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Seller-Orchestrated Inventory Financing Under Bank Capital Regulation

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Abstract

To help small firms secure bank financing, large sellers often orchestrate joint finance programs, linking their small dealers with major banks that lend to all participating dealers based on the information the seller provides. We examine supply chain decisions (pricing and inventory) and lending terms under such seller-orchestrated financing programs. In loan pricing, we highlight a form of financial friction that is of particular importance under such schemes—bank capital regulation. Banks are globally mandated to maintain regulatory capital to mitigate unforeseen loan losses, using either the standardized approach (where regulatory capital is a fixed percentage of the loan amount) or the internal rating-based (IRB) approach (where it depends on the loan's value-at-risk). We consider a game-theoretic model consisting of a large seller and multiple capital-constrained newsvendor-type dealers, who obtain financing from banks that are subject to capital regulation. The seller decides the wholesale price and whether to orchestrate a joint finance program for its dealers by collaborating with a bank, and the dealers choose their inventory level and the financing channel. We find that a seller should only orchestrate the joint financing program when the bank adopts the IRB approach and the dealers are of low risk. Such a program is more profitable to the seller when the demand correlation among dealers is low, and there is a large number of dealers. Although always benefiting the seller, these programs may hurt dealers with intermediate risk. Facing dealers with varying financial situations, the terms under the joint finance program should be designed as if the financially strong dealers subsidize the weak ones. Finally, allowing the seller to share part of the loan loss could further enhance the performance of joint financing, but only when the seller's opportunity cost of capital is low. Our findings provide guidance to large sellers on how to orchestrate joint finance schemes, and to small dealers on making their corresponding operational decisions.

Keywords

Supply chain management, operations–finance interface, bank capital regulation, joint finance program, seller-orchestrated inventory financing, risk pooling

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1 Introduction

Small businesses, which represent over 99% of all employer entities, often encounter hurdles while seeking external financing. According to the Small Business Credit Survey (Federal Reserve Banks, 2017), 64% of small businesses reported that they experienced some form of financial difficulties, with the most common ones being paying operating expenses and purchasing inventory to fulfill contracts. These firms typically lack access to public capital markets (Berger and Udell, 2002), making bank financing a crucial lifeline. However, obtaining bank financing does not always go smoothly for small businesses, who often face high interest rates and/or receive less than their requested amount, adversely affecting their operational performance. International Finance Corporation (2017) estimated that the finance gap from small businesses in 128 developing countries reached $5.2 trillion, with 65 million small businesses capital-constrained, representing 40% of all enterprises in the surveyed economies.

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One way to enable easier access to bank financing for small businesses is through their large supply chain partners, who often have better access to financiers. For example, in 2018, Xiaomi, one of the largest smartphone manufacturers in the world, arranged a joint finance program for its dealers in collaboration with East West Bank (Yuan, 2018). Gree, a major appliance manufacturer in China, also offered similar programs to its dealers through Ping An Bank (Huang et al., 2014). Such seller-orchestrated financing programs, also known as distributor financing and dealer financing, also begin to gain popularity in international supply chains. For example, large exporters are looking to their own global bank service providers, such as HSBC and Standard Chartered, to finance the working capital of their small distributors in developing countries (HSBC, 2019; Kumar, 2018; Salecka, 2015).

While providing an alternative source of bank financing, the impact of seller-orchestrated financing programs on the supply chain could be convoluted. On the one hand, under seller-orchestrated financing programs, as the direct lender, the bank lends to all participating dealers of the seller based on the more comprehensive information that the seller provides. As such, when deciding on loan terms, the bank could take into account not only the financial situation of each borrowing firm, but also the potential synergy among them. On the other hand, these programs enable the dealers' access to large banks, while these dealers often borrow from smaller banks under individual financing (Berger et al., 2005). As small and large banks in practice adopt different approaches in regulation compliance, such differences could affect the interest rates faced by the dealers.

Since 1988, the global banking industry has been governed by the Basel banking regulation (Basel Committee, 1988). The Basel framework requires banks worldwide to retain a certain amount of equity capital (regulatory capital [RC]). This requirement creates a cushion that mitigates the impact of individual loan defaults on the stability of the financial system and public welfare. However, as raising equity capital is more costly for banks than raising deposits,[1] the amount of regulatory capital that the bank needs to hold becomes a major factor that influences bank loan pricing (IMF, 2009). The Basel guidelines specify two options that a bank can adopt when calculating their RC: (a) the standardized approach, under which RC equals a fixed proportion of the face value of the loan, and (b) the internal rating-based (IRB) approach, under which RC is calculated based on the value-at-risk (VaR) of the loan (Basel Committee, 2017). While the IRB approach is more sensitive to risk, executing it requires more sophisticated internal risk management practice and thus is associated with substantial administrative and organizational costs. As such, this approach is more commonly adopted by large banks, while most small banks mostly use the standardized approach. Thereby, one implication for the dealers to join a seller-orchestrated financing program is that the loan will be financed by an IRB bank, while individual financing will be provided by a standardized bank.

In addition to adjusting interest rates based on regulatory capital requirements, banks often require the seller to share the dealer's default risk by providing a first-loss coverage. That is, the seller is subject to cover the dealers' losses up to a threshold, with the rest taken by the bank (Salecka, 2015). While risk-sharing is a common practice to boost supply chain efficiency, it is less clear whether it could create substantial value in this setting especially when the seller's cost of funding is higher than the bank's.

Motivated by the above practice, this paper aims to understand the decision and performance of seller-orchestrated inventory financing in the presence of banking regulatory capital requirements. Specifically, we explore the following questions: (a) Do seller-orchestrated financing programs benefit all parties in the supply chain relative to individual financing? (b) How does the seller tailor these programs for dealers with varying financial situations? (c) How do seller-orchestrated financing programs interact with other risk-sharing mechanisms, such as first-loss provision?

To answer these questions, we consider a supply chain consisting of a seller ("she") and multiple capital-constrained dealers ("he") with correlated newsvendor-type demands. In addition to setting the wholesale price, the seller decides whether or not to orchestrate a joint finance program for her dealers in collaboration with an IRB bank. In response, the dealers decide whether to participate in the joint finance program or obtain financing independently and choose inventory levels correspondingly.

By comparing the loan pricing and the corresponding operational decisions under standardized and IRB approaches, we find that as the IRB approach is more sensitive to the borrower's (default) risk, the IRB bank charges a lower (higher) interest rate for low-risk (high-risk) dealers compared to the standardized bank. As a result, a seller should only orchestrate a joint finance program when its dealers' risk is relatively low. In this case, the joint finance program boosts dealers' order quantity and thus improves supply chain efficiency. Such efficiency improvement is enhanced by a classic operations management (OM) principle: risk pooling, which is solely driven by how the RC is calculated under the IRB approach. As the RC under the IRB approach is based on the VaR of the portfolio of dealers, the RC required when financing a portfolio of dealers is lower than if these dealers are individually financed. Such a pooling effect is magnified when the seller supplies a larger amount of dealers, the dealers' demands are less correlated, and the bank's cost of equity capital is higher.

Furthermore, we find the seller-orchestrated finance program is often associated with a higher wholesale price. While this allows the seller to extract more surplus, the impact on dealers' profitability is mixed: for high-risk dealers, the benefit of lowering financing friction dominates the cost associated with the higher wholesale price, leading to a win–win scenario between the seller and dealers. However, for dealers of intermediate risk-level, the joint finance program leads to a lower profit. In other words, it benefits the seller at the expense of dealers. As such, a seller-orchestrated financing program could be another mechanism through which powerful sellers exploit dealers.

Our numerical studies reveal that seller-orchestrated finance is of practical relevance under calibrated parameters. For example, when the demand correlation between dealers is low ($\rho = 0.1$), the seller should arrange joint finance for dealers with almost all asset levels as long as facing more than eight dealers. Doing so could result in a 2% profit increase for the seller, and as high as 50% for low-risk dealers. In addition, the seller's decision to orchestrate a joint finance program is sensitive with respect to the dealer portfolio's risk: when demand correlation increases to 0.5, offering joint financing to high-risk dealers could cost the seller 20% of her profit.

Next, we underscore an implementation challenge when the seller orchestrates a joint financing scheme across dealers with significantly different financial situations: while the participation of high-risk dealers in the joint finance program may benefit the entire supply chain, it could be in their self-interest to obtain financing independently through a standardized bank. To alleviate this incentive conflict, the joint finance scheme should be designed such that it results in a small gap between the rates that dealers face compared to the rates under which the loan to each dealer breaks even. Put differently, the scheme acts as if the financially stronger dealer subsidizes part of the financing cost borne by the weaker one.

Finally, we examine the interaction of joint-financing choices and mechanisms that allow sellers to share the dealers' borrowing risk. Specifically, we consider two such mechanisms: (a) the seller covers the first part of the loan loss under joint financing ("first loss provision") and (b) the seller offers a buyback contract. These extensions introduce a new driving force: the seller's opportunity cost of holding cash for covering potential loan losses. We find that when this cost is low, offering a first-loss provision could further enhance the coverage of joint-financing. However, the seller's incentive to share risk declines rapidly as her cost of capital increases. When the seller's cost of capital is high, even with the buyback contract, individual financing with the buyback contract still underperforms joint financing (without buyback). Combined, these results suggest that when a bank has a relative advantage over the seller in meeting the dealers' financing needs, the seller has little incentive to further share the dealers' borrowing risk and should follow our previous results in pricing and arrange joint finance.

2 Literature Review

Our work is closely related to three streams of research: (a) the interface of operations and finance; (b) risk pooling; and (c) the banking literature that focuses on the impact of capital regulations on bank loan pricing.

In the growing literature on the interface of operations and finance, many papers examine firms' optimal operational decisions, such as inventory, capacity, and pricing in the presence of various forms of financial market frictions, such as corporate tax (Chod and Zhou, 2013), cost of financial distress (Boyabatlı and Toktay, 2011; Kouvelis and Zhao, 2011), information asymmetry (Lai and Xiao, 2018; Ning and Babich, 2018), and bank's market power (Buzacott and Zhang, 2004; Dada and Hu, 2008). Our paper complements this strand of literature by focusing on another form of financial market imperfection: bank capital regulation. Despite its prevalence and practical importance, bank capital regulation has received scant attention in the OM community. One exception is Zhang et al. (2022), who study the impact of bank capital regulation on a single retailer's inventory management. Our work differs from Zhang et al. (2022) in several aspects. First, we consider the interaction among multiple strategic players, including the seller and multiple dealers, in a supply chain. This highlights that the impact of bank capital regulation on firms' operational decisions depends not only on the financial situations of individual borrowing firms, but also on their collective riskiness as a portfolio. Besides, bank capital regulation not only affects the borrowing firms, but also their supply chain partners. We also discuss how the seller should respond when its downstream dealers face high financing costs due to bank capital regulation, through orchestrating joint-financing and/or sharing part of the risk. Relatedly, our work is also connected to the papers on decision-making under risk-aversion (e.g., Chen et al., 2007; Gaur and Seshadri, 2005), and in particular those related to VaR and CVaR (Chen et al., 2009; Kouvelis and Li, 2019). To complement this literature, we show that even when all players are risk-neutral, risk-aversion type behavior could arise from regulatory requirements, and we find that such regulations could have a significant impact on firms' operational decisions.

Our paper is also related to another stream of research in the OM–Finance literature that focuses on the financing assistance provided by supply chain partners. Such assistance can take the form of trade credit (Devalkar and Krishnan, 2019; Kouvelis and Zhao, 2012; Lee et al., 2018; Luo and Shang, 2019; Yang and Birge, 2018), reverse factoring (Hu et al., 2018; Kouvelis and Xu, 2021; Tunca and Zhu, 2018; Wuttke et al., 2019), and purchase order financing (Reindorp et al., 2018; Tang et al., 2018). In our paper, while the large seller does not directly lend to her small customers, she orchestrates a joint finance program that grants small dealers access to a large IRB bank, which can price the loan based on more comprehensive information that the seller provides (e.g., demand correlation among dealers). Such a scheme is directly related to the focal financial friction in the paper—bank capital regulation. The paper highlights that in the presence of bank capital regulation, even when dealers do not directly compete against each other on the product market, which was modeled in other papers in the literature (Chod et al., 2019; Wu et al., 2019), they are linked financially through joint financing. Thus, it is crucial to consider the synergy, as well as conflict of interests, among them when designing such joint finance programs.

