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Information acquisition and voluntary disclosure with supply chain and capital market interaction

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A B S T R A C T

We investigate a firm's information acquisition and voluntary disclosure decisions regarding demand forecast information. We study the interaction among the firm, its supplier, and the external capital market investors who assess the firm's interim equity price. We first analyze when it is beneficial for the firm to acquire demand forecast information, and if such information is acquired, when the firm should disclose it to the supplier and investors. Then, we investigate how the firm's information acquisition and disclosure decisions influence the investors' and the supplier's pricing strategies. We show that the optimal information disclosure policy for the firm is highly dependent on the corporate myopia level (CML): when the CML is low, the firm discloses low demand information only; when the CML is medium, the firm always withholds demand information; and when the CML is high, the firm discloses high demand information only. Our findings provide a novel plausible explanation to firms' non-disclosure behaviors commonly observed in practice and highlight the importance of considering the interaction between the supply chain and the capital market.

1. Introduction

Voluntary disclosure refers to the provision of information by a firm's management beyond general requirements (such as Securities and Exchange Commission rules), where the information is believed to be relevant to the decision-making of users of the company's annual reports (Meek, Roberts, & Gray, 1995). The disclosure of management forecasts (including demand forecast) is typically voluntary in most major stock markets in the world, i.e., a firm has the discretion to disclose forecast information to the capital market. The main reason is that the accuracy of forecasts and assurance of realization is difficult to achieve, due to many unpredictable events that can take place between the time when forecast is initially generated and the time when the sales and profitability is eventually achieved and officially reported.

There is extensive literature in accounting and finance that studies voluntary forecast disclosure (e.g., Baginski, Hassell, & Kimbrough, 2002; Li & Yang, 2016; McGuinness, 2016; Zaini, Samkin, Sharma, & Davey, 2018). For example, Baginski et al. (2002) compare the voluntary forecast disclosure between U.S. firms and Canadian firms and find that the former tend to issue fewer good-news and long-term forecasts than the latter. Li and Yang (2016) examine the impact of the adoption of the International Financial Reporting Standards (IFRS) on the voluntary disclosure of management earnings forecasts in 26 countries and show that the IFRS adoption increases the likelihood and frequency of voluntary disclosure. Zaini et al. (2018) provides a thorough literature review on the voluntary disclosure practices in emerging countries. The voluntary disclosure rule applies to initial public offering (IPO) as well. For example, McGuinness (2016) examine the link between voluntary forecast disclosures, IPO pricing revisions and post-IPO earnings drift in the Hong Kong stock market.

In this paper, we consider the voluntary disclosure decision regarding demand information. With the rapid development of data collection technologies and analysis tools, firms can obtain more information about demand forecast. Such information can lead to potential operational benefit (e.g., improving inventory ordering decisions); it may also provide strategic advantage (e.g., by intentionally influencing the pricing decisions of its supplier and investors). Nevertheless, investments on data collection and analysis (e.g., hardware, software, personnel) are usually costly, and such investment does not always guarantee to obtain accurate informa-

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tion (Guo, 2009). For instance, sometimes the collected data might be too noisy to generate meaningful information.

Managers, when making the information acquisition and disclosure decisions, often consider not only the firm's long-term profitability but also the short-term valuation in the capital market (see Lai, Xiao, & Yang, 2012). The short term and long term goals often conflict with each other. Consider an example of a Chinese pharmaceutical firm, which is the second largest manufacturer of Heparin Sodium in China. Heparin Sodium is extracted from healthy pig intestines and is widely used in open-heart surgery and for patients confined to bed to prevent blood clotting. On one hand, the firm was planning for IPO to raise more capital to increase production capacity and market share; generally speaking, the higher the demand forecast, the higher the IPO price. Hence, the firm would like to disclose a strong demand outlook and withhold a poor outlook to avoid disappointing investors. On the other hand, the firm was served by large suppliers that provided pig intestines, and the cost of healthy pig intestines accounted for more than 80% of the total production costs. If the firm disclosed high demand forecast, it was likely to face the threat that the suppliers may charge a higher wholesale price.

In the existing literature, the studies on the impact of demand information acquisition and sharing have been disjoint: the *operational* impact of demand information acquisition and sharing has been generally studied in the supply chain and marketing science literature (e.g., Guo, 2009; Ha & Tong, 2008), whereas the *strategic* impact of demand information acquisition and disclosure has been generally studied in the economics, finance and accounting literature (e.g., Grossman & Hart, 1980; Milgrom, 1981). Our paper integrates these two aspects and brings new insights and plausible explanations to the diverse disclosure behaviors observed in practice. More specifically, we consider the following research questions:

- When is it worthwhile for the firm to acquire demand information?
- If the firm has private information about the demand outlook, when should the firm disclose it to the supplier and the capital market?
- How does the firm's information acquisition and disclosure decisions influence the investors' and the supplier's pricing strategies?

