Financing Disruptive Suppliers: Payment Advance, Timeline, and Discount Rate

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This paper considers a dyadic supply chain in which a large and creditworthy buyer procures a product from a capital-constrained supplier subject to disruption risk. In facilitating the production, the buyer may offer direct financing to the supplier by way of advance payment (AP). Concurrently, the buyer may also tailor the advance discount rate (TR) that applies to the AP and extend the payment timeline (PE) for the balance due. We analyze the value and interplay of these elements by comparing optimal contractual terms with different AP, PE, and TR potentials. In general, AP applies to more reliable suppliers, and the coverage could be broadened by the inclusion of PE and TR. Specifically, when the advance discount rate is regulated within a certain limit, the buyer should offer TR without PE to the most reliable suppliers, versus the floor discount rate with PE to those posing higher risk. Although the buyer normally benefits from practicing PE, the supplier benefits from it only when the risk level is relatively high and suffers from it when the risk level is relatively low; these effects persist although they are weakened in the presence of TR. Overall, PE and TR focus on different risk spectrums and are strategic substitutes for each other. The buyer can thereby retain its maximum payoff by properly configuring PE or TR when the other is under strict regulation. These insights offer strategic guidance for buyers to engineer business cash flows with respect to the risk level of their suppliers and the external regulation environment.

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1. Introduction

Small and medium-sized enterprises (SMEs) are known to have insufficient working capital and limited access to external financial markets. As estimated by the Asian Development Bank (2019), 45% of the SMEs around the world face regular rejection by financial institutions for trade finance, contributing to a global financing gap of $1.5 trillion. Most SMEs are shaky, with low to no credit ratings and an average cost of debt varying from 9% in the US and Europe to as high as 26% in Central Asia (Francis et al. 2005, Vander Bauwhede et al. 2015, Prêtet and Klang 2019). Nonetheless, large corporations typically spend a significant portion of their procurement dollars on suppliers with credit ratings of BB+ or lower (Global Business Intelligence 2012), the quadrant where most SMEs reside. In addition to a lack of financing, they also carry higher disruption risk.

This has two effects. The first is that large buyers become more involved in providing supply chain financing (SCF) to their suppliers (please refer to Hofmann et al. 2018 and Kouvelis et al.

2017 for a classification and review of SCF tools). In particular, buyers may extend direct financing (BDF) to the suppliers in the forms of low-to-interest-free loans, advance payment, and provision of working capital to ensure the continuity of production or supply. Recent statistics suggest that cash in advance accounts for 19-22% of the transactions in trade finance industry (IMF 2009) or as much as 42.4% in a single US firm (Antràs and Foley 2015). In France, roughly 26% of the firms receive advance payments from their customers, with more support from financially stronger customers to their financially weaker suppliers (Mateut 2014).

The other effect is the rising awareness of buyers that they can engineer the payment terms[1]. For instance, UK drug giant GlaxoSmithKline made significant loans to small suppliers which had no recourse in the financial markets (Watkins 2012, Tang et al. 2018) but was shortly reported to have changed its payment timeline from 60 days to 90 days (Business Matters 2013). In 2017, Apple started its Advance Manufacturing Fund to provide upfront cash and advance payments to support its suppliers' R&D, capital equipment, and production facilities (Corning Inc. 2017, Eassa 2017). During this time, its days payable outstanding increased from 100 days to 127 days (Forbes 2018). Empirical studies have found that advance payment may be accompanied by more supplier credit (Mateut and Zanchettin 2013) thus longer payment periods, or influence so in the future (Antràs and Foley 2015). Therefore, a buyer may offer BDF with endogonized payment terms.

The benefit of BDF without considering the payment timeline has been explicitly analyzed in various contexts, including assembly systems (Deng et al. 2018), manufacturing (Tang et al. 2018, Chen et al. 2020), online marketplaces (Dong et al. 2019, Gupta and Chen 2020), and FinTech adoption (Dong et al. 2021, Wang and Xu 2021). However, there has been little discussion regarding the impact of payment term configuration associated with BDF. Presumably, by taking over adequate risk from the financial intermediaries and reshuffling payment timelines, the buyer can secure a higher gain in procurement. This is especially pronounced when technology development catalyzes disintermediation in the supply chain (Vembu 2020) and when blockchain-powered Internet of Things (IoT) and smart contracts add to the flexibility in linking the loan amount and timing to supply chain transactions autonomously and frictionlessly (Forbes 2020).

Even though payment terms can be contractual, they may be bounded by regulations that vary across countries and regions. For instance, the UK government recently suspended 17 large companies including Vodafone and Rolls-Royce, for their failing to comply with the Prompt Payment Code and pay 95% of invoices within 60 days (Gustin 2019). According to the Taulia international invoice payment terms database,[2] France allows, subject to both parties' agreement, a maximum 75

[1] We use "payment terms" and "payment timeline" interchangeably throughout the paper.

[2] https://taulia.com/payment-terms/

days from the date of invoice. Florida requires non-stored grain to be paid for within six months of the date of the contract or delivery. China, on the other hand, imposes no restriction on contracted payment terms, but "due on delivery" governs when an agreement is absent.

Alongside payment terms, BDF is frequently accompanied by an inter-temporal discount, henceforth considered as a loan from the buyer to the supplier when an interest rate applies (e.g., Deng et al. 2018, Tang et al. 2018, Gupta and Chen 2020, Chen et al. 2020). Since the initiative of BDF was to enhance SMEs' working capital, it is possible that a buyer may simply keep the interest rate flat and low. For instance, GSK lent to its suppliers at the same rate that it paid the bank (Tang et al. 2018). Jingdong Finance applied a stable 9% interest rate to its suppliers (Chen et al. 2020). As observed, the BDF interest rate could be based on the buyers' internal guidelines (Gustin 2018), or an "altruistic" orientation (Dong et al. 2019), rather than solely for-profit. Should the buyer wish to strategically configure the interest rate, similar to the payment terms, a set of regulations may need to be respected. In the US, individual states have their own usury laws governing the maximum allowable interest rate for non-banking entities. For example, California[3] states that the annual interest rate of loans cannot exceed the higher of 10% or 5% plus a base rate established by the Federal Reserve, whereas Colorado[4][5] allows it to go up to 45%. At the time of this paper being written, China slashed the ceiling of the private lending rate from 36% to around 15.4%, to lower the cost of struggling small businesses (Reuters 2020).

In light of the above, BDF has the potential to be configured along with common contractual terms, such as the payment timeline and advance discount rate, subject to relevant regulations. The synergy among these elements, however, remains unexamined in the literature. The effect of the regulations, which were initiated to protect the interest of suppliers (borrowers), is also unverified in the context of BDF. In this study, we explore these issues through a specific type of BDF, where a supplier can request advance payment from its buyer prior to the commencement of production, but subject to a financing limit specified by the buyer. We are intrigued to investigate the following research questions:

1. Should the buyer jointly engineer the payment timeline and advance discount rate along with the direct financing limit to its supplier?
2. If so, how would the three elements interact with each other? What are their respective values to the parties' operations and payoffs?
3. How would regulations on payment terms and interest rates impact the parties' payoffs?

[3] https://leginfo.legislature.ca.gov/faces/codes_displayText.xhtml?lawCode=CONS&division=&title=&part=&chapter=&article=XV

[4] https://leg.colorado.gov/sites/default/files/images/olls/crs2017-title-05.pdf

[5] https://www.courts.state.co.us/userfiles/file/Court_Probation/Supreme_Court/Opinions/2017/17SC427.pdf

1.1 Summarization of Main Findings

To answer these questions, we consider a large, financially sound buyer (henceforth referred to by feminine pronouns) purchasing from a capital-constrained, disruption-prone supplier (henceforth referred to by masculine pronouns). The buyer, after assessing the supplier's risk profile and working capital, may offer direct financing to the supplier in the form of advance payment. Specifically, the buyer may propose a financing limit up to which the supplier may request as an advance (AP) from the final invoice, a tailored advance discount rate (TR) subject to which the AP will be paid and a payment timeline (PE) for when the invoice balance is due. The supplier, accounting for this financing schedule, quotes a unit wholesale price. The buyer subsequently places an order in satisfying a price-sensitive demand. Once the financing and procurement contracts are in place, the supplier determines the extent to which it will draw on the AP. Production then commences based on the supplier's own working capital plus the AP discounted by TR. Conditioned on satisfactory delivery, the buyer will remit, at the time determined by the PE, the remaining balance to the supplier. In case of disruption or default, any paid AP is sunk, and the balance due becomes void.

In addressing the proposed research questions, we first outline the solution procedure for the general contract with AP and regulated PE and TR. In general, the design of optimal contracts depends heavily on, among other factors, the supplier's risk level. Specifically, the buyer will only grant the necessary AP to facilitate the desired order if the supplier is relatively reliable. She will source from the supplier without extending any AP as the risk level increases, ultimately ceasing the procurement after the risk level passes a certain threshold. The inclusion of PE or TR could help broaden the coverage of AP. That is, a supplier that would not be financed under certain payment or interest terms may be granted AP if these terms could be properly adjusted.

We then investigate the synergy and respective values of AP, PE, and TR by comparing the operations under a number of different contracts. To begin with, we assess the value of AP by comparing a simple wholesale price contract (no financing) to an AP-only contract (no PE or TR). This suggests that AP can effectively reduce the wholesale price and increase production quantity, bringing positive benefits to both the supplier and the buyer, more prominently when the risk level of the supplier is low.

Next, we study the value of PE by comparing an AP+PE contract with the AP-only contract. With the PE add-on, the provision structure of AP persists, and the buyer will commit to payment upon delivery if the supplier is more reliable and practice PE if he possesses a higher level of risk. Compared to the AP-only contract, PE results in non-monotone variations to the operations and the parties' payoffs. Operationally, PE fosters higher production quantity when the supplier's risk level is relatively high. At the same time, the wholesale price may rise due to the extended payment timeline. As a result, PE has different implications for the buyer than for the supplier — although the buyer systematically benefits from the inclusion of PE, the supplier will benefit from it only when his risk level is relatively high (i.e., when he has no chance to be financed without PE) and will suffer from PE when the risk level is relatively low.

Lastly, we explore the role of TR and its interaction with PE by comparing the optimal AP+TR+PE with AP+PE and AP+TR contracts. In particular, we find that an array of contracts constitutes the optimum for AP+TR+PE. These optimal contracts share a common structure where TR without PE (or a fixed payment term) will be offered to the most reliable suppliers, compared to the floor (regulated) advance discount rate plus PE for those in a higher risk category. Therefore, TR and PE focus on different risk spectrums. Operationally, TR may also boost production quantity when the risk level is high, but unlike PE it reduces the wholesale price when the risk level is rather low. Therefore, while the buyer would benefit from TR when dealing with the most reliable suppliers, the latter suffer from it. Although TR and PE work distinctively at the operational level, we underscore the finding that their values are weakened in the presence of the other and are henceforth strategic substitutes for each other.

We close this study by highlighting the insight that the substitution role between PE and TR can help offset the impact of regulation. Specifically, regulation on TR has little impact on the buyer's payoff when it has full autonomy on PE and *vice versa*. This implies that the buyer can retain her maximum payoff by properly configuring PE or TR when the other is under strict regulation.