In the OM literature, risk pooling has been examined extensively as the basic driver behind strategies such as inventory pooling (Bimpikis and Markakis, 2015), manufacturing flexibility (Graves and Tomlin, 2003), component commonality (Van Mieghem, 2004), and delayed product differentiation (Lee and Tang, 1997). This paper complements the above literature by analyzing the benefit of risk pooling through a new angle—financing under bank capital regulation. A seller-orchestrated joint finance program is able to pool the dealers' demand risks and results in a lower regulatory capital requirement for each dealer from an IRB bank than if the dealers obtain financing independently, and the advantage is more pronounced when the number of the dealers is large and demand correlation is low.

Finally, in the banking literature, there are both theoretical and empirical studies on bank capital regulation. On the modeling side, our paper is closely related to Ruthenberg and Landskroner (2008), who compare the loan pricing between the standardized approach and the IRB approach. Our paper extends Ruthenberg and Landskroner (2008) in two aspects. First, by taking into consideration the strategic behavior of different players in the supply chain, we identify how bank capital regulation interacts with various operational parameters. For example, we highlight that the relative advantage of the IRB approach over the standardized one is closely related to the risk pooling effect among different dealers. We also find that although the IRB approach could reduce financial friction, such a benefit is not necessarily shared by all parties in the supply chain. Finally, we highlight the active role of the seller in orchestrating the scheme, especially when facing dealers with heterogeneous risk profiles. On the empirical side, Wallen (2017) quantifies the impact of bank capital regulation on loan pricing. Schwert (2018) finds that bank-dependent firms tend to borrow from well-capitalized banks, while firms with access to the public bond market borrow from banks with less capital. Our results complement these papers by showing that bank capital regulation has a significant influence on firms' lending rates and choice of banks in practice.

3 The Model

To focus on the impact of bank capital regulation and seller orchestration, we consider a supply chain consisting of a seller ("she"), multiple financially constrained newsvendor-type dealers ("he"), and a competitive banking industry consisting of two types of banks: small banks following the standardized approach for regulatory capital, and large banks following the IRB approach.

On the operational side, the seller with unit product cost c sells to the dealers via a wholesale price contract. Dealers sell the product at retail price p to uncertain demand $\widetilde{\mathbb{D}} = (\widetilde{D}_1, \widetilde{D}_2, \dots, \widetilde{D}_n)^T$. For tractability, we follow the literature (Erkip et al., 1990; Aviv, 2001; Netessine and Rudi, 2003) and assume that each $\widetilde{D}_i$ $(1 \le i \le n)$ follows a normal distribution with positive support with mean μ and standard deviation σ. We use $\Phi(\cdot)$ to denote the cumulative distribution function (CDF) of a single dealer's demand and $\phi(\cdot)$ for the corresponding probability density function (PDF). While different dealers do not compete directly, their demands are correlated due to a variety of reasons such as geographic location and customer preference. To capture this correlation, we assume that the (average) coefficient of correlation between any two dealers is $\rho \in [0, 1]$. ρ captures the systemic risk component of demand uncertainty that the seller faces when supplying a portfolio of dealers. A low ρ suggests that the demand risk is mostly idiosyncratic to each dealer. Finally, in our model, as separate entities, dealers do not share inventory with each other. That is, there is no transshipment arrangement among dealers.

On the financial side, each dealer is endowed with an initial asset A_i for inventory investment and can borrow a bank loan if needed. A_i captures the risk profile of each dealer: a lower A suggests that the dealer needs more external financing for inventory and hence is riskier. We first consider the case where all dealers have identical initial assets. Here, we omit the index i and denote each dealer's asset as A for expositional brevity. We extend our analysis to the case where dealers have heterogeneous initial assets in Section 6.

When the dealer's initial asset A is not sufficient for his inventory investment, he can obtain a bank loan through two channels: he can either obtain the loan from a small standardized bank with whom he had an existing relationship or obtain the loan from an IRB bank if the seller orchestrates a joint finance program.[2] To focus on the impact of bank capital regulation, we take away other forms of financial frictions.

For loan pricing, as the banking industry is perfectly competitive, the bank sets the interest rate r such that its expected cost equals the expected payoff. Formally, let the bank's cost of deposit be r_f (risk-free rate) and its cost of (equity) capital be δ $(\delta > r_f)$.[3] When it lends to a borrower a loan with amount B and random loss $\tilde{L}$, the bank is required by banking regulation to hold regulatory capital with amount C, the interest rate r is determined by:

$$B(1 + r) - \mathbb{E}[\tilde{L}] = (1 + r_f)(B - C) + (1 + \delta)C \qquad (1)$$

The left-hand-side of the equation is the expected payoff of the loan, while the right-hand-side is the cost of the loan: the amount of regulatory capital (C) is financed at the cost of equity δ, whereas the rest ($B - C$) is financed at the risk-free rate. Note that when $\delta = r_f$, the above equation reduces to the competitive loan pricing formula without any market imperfection.

Depending on the regulatory approach the bank follows, the RC is calculated differently. Here, we follow the Basel guidelines when calculating RC (C) under each regulatory approach. Specifically, when the bank follows the standardized approach, its regulatory capital C^S follows:[4]

$$C^S = \beta^S B, \qquad (2)$$

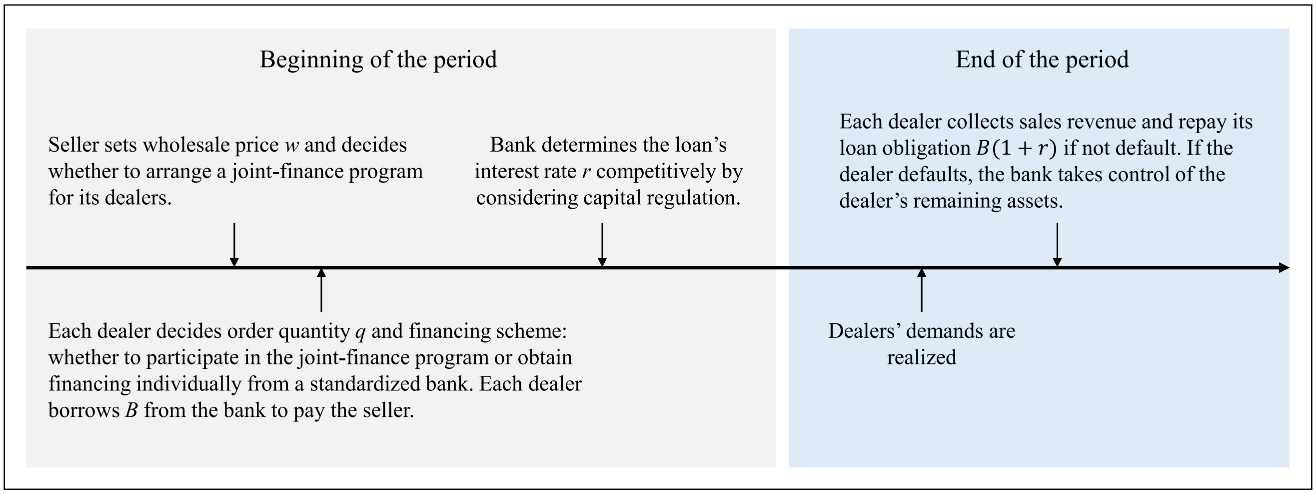

Figure 1. Sequence of events.

with β^S indicating the capital adequacy ratio under the standardized approach.

On the other hand, if the bank follows the IRB approach, the regulatory capital associated with the loan is calculated as the difference between VaR and expected loss (Basel Committee, 2006; Cummings and Durrani, 2016; Krüger et al., 2018; Ruthenberg and Landskroner, 2008),[5] where VaR is the quantile of the loan's loss distribution corresponding to a certain confidence level α. That is, $\text{Prob}(\tilde{L} \leq \text{VaR}) = \alpha$. This confidence level α is often related to the bank's credit rating and is required to be no less than 99.9% under the IRB approach (Basel Committee, 2006, Paragraph 346).[6] Under most circumstances, with such high confidence levels, the loan's VaR is often higher than its expected loss, therefore, the bank reserves a positive amount of capital for the loan. However, under the extreme situation when the dealer is of very high quality, the bank may estimate the loan as having very low risk ($\text{VaR} - \mathbb{E}[\tilde{L}]$ is close to zero). In this case, the Basel guideline sets a minimum capital amount of $\beta^{IS}B$ to be reserved for contingencies, where β^{IS} is the minimum required capital adequacy ratio under the IRB approach and $\beta^{IS} < \beta^S$ (Basel Committee, 2006, Paragraphs 285 and 295). Combining the above two conditions, the regulatory capital under IRB approach C^I is:

$$C^I = \max(\text{VaR} - \mathbb{E}[\tilde{L}],\ \beta^{IS}B). \tag{3}$$

To illustrate how regulatory capital is calculated under the IRB approach, consider the following stylized example. The dealer, who has no initial assets, faces a wholesale price of \$1 per unit; a retail price of \$2 per unit, and a salvage value of 0. The demand is 0 or 1, each with probability 0.5; the bank's confidence level used to calculate VaR is $\alpha = 99.9\%$, and the minimum required capital adequacy ratio $\beta^{IS} = 1\%$. In this simple case, the dealer borrows \$1 from the bank to purchase one unit of inventory. The bank's expected loss is \$0.5 and its $\text{VaR} = 1$. We have the bank's regulatory capital under the IRB approach as $C^I = \max(0.5, 0.01) = 0.5$.

Combining the operational and financial aspects of the model, the sequence of events is illustrated in Figure 1. At the beginning of the period, as the Stackelberg leader, the seller sets a wholesale price w for her dealers and decides whether to arrange a joint finance program for them under an IRB bank. If the seller arranges a joint finance program with an IRB bank, each dealer, under a rational belief about other dealers' behavior, simultaneously decides his stocking level q, and then borrows $B = (wq - A)^+$ either through the joint finance program or individually from a standardized bank. If the seller chooses not to arrange a joint finance program, each dealer can only finance individually from a standardized bank (the individual-finance equilibrium). At the end of the period, demands $\tilde{\mathbb{D}}$ are realized and each dealer collects sale proceeds $p\ \min(\tilde{D}, q)$, and, under limited liability, repay the loan to the extent possible. To avoid trivial cases, we limit the analysis within the parameter space such that $p \geq w(1+r)$, as otherwise, the bank loan will always default.

4 Individual Finance With Standardized Banks

We first analyze the benchmark scenario where the seller does not orchestrate a joint finance program. Instead, she offers a wholesale price contract and the dealers seek financing individually from their local banks, who adopt the standardized approach for capital regulation. We solve the model using backward induction. First, given the seller's wholesale price and each dealer's order quantity, we analyze the bank's equilibrium interest rate. Second, we solve for each dealer's optimal order quantity. Lastly, anticipating the dealers' responses, the seller optimizes her wholesale price.

By the analysis of the first two steps,[7] we show that because the bank's regulatory capital is a fixed fraction of the borrowed amount under the standardized approach, conditional on the dealer's order quantity, the interest rate that the bank charges on the loan is independent of other dealers' order quantities or financing channels (individual finance or joint finance). Thus, the dealer's optimal order quantity with standardized banks under the exogenous wholesale price [$q^{S*}(w)$ is given in Lemma 3 in Appendix D.2 in the E-Companion] is also independent of other dealers' behavior. As such, when borrowing from standardized banks, the dealer is indifferent between obtaining a loan independently or through a joint finance program. This in turn rationalizes the seller's decision of not orchestrating a joint finance program by collaborating with standardized banks.

We further find that when the dealer is capital-constrained and borrows from a standardized bank, $q^{S*}(w)$ is also independent of the dealer's initial asset level A, while decreases when borrowing from the standardized bank becomes more costly, such as facing a higher cost of equity capital (δ) during the financial crisis, or required by the government to increase the capital adequacy ratio (β^S).[8]

Given the dealers' best response $q^{S*}(w)$, the seller maximizes her end-of-period profit $\pi_s = n(1+r_f)(w-c)q^{S*}(w)$, where c is the seller's per unit production cost.

