tau^* r_f}{365}\right)}{(1 - \theta)E[\min\{q, d\}] + \theta E[\min\left\{\frac{A_0}{c_p}, d\right\}]].$$

(A.37)

Finally, by plugging (A.37) in the buyer’s objective function, we have

$$\prod_b^{\text{op}}(q, w^*(q), \tau^*) = \prod_b^3(q) \Delta E\left[(1 - \theta)p_{\text{min}}(q, d) + \theta p_{\text{min}}\left\{\frac{A_0}{c_p}, d\right\}\right] - \left(A_0(1 + r_f) + (1 - \theta)(c_p q - A_0) \left(1 + \frac{\tau^* r_f}{365}\right)\right) - c_{\text{g}} E\left[(1 - \theta)(d - q)^+\right]$$

$$+ \theta\left(d - \min\left\{\frac{A_0}{c_p}, q\right\}\right)^+],$$

(A.38)

on $A_0 < c_p q$, which is also concave in $q$, and has a unique maximum at

$$q_{\text{op}}^* = F^{-1}\left(1 - \frac{c_p \left(1 + \frac{\tau^* r_f}{365}\right)}{p + c_{\text{g}}}\right),$$

(A.39)
since $c_p q^*_b r_f \geq r_f$ to ensure the online platform’s nonnegative profit, given the proportion rate $0 < \lambda \leq 1$, thus $c_p q^*_b \geq r_f$. Therefore, we can obtain $q^*_o \leq q^*_b$. Ultimately, in the case that $A_0 < c_p q$ and the online platform quits the market, the analysis is the same as the bank-loan scenario and the results stay the same as presented in Proposition 1, and thus can be ignored. Let $\theta = 0$, so we can derive the results as presented in Proposition 3. Q.E.D.

**Proof of Proposition 4.** To see part (i), first, from (A.4), under the bank-loan scenario, $r_b \in \left( r_f, \frac{c_p q^*_b (1 + r_f) - c_o}{c_p q^*_b - A_0} - 1 \right)$; under the online platform financing, the service rate is $c_p q^*_b r_f$. Usually, the online platform charges a higher service rate to hedge the risky behaviors from customers than the bank, so we need to ensure that $c_p q^*_b r_f \geq \frac{c_p q^*_b (1 + r_f) - c_o}{c_p q^*_b - A_0} - 1$, then we have

$$\tau^* \geq \frac{365 \left( c_p q^*_b r_f + A_0 - c_o \right)}{\left( c_p q^*_b - A_0 \right) r_f}, \quad (A.40)$$

For part (ii), first, for the bank-loan scenario, we have

$$w^*_b = \begin{cases} \frac{A_0 (1 + r_f)}{E \left[ \min \left( \frac{A_0}{c_p}, d \right) \right]}, & \text{when the bank quits} \\ \frac{\left( c_o + c_p q^*_b (1 + r_f) \right)}{E \left[ \min \left( q^*_b, d \right) \right]}, & \text{when the bank does not quit} \end{cases} \quad (A.41)$$

and

$$q^*_b = \begin{cases} \frac{A_0}{c_p}, & \text{when the bank quits} \\ q^*_b, & \text{when the bank does not quit} \end{cases} \quad (A.42)$$

For the online platform financing scenario, we have

$$w^*_o = \begin{cases} \frac{A_0 (1 + r_f)}{E \left[ \min \left( \frac{A_0}{c_p}, d \right) \right]}, & \text{when the online platform quits} \\ \frac{A_0 (1 + r_f) + \left( c_p q^*_o - A_0 \right) \left( 1 + \tau^* r_f / 365 \lambda \right)}{E \left[ \min \left( q^*_o, d \right) \right]}, & \text{when the online platform does not quit} \end{cases} \quad (A.43)$$

and
(IMDS)

\[
q_{\text{op}}^* = \begin{cases} 
\frac{A_0}{c_p} & \text{when the online platform quits} \\
F^{-1}\left(1 - \frac{c_p(1 + r_f)}{p + c_g}\right) & \text{when the online platform does not quit}
\end{cases}
\] (A.44)