1.2 Relation to Literature and Contributions

This paper is most relevant to two streams of literature–one that considers financing SME suppliers and another that studies managing the disruption risk to one's supply base.

Financing SME suppliers may involve the buyer to different degrees. Without the buyer's presence, the lending is often conditioned on physical assets (e.g., Buzacott and Zhang 2004, Alan and Gaur 2018) or intangible assets of the suppliers (e.g., Kouvelis and Zhao 2018, Xu et al. 2019) to facilitate activities like R&D and production. When the buyer is involved *indirectly*, a financier such as bank, factor, or social lending platform is usually invited into the landscape. In this case, the financing may be based on account receivables after successful delivery of the products (e.g., Chen et al. 2019, Devalkar and Krishnan 2019, Kouvelis and Xu 2021) or based on purchase orders prior to the shipment or even before the commencement of production (e.g., Tanrisever et al. 2017, Tunca and Zhu 2018, Zha et al. 2019). Similarly, when the buyer is involved *directly*, the financing could be post-shipment, account-receivable based or pre-shipment, purchase-order based. In this regard, the SCF literature has focused on the latter and refers to *direct, pre-shipment* financing from the buyer to the supplier in support of the continuity of production or supply as *buyer direct financing*, namely BDF.

A number of recent studies have investigated the merits of BDF, as the buyer may possess more accurate and thorough knowledge of the supplier's intrinsic operations and the purchase order and thus have more clout over the supplier's performance (Tang et al. 2018, Gupta and Chutani 2020). The advantage also extends to assembly systems with more than one supplier, in which BDF is found to reduce the interest rate and purchase price and promote higher inventory backup (Deng et al. 2018), and other scenarios, in which *direct* financing, compared to *indirect* financing, may achieve supply chain coordination (Zhao and Huchzermeier 2019, Gupta and Chen 2020). Relevant research also discusses various incarnations of BDF, such as in-house loans in comparison to interest-free early payment (Chen et al. 2020) and platform-based financing's impact on competing suppliers (Dong et al. 2019). Recently, researchers explored how blockchain and FinTech adoption may alter the effect of BDF in the form of advance payment along multi-tier supply chains (Dong et al. 2021) and affect the dynamics between pre-shipment and post-shipment financing (Wang and Xu 2021). However, in these studies, the payment timeline is typically assumed exogenous. Thus, the interplay among BDF advance payment, the payment timeline, and the advance discount rate still requires further investigation.

To some extent, the payment terms or PE considered in this paper exhibit similar traits to trade credit, a short-term loan extended by the supplier allowing the buyer to delay payment for goods already delivered (Cuñat 2007). Initially a financial tool for large and resourceful suppliers to assist small and credit-constrained buyers (e.g., Petersen and Rajan 1997), recent empirical evidence suggests that the opposite is also observed (e.g., Klapper et al. 2012, Mateut 2014, Lee et al. 2018). For this reason, the operations literature studies trade credit with a focus on capital-constrained buyers and its role in risk sharing, competition, and coordination among supply chain members (e.g., Jing et al. 2012, Kouvelis and Zhao 2012, Peura et al. 2017, Yang and Birge 2018), with little consideration of engineering the payment timeline. The reverse scenario with large and creditworthy buyers setting payment terms, as considered in this paper, is observed in more recent literature that discusses trade credit with post-shipment *indirect* financing (e.g., Devalkar and Krishnan 2019, Kouvelis and Xu 2021). In these papers, PE generates financial benefit to the buyer at the cost of the supplier. This effect, however, has been isolated in our paper through a setting in which the buyer is neutral to PE in absence of AP. Therefore, by modelling PE as a pure operational leverage in conjunction with the application of AP, our paper highlights a novel rationale for the buyer to adopt PE in addition to reasons already discussed in literature.

Lastly, this paper is related to the stream of literature that considers how to manage disruptive suppliers. Some commonly discussed measures in dealing with supplier disruption risk include inventory (e.g., Tomlin 2006), process improvement (e.g., Bakshi and Kleindorfer 2009, Wang et al. 2010), diversification (e.g., Babich et al. 2007, Yang et al. 2012), contracting (e.g., Swinney and

Netessine 2009, Gümüş et al. 2012), alliance (e.g., Huang et al. 2016), subsidies (e.g., Wadecki et al. 2012, Tang et al. 2014), and insurance (e.g., Dong and Tomlin 2012, Serpa and Krishnan 2017, Dong et al. 2018). Among the limited number of papers that have examined the use of SCF under supplier disruption, Tunca and Zhu (2018) considered how buyer *indirect* financing can distribute such risk along the supply chain and improve channel performance. Tang et al. (2018) found that BDF allows a manufacturer to capitalize on its superior information about the risk of the supplier.

This paper contributes to the literature by suggesting that a holistic design of BDF, through the joint engineering of payment advance, timeline, and discount rate, can broaden the working zone of disruptive suppliers and create a possible win–win for both parties. Through an in-depth characterization of the interplay among the three components, the paper decomposes their application zones, values, and impacts on operations with respect to the supplier's risk level. The results offer strategic guidance for the buyer to engineer her business cash flow with respect to the risk profile of the supplier and the external regulation environment.

The rest of the paper is organized as follows. Section 2 introduces the model. Section 3 discusses the solution procedure for general contracts with AP and regulated PE and TR. Section 4 analyzes the synergy among AP, PE, and TR by comparing optimal terms across a number of contracts. Specifically, Section 4.1 assesses the value of AP and PE, while Section 4.2 focuses on the value of TR and its interaction with PE. Section 5 discusses the impact of regulation. Finally, Section 6 summarizes the managerial insights and future extensions of the study. All analytical proofs and glossaries of notations are relegated to the online appendix.

2. The Model

Consider a supply chain with a small, capital-constrained supplier and a large, financially sound buyer. The buyer procures a product from the supplier, which, after some assembling and processing, is sold to a deterministic, price-sensitive market characterized by linear demand function $D(p) = a - bp$, where $a, b > 0$. This setting reflects a general bi-party purchasing relationship driven by a stable external market. The parties procure through a wholesale price contract, where the supplier submits a unit wholesale price w, and the buyer determines her ordering quantity q accordingly. Subsequently, the retail price for the market follows $p = D^{-1}(q)$. Without loss of generality, we assume that relevant assembling and processing costs are static and ignorable.

The supplier has limited working capital M for the forthcoming production. Hence, given the unit production cost c, the supplier can only manufacture up to M/c units without additional financing. Further, the supplier is subject to some exogenous risks such that whatever he produces may be disrupted with probability θ or satisfactorily delivered at period $t = 1$ with probability $\bar{\theta} = 1 - \theta$. This could be inherent in the nature of the product or process, such as defective design and tampered raw material, or events from the external environment, such as natural disasters, fires, and financial crisis.[6] We assume that the buyer possesses accurate information pertaining to the supplier's working capital and risk level. This can be assessed through historical transactions, commercial databases, supplier ratings, and intra-organizational experiences from the existing relationship between the parties. Thus, both M and θ are common knowledge along the supply chain.

In facilitating production, the buyer may offer direct financing to the supplier. Specifically, the buyer can allow the supplier to request an advance (AP) up to $\bar{L}$, subject to an interest rate r, from his final invoice prior to the commencement of production. The $\bar{L}$ can be considered as the loan limit or line of credit applied in practice and in the literature, and each dollar the supplier requests as an advance from $\bar{L}$ will be subject to a discount rate $\tau = e^{-r}$. Given the equivalency between r and τ and in a slight abuse of notation, we will focus on and refer to τ as the *advance discount rate* for the rest of the paper. The advance discount rate can be anchored to the industry norm, capital opportunity cost, target return, or simply be nominal between the parties.[7] In these cases, τ can be considered exogenously given. Alternatively, the buyer may enhance her own payoff by tailoring the advance discount rate (TR) with respect to the inherent characteristics of the supplier. Should TR be subject to any loan interest regulation, e.g., $r \leq r_0$ for some ceiling interest rate r_0, τ will be determined within the interval of $[\delta_0, 1]$, where $\delta_0 = e^{-r_0}$. For the rest of the paper, we refer to δ_0 as the *floor discount rate*.

The production commences at $t = 0$ and will take precisely one period to complete. Conditioned upon successful delivery at $t = 1$, the buyer pays the invoice at $t = x \geq 1$. The buyer may configure the payment timeline x (PE) within the range of $[1, x_r]$, where $x_r \geq 1$ represents the maximum payment term tolerated by regulation. Therefore, $x_r = \infty$ implies a free market with no payment term regulation, versus $x_r = 1$ is the strictest regulation that enforces payment upon delivery.

The timing of relevant events is summarized in Figure 1. The buyer first announces the advance limit $\bar{L}$, the advance discount rate τ, and the payment timeline x. The parties then set the wholesale price contract (w, q) overarched by the financing terms. At $t = 0$, the supplier requests an advance from the future invoice subject to $L \leq \bar{L}$. The buyer immediately remits $L\tau^x$ to the supplier, who then initiates a production $\hat{q} = \min\{q, \frac{M + L\tau^x}{c}\}$ in accordance with the contract terms and his

[6] For instance, the 2008 financial crisis crashed over 20% of SMEs in China (CIBC 2009), and the 2011 Japan tsunami severely disrupted outbound electronic supplies (Lohr 2011). Further, what appears to be operational disruptions at the beginning usually develop into credit risks that threat the suppliers and OEMs (Gerken et al. 2014, Carruthers and Makova 2018).

[7] Recall that GSK lent to its suppliers at the same interest rate that GSK paid the bank (Tang et al. 2018). JingDong Finance has consistently set its interest rate around 9% (Chen et al. 2020). It may also be based on borrows' opportunity cost (Deng et al. 2018) or the buyer's internal return guidelines (Gustin 2018, Dong et al. 2019).

enhanced capital.[8] If the process remains undisrupted, at $t = 1$ the supplier delivers $\hat{q}$ units, and the buyer collects revenue $D^{-1}(\hat{q})\hat{q}$; at $t = x$, the buyer pays the remainder of the invoice $w\hat{q} - L$. Otherwise, the supplier defaults, and no goods or monetary exchanges take place on or after $t = 1$.