PROPOSITION 1. *Without orchestrating a joint finance program, the seller's optimal wholesale price is:*

$$w^* = \begin{cases} w^N, & \text{if } A \geq w^N q^N \\ w^E(A), & \text{if } \hat{A}^S \leq A < w^N q^N \\ w^S, & \text{if } 0 \leq A < \hat{A}^S \end{cases} \tag{4}$$

where w^N, q^N, $w^E(A)$, $q^E(A)$, w^S, q^S, and $\hat{A}^S$ satisfy:

$$\bar{\Phi}(q^N) - q^N\phi(q^N) - \frac{c(1+r_f)}{p} = 0, \quad w^N = \frac{p\bar{\Phi}(q^N)}{1+r_f}; \tag{5}$$

$$q^E(A)\bar{\Phi}[q^E(A)] - \frac{A(1+r_f)}{p} = 0, \quad w^E(A) = \frac{A}{q^E(A)}; \tag{6}$$

$$\bar{\Phi}(q^S) - q^S\phi(q^S) - \frac{c[1+r_f+\beta^S(\delta-r_f)]}{p} = 0,$$

$$w^S = \frac{p\bar{\Phi}(q^S)}{1+r_f+\beta^S(\delta-r_f)}; \tag{7}$$

$$\hat{A}^S - cq^E(\hat{A}^S) - (w^S - c)q^S = 0. \tag{8}$$

Furthermore, $w^S < w^N$, $q^S < q^N$, $q^E(A)$ increases in A while $w^E(A)$ decreases in A.

Proposition 1 implies that the seller charges different wholesale prices to dealers with varying initial assets. When the dealer has abundant initial asset ($A \geq w^N q^N$), the optimal wholesale price w^N and corresponding order quantity q^N in equation (5) are the same as the traditional newsvendor case. When the dealer's initial asset decreases ($\hat{A}^S \leq A < w^N q^N$), the dealer first uses up all his initial asset to purchase goods [$wq^{S*}(w) = A$]. In this case, the seller's profit is $\pi_s = n(1+r_f)[A - cq^{S*}(w)]$, therefore, the seller's problem turns into minimizing her production cost, which is equivalent to reducing the dealer's order quantity. Therefore, the seller will charge a wholesale price higher than the traditional newsvendor [$w^E(A) > w^N$ for $A < w^N q^N$] to motivate the dealer to order less [$q^E(A) < q^N$ for $A < w^N q^N$]. When the dealer's initial asset further decreases ($0 \leq A < \hat{A}^S$), the dealer borrows from the bank and incurs a positive financing cost. The seller partially compensates the dealer for his financing cost by decreasing her wholesale price to w^S ($w^S < w^N$). Since the dealer still bears part of the financing cost, his optimal order quantity with endogenous wholesale price q^S is lower than the traditional newsvendor amount q^N. Finally, we note that when the dealer is capital-constrained and borrows from a standardized bank, due to the independence between $q^{S*}(w)$ and A, the seller's optimal wholesale price w^S is also independent of the dealer's initial asset.

5 Seller-Orchestrated Joint Finance With an IRB Bank

As the standardized approach does not account for the risk profile of the loans as a portfolio, it calls for more sophisticated approaches. The IRB approach offers a possible solution. In this section, we study whether the seller should orchestrate a joint finance program with an IRB bank, as well as the seller and dealers' operational decisions under the joint finance program. As all dealers are homogeneous, we focus on the symmetric pure strategy equilibrium. That is, either all dealers participate in the joint finance program or all finance individually.

5.1 Loan Pricing Under the IRB Approach

Similar to the previous section, we conduct the analysis using backward induction, first by characterizing the loan terms under the IRB approach. Differently, under this approach, the regulatory capital that the bank is required to hold for each loan depends on the VaR of the portfolio of loans borrowed by dealers.[9] To calculate that, we need to characterize the aggregated uncertainty for the portfolio of loans. Here, as the demand $\widetilde{D}_i$ faced by each dealer follows a normal distribution with mean μ and standard deviation σ, the aggregate demand $\widetilde{D}_p = \sum_{i=1}^n \widetilde{D}_i$ follows a normal distribution with mean $\mu_p = n\mu$ and variance $\sigma_p^2 = [n + n(n-1)\rho]\sigma^2$. The portfolio VaR satisfies Prob [$\text{VaR}_p \geq p(n\theta^I - \widetilde{D}_p)$] $= \alpha$, which yields:

$$\text{VaR}_p = p\left[n\theta^I - n\mu - \sigma Z_{1-\alpha}\sqrt{n + n(n-1)\rho}\right], \tag{9}$$

where $\theta^I := B(1+r^I)/p$ is the default threshold, which is the minimum demand so that the dealer will not default on the bank loan. $Z_{1-\alpha}$ is the $1-\alpha$ quantile of the standard normal distribution. Therefore, the IRB bank's expected loss for each loan is:

$$\mathbb{E}[\tilde{L}^I] = p\left[\theta^I - \int_0^{\theta^I} \bar{\Phi}(x)\mathrm{d}x\right]. \tag{10}$$

Since the loan portfolio's expected loss is the sum of the expected loss of each dealer's loan, the regulatory capital for each dealer's loan in the portfolio is determined by:

$$\begin{aligned}\frac{C_p^I}{n} &= \max\left(\frac{\mathrm{VaR}_p}{n} - \mathbb{E}[\tilde{L}^I],\ \beta^{IS}B\right)\\ &= \max\left[p\left(\int_0^{\theta^I}\bar{\Phi}(x)\mathrm{d}x\right.\right.\\ &\qquad \left.\left. -\mu - \sigma Z_{1-\alpha}\sqrt{\frac{1+(n-1)\rho}{n}}\right),\ \beta^{IS}B\right].\end{aligned} \tag{11}$$

As Basel II requires $\alpha \geq 99.9\%$, we have $Z_{1-\alpha} < 0$. Then (11) indicates that the dealer's regulatory capital when evaluated in a portfolio (C_p^I/n) convexly decreases in n (see Technical Lemma 1 in Appendix C in the E-Companion). That is, by pooling the risk from different dealers together, the bank is required to hold less regulatory capital under the IRB approach, and the marginal risk pooling benefit of adding one more dealer decreases with the size of the dealer portfolio. Such risk pooling benefit is further amplified when the dealer portfolio is more diversified (low ρ).

Taking equations (10) and (11) into (1), the bank's equilibrium interest rate under the IRB approach is determined by:

$$p\int_0^{\theta^I}\bar{\Phi}(x)\mathrm{d}x = (1+r_f)B + (\delta - r_f)\frac{C_p^I}{n}. \tag{12}$$

We can prove that $\partial r^I/\partial q > 0$, indicating that there is a unique equilibrium interest rate for the dealer's loan and that this rate rises as the dealer increases his order quantity.

5.2 Dealers' Operational Decision and Financing Choice

Anticipating the loan terms, if all dealers participate in the joint finance program, their equilibrium order quantity under the wholesale price w is as follows.

Lemma 1. *When all dealers participate in the seller-orchestrated joint finance program, the equilibrium order quantity for each dealer is:*

$$q^{I*}(w) = \begin{cases} q^N(w), & \text{if } A \geq wq^N(w)\\ q^E(w,A), & \text{if } wq^{IS}(w) \leq A < wq^N(w)\\ q^{IS}(w), & \text{if } A^{IB}(w,\rho,n) \leq A < wq^{IS}(w)\\ q^{IB}(w,\rho,n,A), & \text{if } A^{IV}(w,\rho,n) \leq A < A^{IB}(w,\rho,n)\\ q^{IV}(w), & \text{if } 0 \leq A < A^{IV}(w,\rho,n)\end{cases} \tag{13}$$

where $q^N(w) = \bar{\Phi}^{-1}[w(1+r_f)/p]$, $q^E(w,A) = A/w$, $q^{IS}(w) = \bar{\Phi}^{-1}\{w[1+r_f+\beta^{IS}(\delta-r_f)]/p\}$, $q^{IV}(w) = \bar{\Phi}^{-1}[w(1+r_f)/p(1+r_f-\delta)]$,

$$q^{IB}(w,\rho,n,A) = \frac{A}{w} + \frac{p\{\mu + \sigma Z_{1-\alpha}\sqrt{[1+(n-1)\rho]/n}\}}{w[1+r_f-\beta^{IS}(1+r_f-\delta)]},$$

$$A^{IV}(w,\rho,n) = wq^{IV}(w) - \frac{p\{\mu + \sigma Z_{1-\alpha}\sqrt{[1+(n-1)\rho]/n}\}}{1+r_f-\beta^{IS}(1+r_f-\delta)},$$

and

$$A^{IB}(w,\rho,n) = wq^{IS}(w) - \frac{p\{\mu + \sigma Z_{1-\alpha}\sqrt{[1+(n-1)\rho]/n}\}}{1+r_f-\beta^{IS}(1+r_f-\delta)}.$$

This result is similar to Proposition 3 in Zhang et al. (2022). However, it considers the interaction between multiple dealers. Thus, the asset thresholds and order quantities depend not only on the wholesale price, but also on the number of dealers jointly financed and the demand correlation across the dealers. The next proposition, which extends Proposition 4 in Zhang et al. (2022), captures the dealers' preference between individual and joint finance.

Proposition 2. *Dealers strictly prefer the joint finance program if and only if their initial asset* $A \in [\bar{A}(w,\rho,n),\ wq^{IS}(w)]$, *where* $\bar{A}(w,\rho,n) < A^{IB}(w,\rho,n)$.

As the proposition suggests, when dealers' initial assets are reasonably high [$A > \bar{A}(w,\rho,n)$], they are more likely to participate in the joint finance program. On the other hand, the dealers with low initial assets are better off with individual finance, which is less sensitive to their riskiness. Furthermore, we note that the threshold $\bar{A}(w,\rho,n)$ decreases in n and increases in ρ (see Technical Lemma 2 in Appendix C and the proof in E-Companion for details). That is, the region where the joint finance program is preferred by the dealers enlarges as the seller faces a larger number of dealers (n) with less correlated demand (ρ), and this highlights that the benefit of joint finance lays in the role of risk pooling.

5.3 Optimal Wholesale Price Under Joint Finance

Anticipating the dealers' response, the seller's optimal wholesale price w under the joint finance program is characterized below.

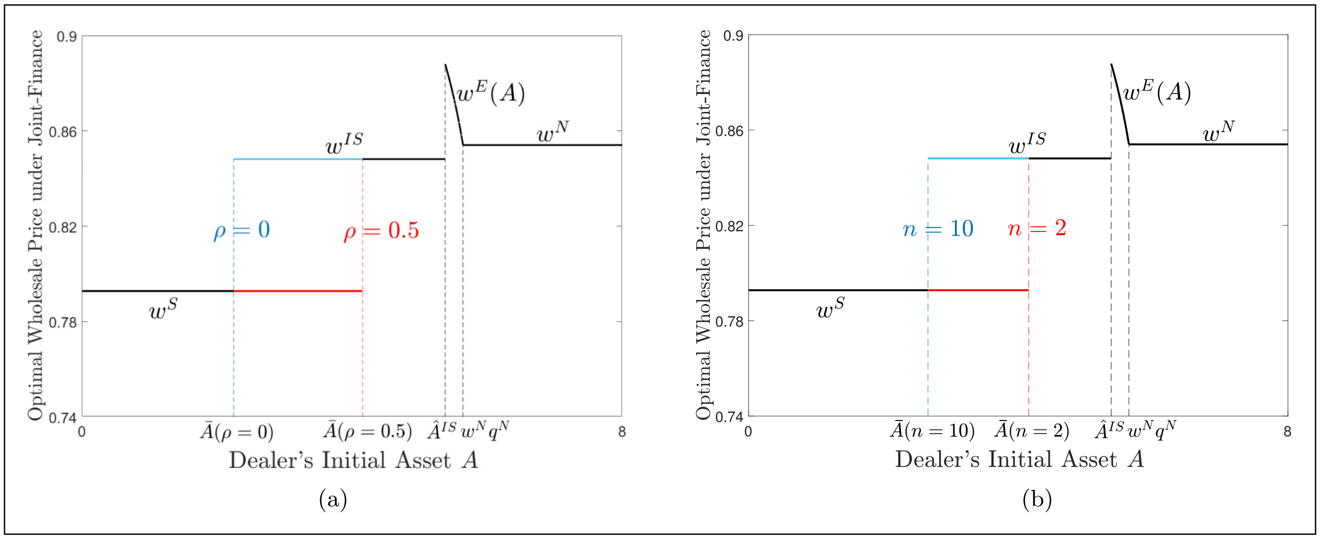

Figure 2. Seller's optimal wholesale price under joint finance. (a) Varying demand correlation; (b) varying portfolio size.
Notes. Parameter values for the above figure: $p = 1$, $c = 0.4$, $\delta = 0.1$, $r_f = 0.02$, $\beta^S = 0.1$, $\beta^{IS} = 0.01$, $\alpha = 99.99\%$, $\mu = 10$, $\sigma = 3$, $n = 2$ (for (a)), and $\rho = 0.5$ (for (b)).