When \(l > 0\) and the bank does not quit, by (A.42), we have

\[
F(q_{bk}^*) = \int_0^{q_{bk}^*} f(d)dd = 1 - \frac{c_p(1 + r_f)}{p + c_g} > 0,
\] (A.45)

and the right-hand side of the last equality in (A.45) is independent of \(\text{Var}[d]\). When \(\text{Var}[d] \to 0\), for any \(d \not\in \text{E}[d], f(d) \to 0\). Hence, \(\lim_{\text{Var}[d] \to 0} q_{bk}^* = \text{E}[d]\). Similarly, \(\lim q_{op}^* = \text{E}[d]\). Moreover, when \(\text{Var}[d] \to 0\), \(d \overset{D}{\to} \text{E}[d]\) as well, which implies that for \(i = bk, op\),

\[
\lim_{\text{Var}[d] \to 0} \text{E}\left[\min \left\{ q_i^*, d \right\} \right] = \text{E}[d].
\] (A.46)

Plugging into (A.41) and (A.43), then we obtain

\[
\lim_{\text{Var}[d] \to 0} \left( w_{bk} - w_{op}^* \right) = \frac{c_p \text{E}[d](1 + r_f) + c_o}{\text{E}[d]} - \frac{A_0(1 + r_f) + (c_p \text{E}[d] - A_0)\left(1 + \frac{r_f}{365}\right)}{\text{E}[d]}
\]

\[
= \left( c_p \text{E}[d] - A_0 \right) \left( r_f - \frac{r_f}{365} \right) + c_o \bigg/ \text{E}[d],
\] (A.47)

Notice that we are now discussing the loan-required scenarios, i.e. \(l > 0\), \(c_p q_{bk}^* > A_0\). Since \(\lim_{\text{Var}[d] \to 0} q_{bk}^* = \text{E}[d]\), if \(c_p \text{E}[d] < A_0\), then \(q_{bk}^* > \text{E}[d]\), so there exists \(e > 0\), such that for all \(\text{Var}[d] < e\), \(l = 0\). This contradicts the setting that \(l > 0\). Therefore, there exists \(e > 0\), such that for all \(\text{Var}[d] < e\), \(c_p \text{E}[d] > A_0\) must hold.

In addition, in the proof of Proposition 3, we have \(\lambda \leq r_f\), hence we obtain \(w_{op}^* \geq w_{bk}\). Next, as \(\lambda > r_f\), \(F^{-1}(\cdot)\) is a non-decreasing function, then we can obtain \(q_{bk}^* \geq q_{op}^*\). Then, based on the supplier’s objective function in (2) and combines the bank’s competitive interest setting equation, given \(l > 0, \beta_l = 0\), we then obtain

\[
\prod_{i}^{bk} = w_{bk}^* \min\left\{ q_{bk}^*, d \right\} - l_{bk}^* (1 + r_f^*) - c_o = A_0(1 + r_f^*) - c_p q_{bk}^* (r_f^* - r_f),
\] (A.48)

and according to the supplier’s objective function in (6), given \(l > 0, \theta = 0\), we have

\[
\prod_{i}^{op} = w_{op}^* \min\left\{ q_{op}^*, d \right\} - l_{op}^* \left( \lambda + \frac{r_f}{365} \right) = A_0(1 + r_f).
\] (A.49)

so it is easy to derive that \(\prod_{i}^{bk} < \prod_{i}^{op}\). To compare the buyer’s profit, by (A.18) and (A.38), we have

\[
\lim_{\text{Var}[d] \to 0} \left( \prod_{i}^{bk} - \prod_{i}^{op} \right) = \lim_{\text{Var}[d] \to 0} \left( \prod_{i}^{op}(q) - \prod_{i}^{op}(q) \right) \geq 0.
\]

Therefore, \(\prod_{i}^{bk} \geq \prod_{i}^{op}\). For the supply chain’s profit comparison, we denote \(\prod_{i}^{c}\) as the supply chain’s profit under financing scheme \(i\), where \(\prod_{i}^{c} = \prod_{i}^{b} + \prod_{i}^{o}, i = bk, op\). Therefore, for \(\prod_{i}^{bk} \geq \prod_{i}^{op}\), we need to have \(\prod_{i}^{bk} - \prod_{i}^{op} \geq l_{bk}^* (r_f^* - r_f)\). Hence, the proof of part (ii) is completed.
Recall that all the above proofs are based on the condition that the bank or the online platform does not quit the market given $l > 0$. As discussed above, when the FSPs decide to quit the market, it is easy to observe that all operations are performed identically, so we ignore this part. This completes the proof. Q.E.D.

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