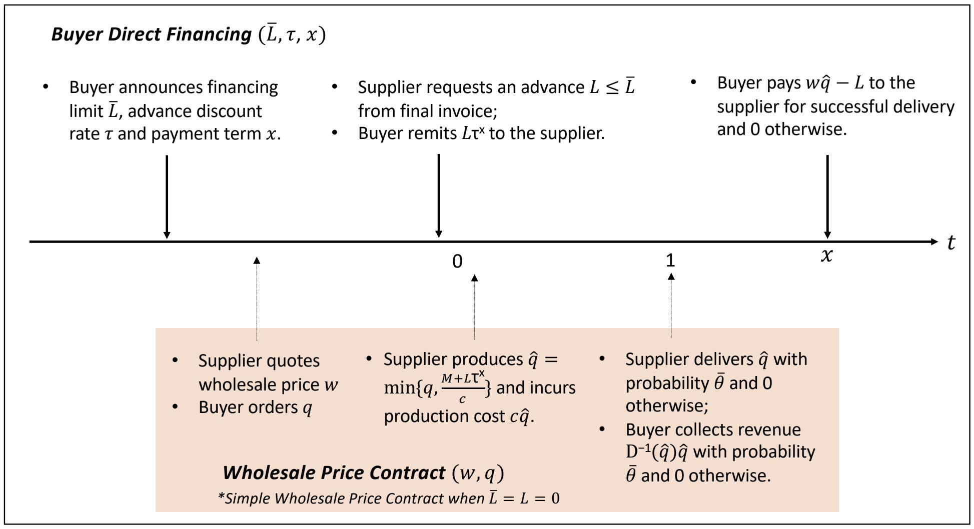


Figure 1 Timing of the events

We assume that the supplier has limited liability and that both the buyer and the supplier aim at maximizing their expected equity values at a given terminal date $t = T$ beyond the payment timeline. In addition, any cash or working capital will be invested at the risk-free interest rate r_f. These are common assumptions that have been used in the relevant literature, such as Kouvelis and Zhao (2012) and Tunca and Zhu (2018). Narrowly in this model, this objective is equivalent to maximizing the cash positions discounted at the risk-free discount rate $\delta = e^{-r_f}$ back to time $t = 0$ (thereafter referred to as the "payoff"). Following the cash flow characterized in Figure 1, the respective payoffs for the buyer and for the supplier are as follows:

$$\Pi_R = \bar{\theta} D^{-1}(\hat{q})\hat{q}\delta - \bar{\theta}(w\hat{q} - L)\delta^x - L\tau^x, \tag{1}$$

$$\Pi_S = L\tau^x - c\hat{q} + \bar{\theta}(w\hat{q} - L)\delta^x. \tag{2}$$

The first term in Π_R represents the buyer's expected revenue at $t = 1$ discounted by the risk-free rate, the second term is her expected discount payment from $t = x$, and the last term is the advance payment received at $t = 0$. Similarly, the first and last terms in Π_S are the advance payment and the expected discount payment collected by the supplier at $t = 0$ and $t = x$, respectively, and the middle term is the production cost incurred up front at $t = 0$.

[8] In alignment with the literature, we do not account for unethical behaviours such as a supplier taking an advance payment without engaging in any future production. By focusing on a close buyer–supplier relationship that supports direct financing and public information in risk level and working capital, it is reasonable to assume that unfaithful production can be properly verified or circumvented by various means.

When $\bar{L}=0$, the buyer offers no financing. The contract is reduced to a simple wholesale price contract, as highlighted in the lower block of Figure 1. As a benchmark, we characterize the equilibrium procurement terms in a simple wholesale price contract in what follows.

2.1 Benchmark: Simple Wholesale Price Contract (No Financing)

In the absence of buyer financing ($\bar{L}=0$), the payoffs of the buyer and the seller as formulated in (1) and (2) become $\Pi_R^N=\bar{\theta}[D^{-1}(\hat{q})-w\delta^{x-1}]\hat{q}\delta$ and $\Pi_S^N=\bar{\theta}w\hat{q}\delta^x-c\hat{q}$, respectively. Denote the equilibrium wholesale price and order quantity as w^N and q^N, respectively. It can be verified that, in equilibrium, the risk-free-rate-adjusted wholesale price ($w^N\delta^{x-1}$), the order quantity q^N, and the parties' payoffs are all independent of the payment term x. Overall,

Lemma 1. *The simple wholesale price contract is insensitive to the payment term.*

Therefore, in our model PE is only relevant in the presence of AP. Without loss of generality, we assume $x=1$ in the simple wholesale price contract. The payoffs of the parties are then reduced to $\Pi_R^N=\bar{\theta}[D^{-1}(\hat{q})-w]\hat{q}\delta$ and $\Pi_S^N=\bar{\theta}w\hat{q}\delta-c\hat{q}$.

Denote $\theta_0=1-\frac{bc}{a\delta}$, $\theta_c=1-\frac{bc}{(a-4M/c)\delta}$, $q_u=\frac{a}{4}-\frac{bc}{4\bar{\theta}\delta}$, and $w_u=\frac{a}{2b}+\frac{c}{2\bar{\theta}\delta}$. The equilibrium contractual terms without financing can be explicitly characterized as follows:

Proposition 1. **(Simple Wholesale Price Contract)** *In the absence of financing,*

(i) when $\theta\in[0,\theta_c]$, the wholesale price is $w^N=\frac{a}{b}-\frac{2M}{cb}$, and the buyer orders at $q^N=M/c$. The supplier produces up to capacity $\hat{q}=q^N=\frac{M}{c}$;

(ii) when $\theta\in(\theta_c,\theta_0)$, the wholesale price is $w^N=w_u$, and the buyer orders at $q^N=q_u$. The supplier produces under capacity $\hat{q}^N=q_u<\frac{M}{c}$;

(iii) when $\theta\in[\theta_0,1]$, the buyer would not procure from the supplier, i.e., $q^N=0$.

In general, the procurement or production quantity decreases with the risk level θ, while the wholesale price is affected in the opposite direction. The lower threshold θ_c suggests whether the supplier will operate at full or partial capacity ($q^N<\frac{M}{c}$), and the upper threshold θ_0 serves as the condition of procurement ($q^N>0$). Note that θ_0 is irrelevant to working capital M thus will not be affected by financing. We will limit our discussion to $\theta\in[0,\theta_0)$ whenever applicable. Also, notice that the supplier operates under partial capacity in case (ii). Thus, we refer to q_u as *unconstrained optimal production* and w_u as *unconstrained optimal wholesale price* for the remainder of the paper.

3. Optimal Contractual Terms

In this section, we outline how to solve the optimal contractual terms via backward induction. We first tackle the procurement terms — the wholesale price w^*, the order quantity q^*, as well as the requested advance L^* in support of the production — under given financing terms $(\bar{L},\tau,x)$. We then analyze the financing terms — the optimal advance limit $\bar{L}^*$ given payment term x and advance discount rate τ, the optimal payment timeline x^* given τ, and lastly the optimal tailored discount rate τ^*. For the sake of exposition parsimony, we omit the dependent variables in some mathematical presentations when they are self-evident.

3.1 Procurement Terms

In accordance with the game sequence illustrated in Figure 1, we first derive the advance L^* under contractual terms $(\bar{L}, x, \tau, w, q)$. Essentially, the supplier solves the following problem:

$$\begin{aligned} \max_{L \geq 0} \ \ & \Pi_S = (\tau^x - \bar{\theta}\delta^x)L + (\bar{\theta}\delta^x w - c)\hat{q} \\ s.t. \ \ & L \leq \bar{L},\ \hat{q} = \min\{\frac{M + L\tau^x}{c}, q\}. \end{aligned}$$

Clearly, the advance L is subject to the financing limit $\bar{L}$ determined earlier by the buyer, and the production quantity $\hat{q}$ is bounded by the order size q and the enhanced capacity $(M + L\tau^x)/c$.

Once L^* is obtained, the buyer should account it in determining her order quantity $q^*(\bar{L}, x, \tau, w)$:

$$\begin{aligned} \max_{q \geq 0} \ \ & \Pi_R = \bar{\theta}(D^{-1}(\hat{q})\delta - w\delta^x)\hat{q} + (\bar{\theta}\delta^x - \tau^x)L \\ s.t. \ \ & L = L^*(\bar{L}, x, \tau, w, q),\ \hat{q} = \min\{\frac{M + L\tau^x}{c}, q\}. \end{aligned}$$

Note that whenever the optimal $q^*(\bar{L}, x, \tau, w)$ is not unique, we take the minimum among all such that there is always $q^* = \hat{q}^*$.

Lastly, the supplier decides his wholesale price $w^*(\bar{L}, x, \tau)$ by accounting for the responses $q^*(\bar{L}, x, \tau, w)$ and $L^*(\bar{L}, x, \tau, w, q)$ and solving:

$$\begin{aligned} \max_{w \geq 0} \Pi_S \ \ & = (\tau^x - \bar{\theta}\delta^x)L + (\bar{\theta}\delta^x w - c)q \\ s.t. \ \ & L = L^*(\bar{L}, x, \tau, w, q),\ q = q^*(\bar{L}, x, \tau, w). \end{aligned}$$

The explicit solutions for $L^*(\bar{L}, x, \tau, w, q)$, $q^*(\bar{L}, x, \tau, w)$ and $w^*(\bar{L}, x, \tau)$ are summarized in Lemmas A2, A3, and A4, respectively, in the appendix. Combining these results leads to the equilibrium procurement terms (w^*, q^*, L^*) given financing parameters $(\bar{L}, x, \tau)$.

LEMMA 2. **(Procurement Terms)** *Given the financing terms $(\bar{L}, x, \tau)$, the equilibrium wholesale price w^*, order quantity q^*, and the advance L^* are as follows:*

(i) if $\bar{\theta}\delta^x \leq \tau^x$, then $w^* = \max\{\frac{a}{2b\delta^{x-1}} + \frac{c}{2\bar{\theta}\delta^x}, \frac{a - 2(M + \bar{L}\tau^x)/c}{b\delta^{x-1}}\}$ and

- *if $w^* < \frac{c}{\tau^x}$, $q^* = \max\{0, \min\{\frac{M}{c}, \frac{a - b\delta^{x-1}w^*}{2}\}\}$ and $L^* = \bar{L}$;*
- *if $w^* \geq \frac{c}{\tau^x}$, $q^* = \max\{0, \min\{\frac{M + \bar{L}\tau^x}{c}, \frac{a - b\delta^{x-1}w^*}{2}\}\}$ and $L^* = \bar{L}$;*

(ii) if $\tau^x < \bar{\theta}\delta^x$, then $w^* = \arg\max_{w \in \{w_1, w_2, w_3\}} \Pi_S$ where $w_1 = \min\{\max\{\frac{a}{2b\delta^{x-1}} + \frac{c}{2\bar{\theta}\delta^x}, \frac{a - 2M/c}{b\delta^{x-1}}\}, \frac{c}{\tau^x}\}$, $w_2 = \min\{\max\{\frac{a}{2b\delta^{x-1}} + \frac{c}{\tau^x} - \frac{c}{2\bar{\theta}\delta^x}, \frac{c}{\tau^x}, \frac{a - 2(M + \bar{L}\tau^x)/c}{b\delta^{x-1}} + \frac{c}{\tau^x} - \frac{c}{\bar{\theta}\delta^x}\}, \bar{w}\}$, and $w_3 = \max\{\frac{a}{2b\delta^{x-1}} + \frac{c}{2\bar{\theta}\delta^x}, \bar{w}, \frac{a - 2M/c}{b\delta^{x-1}}\}$ for some $\bar{w} \geq \frac{c}{\tau^x}$, and

- *if* $w^* < \frac{c}{\tau^x}$ *or* $w^* \geq \bar{w}$, $q^* = \max\{0, \min\{\frac{M}{c}, \frac{a-b\delta^{x-1}w}{2}\}\}$ *and* $L^* = 0$;
- *if* $\frac{c}{\tau^x} \leq w^* < \bar{w}$, $q^* = \max\{\frac{M}{c}, \min\{\frac{M+\bar{L}\tau^x}{c}, \frac{a-b\delta^{x-1}w}{2} + \frac{\frac{\delta^x}{\tau^x}-\frac{1}{\bar{\theta}}}{2\delta}bc\}\}$ *and* $L^* = \min\{\max\{0, \frac{cq^*-M}{\tau^x}\}, \bar{L}\}$.