PROPOSITION 3. *When the seller orchestrates a joint finance program, her optimal wholesale price is:*

$$w^* = \begin{cases} w^N, & \text{if } A \geq w^N q^N \\ w^E(A), & \text{if } \hat{A}^{IS} \leq A < w^N q^N \\ w^{IS}, & \text{if } \bar{A}(\rho, n) \leq A < \hat{A}^{IS} \\ w^S, & \text{if } 0 \leq A < \bar{A}(\rho, n) \end{cases} \tag{14}$$

where w^N, $w^E(A)$ and w^S are defined in Proposition 1, and w^{IS}, q^{IS}, $\bar{A}(\rho, n)$ and $\hat{A}^{IS}$ are determined as follows:

$$\bar{\Phi}(q^{IS}) - q^{IS}\phi(q^{IS}) - \frac{c[1 + r_f + \beta^{IS}(\delta - r_f)]}{p} = 0,$$

$$w^{IS} = \frac{p\bar{\Phi}(q^{IS})}{1 + r_f + \beta^{IS}(\delta - r_f)}; \tag{15}$$

$$\bar{A}(\rho, n) = w^{IS}q^{IS} - \frac{p\{\mu + \sigma Z_{1-\alpha}\sqrt{[1 + (n-1)\rho]/n}\}}{1 + r_f - \beta^{IS}(1 + r_f - \delta)}; \tag{16}$$

$$\hat{A}^{IS} - cq^E(\hat{A}^{IS}) - (w^{IS} - c)q^{IS} = 0. \tag{17}$$

COROLLARY 1. *In equilibrium, when bank financing is needed, the wholesale price and order quantity increase in the dealers' asset level (A) and the number of dealers (n), decrease in demand correlation (ρ) and bank's confidence level (α).*

The above results are illustrated in Figure 2. When dealers' default risk is high ($0 \leq A < \bar{A}(\rho, n)$), as they do not participate in the joint finance program, the seller charges the same wholesale price w^S as when she does not arrange the program. For low-risk dealers ($\bar{A}(\rho, n) \leq A < \hat{A}^{IS}$), they participate in the joint finance program for the benefits of risk pooling and lower capital regulation cost. These benefits are extracted by the seller, as the Stackelberg leader, through a wholesale price higher than that under individual finance, that is, $w^{IS} > w^S$. However, due to the reduction in financial friction, the dealer's equilibrium order quantity q^{IS} is higher than that without joint finance q^S despite the higher wholesale price.

The above results also highlight the impact of ρ and n on the equilibrium operational decisions. Such dependence is solely due to the risk-pooling benefit of joint finance under bank capital regulation. That is, financing a portfolio of more diversified dealers together (characterized by a lower demand correlation ρ and a larger number of dealers n), allows the bank to further reduce the required regulatory capital under the IRB approach, thus lowering the dealers' financing cost and motivating them to order more. In anticipation of this response, the seller will also increase the wholesale price to extract a higher profit.

5.4 Seller's Decision in Orchestrating Joint Finance

By comparing her profits with the joint finance program and without, the seller decides when to orchestrate a joint finance program for the dealers.

PROPOSITION 4. *The seller orchestrates the joint finance program with an IRB bank if and only if $A \in [\bar{A}(\rho, n), \hat{A}^{IS}]$.*

By comparing Propositions 1 and 3, we note that when the dealers' asset $A > \hat{A}^{IS}$, dealers are self-financed with or without the joint finance program, and when $A < \bar{A}(\rho, n)$, the dealers would not participate joint finance even if it is offered. Thus, the seller should only orchestrate the joint finance program when the dealers' assets are in between. In this region, the joint finance benefits the seller by allowing her to charge a higher wholesale price ($w^{IS} > w^S$) and also receive a larger order quantity ($q^{IS} > q^S$).

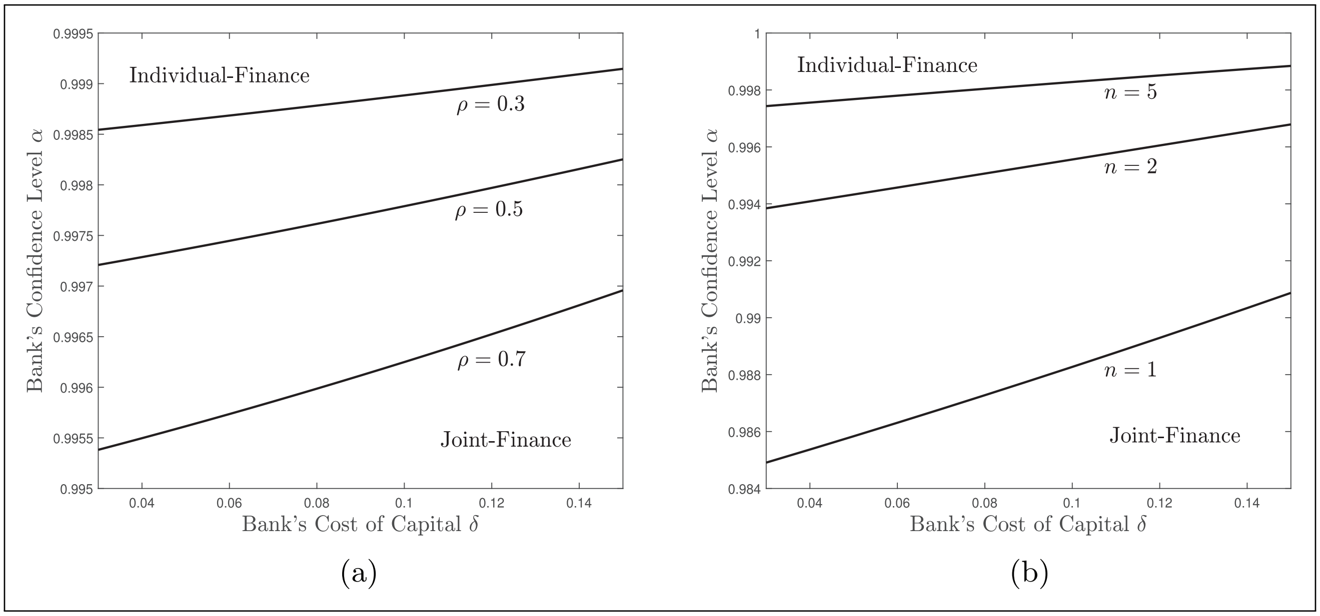

Figure 3. Indifference curves for the choice of financing schemes. (a) Demand correlation; (b) portfolio size.
Notes: Parameter values for the above figure: $p = 1$, $c = 0.4$, $\delta = 0.1$, $r_f = 0.02$, $\beta^S = 0.1$, $\beta^{IS} = 0.01$, $\alpha = 99.99\%$, $\mu = 10$, $\sigma = 3$, $n = 2$ (for (a)), and $\rho = 0.5$ (for (b)).

Figure 3 plots the seller's indifference curves between orchestrating joint finance or not under various operational and financial parameters. It suggests that the joint finance program is more likely to prevail when the benefit of risk pooling is larger, characterized by a lower demand correlation and a larger portfolio size. Furthermore, a lower confidence level and a higher cost of capital will also make joint finance more favorable. This is because an IRB bank with a lower confidence level requires less regulatory capital and thus can offer a lower interest rate. An increase in the bank's cost of capital, for example, during a financial crisis, raises the cost borne by the dealers due to capital regulation under both financing schemes. However, the marginal increase under the standardized approach is higher than that under the IRB approach, giving the joint finance program a competitive edge.

5.5 Is Joint Finance a Win–Win Solution?

As an option for the seller, joint finance is offered when it benefits the seller. However, as the dealers face a higher wholesale price under joint finance, it is not immediately clear if the dealers are always better off when joint finance is offered.

PROPOSITION 5. *There exists a threshold $\bar{\bar{A}} \in [\bar{A}(\rho, n),\ \hat{A}^S]$ such that the joint finance program hurts the dealers when $A \in [\bar{\bar{A}}, \hat{A}^S]$, and benefits the dealers otherwise.*

The proposition is further illustrated in Figure 4, where ΔV_s, ΔV_d and ΔV_{sc} ($= \Delta V_s + \Delta V_d$) denote the difference between the payoff under joint finance and that under individual finance for the seller, the dealers, and the entire supply chain, respectively.

As shown, in equilibrium, the joint finance program benefits the dealers in two scenarios, that is, when $A \in (\hat{A}^S,\ \hat{A}^{IS})$ and $A \in [\bar{A}(\rho, n), \bar{\bar{A}}]$. For the first scenario, that is, when $A \in (\hat{A}^S, \hat{A}^{IS})$, recall that if the dealers only have access to individual finance, they would not borrow given the higher interest rate, and would then use up all their initial assets. However, under joint finance, due to the lower financing costs, dealers do borrow. Thus, the joint finance program expands the region of assets under which dealers adopt external financing.

On the other hand, when $A \in [\bar{A}(\rho, n), \bar{\bar{A}}]$, the dealers borrow under both individual finance and joint finance. To better understand the related trade-off, we deconstruct the value of joint finance for dealers (ΔV_d) into the following two parts, where $q^{IS}(w^S)$ represents the dealers' order quantity when they participate in joint finance with the seller's wholesale price being the same as in individual finance (w^S).

$$\Delta V_d = n\left\{\underbrace{\mathbb{E}[\pi_d(w^{IS}, q^{IS}(w^{IS}))] - \mathbb{E}[\pi_d(w^S, q^{IS}(w^S))]}_{\text{Effect of rent extraction } (\Delta V_d^e)}\right\} + n\left\{\underbrace{\mathbb{E}[\pi_d(w^S, q^{IS}(w^S))] - \mathbb{E}[\pi_d(w^S, q^S(w^S))]}_{\text{Effect of risk pooling } (\Delta V_d^p)}\right\}. \quad (18)$$

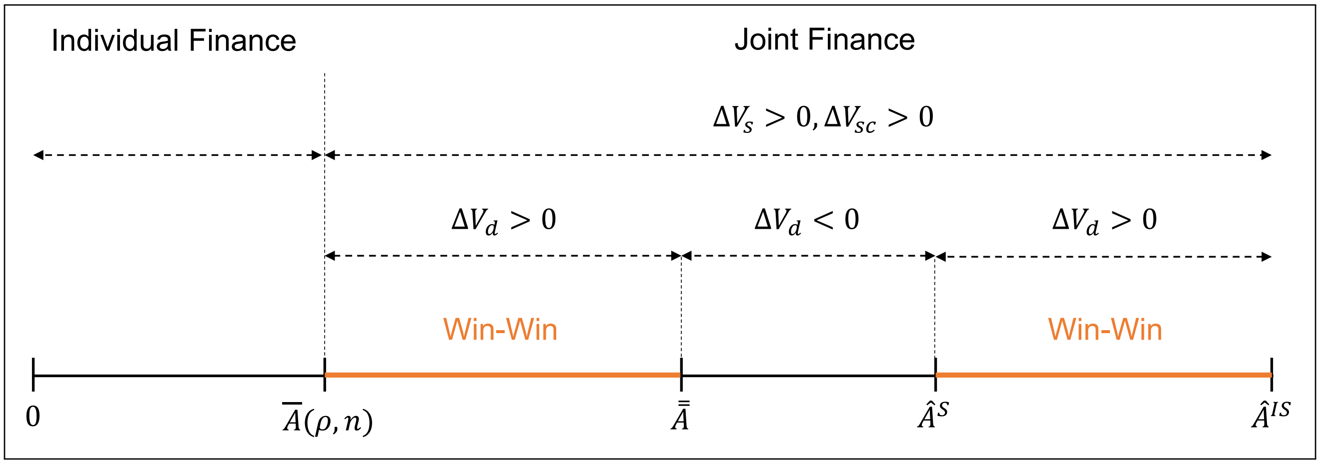

Figure 4. Impact of joint finance on seller and dealers.

As shown, the value of joint finance depends on a trade-off between the risk pooling benefit and the negative rent extraction effect, which is due to the higher wholesale price. On the risk pooling benefit, given the seller's wholesale price, as the dealers' initial asset increases, they borrow less from the bank. Since the benefit of risk pooling only accrues on the borrowing amount, the benefit decreases as the dealers borrow less ($\partial \Delta V_d^p / \partial A < 0$). On the other hand, the effect of rent extraction remains unchanged with varying initial assets. As such, there will be an asset threshold $\bar{\bar{A}}$ that separates the relative dominance of these two effects. When the dealers' initial asset is below $\bar{\bar{A}}$, the large benefit from risk pooling dominates the negative impact of allocating more profits to the seller; therefore, joint finance is beneficial for the dealers, creating a win–win situation. On the other hand, when the dealers' initial asset is above $\bar{\bar{A}}$, the negative impact of profit allocation dominates the decreasing benefit of risk pooling, and joint finance benefits the seller at the expense of the dealers.

COROLLARY 2. *In equilibrium, the value of joint finance to the entire supply chain increases in the number of dealers (n),*

(i) *when $A \in [\bar{A}(\rho, n), \hat{A}^S)$, the value of joint finance also increases in bank's cost of capital (δ), and decreases in demand correlation (ρ) and bank's confidence level (α);*
(ii) *when $A \in [\hat{A}^S, \hat{A}^{IS})$, the value of joint finance decreases in bank's cost of capital (δ).*

The above result reveals that when $A \in [\bar{A}(\rho, n), \hat{A}^S)$, from the supply chain perspective, the effect of rent extraction cancels out between the seller and the dealers. Therefore, the supply chain always benefits from joint finance due to risk pooling. As the benefit of risk pooling is strengthened by a more diversified dealer portfolio (low ρ and large n), an easing regulatory requirement (low α), and a higher bank's cost of capital, orchestrating a joint finance program becomes more rewarding in such circumstances. When $A \in [\hat{A}^S, \hat{A}^{IS})$, as dealers borrow from banks under joint finance but do not borrow under individual finance, a higher bank's cost of capital will lead to a lower supply chain profit only under joint finance. Therefore, the value of joint finance decreases with bank's cost of capital.

5.6 Numerical Study

To quantify the economic impact of orchestrating a joint finance program for the seller and the dealers, we calibrate our modeling parameters using actual data. For demand distribution, we follow Jain et al. (2021), who use the A. C. Nielsen Homescan panel data set over the period of 2004–2009 and estimate the average monthly coefficient of variation (cv) for normal distribution to be 0.51. We transform monthly cv into quarterly cv by assuming independence of demand across months. Therefore, the average quarterly $cv = (0.51/\sqrt{3}) = 0.29$. For profit margin, we follow Zhang et al. (2022), who use the Worldscope firms' financial information over 2004–2009 and estimate the median of quarterly profit margin to be 0.29. For banking regulatory parameters, we follow Basel Committee (2006) and set $\beta^S = 8\%$, $\beta^{IS} = 0.1\%$, and $\alpha = 99.99\%$. The bank's cost of capital and the risk-free rate are set to be 7% and 2%, respectively, according to Damodaran (2018).[10]

Figure 5 presents the seller's relative profit difference between joint finance and individual finance across low- and high-demand correlation scenarios. Seller's relative profit difference is defined as the seller's profit difference between joint finance and individual finance as a percentage of the seller's profit under individual finance, that is, $(\pi_s^I - \pi_s^S)/\pi_s^S$. This measure quantifies the economic impact of orchestrating a joint finance program for the seller. Therefore, the seller will only orchestrate a joint finance program when this value is positive, while letting the dealers individually finance from standardized banks otherwise. On the x-axis, we normalize the dealer's initial asset A by the amount of capital the dealer would need

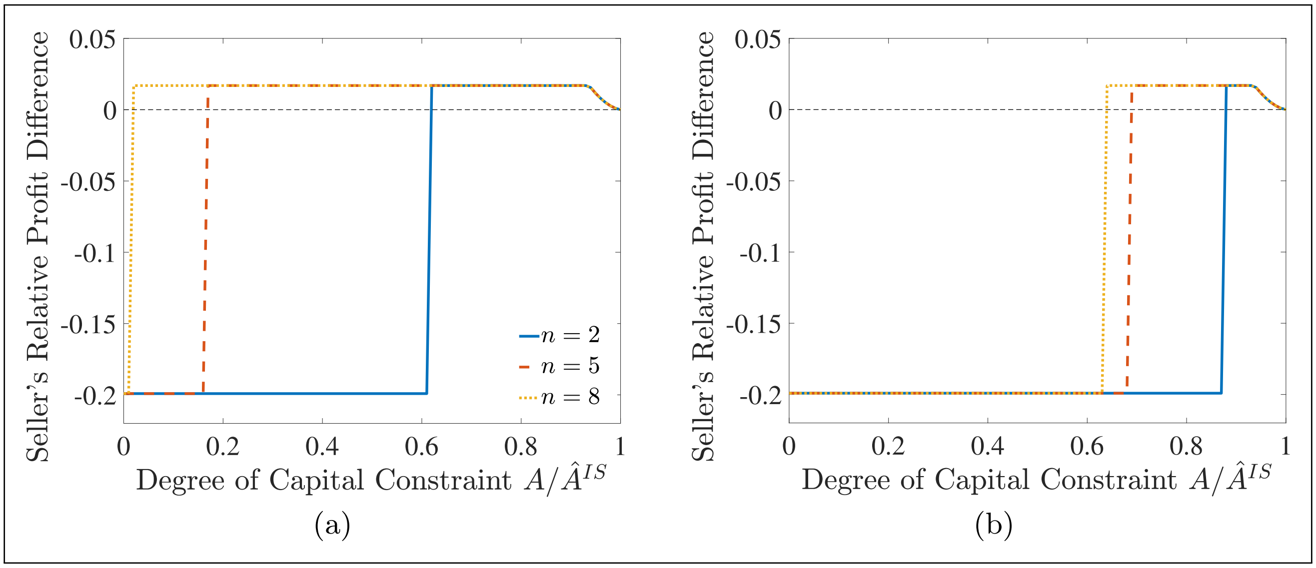

Figure 5. Seller's profit under joint finance (relative to individual finance). (a) Low correlation ($\rho = 0.1$); (b) high correlation ($\rho = 0.5$).
Notes: Seller's relative profit difference is defined as $(\pi_s^I - \pi_s^S)/\pi_s^S$, where π_s^S (π_s^I) is the seller's profit when dealers individually (jointly) borrowing from a standardized bank (an IRB bank). $\hat{A}^{IS}$ is the asset level above which dealers do not borrow. We normalize $\mu = 1000$ and $c = 1$.

to finance the unconstrained level of inventory ($\hat{A}^{IS}$). Numerical results suggest that seller-orchestrated financing is relevant under reasonable parameter ranges. For example, when demand correlation is low ($\rho = 0.1$) and the number of dealers is large ($n \geq 8$), the seller is willing to arrange a joint finance program for almost all dealers, irrespective of their degree of capital constraint. However, it also shows that the decision to adopt joint financing is sensitive to the dealer portfolio's risk (ρ and n): when demand correlation increases ($\rho = 0.5$) and the number of dealers decreases ($n = 2$), the seller will only orchestrate a joint finance program when the dealer's asset level is no less than 15% below the unconstrained level ($\hat{A}^{IS}$). Finally, we observe that although whether to arrange joint finance is highly sensitive to risk, the actual economic benefit it brings is relatively robust across various ρ, n, and A. When arranging joint finance is optimal, it brings about 2% profit gain relative to individual finance; however, when individual finance is optimal, it costs the seller 20% of her profit by arranging joint finance. Therefore, the seller should carefully scrutinize her dealer portfolio's risk before deciding on whether or not to orchestrate a joint finance program for the dealers.

Symmetrically, Figure 6 presents the dealers' corresponding relative profit difference between joint finance and individual finance. We note that when the dealer is severely capital-constrained (small A), the dealer's relative profit difference is lower when the dealer is of higher risk, which is characterized by a larger demand correlation (ρ), a smaller number of dealers (n), and a relatively low initial asset level (A). This is because, under joint finance, the amount of capital an IRB bank needs to reserve for each dealer is $\text{VaR}_p/n - \mathbb{E}[\tilde{L}^I]$, which increases in the dealer's risk and is more risk-sensitive than that under the standardized approach. Furthermore, note from Figure 6(a) that, consistent with Proposition 5, joint finance is a win–win solution for both the seller and the dealer when $A \in [\bar{A}(\rho, n), \bar{\bar{A}}]$.

On the other hand, when the dealer's asset level is high ($A \geq \bar{\bar{A}}$), the amount of capital the IRB bank needs to reserve is $\beta^{IS}B$ under joint finance, which is smaller than that of a standardized bank ($\beta^S B$). But some of such financing benefit is extracted by the seller through charging a higher wholesale price ($w^{IS} > w^S$), therefore, the dealers may not be better-off under joint finance. However, when $A \in (\hat{A}^S, \hat{A}^{IS})$, joint finance brings benefit to the dealer by extending his borrowing region, also creating a win–win situation.

6 Orchestrating Joint Finance Under Heterogeneous Dealers

Focusing on the impact of bank capital regulation and seller orchestration on operational decisions, the previous sections consider a model with multiple homogeneous dealers. In this section, we extend the model to study the impact of different initial asset levels among dealers on the design of joint finance programs. We focus on the case with n_1 high-risk dealers with initial asset level A_1 and n_2 low-risk dealers with initial asset level A_2, where $A_1 < A_2$.

Intuitively, the challenge in this case is due to dealers' preferences toward different finance programs. As earlier results show, in general, when the bank sets the loan terms such that the loan to each (homogeneous) dealer breaks even, dealers with low assets prefer individual finance, while those with high assets prefer joint finance. With such preferences, when facing dealers with different asset levels, if the IRB bank continues to

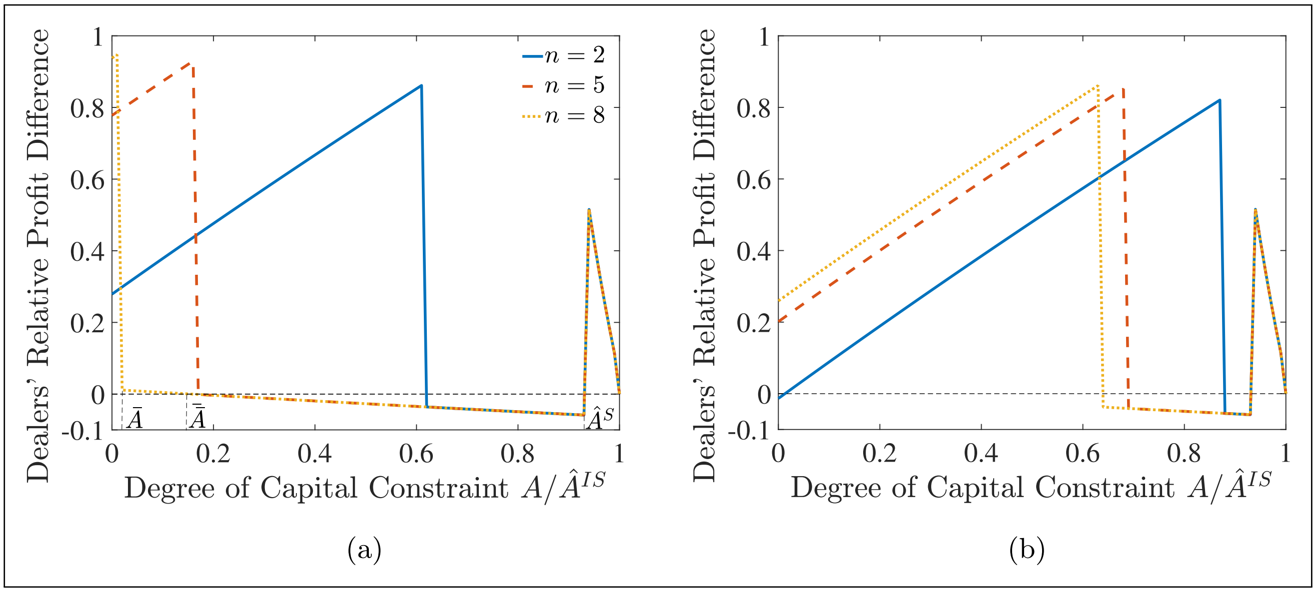

Figure 6. Dealers' profit under joint finance (relative to individual finance). (a) Low correlation ($\rho = 0.1$); (b) high correlation ($\rho = 0.5$). Notes: Dealers' relative profit difference is defined as $(\mathbb{E}[\pi_d^I] - \mathbb{E}[\pi_d^S])/\mathbb{E}[\pi_d^S]$, where $\mathbb{E}[\pi_d^S]$ ($\mathbb{E}[\pi_d^I]$) is the dealers' expected profit when dealers individually (jointly) borrowing from a standardized bank (an IRB bank). $\hat{A}^{IS}$ is the asset level above which dealers do not borrow. We normalize $\mu = 1000$ and $c = 1$.

set the loan term such that the loan to each dealer breaks even, then the financially weak dealers, facing high interest rates, prefer to finance individually through a standardized bank. Such an action reduces the portfolio size under joint finance and the risk pooling benefit, imposing a negative externality on financially stronger dealers.