The results suggest that when $\bar{\theta}\delta^x \leq \tau^x$, the short payment timeline x or high advance discount rate τ are insufficient to counter the supplier's risk level θ. As a result, the supplier will request an advance up to the full limit $\bar{L}$, even if it exceeds his actual need to produce q^*. We refer to this as a *tactical cash advance*. When the reverse applies ($\tau^x < \bar{\theta}\delta^x$), longer payment timeline x or lower advance discount rate τ adds to the cost of borrowing. Therefore, the supplier will only request the exact amount (subject to the loan limit $\bar{L}$) that covers the gap between his own working capital and the total cost of producing q^*. We refer to this as a *practical cash advance*. As will be discussed in later sections of the paper, adjusting the payment timeline or advance discount rate may help *neutralize* either type of cash advance.

3.2 Financing Limit

Considering the procurement terms as analyzed in §3.1, the buyer needs to design the financing terms $(\bar{L}, x, \tau)$ that maximize her payoff:

$$\max_{\bar{L}\geq 0, x\in[1,x_r], \tau\in[\delta_0,1]} \Pi_R = \bar{\theta}(D^{-1}(q^*)\delta - w^*\delta^x)q^* + (\bar{\theta}\delta^x - \tau^x)L^*.$$

We first derive the optimal financing limit $\bar{L}^*$ given payment term x and advance discount rate τ:

Proposition 2. **(Financing Limit)** *Given the payment term x and advance discount rate τ, the buyer's financing limit $\bar{L}^*$ is determined by*

$$\bar{L}^* = \begin{cases} (cq_u - M)\Big/\tau^x & \text{for } \theta \in [0, \theta_f], \\ 0 & \text{for } \theta \in (\theta_f, 1], \end{cases} \tag{3}$$

where $\theta_f = \theta_f(x,\tau) = \min\{\max\{1 - \frac{5bc}{4bc\frac{\delta^x}{\tau^x} + (a+4M/c)\delta}, 1 - \frac{\tau^x}{\delta^x}\}, \theta_c\}$.

The result suggests that the buyer will either not offer any AP or provide exactly what is needed in support of the *unconstrained optimal production* q_u. However, whether a supplier can secure the financing depends upon his risk level. As Proposition 2 states, there exits a threshold risk level θ_f above which the buyer will not extend any AP. In other words, the buyer will only finance a more reliable supplier.

Further, Proposition 2 implies that $\theta_f \leq \theta_c$. Therefore, the buyer will only finance a supplier who would operate at full capacity without financing. However, not all fully loaded suppliers are qualified for AP. In this sense, AP is *selective* in that both the need and risk profile of a supplier must pass certain thresholds in securing the financing. This point is summarized in Corollary 1 (i).

It can also be inferred from Proposition 2 that both PE and TR have a positive impact on AP coverage. That is, as the payment term x extends or the advance discount rate τ reduces, the buyer would be willing to finance a supplier with a higher risk exposure who would have been uncovered otherwise. This leads to Corollary 1 (ii).

COROLLARY 1. *(i) AP is selective to more reliable suppliers, i.e.,* $\theta_f \le \theta_c \le \theta_0$.
(ii) PE and TR broaden AP coverage, i.e., θ_f *increases in* x *and decreases in* τ.

3.3 Payment Term

We next configure PE conditioned upon τ. The following proposition finds that the optimal payment term x^* is affected by the operational risk factor θ as well as the financial risk factors, i.e., the discount rates (τ, δ), and capped by the payment term boundaries $[1, x_r]$.

PROPOSITION 3. **(Payment Timeline)** *The buyer will set* $x^* = \max\{\min\{\ln(\bar{\theta})/\ln(\frac{\tau}{\delta}), x_r\}, 1\}$.

It follows immediately after Proposition 3 that when the interest rate is high or the risk level is low ($\tau < \bar{\theta}\delta$), there will be no PE ($x^* = 1$), and the supplier will only execute a *practical cash advance*. However, when the interest rate is low or risk level is high ($\tau \ge \bar{\theta}\delta$), the buyer should extend the payment timeline ($x^* > 1$) possibly to the maximum ($x^* = x_r$) and offset any *tactical cash advance*. That is, under a given advance discount rate, the buyer can properly align her interest with the supply side risk by adjusting the payment term for more risky suppliers. Apparently, this role of alignment is limited by the regulation subject to which the buyer can engineer PE.

Denote $x_c = \ln(\bar{\theta}_c)/\ln(\frac{\tau}{\delta})$, $\theta_e = \min\{1 - \frac{\tau}{\delta}, \theta_c\}$, and $\theta_r = \min\{1 - \frac{\tau^{x_r}}{\delta^{x_r}}, \theta_c\}$. Corollary 2 summarizes the impact of payment term regulation:

COROLLARY 2. **(Impact of PE Regulation)** *Given advance discount rate* τ,
(i) when regulation is weak, i.e., $x_r \ge x_c$, *there are* $\theta_f(x^*, \tau) = \theta_c$ *and*

$$x^* = \begin{cases} 1 & 0 \le \theta \le \theta_e, \\ \ln(\bar{\theta})/\ln(\frac{\tau}{\delta}) & \text{when } \theta_e < \theta \le \theta_c; \end{cases}$$

(ii) when regulation is strict, i.e., $x_r < x_c$, *there are* $\theta_f(x^*, \tau) < \theta_c$ *and*

$$x^* = \begin{cases} 1 & \text{when } 0 \le \theta \le \theta_e, \\ \ln(\bar{\theta})/\ln(\frac{\tau}{\delta}) & \text{when } \theta_e < \theta < \theta_r, \\ x_r & \text{when } \theta_r \le \theta \le \theta_f(x_r, \tau). \end{cases}$$

The result suggests that weak payment term regulation has the same effect as no regulation, under which the financing threshold θ_f will be the same as the utilization threshold θ_c. That is, no supplier will be operating at full capacity without buyer financing. On the other hand, strict payment term regulation will ease the payment term for suppliers at some risk levels, i.e., $\theta \in [\theta_r, \theta_f]$, but that comes at the cost of withdrawing financing from those with higher risk profiles, i.e., $\theta \in (\theta_f, \theta_c)$.

3.4 Advance Discount Rate

Returning to the last stage of backward induction, we investigate the optimal τ^*. The following lemma characterizes how the buyer's payoff varies with τ in general:

LEMMA 3. *The buyer's payoff increases in τ when $\theta \le \theta_e$, is indifferent to τ when $\theta_e < \theta < \theta_r$, and decreases in τ when $\theta_r < \theta < \theta_f$.*

Counterintuitively, the buyer's payoff does not always increase in the interest rate she charges the supplier (or decreases in τ). In connection with Corollary 2 (ii), the buyer may benefit from a more lenient interest rate when the supplier's risk is reasonably low ($\theta \le \theta_e$) such that it is optimal to finance the supplier even without PE ($x^* = 1$). Once a supplier's risk level exceeds this threshold, the buyer's payoff becomes either indifferent to the interest rate when PE applies ($\theta_e < \theta < \theta_r$) or increases in the interest rate (or decreases in τ) when PE is constrained by regulation ($\theta_r < \theta < \theta_f$).

Based on this result, we derive the optimal advance discount rate τ for the buyer. Specifically, we find that the buyer should offer a tailored discount rate (i.e., TR) when the supplier's risk level is below some threshold and stay with the floor discount rate δ_0 otherwise.

PROPOSITION 4. **(Advance Discount Rate)** *Suppose the advance discount rate τ is bounded by $[\delta_0, 1]$. Then, the buyer should offer a tailored discount rate $\tau^*(\theta) \in [\delta_0, \delta]$ to a low-risk supplier and the floor discount rate $\tau^* = \delta_0$ to a high-risk supplier. Specifically, $\tau^* \in \{\tau_X : [0,1] \to [\delta_0, \delta],\ X \in [1, \infty)\}$ when $x_r \ge x_c$, and $\tau^* \in \{\tau_X : [0,1] \to [\delta_0, \delta],\ X \in [1, x_r]\}$ when $x_r < x_c$, where*

$$\tau_X(\theta) = \begin{cases} (\bar{\theta})^{\frac{1}{X}} \delta & \text{if } \theta < \hat{\theta}, \\ \delta_0 & \text{if } \theta \ge \hat{\theta}, \end{cases} \tag{4}$$

for $\hat{\theta} = \min\{1 - \frac{\delta_0^X}{\delta^X}, \theta_c\}$.

This scheme simply suggests that only the most reliable suppliers ($\theta \le \hat{\theta}$) could enjoy TR. Moreover, a risk-less supplier will be awarded the risk-free interest rate, i.e., $\tau_X(0) = \delta$.

Further, the optimal TR scheme τ_X is not unique. For instance, the buyer can decide whether to apply higher tailored discount rates to a wider range of suppliers (larger X) or lower tailored discount rates to a narrower range of suppliers (smaller X). As $X \in [1, x_r]$, the variety of this selection is largely driven by the degree of regulation in PE. This is summarized as Corollary 3 (i).

For any candidate scheme τ_X, a more strict interest rate regulation (higher δ_0) will lead to a narrower range of suppliers receiving TR. As can be inferred from (4), the cut-off risk level $\hat{\theta}$ strictly decreases in δ_0 until the latter goes beneath some $\delta_c = \frac{bc}{a-4M/c}$, after which $\hat{\theta}$ holds onto θ_c. Recall from §3.2 that no AP will be granted when $\theta \ge \theta_c$. Therefore, under weak interest rate regulation ($\delta_0 \le \delta_c$), TR universally applies ($\hat{\theta} = \theta_c$), while under strict interest rate regulation ($\delta_0 > \delta_c$), only a fraction of the supplier may enjoy TR ($\hat{\theta} < \theta_c$). This is summarized as Corollary 3 (ii).

COROLLARY 3. *(i) Weak payment term regulation allows more optimal TR schemes;*
(ii) Weak interest rate regulation widens the application of TR.

4. Synergy of Financing Components

In this section, we further explore the value and interplay of AP, PE, and TR by comparing the parties' operations and payoffs under various contracts. In §4.1, we characterize the contractual terms when the advance discount rate τ is exogenously given. This allows us to assess the value of AP by comparing an AP-only contract ($x_r = 1$) versus the simple wholesale price contract and the value of PE by comparing the AP+PE contract ($x_r > 1$) versus the AP-only contract ($x_r = 1$). In §4.2, we let the advance discount rate τ be endogenously determined and characterize the optimal AP+TR+PE contract. Comparing the optimal AP+TR+PE with AP+PE and AP+TR contracts allows us to investigate the value of TR and its interaction with PE.

4.1 Exogenous Advance Discount Rate

Following the results from §3, the contractual terms when both PE and TR are inactive ($x_r = 1, \tau$ given) are characterized in Theorem 1 and further summarized in Table 1.