To overcome this challenge and unleash the potential value of joint finance to the greatest extent, as the following proposition shows, the terms under the joint finance program should be set as if the financially stronger dealers (with initial asset A_2) subsidize the financially weaker ones (with initial asset A_1).

PROPOSITION 6. *The seller orchestrates the joint finance program if and only if* $A_2 \leq \hat{A}^{IS}$ *and* $[n_1/(n_1+n_2)]A_1 + [n_2/(n_1+n_2)]A_2 \geq \bar{A}(\rho, n_1+n_2)$. *Furthermore, when* $A_1 < \bar{A}(\rho, n_1+n_2)$,[11] *there exists a set of loan contracts* (r_1, r_2) *that are Pareto improving for both the seller and dealers relative to individual finance, where the contract terms* (r_1, r_2) *satisfy:*

$$p\sum_{i=1}^{2} n_i \int_0^{\theta_i} \bar{\Phi}(x)\mathrm{d}x = [1 + r_f + \beta^{IS}(\delta - r_f)] \times \left[(n_1+n_2)w^{IS}q^{IS} - \sum_{i=1}^{2} n_i A_i\right], \quad (19)$$

$$p\int_{\theta_i}^{q^{IS}} \bar{\Phi}(x)\mathrm{d}x \geq p\int_0^{q^S(w^{IS})} \bar{\Phi}(x)\mathrm{d}x - [1 + r_f + \beta^S(\delta - r_f)][w^{IS}q^S(w^{IS}) - A_i], \quad i = 1, 2, \quad (20)$$

where $\theta_i = [(w^{IS}q^{IS} - A_i)(1 + r_i)]/p$ *for* $i = 1, 2$, $q^S(w^{IS}) = \bar{\Phi}^{-1}\{w^{IS}[1 + r_f + \beta^S(\delta - r_f)]/p\}$, w^{IS} *and* q^{IS} *are defined in Proposition 3. Under such a loan contact, the bank breaks even at the portfolio level; it earns a positive profit on the loans to low-risk dealers (with initial asset* A_2*) while incurring a loss of an equal amount on the loans to high-risk ones (with initial asset* A_1*).*

Proposition 6 reveals that the seller should orchestrate a joint finance program as long as all dealers need financing ($A_2 \leq \hat{A}^{IS}$), and the weighted average asset of the portfolio is reasonably large

$$\left[\frac{n_1}{n_1+n_2}A_1 + \frac{n_2}{n_1+n_2}A_2 \geq \bar{A}(\rho, n_1+n_2)\right],$$

regardless of the allocation of assets among the dealers. This again highlights the risk-pooling role of the joint finance program. In loan terms, when all dealers have a relatively high asset, that is, $A_1 > \bar{A}(\rho, n_1+n_2)$, all dealers have incentives to participate in the joint finance program when the IRB bank sets the terms such that each loan has to break even. This echoes the results in Proposition 4. However, if the asset allocation between high-risk and low-risk dealers becomes less balanced, that is,

$$A_1 \in \left[\frac{n_1+n_2}{n_1}\bar{A}(\rho, n_1+n_2) - \frac{n_2}{n_1}A_2, \bar{A}(\rho, n_1+n_2)\right],$$

if the terms are still set such that each loan breaks even individually, then high-risk dealers (with initial asset A_1) have

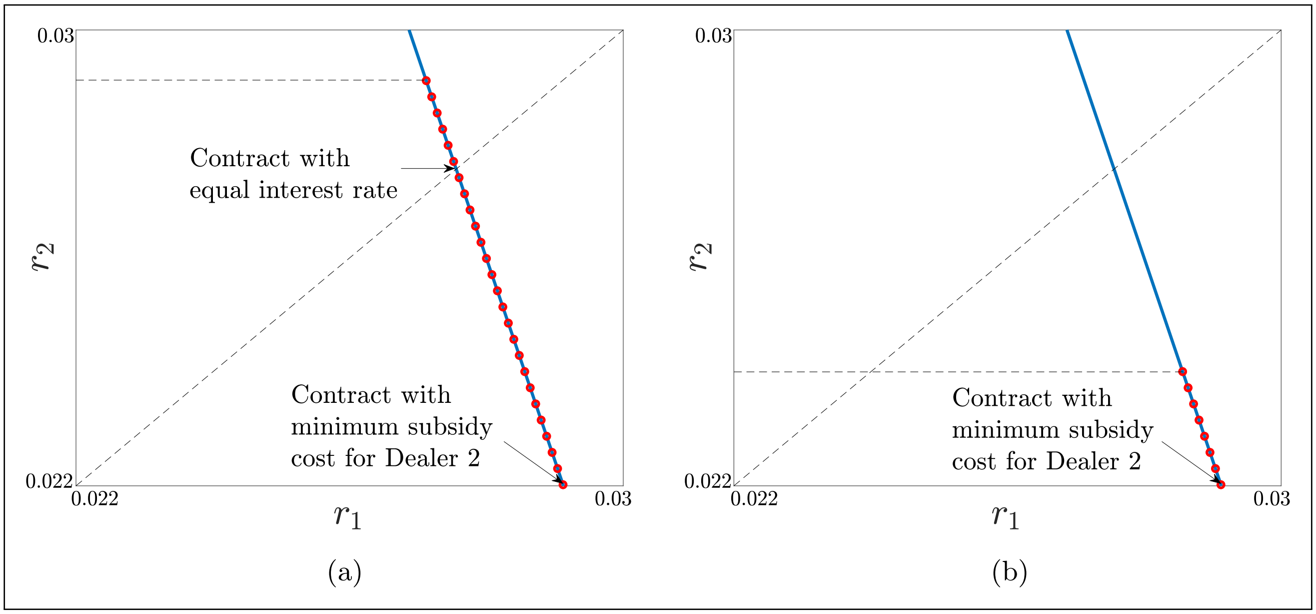

Figure 7. The set of all feasible loan contracts for heterogeneous dealers. (a) $\beta^S = 10\%$; (b) $\beta^S = 2\%$.
Notes: The blue solid line represents all loan contracts (r_1, r_2) that allow the bank to break even at the portfolio level (equation (19)). Additionally, part of the blue line marked by red circles further incorporates the participation constraints of the dealers (equation (20)). This portion illustrates the set of all feasible loan contracts that can implement the joint finance program for heterogeneous dealers based on Proposition 6. Parameter values for the above figure: $p = 1$, $c = 0.4$, $\delta = 0.1$, $r_f = 0.02$, $\alpha = 99.9\%$, $\mu = 10$, $\sigma = 3$, $\beta^{IS} = 0.01$, $\rho = 0.1$, $n_1 = 1$, $n_2 = 1$, $A_1 = 1.5$, and $A_2 = 4.5$.

no incentive to participate in joint finance, depriving low-risk dealers' (with initial asset A_2) opportunity to enjoy the risk pooling benefit.

To mitigate such inefficiency, the loan terms should be set such that even though the bank still breaks even for the entire loan portfolio, it earns a positive profit on the loans lent to the financially stronger dealers (with initial asset A_2), and uses the profit to subsidize the loans that it lends to the financially weaker ones (with initial asset A_1). Economically, this is equivalent to financially stronger dealers subsidizing financially weaker ones for the positive externality provided by financially weaker dealers under joint finance. We characterize the set of such loan terms (r_1, r_2) using equations (19) and (20) outlined in Proposition 6. Here, equation (19) ensures that the bank breaks even on the entire portfolio, while equation (20) represents the participation constraints for each dealer. These constraints stipulate that their profits under joint finance should not be lower than those under individual finance from standardized banks. Figure 7 illustrates the set of feasible loan contracts that satisfy the aforementioned constraints. The blue solid line represents all the contracts that allow the bank to break even at the portfolio level (equation (19)), part of the blue line with red circle markers further incorporates the participation constraints of the dealers (equation (20)).

Among all feasible loan contracts that can implement the joint finance program, we focus on two special cases that are particularly relevant in practice. The first case is the loan contract with the minimum subsidy cost to low-risk dealers, located at the bottom right of Figure 7 with a minimum r_2 and maximum r_1. This contract ensures fairness to low-risk dealers, as it requires the minimum amount of subsidy necessary to motivate high-risk dealers' participation in joint finance. Importantly, such a contract always exists under varying parameter values. The other commonly implemented loan contract is the equal interest rate contract, where all dealers are charged the same interest rates ($r_1 = r_2$). This type of contract is popular due to its simplicity, as the bank no longer needs to differentiate between the dealers (Bhoir and Ray, 2015). However, we discovered that an equal interest rate contract is not always feasible, especially when the financing cost from standardized banks decreases significantly (e.g., when the capital adequacy ratio β^S decreases). This is because as individual financing becomes more advantageous, high-risk dealers will request a higher subsidy to participate in joint finance, while low-risk dealers become less willing to provide subsidies. As a result, the conditions for an equal interest rate contract are no longer met (Figure 7(b)).

Corollary 3. *When the seller orchestrates the joint finance program* $\{A_2 \le \hat{A}^{IS}$ *and* $[n_1/(n_1+n_2)]A_1 + [n_2/(n_1+n_2)]A_2 \ge \bar{A}(\rho, n_1+n_2)\}$, *we have:*

1. *given a fixed number of dealers, when the fraction of high-risk dealers* $[n_1/(n_1+n_2)]$ *increases, the seller is less likely to orchestrate the joint finance program;*

2. *given a fixed fraction of high-risk dealers, when the number of dealers* $(n_1 + n_2)$ *increases, the seller is more likely to orchestrate the joint finance program.*

Corollary 3 suggests that consistent with the results for homogeneous dealers, the seller is more likely to orchestrate a joint finance program when the dealer portfolio is of lower risk, that is, the portfolio with a lower fraction of high-risk dealers $[n_1/(n_1+n_2)]$, or a larger number of dealers (n_1+n_2).

7 Mechanisms With Seller Sharing the Borrowing Risk

Thus far, we have focused on the setting where dealers rely on bank finance (either a standardized bank or an IRB bank) to alleviate their capital constraints and bear demand risks entirely by themselves. The seller's role under joint finance is providing access to IRB banks and sharing dealers' demand information to help IRB banks assess dealer portfolio's risk. In this section, we extend the model inSection 3 by incorporating two such risk-sharing mechanisms: (a) the seller providing first loss provision for the loan (Section 7.1), and (b) the seller offering a buyback contract (Section 7.2). As in the base model, dealers are assumed to be homogeneous.