Theorem 1. **(AP only)** *Given the advance discount rate τ and payment term regulation $x_r = 1$,*

(i) when $\theta \in [0, \theta_1]$, the buyer will grant AP ($\bar{L}^* > 0$). The supplier will request an advance up to the full limit ($L^* = \bar{L}^*$) and produce at full capacity ($q^* = \hat{q}^* = \frac{M+\bar{L}^*}{c} = q_u$). Specifically, the wholesale price is $w^* = \frac{a}{2b} + \frac{c}{\tau} - \frac{c}{2\theta\delta}$ when $\theta \in [0, \theta_e]$ and $w^* = w_u$ when $\theta \in (\theta_e, \theta_1]$;

(ii) when $\theta \in (\theta_1, \theta_0)$, the buyer will not grant any AP ($\bar{L}^* = 0$). The terms follow Proposition 1.

As summarized in Table 1, throughout all cases, the capacity utilization, production quantity, and financing limit naturally decrease in the supplier's risk level θ. Further, as long as the risk level θ is beyond the threshold θ_1, no AP will be granted, and the contract terms will be the same as in the simple wholesale price contract without financing, as characterized in Proposition 1. When the risk level falls below θ_1, the supplier will be financed toward the *unconstrained optimal production* q_u. In this region, as discussed after Lemma 2, the supplier will draw on a *tactical cash advance* when he is more risky ($\theta_e < \theta < \theta_1$) and a *practical cash advance* when he is more reliable ($\theta \leq \theta_e$).

When the buyer is allowed to practice some PE ($x_r > 1$), relevant contractual terms are summarized as follows and in Table 2:

Theorem 2. **(AP+PE)** *Given the advance discount rate τ,*

(i) when $\theta \in [0, \theta_e]$, the buyer should grant AP with no PE ($\bar{L}^* > 0,\ x^* = 1$). The supplier will request an advance up to the full limit ($L^* = \bar{L}^*$), produce at full capacity ($q^* = \hat{q}^* = \frac{M+\bar{L}^*\tau}{c} = q_u$), and set the wholesale price $w^* = \frac{a}{2b} + \frac{c}{\tau} - \frac{c}{2\theta\delta}$;

(ii) when $\theta \in (\theta_e, \theta_{x_r})$, the buyer should grant AP with PE ($\bar{L}^* > 0,\ x^* > 1$). The supplier will request an advance up to the full limit ($L^* = \bar{L}^*$), produce at full capacity ($q^* = \hat{q}^* = \frac{M+\bar{L}^*\tau^{x^*}}{c} = q_u$), and set the wholesale price $w^* = w_u/\delta^{x^*-1}$. Specifically,

Table 1 Contractual Terms: AP only

	AP		No AP	
Disruption Risk θ	$[0,\theta_e]$	$(\theta_e,\theta_1]$	(θ_1,θ_c)	$[\theta_c,\theta_0)$
Financing Limit $\bar{L}$	$\frac{c(\frac{a}{4}-\frac{bc}{4\theta\delta})-M}{\tau}$		0	
Cash Advance Tactic	Practical	Tactical	-	-
Wholesale Price w	$\frac{a}{2b}+\frac{c}{\tau}-\frac{c}{2\theta\delta}$	$\frac{a}{2b}+\frac{c}{2\theta\delta}$	$\frac{a-2M/c}{b}$	$\frac{a}{2b}+\frac{c}{2\theta\delta}$
Order Quantity q	$\frac{a}{4}-\frac{bc}{4\theta\delta}$		$\frac{M}{c}$	$\frac{a}{4}-\frac{bc}{4\theta\delta}$
Utilization $q\Big/\frac{M+\bar{L}\tau^x}{c}$	Full		Full	Partial

where $\theta_e=\min\{1-\frac{\tau}{\delta},\theta_c\}$, $\theta_1=\theta_f(1,\tau)$, $\theta_c=1-\frac{bc}{\delta(a-4M/c)}$, and $\theta_0=1-\frac{bc}{\delta a}$.

Table 2 Contractual Terms: AP + PE

	AP only	AP + PE		No AP	
Disruption Risk θ	$[0,\theta_e]$	(θ_e,θ_r)	$[\theta_r,\theta_{x_r})$	$[\theta_{x_r},\theta_c)$	$[\theta_c,\theta_0)$
Payment Timeline x	1	$\ln(\bar{\theta})\Big/\ln(\frac{\tau}{\delta})$	x_r	1	
Financing Limit $\bar{L}$	$\frac{c(\frac{a}{4}-\frac{bc}{4\theta\delta})-M}{\tau}$	$\frac{c(\frac{a}{4}-\frac{bc}{4\theta\delta})-M}{\tau^x}$		0	
Cash Advance Tactic	Practical	Neutral	Tactical	-	
Wholesale Price w	$\frac{a}{2b}+\frac{c}{\tau}-\frac{c}{2\delta\theta}$	$\frac{a}{2b\delta^{x-1}}+\frac{c}{2\theta\delta^x}$		$\frac{a-2M/c}{b}$	$\frac{a}{2b}+\frac{c}{2\theta\delta}$
Order Quantity q	$\frac{a}{4}-\frac{bc}{4\theta\delta}$	$\frac{a}{4}-\frac{bc}{4\theta\delta}$		$\frac{M}{c}$	$\frac{a}{4}-\frac{bc}{4\theta\delta}$
Utilization $q\Big/\frac{M+\bar{L}\tau^x}{c}$	Full	Full		Full	Partial

where $\theta_e=\min\{1-\frac{\tau}{\delta},\theta_c\}$, $\theta_r=\min\{1-\frac{\tau^{x_r}}{\delta^{x_r}},\theta_c\}$, $\theta_{x_r}=\theta_f(x_r,\tau)$, $\theta_c=1-\frac{bc}{\delta(a-4M/c)}$, and $\theta_0=1-\frac{bc}{\delta a}$.

- *customized payment term ($1<x^*<x_r$) applies when $\theta\in(\theta_e,\theta_r)$, and*
- *regulated payment term ($x^*=x_r$) applies when $\theta\in[\theta_r,\theta_{x_r})$;*

(iii) when $\theta\in[\theta_{x_r},\theta_0)$, the buyer will not grant any AP ($\bar{L}^*=0$). The terms follow Proposition 1.

Similar to Theorem 1, AP is only open to more reliable suppliers, i.e., $\theta\le\theta_{x_r}$, and provides the exact amount in support of the unconstrained optimal production quantity q_u. Specifically, for the most reliable suppliers, i.e., $\theta\in[0,\theta_e]$, the buyer will not request any PE, and all amounts due will be paid immediately upon successful delivery. For suppliers with moderately low risk levels, i.e., $\theta\in(\theta_e,\theta_{x_r})$, the buyer will request a PE depending on the supplier's risk level. That is, the buyer will set a longer payment term for suppliers exposed to a higher level of risk when $\theta_e<\theta<\theta_r$ and apply the regulated payment term when $\theta_r\le\theta<\theta_{x_r}$. In the former case with customized payment terms, the buyer is essentially employing PE to neutralize *tactical cash advance* and realign the financing terms with the supplier's risk level. When the supplier's risk level goes beyond θ_{x_r}, there will be no financing, and the contractual terms can be traced back to Proposition 1.

COROLLARY 4. *Under weak payment term regulation, i.e.,* $x_r \geq x_c$, *there is* $\theta_r = \theta_{x_r} = \theta_c$.

Recall from Corollary 2 that weak payment term regulation ($x_r \geq x_c$) has the same effect as no regulation. It follows immediately from Corollary 4 that when payment term regulation is weak, the second instance in Theorem 2 (ii) will degenerate, and thus any supplier with $\theta \in (\theta_e, \theta_c)$ will be paid on a timeline commensurate to his risk level. The reduced contractual terms under weak payment regulation can be found in Table A3 in the appendix.

4.1.1 Numerical Illustration Before assessing the value of AP and PE, we first provide some visual illustration to highlight the distinctions in contractual terms among the simple wholesale price contract (no financing), the AP-only, and AP + PE contracts with strict and weak regulations. Consider that the demand follows $D = 20 - 1.98p$, the production cost $c = 3$, the risk-free discount rate $\delta = e^{-r_f} = 0.99$, the advance discount rate $\tau = e^{-r} = 0.95$, and the supplier's initial capital $M = 3$. According to Corollary 2, any $x_r \geq x_c = 23.78$ will be considered a weak payment term regulation and otherwise a strict regulation.

Figure 2 depicts how the financing limit, payment timeline, wholesale price, and order/production quantity vary with the risk level θ, and Figure 3 shows how the buyer's and supplier's payoffs are impacted by the same factor. In both figures, we mark the following threshold values of θ:

- $\theta_e = 0.04$: the threshold of PE ($x^* > 1$);
- $\theta_1 = 0.39$: the threshold of financing under the AP-only contract;
- $\theta_{x_r} = 0.48$: the threshold of financing under the AP+PE contract with $x_r = 8$;
- $\theta_c = 0.625$: the threshold of financing under the AP+PE contract with $x_r > x_c$ and the threshold of full versus partial capacity utilization.

All graphs cut off at $\theta = \theta_0 = 0.7$, the threshold of procurement identified in Proposition 1.

As can be observed from the graphs, when the risk level is rather low ($\theta \leq \theta_e = 0.04$), AP+PE contracts will offer financing with payment upon delivery. Thus, the curves of AP-only and AP+PE contracts coincide with each other in this region. It can be further observed from Figure 2 that the supply chain achieves a lower wholesale price and a higher production quantity with the aid of financing. As shown in Figure 3, both the buyer and the supplier significantly benefit from AP.