Before proceeding to the analysis, we note that despite its potential to alleviate the dealers' financial constraints, such risk-sharing could be costly to the seller, who needs to hold a certain amount of cash to fulfill her responsibility for covering losses or engaging in buybacks. Empirical evidence suggests that holding such cash reserve leads to an opportunity cost for the seller, such as losing the opportunity of making an alternative investment (Allen and Hafer, 1984; Heller and Khan, 1979). Similar to papers in the OM–Finance interface literature that consider such opportunity costs (Chen et al., 2019; Deng et al., 2018; Du et al., 2023; Luo and Shang, 2015), we assume that the seller incurs an opportunity cost of $\gamma \geq 0$ per unit of cash held under these risk-sharing mechanisms. More specifically, by holding a cash reserve C over the selling horizon, the seller could earn an interest at the risk-free rate r_f, but forgoes an opportunity to invest in other projects that offer a higher return rate at $r_f + \gamma$. This results in an opportunity cost of γC.

7.1 Joint Finance With First Loss Provision

We first consider the first loss provision contract. In practice, when orchestrating a joint finance program with an IRB bank, the seller is sometimes required by the bank to offer a first loss provision, under which dealers' losses up to an agreed threshold are covered by the seller, with the rest taken by the bank (Salecka, 2015). Under this arrangement, with the first loss provision η, if a dealer defaults, the first 100η percent of the losses are covered by the seller, with the remainder taken on by the bank. We examine two scenarios: first, the first loss provision level η is exogenously determined (e.g., following the industry norm) and the seller optimizes only her wholesale price w (Section 7.1.1), and second, the seller chooses both w and first loss provision level η (Section 7.1.2). As in Section 5, the bank's regulatory capital is determined using the VaR measure (equation (11)).

7.1.1 Seller's Optimal Wholesale Price Under Exogenous η. We conduct the analysis through backward induction, first analyzing the bank's loan pricing given dealers' order quantity, the seller's wholesale price w, and the first loss provision η. As the seller is responsible for the first 100η percent of losses, the bank loan defaults when the realized demand D is smaller than the default threshold $\theta^I = [(1-\eta)B(1+r^I)]/p$. Substituting θ^I into the bank's competitive loan pricing equation (equation (1)), the bank's interest rate r^I satisfies:

$$\frac{\eta}{1-\eta}p\theta^I + p\int_0^{\theta^I}\bar{\Phi}(x)\mathrm{d}x = (1+r_f)B + (\delta - r_f)\frac{C_p^I}{n}, \quad (21)$$

where C_p^I/n follows equation (11). Anticipating the bank's competitive loan pricing, each dealer determines their order quantity $q^{IV}(w,\eta)$ based on the following lemma.

LEMMA 2. *When all dealers participate in the seller-orchestrated joint finance program with first loss provision, when the initial asset level of the dealers is sufficiently low, the equilibrium order quantity for each dealer* $[q^{IV}(w,\eta)]$ *satisfies:*

$$\bar{\Phi}\left[q^{IV}(w,\eta)\right] = \frac{w(1+r_f)\bar{\Phi}\left[\theta^I/(1-\eta)\right]}{p\left[\eta + (1-\eta)(1+r_f-\delta)\bar{\Phi}(\theta^I)\right]}, \quad (22)$$

where θ^I is determined according to equation (21).

In order to ensure that the seller has enough cash to cover a maximum loss of $\eta B(1+r^I)$ for each dealer, the seller needs to hold $n\eta B(1+r^I)/(1+r_f)$ cash during the period (which becomes $n\eta B(1+r^I)$ at the end of the period due to the risk-free rate it earns during the period), resulting in an opportunity cost of $\gamma n\eta B(1+r^I)/(1+r_f)$.

In addition to incurring the opportunity cost of holding cash, the seller also incurs an expected loss for the dealers' risk. Specifically, when the realized demand D_i of dealer i $(1 \leq i \leq n)$ is smaller than $\theta^I/(1-\eta)$, the realized loss of the loan is $L^I = B(1+r^I) - pD_i$. If $L^I < \eta B(1+r^I)$, which is $\theta^I < D_i < \theta^I/(1-\eta)$, the loan's loss is fully covered by the seller; if $L^I \geq \eta B(1+r^I)$, which is $D_i \leq \theta^I$, the seller only covers $\eta B(1+r^I)$, while the rest is taken by the bank. Combining

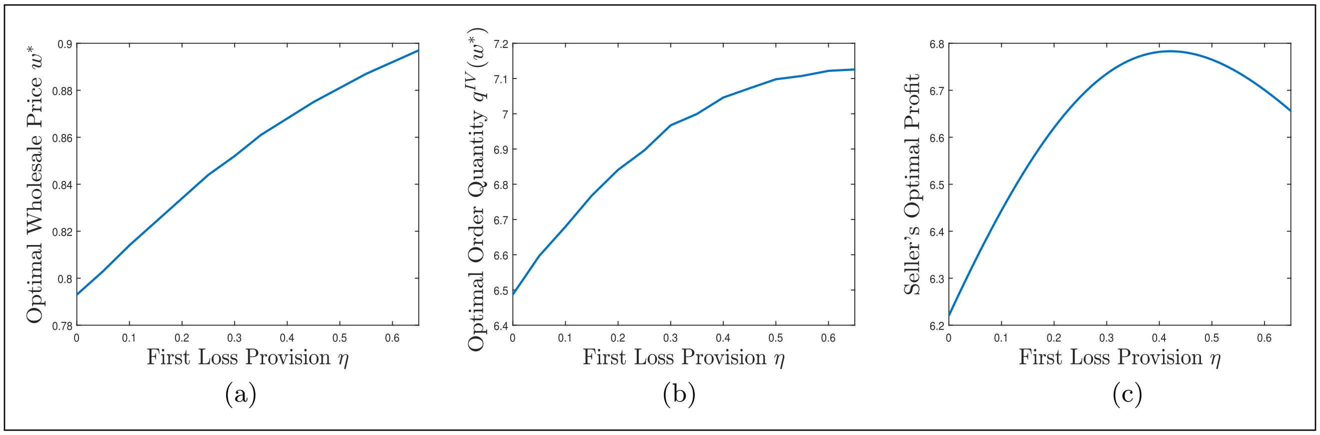

Figure 8. Optimal decisions and profit with varying η. (a) Optimal wholesale price; (b) optimal order quantity; (c) seller's optimal profit.
Notes: Parameter values for the above figure: $p = 1$, $c = 0.4$, $\delta = 0.1$, $r_f = 0.02$, $\alpha = 99.9\%$, $\mu = 10$, $\sigma = 3$, $\rho = 0.1$, $n = 2$, $A = 0$, and $\gamma = 0.2$.

the above, the seller's expected profit is:

$$\mathbb{E}[\pi_s^I] = n\left[(w-c)q^{IV}(w,\eta)(1+r_f+\gamma) - \frac{\gamma\eta B(1+r^I)}{1+r_f} - p\int_{\theta^I}^{\theta^I/(1-\eta)}\Phi(x)\mathrm{d}x\right], \qquad (23)$$

where the second term is the seller's opportunity cost of holding cash, and the third term is the seller's expected loss coverage for the dealers' loans.

The seller thus chooses the wholesale price w to maximize her expected profit $\mathbb{E}[\pi_s^I]$. Due to the highly nonlinear nature of the problem, we numerically present the optimal results in Figure 8, which illustrates the seller's optimal wholesale price, each dealer's optimal order quantity, and the seller's corresponding optimal profit under different levels of η. As the first loss provision level (η) increases, indicating that the seller assumes more of the dealers' borrowing risk, the seller is able to set a higher wholesale price (Figure 8(a)) and also receive larger order quantities from dealers (Figure 8(b)), leading to increased revenue from selling goods. However, the increased loss coverage responsibility (with increasing η) requires the seller to hold more cash and expect higher expenses to cover potential loan losses, ultimately reducing the seller's overall profit. This trade-off between the above two factors results in a concave relationship between the seller's optimal profit and the first loss provision level, as demonstrated in Figure 8(c).

7.1.2 Seller's Optimal Decisions Under Endogenous η. When the seller can determine both the first loss provision level (η) and the wholesale price (w), Figure 9 shows the seller's optimal decisions and corresponding profit with varying opportunity cost of holding cash γ. As γ increases, the seller opts for a lower first loss provision level (Figure 9(a)), thereby decreasing the amount of cash needed to be held by assuming less of the dealers' borrowing risk. When the cost of holding cash becomes exceedingly high (e.g., $\gamma \geq 0.6$), the seller decides not to offer a first loss provision, reverting back to our base model inSection 3. Additionally, we observe that the optimal wholesale price decreases in tandem with the first loss provision level as γ increases (Figure 9(b)). A lower wholesale price helps counterbalance the reduction in order quantity resulting from the seller sharing less of the dealers' risk. Concerning the seller's overall profit, it initially decreases and then increases with the opportunity cost of holding cash (Figure 9(c)). This is because a higher γ implies that the seller's revenue from selling goods can earn a higher rate of return ($r_f + \gamma$), and the seller also holds less cash by reducing the first loss provision level. Consequently, when γ is relatively high, the seller's profit increases with the opportunity cost of holding cash (γ).

Finally, Figure 10 presents the seller's relative profit difference between joint finance with first loss provision and individual finance for high-risk dealers with varying opportunity cost of holding cash γ. Relative profit difference (y-axis) is defined as the seller's profit difference between joint finance with first loss provision and individual finance as a percentage of the seller's profit under individual finance. Thereby, when this value is positive, the seller's optimal decision is to orchestrate a joint finance program and provide first loss provision for high-risk dealers; whereas negative value suggests that the seller will not arrange joint finance, leaving the high-risk dealers individually finance from standardized banks. As shown, orchestrating a joint finance program with first loss provision becomes less profitable as the seller's opportunity cost of holding cash (γ) increases. This is because the seller's risk-sharing under first loss provision has a mixed impact on her profit: on the one hand, sharing the dealers' borrowing risk reduces the dealers' financing cost, thus increasing their order quantity; on the other hand, such loss covering responsibility requires the seller to hold a certain amount of cash, which becomes more costly as γ rises. Therefore, when γ is relatively

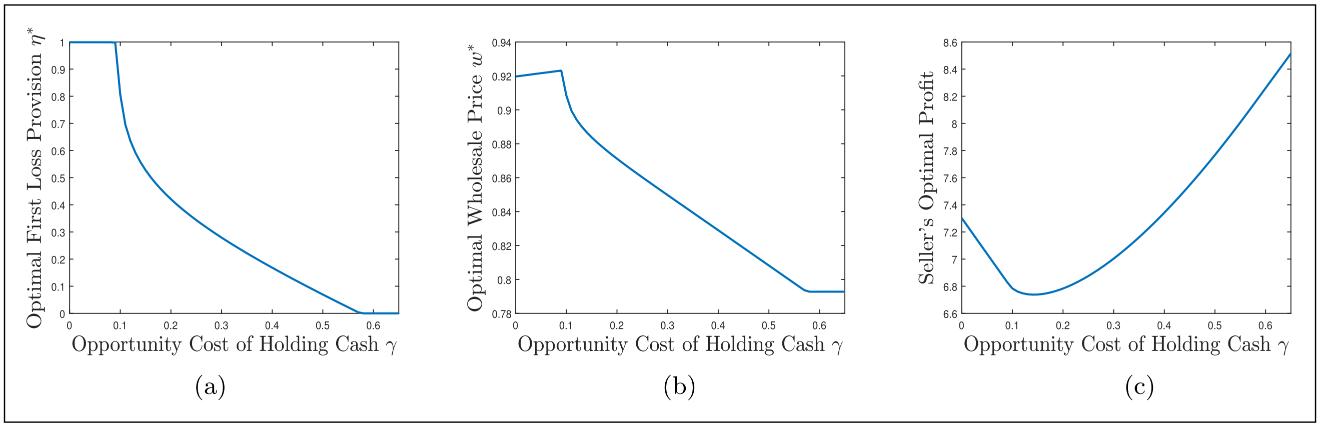

Figure 9. Seller's optimal decisions and profit with varying γ. (a) Optimal first loss provision; (b) optimal wholesale price; and (c) seller's optimal profit.

Notes: Parameter values for the above figure: $p = 1$, $c = 0.4$, $\delta = 0.1$, $r_f = 0.02$, $\alpha = 99.9\%$, $\mu = 10$, $\sigma = 3$, $\rho = 0.1$, $n = 2$, and $A = 0$.