As the risk level grows from $\theta_e = 0.04$ but is still less than $\theta_1 = 0.39$, the AP+PE contracts will offer financing with PE. In return, the financing limit will go beyond that in an AP-only contract in soothing the supplier's financing cost during the extended periods, as reflected in the top left panel in Figure 2. Granting AP results in a lower wholesale price and a higher production quantity compared to no financing. The influence of PE, however, is different. As shown in the bottom panels in Figure 2, adding PE to an AP-only contract (or weakening the payment term regulation

Figure 2 Contractual Terms: Simple Wholesale Price Contract, AP only, and AP+PE

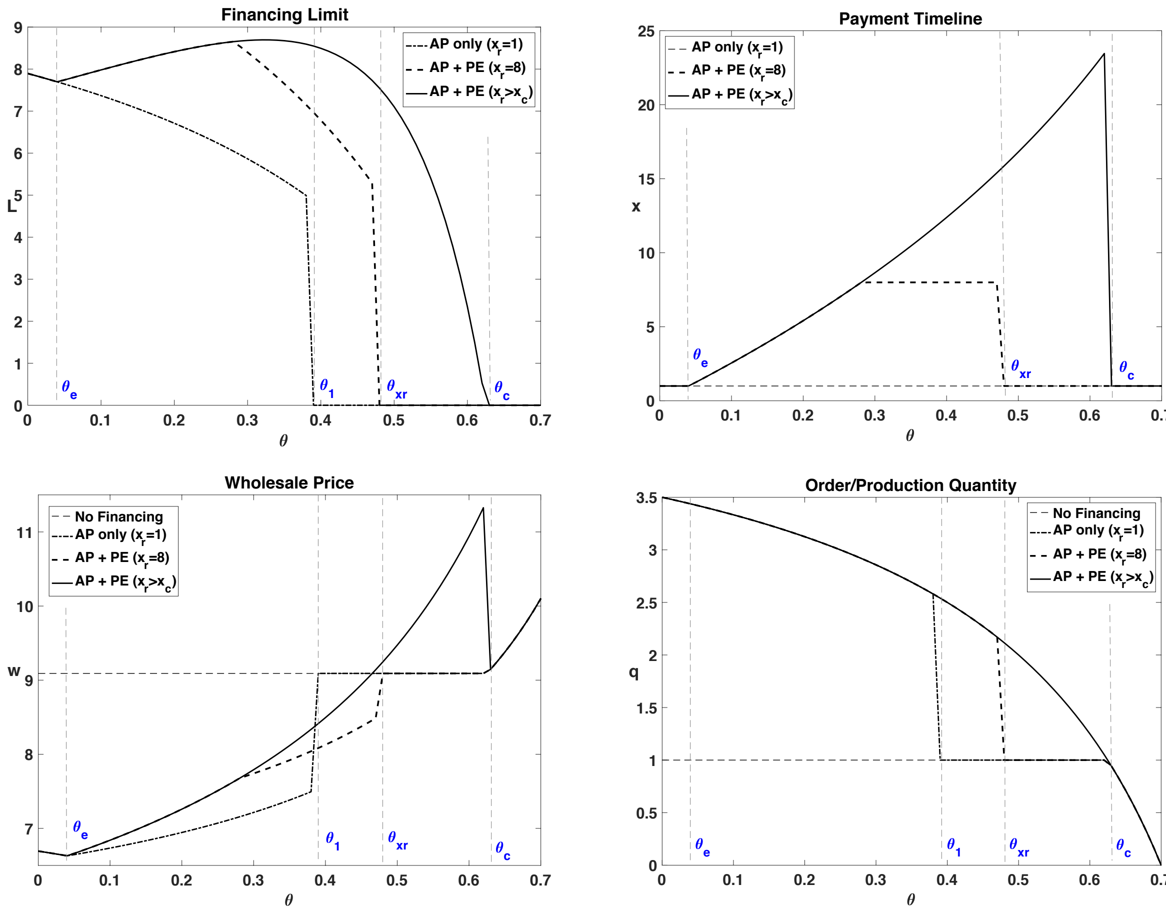
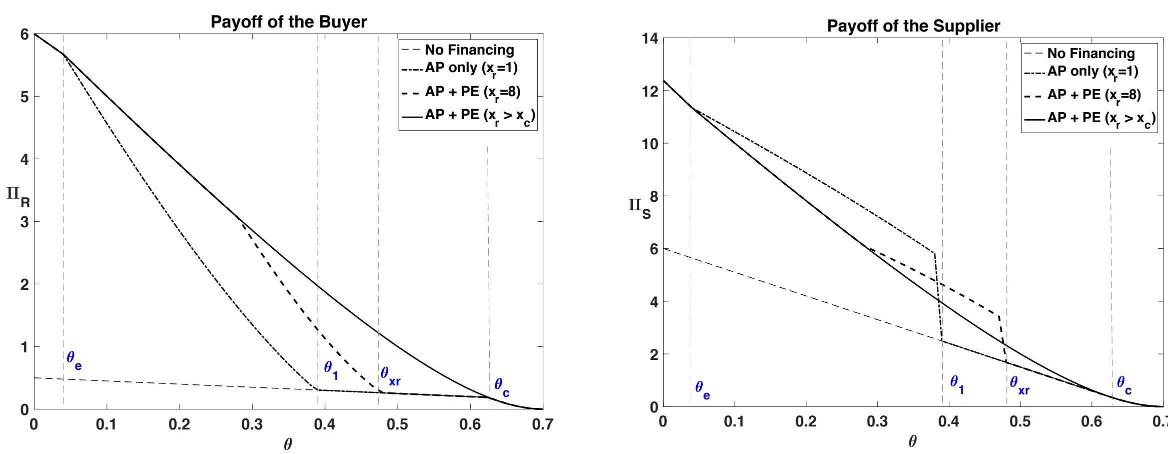


Figure 3 Payoffs: Simple Wholesale Price Contract, AP only, and AP+PE



in an AP+PE contract) will raise the wholesale price without impacting the production quantity. This suggests that the pressure of PE on the supplier may bounce back to the buyer in the form of a higher wholesale price. However, this dynamic will be absorbed within the supply chain itself, with no spillover effect on the production quantity or the retail price that the end market has to pay. Finally, as illustrated in Figure 3, within this region, the buyer is better off with PE or weaker payment term regulation whereas the supplier suffers from the same.

When the risk level rises to $0.39 = \theta_1 \le \theta < \theta_c = 0.625$, an AP-only contract will cease financing, while AP+PE contracts may continue with both AP and PE. In other words, the supplier could only be financed under a longer payment term. Further, the AP coverage broadens as the payment term regulation looses, and the financing limit decreases with the supplier's risk level. The reduced AP and the addition of PE together at some point (e.g., around $\theta = 0.47$ for weak regulation) may push the wholesale price even higher than no financing, as shown in the bottom left of Figure 2. The production quantity, though decreasing with the risk level, remains higher compared to no financing. Combined, this leads to a scenario in which both the buyer and the supplier benefit from the inclusion of PE, as depicted in Figure 3. However, although the buyer consistently benefits from weaker payment term regulation, the supplier prefers the same only when he could not be granted AP otherwise, e.g., $\theta \in (\theta_{x_r}, \theta_c)$.

Finally, at a rather high risk level ($\theta \ge \theta_c = 0.625$), none of the contracts will grant any financing, and the supplier will rely solely upon his original working capital M for the production. Due to the absence of financing costs, the wholesale price precipitates but still increases with the risk level.

4.1.2 The Value of AP and PE The comparison among the three benchmark contracts helps us understand the value of AP and PE for each stakeholder. To begin with, we assess the value of AP by comparing each party's payoff with or without AP. In particular, to rule out the effect of PE, we focus on the distinction between an AP-only contract and the simple wholesale price contract (no financing).

PROPOSITION 5. **(Impact of AP)** *AP increases the production quantity, reduces the wholesale price, and increases the payoffs for both the buyer and the supplier. These effects are more significant as the risk level becomes lower.*

This finding suggests that AP is more useful in relieving the supplier's capital constraint than offsetting his risk. As can be inferred from Figure 3, AP is granted as long as the risk level is below θ_1. As the risk level θ declines from 0.38 to 0, the expected buyer's payoff climbs from 0.39 to 5.99 under AP, versus from 0.31 to 0.5 without AP. The benefit of AP to the buyer is therefore 0.08 at $\theta = 0.38$ versus 5.5 when $\theta = 0$. Similarly, the benefit of AP to the supplier is 3.22 at $\theta = 0.38$, much lower than 6.38 when $\theta = 0$.

Part of this effect is due to the fact that it is more desirable to grant more financing to a more reliable supplier who possesses a higher *unconstrained optimal production* q_u. As can be observed from Figure 2, a supplier with $\theta = 0.38$ will be funded at $L = 5$, while one with $\theta = 0$ will be funded at $L = 7.89$. Sufficient financing will scale up the production ($q = 2.58$ when $\theta = 0.38$ and $q = 3.5$

when $\theta = 0$ under AP versus $q = 1$ without AP) and subsequently result in a lower wholesale price ($w = 7.49$ when $\theta = 0.39$ and $w = 6.69$ when $\theta = 0$ under AP versus $w = 9.09$ without AP). This leads to a higher degree of benefit as the risk level is reduced.

Similarly, we could derive the value of PE by comparing the payoffs under the AP-only vs. AP+PE contracts. To rule out the effect of regulation, we consider the scenario where PE is under weak regulation, in accordance with Corollary 4:

PROPOSITION 6. **(Impact of PE)** *With PE under weak regulation,*

(i) AP coverage is extended from $\theta \in [0, \theta_1)$ to $\theta \in [0, \theta_c)$;

(ii) the buyer is always better off; the value of PE is maximized at a moderate risk level, i.e., $\theta = \theta_1$, and minimized at extreme risk levels, i.e., $\theta \geq \theta_c$ or $\theta \leq \theta_e$;

(iii) the supplier is better off when the risk level is relatively high, i.e., $\theta \in [\theta_1, \theta_c]$, and worse off when the risk level is relatively low, i.e., $\theta \in [\theta_e, \theta_1]$.

First, PE expands AP coverage for the suppliers from $\theta \in [0, \theta_1)$ to $[0, \theta_c)$. That is, a supplier with $\theta \in (\theta_1, \theta_c)$ would not be financed under an AP-only contract, resulting in under-production and lower payoffs for both parties. By allowing a PE, this supplier could ultimately be financed under an AP+PE contract, with the compromise that any balance due will be subject to longer payment terms. This point is summarized in Proposition 6 (i).

Second, PE enhances the buyer's payoff in general. As can be observed from Figure 3, except when the risk level is extremely low or high ($\theta \leq \theta_e$ or $\theta \geq \theta_c$), the buyer earns strictly more with a PE than without. This is less surprising considering the flexibility accompanying a PE. What we would like to highlight is that PE's value is maximized at a moderate point ($\theta = \theta_1$), as illustrated in Figure 3. In other words, PE is most rewarding for the buyer when dealing with a supplier at the threshold that would otherwise not be financed under an AP-only contract.

Lastly, the implication of PE is mixed for the suppliers, largely due to fact the PE may neutralize *tactical cash advance*. To this effect, recall that (θ_e, θ_1) is the same region where a supplier could receive *tactical cash advance* without PE ($\tau > \bar{\theta}\delta$) but not so with PE ($\tau^{x^*} = \bar{\theta}\delta^{x^*}$). As Figure 3 depicts, when $\theta \in (\theta_1, \theta_c)$, the supplier could extract a higher payoff under PE, which creates a win-win between the parties. However, when $\theta \in (\theta_e, \theta_1)$, the supplier is strictly worse off in the presence of PE. Therefore, PE is more of a positive message for a relatively risky supplier, but negative for one at relatively low risk level.

4.2 Endogenous Advance Discount Rate

We now assess the value of TR by examining the scenario in which the advance discount rate could be endogenously determined. Denote $\hat{\theta} = \min\{1 - \frac{\delta_0^X}{\delta^X}, \theta_c\}$, $\hat{\theta}_1 = \theta_f(1, \delta_0)$, $\hat{\theta}_r = \min\{1 - \frac{\delta_0^{x_r}}{\delta^{x_r}}, \theta_c\}$, and $\hat{\theta}_{x_r} = \theta_f(x_r, \delta_0)$. Substituting the τ^* obtained in Proposition 4 back to Table 2, we obtain the optimal AP+TR+PE contract, as provided in Table 3. Since the optimal AP+TR+PE contract is not unique, i.e., the fixed payment term X may take any value within $[1, x_r]$, to properly align it with other contracts, Theorem 3 presents the optimal contract terms with $X = 1$.