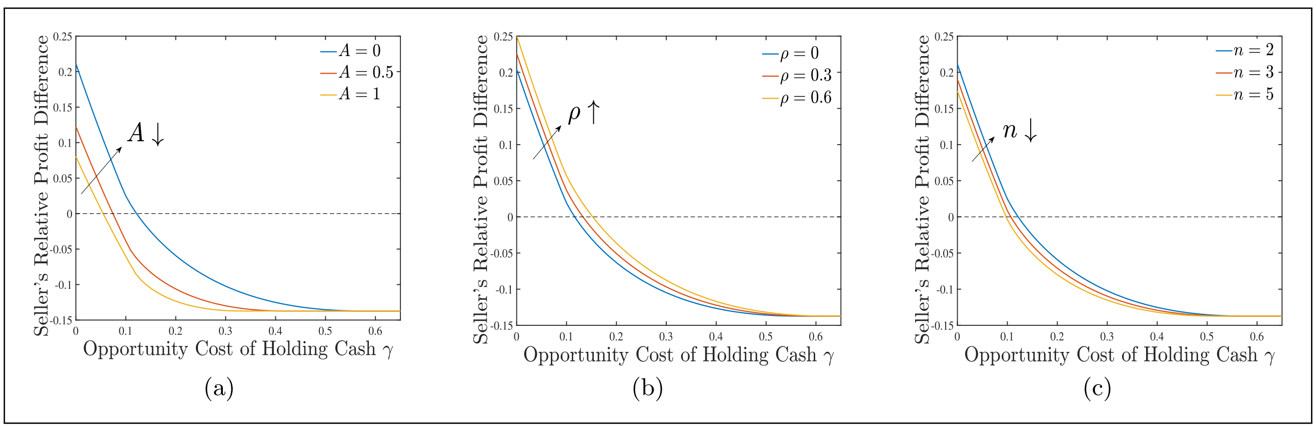

Figure 10. Seller's relative profit difference between joint finance with first loss provision and individual finance with varying γ. (a) Varying initial asset level; (b) varying demand correlation; and (c) varying number of dealers.

Notes: Seller's relative profit difference is defined as the seller's profit difference between joint finance with first loss provision and individual finance as a percentage of the seller's profit under individual finance, that is, $(\mathbb{E}[\pi_s^J]|_{\text{with first loss provision}} - \mathbb{E}[\pi_s^S])/\mathbb{E}[\pi_s^S]$, where $\mathbb{E}[\pi_s^S] = n(w^S - c)q^S(1 + r_f + \gamma)$. Parameter values for the above figure: $p = 1$, $c = 0.4$, $\delta = 0.1$, $r_f = 0.02$, $\alpha = 99.9\%$, $\mu = 10$, $\sigma = 3$, $\rho = 0.1$ for (a) and (c), $n = 2$ for (a) and (b), and $A = 0$ for (b) and (c).

small, the risk-sharing benefit dominates the cost of holding cash, and the seller will orchestrate a joint finance program for all dealers. However, when γ is quite large (e.g., due to favorable alternative investment opportunities), the seller will reduce the first loss provision it provides to the dealers, thus limiting her ability to extract profits. In such cases, the seller will not orchestrate a joint finance program for high-risk dealers, even considering the risk-sharing effect under the first loss provision.

Figure 10 also reveals that orchestrating a joint finance program with first loss provision becomes more favorable for the seller when facing dealers of higher risk, that is, dealers with lower initial asset level, or with higher demand correlation, or with fewer participants in the portfolio. This is because bank finance becomes more costly for dealers of higher risk, motivating the seller to share more of the dealers' risk (higher η) and also extracting more profits. This suggests that the offering of first loss provision is more likely to be accompanied by dealers of higher risk, which is consistent with the anecdotal evidence in Salecka (2015).

7.2 *Individual Finance With Buyback Contract*

In this section, we extend the basic model by allowing the seller to offer a buyback contract to the dealers under individual finance. Specifically, the seller chooses a wholesale price w and a buyback price b. Similar to first-loss provision, fulfilling this buy-back responsibility also requires the seller to set aside a certain amount of cash, which is associated with the per-unit opportunity cost γ. We examine whether the seller's risk-sharing through a buyback contract under individual finance

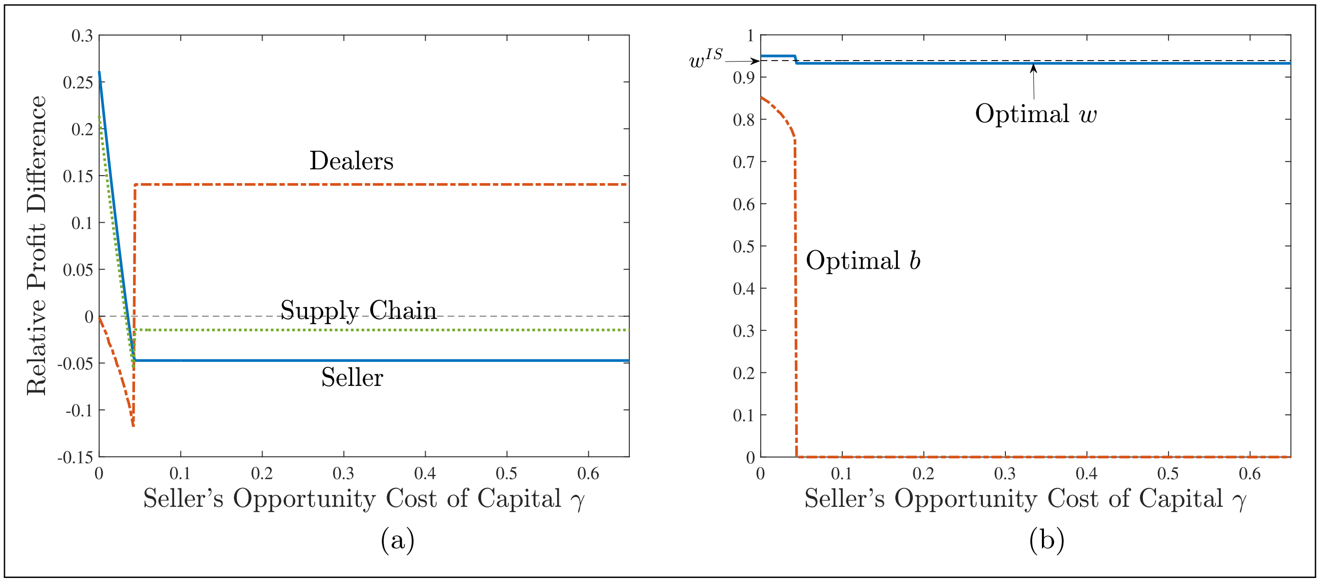

Figure 11. Individual finance with buyback contract for low-risk dealers ($A \in (\bar{A}(\rho, n),\ \hat{A}^{IS})$). (a) Relative profit difference and (b) optimal buyback contract.

Notes: Relative profit difference is defined as the seller's or the dealers' or the supply chain's profit difference between individual finance with buyback contract and joint finance as a percentage of the seller's or the dealers' or the supply chain's profit under joint finance, that is, $(\mathbb{E}[\pi_j^S]|_{\text{with buyback}} - \mathbb{E}[\pi_j^I])/\mathbb{E}[\pi_j^I]$ ($j \in \{s, d, sc\}$). Parameter values for the above figure: $p = 1$, $c = 0.8$, $A = 3$, $\delta = 0.1$, $r_f = 0.02$, $\beta^S = 0.1$, $\beta^{IS} = 0.01$, $\alpha = 99.9\%$, $\mu = 10$, $\sigma = 3$, $\rho = 0.5$, and $n = 2$.

mitigates the necessity of orchestrating a joint finance program for low-risk dealers. We present the optimal results in Figure 11 and give the technical details in Appendix F in the E-Companion. Figure 11 presents the seller, the dealers', and the entire supply chain's profit between individual finance with buyback contract (relative to joint finance without buyback) and the corresponding optimal buyback contract. We focus on the parameter values where joint financing is preferred over individual financing without buyback ($A \in (\bar{A}(\rho, n),\ \hat{A}^{IS})$). As shown in Figure 11(a), for small γ, the buyback feature allows the seller to extract more profit from the dealers under individual financing. However, as γ increases, the seller lowers the buyback price (Figure 11(b)) to reduce the amount of cash she needs to reserve. Consequently, both the seller and dealers' profit decline. Finally, for even larger γ, the seller decides not to offer a buyback contract, reverting back to our base model inSection 3. By doing so, the positive impact of the buyback contract on the seller's profit is eliminated, nudging the seller to favor joint financing (without buyback) instead. The entire supply chain's profit is also higher under joint financing (without buyback) when γ is relatively large.

8 Conclusion

Seller-orchestrated inventory finance is an innovative financing scheme for small businesses to have access to large banks through their focal supply chain partners. This mechanism is particularly relevant to bank capital regulation, which determines how banks price their loans. In this paper, we analyze when a seller should orchestrate a joint finance program for its downstream dealers and the impact of such orchestration on the seller, the dealers, and the entire supply chain.

By orchestrating a joint finance program, the seller allows low-risk dealers to have access to an IRB bank, which results in higher inventory levels and wholesale prices, thus improving the seller and the entire supply chain's profit. Such an efficiency gain is enhanced by risk pooling. Specifically, by pooling risks from different dealers, the joint finance program reduces the amount of regulatory capital under the IRB approach and hence lowers the financial friction. Such a pooling benefit is more pronounced when the seller has a large number of dealers with low demand correlation. However, the impact of the joint finance program on dealers' profits is mixed: for high-risk dealers, seller-orchestrated joint finance leads to a win–win situation between the seller and dealers; whereas for dealers of intermediate risk level, the joint finance program benefits the seller at the expense of dealers. Finally, we find that to encourage participation from dealers with different asset levels, the joint finance program should be designed such that the financially stronger dealers subsidize the weaker ones. When the seller's opportunity cost of capital is relatively large, our results are robust under more sophisticated supply chain contracts such as buyback contract and the seller's first loss provision.

Our modeling results can be extended to a buyer-orchestrated financing scenario under a pull supply chain setting, where a large downstream retailer determines the wholesale price and then the SME suppliers decide how much inventory to produce and stock at the retailer's location. Similar to the dealers in our model, the suppliers in a pull supply chain setting are likely to face correlated demand risks, especially when providing complementary goods. But we should note that besides demand risk, suppliers' performance risk also merits consideration under a buyer-orchestrated financing case. Thus, it could be valuable to examine a buyer-orchestrated joint finance program under more sophisticated risk profiles.

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Notes

1. For example, between 1998 and 2018, the average cost of equity capital among US banks is around 7%, while the 3-month treasury bill rates, which can be used as a proxy for the cost of raising deposit, is around 2%. See Appendix B in the E-Companion for a detailed summary and illustration of the data.
2. In practice, the seller also has access to small standardized banks. However, as the following analysis reveals, under a standardized bank, since there is no transshipment among the dealers, each dealer is indifferent between obtaining a loan independently or through a joint finance program.
3. For expositional brevity, we assume that the cost of equity capital is the same for all banks. In practice, different banks' costs of equity may be different. However, our results remain unchanged qualitatively if we allow the large IRB banks to have a lower cost of equity than small standardized banks.
4. In the following analysis, we use superscript S for quantities under the standardized approach and I for those under the IRB approach. The same notation is also adopted in Zhang et al. (2022).
5. In some studies, the regulatory capital under IRB approach is simply calculated as the loan's VaR (Prokopczuk et al., 2007). Our managerial insights are robust under this alternative calculation method.
6. For example, to be consistent with a credit rating of AA, Bank of America reserves capital according to a 99.97% confidence level (Zaik et al., 1996).
7. The technical details for the first two steps are similar to Proposition 2 in Zhang et al. (2022), and thus are provided in Appendix D in the E-Companion for expositional brevity.
8. We refer the readers to Lemma 3 in Appendix D.2 in the E-Companion for expressions of $q^{S*}(w)$.
9. Following the Basel III regulation (Basel Committee, 2017), which governs how banks calculate their regulatory capital, we assume that a bank determines its level of regulatory capital by calculating RC at the individual exposure level and then adding them together. In our context, the loan program orchestrated by the seller is considered as a single exposure to the bank.
10. We refer the readers to Appendix B in the E-Companion for more details.
11. Here, we focus on the case where $\bar{A}(\rho, n_1 + n_2) < A_2 < \bar{A}(\rho, n_2)$, so that without high-risk dealers' participation, low-risk dealers will individually finance from standardized banks.

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