THEOREM 3. **(AP+TR+PE)** *Given that the buyer can practice both TR and PE,*

(i) when $\theta \in [0, \hat{\theta}]$, the buyer will grant AP with TR but no PE ($\bar{L}^* > 0$, $x^* = 1$, $\tau^* = \bar{\theta}\delta$). The supplier will advance up to the full limit ($L^* = \bar{L}^*$) and produce at full capacity $q^* = \hat{q}^* = \frac{M+\bar{L}^*\tau^*}{c} = q_u$ and charge wholesale price $w^* = w_u$;

(ii) when $\theta \in (\hat{\theta}, \hat{\theta}_{x_r})$, the buyer will grant AP at floor discount rate with PE ($\bar{L}^* > 0$, $x^* > 1$, $\tau^* = \delta_0$). The supplier will always advance up to the full limit ($L^* = \bar{L}^*$), produce up to capacity $q^* = \hat{q}^* = \frac{M+\bar{L}^*\tau^{x^*}}{c} = q_u$, and charge wholesale price $w^* = w_u/\delta^{x^*-1}$. Specifically,

- *customized payment term ($1 < x^* < x_r$) will be offered when $\theta \in (\hat{\theta}, \hat{\theta}_r)$, and*
- *regulated payment term ($x^* = x_r$) applies when $\theta \in [\hat{\theta}_r, \hat{\theta}_{x_r})$;*

(iii) when $\theta \in (\hat{\theta}_{x_r}, \theta_0)$, the buyer will not grant any AP ($\bar{L}^* = 0$). The terms follow Proposition 1.

The special cases where PE is regulated by $x_r = 1$ or $x_r > x_c$, namely, the AP+TR and AP+TR+PE (weak regulation) contracts, are furnished in Tables A4 and A5 of the appendix, respectively. Compared to §4.1, the general structure of the contractual terms is retained under TR, with the threshold values θ_e, θ_1, θ_r and θ_{x_r} being replaced by $\hat{\theta}$, $\hat{\theta}_1$, $\hat{\theta}_r$, and $\hat{\theta}_{x_r}$ respectively, where $\hat{\theta} \geq \theta_e$, $\hat{\theta}_1 \geq \theta_1$, $\hat{\theta}_r \geq \theta_r$, and $\hat{\theta}_{x_r} \geq \theta_{x_r}$.

The optimal AP+TR+PE terms further give rise to the following insights:

COROLLARY 5. *(i) TR is exclusive to a set of most reliable suppliers, i.e., $\hat{\theta} \leq \hat{\theta}_1 \leq \theta_c$;*
(ii) TR and PE substitute each other from opposite ends of the risk spectrum.

As can be observed from Table 3, only the set of most reliable suppliers ($\theta \leq \hat{\theta}$) could enjoy TR; for the rest, the buyer should apply the floor discount rate δ_0 whenever AP is granted. Therefore, the application of TR is even more limited than AP, which was found to be *selective* in Corollary 1 (i), henceforth considered *exclusive.*

Further, the optimal contract terms under AP+TR+PE reveal the synergy between PE and TR. For a low-risk supplier ($\theta \leq \hat{\theta}$), the buyer can rely solely upon TR without a PE. For a moderate-risk supplier ($\hat{\theta} < \theta < \hat{\theta}_r$), the supplier should switch to PE without TR. For a supplier at a higher risk level ($\theta \geq \hat{\theta}_r$), the buyer should adhere to the regulation limit for both the advance discount rate and the payment term. Therefore, TR and PE do not co-exist, and the buyer should employ at most one of them along with AP; hence, they are substitutes for each other.

Despite their substitution role at the macro level, we underscore that TR and PE encroach from different ends of the risk spectrum (with TR on the more reliable end and PE the riskier end),

Table 3 Contractual Terms under AP + TR + PE

	AP + TR	**AP + PE**		**No AP**	
Disruption Risk θ	$[0,\hat{\theta}]$	$(\hat{\theta},\hat{\theta}_r)$	$[\hat{\theta}_r,\hat{\theta}_{x_r})$	$[\hat{\theta}_{x_r},\theta_c)$	$[\theta_c,\theta_0)$
Advance Discount Rate τ	$(\bar{\theta})^{\frac{1}{X}}\delta$	δ_0	δ_0	–	–
Payment Timeline x	X	$\ln(\bar{\theta})\Big/\ln(\frac{\delta_0}{\delta})$	x_r	1	
Financing Limit $\bar{L}$	$\frac{c(\frac{a}{4}-\frac{bc}{4\bar{\theta}\delta})-M}{\tau^x}$			0	
Cash Advance Tactic	Neutral	Neutral	Tactical	-	
Wholesale Price w	$\frac{a}{2b\delta^{x-1}}+\frac{c}{2\bar{\theta}\delta^x}$			$\frac{a-2M/c}{b}$	$\frac{a}{2b}+\frac{c}{2\bar{\theta}\delta}$
Order Quantity q	$\frac{a}{4}-\frac{bc}{4\bar{\theta}\delta}$			$\frac{M}{c}$	$\frac{a}{4}-\frac{bc}{4\bar{\theta}\delta}$
Utilization $q\Big/\frac{M+\bar{L}\tau^x}{c}$	Full			Full	Partial

where $X\in[1,x_r]$, $\hat{\theta}=\min\{1-\frac{\delta_0^X}{\delta^X},\theta_c\}$, $\hat{\theta}_r=\min\{1-\frac{\delta_0^{x_r}}{\delta^{x_r}},\theta_c\}$, $\hat{\theta}_{x_r}=\theta_f(x_r,\delta_0)$, $\theta_c=1-\frac{bc}{\delta(a-4M/c)}$, and $\theta_0=1-\frac{bc}{\delta a}$.

and their impacts on cash advance tactics are distinct. Recall from Table 2 that PE can neutralize *tactical cash advance* for suppliers at the moderate risk level (θ_e,θ_1). In Table 3, we conclude that TR can neutralize *practical cash advance* for the most reliable suppliers within $[0,\theta_e)$. Without TR, a supplier in this spectrum will be financed with payment upon delivery. Since there is little room to tailor the payment term any further, the supplier will have to live with a relatively high interest rate and a *practical cash advance*. TR essentially allows the most reliable suppliers be financed at a nearly risk-free rate, thereby reducing the financing cost and neutralizing *practical cash advance*.

4.2.1 The Value of TR Comparing the contractual terms under AP+TR+PE vs. AP+PE, we could infer the impact of TR under various PE regulations as follows.

PROPOSITION 7. **(Impact of TR)** *By allowing TR,*

(i) AP coverage is broadened under strict PE regulation and unaffected under weak PE regulation;

(ii) PE may be offset at some risk levels, i.e., when $\theta\in(\theta_e,\hat{\theta}]$*;*

(iii) the wholesale price is reduced when the risk level is considerably low, i.e., $\theta\in[0,\theta_e]$*, and the production quantity is increased when the risk level is rather high, i.e.,* $\theta\in[\theta_{x_r},\hat{\theta}_{x_r})$*;*

(iv) the buyer is always better off; the supplier is worse off when the risk level is considerably low, i.e., $\theta\in[0,\theta_e]$*, and better off when the risk level is rather high, i.e.,* $\theta\in[\theta_{x_r},\hat{\theta}_{x_r})$*.*

Similar to PE, TR also extends AP coverage, albeit with a weaker effect. For instance, for an AP-only contract, a TR add-on only extends the boundary supplier from θ_1 to $\hat{\theta}_1$, whereas PE can stretch it to θ_c. This AP-broadening effect of TR is unsurprisingly overshadowed by PE's full force in the AP+TR+PE contract. However, TR can partially offset PE at some risk levels, i.e., after including TR in an AP+PE contract, the optimal payment term is reduced from $x^*>1$ to $x^*=1$

for a supplier with $\theta \in [\theta_e, \hat{\theta}]$. This echoes Corollary 5 (ii), as TR and PE may substitute each other by encroaching from different ends of the risk spectrum.

The last two items of Proposition 7 suggest that the impact of TR in the presence of PE is limited. This is partially due to TR *exclusively* being applied to the set of most reliable suppliers who will produce up to the *unconstrained optimum* q_u even without TR. Recall from Table 3 that TR in this regard neutralizes *practical cash advance* by aligning the financing rate with a supplier's risk level. This effectively reduces the wholesale price and allows the buyer to extract more surplus from the most reliable suppliers. Hence, the buyer is better off and the supplier is worse off when the risk level is rather low. On the other hand, TR broadens AP coverage for suppliers at a high risk level, with $\theta \in [\theta_{x_r}, \hat{\theta}_{x_r})$. This is essentially the win–win zone for both parties. However, this range could be narrow or even disappear under weak PE regulation, e.g., when $x_r \geq x_c$. Overall, TR's value is marginal when the buyer can also configure PE.

Similarly, through the comparison of contractual terms under AP+TR+PE versus AP+TR, we could obtain the value of PE in the presence of TR. Comparing it with that in the absence of TR, as analyzed in Proposition 6, we could conclude how TR might affect the value of PE.

Proposition 8. **(TR Weakens the Value of PE)** *PE impacts the parties' payoff in the same way with or without TR, but the overall effect is weaker in the presence of TR.*

In a nutshell, TR and PE do not co-exist, and the presence of one weakens the value of the other. Hence, they could be considered strategic substitutes alongside AP. However, this does not change the fact that the buyer will benefit from having both in her toolbox in dealing with a full spectrum of suppliers – TR for the most reliable ones and PE for those at a higher risk category. This substitution role is vital when one of TR or PE is under strict regulation, as will be discussed in the next section.

5. Impact of Regulation

At the end of this study, we comment on the impact of regulations (i.e., the floor discount rate δ_0 for TR and the maximum payment term x_r for PE) on the buyer's payoff and how the buyer could maneuver her strategy space as the regulatory climate changes.

Recall that x_c and δ_c are the thresholds between weak and strict regulations for PE and TR, respectively. In connection with the optimal contractual terms derived in §4, we find that the buyer is not entirely handicapped in the face of strict regulation on TR. She may, instead, apply a PE to exploit the benefit when dealing with suppliers at higher risk levels. Similarly, in the presence of strict PE regulation, the buyer can focus on trimming the advance discount rate among a broader set of suppliers at lower risk levels.

As shown in Proposition 9, as long as the buyer has autonomy in at least one of TR or PE ($\delta_0 \le \delta_c$ or $x_r \ge x_c$), she can focus on fine-tuning this channel to maximize her payoff. Even if both TR and PE are subject to strict regulation ($\delta_0 > \delta_c$ and $x_r < x_c$), the buyer would only be affected when dealing with a supplier at a moderate risk level.

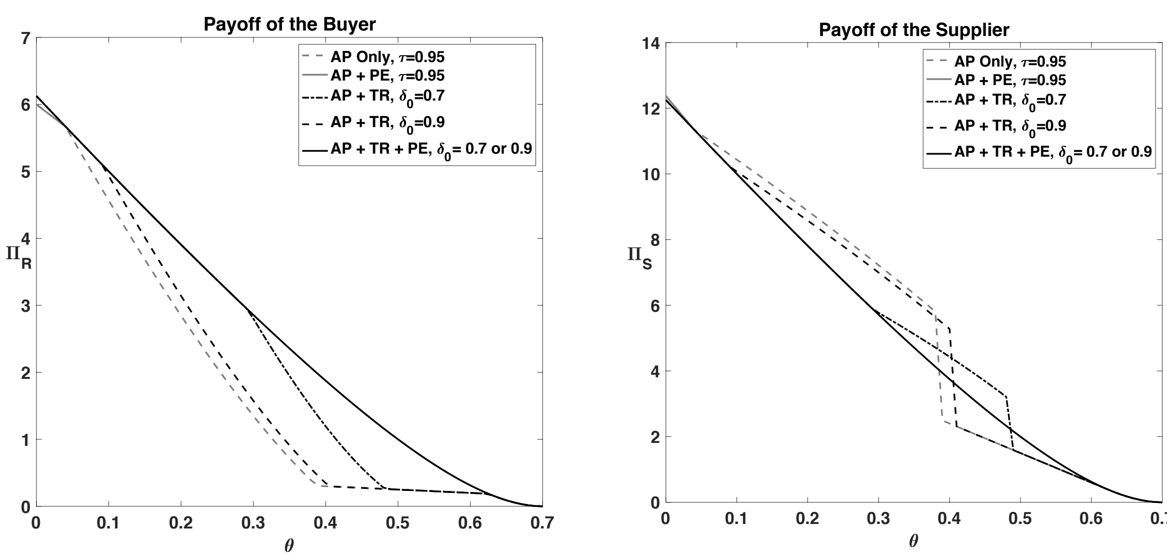
PROPOSITION 9. **(Limited Impact of Regulation)**

(i) The buyer's payoff decreases in δ_0 only when PE is under strict regulation, i.e., $x_r < x_c$, and the supplier's risk level is moderate; otherwise, the buyer's payoff is independent of the floor discount rate δ_0;

(ii) The buyer's payoff increases in x_r only when TR is under strict regulation, i.e., $\delta_0 > \delta_c$, and the supplier's risk level is moderate; otherwise, the buyer's payoff is independent of the maximum payment term x_r.

We illustrate the impact of regulation via an extended numerical example in Figure 4. All existing parameters are the same as in §4.1.1, with the floor discount rate δ_0 varying between $\{0.7, 0.9\}$ and the fixed payment term X set to 1. For the sake of visual clarity, we only depict the buyer's and supplier's payoffs under the AP-only, AP+TR, AP+PE, and AP+TR+PE contracts with $x_r \ge x_c$ for the latter two, capturing two extremes of PE regulation. Throughout the panels, dashed curves represent strict PE regulation (AP only, AP+TR) and solid curves are for weak PE regulation (AP+PE, AP+TR+PE); black curves apply endogenous τ with floor discount rate δ_0, and gray curves represent exogenous advance discount rate $\tau = 0.95$.

Figure 4 Payoffs: AP+TR, AP+TR+PE, AP only, and AP+PE



For the buyer, as the dashed curves show, a stronger TR regulation (higher δ_0) negatively affects her payoff when PE regulation is strict (as in AP+TR). This is consistent with our finding in

Proposition 9 (i). In particular, under strict PE regulation, TR strictly improves the buyer's payoff when the risk level is moderate. These effects are rather different when PE is under weak regulation (as in AP+TR+PE). As Proposition 9 (i) states, the buyer's payoff is not sensitive to the floor discount rate δ_0 when the buyer has full autonomy in PE. Indeed, whether $\delta_0 = 0.7$ or 0.9, the buyer's payoff falls into the same solid black curve in the left panel. The same graph also confirms the finding in Proposition 9 (ii). Since all candidates δ_0 exceed $\delta_c = 0.37$, the buyer's payoff increases as the PE regulation eases, reflected by the gaps between the solid curve and dashed curves in black. As can be seen, the gap shrinks with smaller δ_0, representing the limited impact of PE regulation when TR has more configuration room (lower δ_0).

For the supplier, the impact of TR regulation is in an opposite direction under strict PE regulation (as in AP+TR), where stronger TR regulation (higher δ_0) improves the payoff for more reliable suppliers but worsens the payoff for suppliers with higher risk exposure. Under weak PE regulation (as in AP+TR+PE), TR regulation has no impact on the supplier's payoff. The impact of PE on the supplier's payoff, captured by the gaps between the solid curve and dashed curves in black in the right panel of Figure 4, also becomes less significant with more room in TR (lower δ_0).

In summary, the regulation of TR only has a limited impact on the buyer's or supplier's payoff and can be countered by a properly configured PE. The converse is true for the regulation of PE. Therefore, as concluded in Corollary 6, a buyer does not necessarily need full autonomy in *both* PE and TR to maximize the payoff; decent configuration room in PE *or* TR alone is sufficient.

Corollary 6. *A buyer can rely upon PE (resp. TR) to achieve the maximum payoff when TR (resp. PE) is under strict regulation.*

6. Concluding Remarks

Motivated by the trend of pre-shipment financing and the awareness of adjusting payment terms, we explore the role of the payment timeline and advance discount rate when large buyers provide direct financing to their SME suppliers who are subject to disruption risk. For this purpose, we consider a dyadic supply chain, in which a buyer can determine an overarching financing contract on top of wholesale-price-based procurement. The financing contract constitutes a financing limit (AP), a payment timeline (PE), and an advance discount rate (TR) subject to which AP will be paid. This infuses dynamics into the business cash flow and ultimately impacts the operations along the supply chain, as summarized in Table 4.

We explicitly characterize the optimal contractual terms and decompose the values of AP, PE, and TR by comparing contracts with different AP, PE, and TR potentials: a simple wholesale price contract with no financing, AP-only, AP+PE, AP+TR, and AP+TR+PE contracts. In summary,

Table 4 Effects of Financing Components: AP, PE and TR*

	Advance Payment (**AP**)	Extended Payment Timeline (**PE**)	Tailored Discount Rate (**TR**)
Application Zone (Supplier's Risk Profile)	Risk Free to Moderate	Low to Moderate	Risk Free to Low
Cash Advance Tactic	Foster both *practical* and *tactical* cash advance	Neutralize *tactical* cash advance	Neutralize *practical* cash advance
Wholesale Price	↓	↑	↓
Production Quantity	↑	↑	None
Buyer's Payoff	+ and maximized when the supplier is risk free	+ and maximized when the supplier's risk level is moderate	+ when the supplier's risk level is rather low
Supplier's Payoff	+ and maximized when the supplier is risk free	+ when the supplier's risk level is relatively high; − when the supplier's risk level is relatively low	- when the supplier's risk level is rather low

*The effect of PE is based on top of an AP-only contract; the effect of TR is based on top of an AP+PE (weak regulation) contract.

AP caters to more reliable suppliers, among which TR will be applied to the most reliable ones and PE for those with higher risk levels.

Specifically for AP, we find that it can reduce wholesale price and boom product availability. As a result, both the buyer and the supplier are better off, most significantly when the supplier is of lower risk. However, with a common payment timeline and interest rate among all risk levels, AP invites *practical cash advance* when the supplier's risk level is low and *tactical cash advance* when the risk level is moderate. This implies a misalignment between financing terms and the supply side risk in the absence of PE or TR.

When the buyer can properly engineer PE, *tactical cash advance* can be neutralized, and AP will be expanded to cover suppliers with higher risk profiles. This still enhances product availability, but at the same time it may increase the wholesale price. Further, the impact of PE on the parties' payoff is manifold. While a supplier at a relatively high risk level benefits from the inclusion of PE, one at a relatively low risk level may suffer from the same. The buyer generally benefits from the practice of PE, and this benefit is most evident when the supplier is at a moderate risk level.

When the buyer can also configure TR, *practical cash advance* can be neutralized, and the AP coverage may be enhanced even further. The impact of TR, however, is limited when PE is in full force. Specifically, TR focuses on the most reliable suppliers where PE cannot be further engineered. By fine-tuning the financing rate of such a supplier, the wholesale price could be reduced while the production quantity remains unaffected, making the buyer better off and the supplier worse off.

We underscore the insight that although TR and PE focus on different ends of the risk spectrum, they are strategic substitutes for each other. Particularly when the regulation is strict for one of TR or PE, the buyer can rely on configuring the other to retain her maximum payoff.

6.1 Future Extensions

To the best of our knowledge, this work represents the first attempt to explore a joint engineering of AP, PE, and TR and investigate their impacts on production and procurement. Consequently, we expect this paper to stimulate many relevant works in this research stream.

One potential avenue would be to examine the tradeoff between buyer *indirect* financing (e.g., bank financing, reverse factoring) and PE (Huang et al. 2018). Since buyer indirect financing will involve third-party intermediaries, the issue of information flow can be more prominent. This has been examined in some work without PE (e.g., Tang et al. 2018), but not as much in studies with PE (e.g., Kouvelis and Xu 2021). Future research may look into whether PE can ease or aggravate any existing issues related to information asymmetry for third-party intermediaries, such as banks, factors, or social-lending platforms, and its role in the game among the three stakeholders. In addition, when the supplier has access to external capital markets, one may consider using bank financing (Kouvelis and Zhao 2018, Kouvelis and Xu 2021) as a benchmark for the design of AP, PE, and TR. This could introduce dynamics to the threshold interest rates TR needs to abide to, and more fundamentally, the consideration of operational and financial risk alignment among the supply chain members and the bank.

Further, it is also tempting to examine the role of PE and TR in deep-tier finance; that is, whether and how a buyer may properly configure contracts to make working capital available to the first manufacturer in the supply chain (White 2020, Dong et al. 2021). In parallel, one could investigate the potential of TR to offer a zero interest rate in a grace period (as discussed in Deng et al. 2018, Chen et al. 2020) and the configuration of the "net" terms (Daripa and Nilsen 2011). Some other directions to explore involve whether PE or TR can incentivize the supplier to improve his process and reduce intrinsic risks that lead to a disruption as well as how game sequence, bargaining power, or different discount rates between the buyer and the supplier may affect the design of these components.

We wish to mention that this paper opens the door to a number of issues that could be validated or quantified empirically. Thus far, our findings on the interaction between AP and PE are fairly consistent with those reported in empirical trade finance literature. These studies, however, have focused on a set of different drivers, e.g., firm size and nature of the goods (Mateut and Zanchettin 2013), risks associated with the buyer (Mateut 2014, Antràs and Foley 2015), impact of payment term regulation on a seller's default probability (Barrot 2016). Conversely, in the context of buyer financing one could examine the (causal) relations between the risk level of one's supply base and the average payment timeline as well as their connections with corporate metrics and macro economic indicators, as considered in this paper.

From a broader perspective, this research invites the consideration of cash flow dynamics contingent upon numerous commitments and deliverables throughout the long course of a project. As discussed in some of the recent studies (e.g., Wang and Xu 2021, Dong et al. 2021), this has been costly to enforce in the past but can be rather autonomous and frictionless today with the aid of blockchain-powered FinTech and smart contracts. In this way, contractual parties can engage in real-time monitoring of a project and determine the value and timing of fund release accordingly.

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