We develop a game theoretical model with three players: a firm's manager, the upstream supplier, and the capital market investor. The manager may possess private demand forecast information, and the disclosure decision will affect both the interim share price and the wholesale price. We derive several interesting findings, which are distinct from the existing literature. The key contributions of our study are as follows:

- We characterize the optimal information disclosure strategy. We show that the equilibrium disclosure policy is highly dependent on the corporate myopia level (CML): when the CML is low, the firm discloses the information only when demand is *lower* than a threshold; when the CML is high, the firm discloses the information only when demand is *higher* than a threshold; and when the CML is medium, the firm always withholds the demand information.
- We provide an alternative explanation to the non-disclosure behaviors observed in practice. While prior research has identified the cost of procuring information and decreased market competitive advantage as the causes to the non-disclosure decision, our study reveals a new perspective, i.e., the conflicting effect of information disclosure on supplier and capital market decisions.
- We evaluate the benefit of information acquisition and show that it is more beneficial for the manager to acquire information when the CML is either low or high, than when it is medium.

2. Literature

There is a great deal of literature on information sharing in management science and marketing science areas. Chen (2003) provided an excellent review of earlier works on this topic, which discussed papers that study the value of information (including downstream information such as customer demand and inventory, and upstream information such as cost, lead time, capacity, and product quality), the consequences of imperfect transmission of information, and incentive issues in information sharing.

Recent years continue to see new and interesting development in this area, particularly related to the sharing of demand information (e.g., Arya, Frimor, & Mittendorf, 2010; Dominguez, Cannella, Barbosa-Póvoa, & Framinan, 2018; Guo, 2009; Guo, Li, & Zhang, 2014; Ha, Tong, & Zhang, 2011; Ha & Tong, 2008; Jeon, 2019; Lai et al., 2012; Li & Zhang, 2008; Taylor & Xiao, 2009; Wu, Wang, & Shang, 2019;Choi, Feng, & Li, 2020). For instance, Li and Zhang (2008) considered one manufacturer supplying to multiple retailers competing in price; each retailer has some private demand information. The authors showed that if the manufacturer keeps the received information to herself, all retailers then have an incentive to engage in information sharing if retail competition is intense. Moreover, the retailers can infer the shared information from the wholesale price and this gives rise to a signaling effect that makes the manufacturer's demand more price elastic, resulting in a lower equilibrium wholesale price and a higher supply chain profit. Ha et al. (2011) investigated the impact of information sharing in competing supply chains with production diseconomics. The authors showed that for both Cournot and Bertrand retail competition, information sharing benefits a supply chain either when the production diseconomy is large or competition is less intense. However, under a Bertrand competition, a manufacturer may be worse off by receiving information, which is never the case under a Cournot competition. Zhang, Li, Lai, and Leung (2018) investigate how the intermediary and sellers manage consumer uncertainty and returns/exchanges by disclosing product information. The authors find that the competitive sellers always choose to disclose as much information as possible, while the intermediary's optimal information strategy is determined by the disclosure cost and product characteristics.

Guo (2009) considered a distribution channel consisting of one manufacturer and one retailer with a binary demand signal and examined when the retailer will acquire demand information and disclose it to the supplier. Two effects of information acquisition were identified: the efficiency effect that improves retail pricing decision making in an uncertain environment, and the strategic effect whereby the retailer voluntarily discloses the acquired private information to influence the upstream manufacturer's wholesale pricing behavior. The author shows that the efficiency effect benefits the retailer without affecting the manufacturer, while the strategic effect works to the detriment of the retailer but to the advantage of the manufacturer. Moreover, unobservable information acquisition can mitigate the retailer's loss and the manufacturer's benefit from the strategic effect of information disclosure. Guo et al. (2014) generalized the model of Guo (2009) to a continuous demand distribution and the case of two competing channels. The authors show that when there is the equilibrium disclosure strategy is characterized by a threshold above which the retailer will disclose the demand information. Lai et al. (2012) considered the case in which a downstream buyer receives private demand information and has the incentive to influence her capital market valuation. The authors show that the buyer stocking decision can be distorted in equilibrium under a general, single buyback contract. The authors then characterize conditions under which a menu of buyback contracts can prevent downstream stocking distortion and restore full efficiency in the channel.

There are several recent papers which examine the interaction between operational decisions and the pressure from the financial market. These articles usually consider a two-period model where the decision maker objective is to maximize a convex combination of the interim share price and the terminal cash flows. For example, Schmidt (2015) investigates how financial investors could influence the firm actions in mitigating or exacerbating supply disruptions. Yang, Lu, and Xu (2016) study how the supplier concern about share prices could mitigate the signaling decision on the product quality. Lai and Xiao (2018) consider the firm's disclosure of the demand variability.

A key difference between our paper and the previous papers is that we not only consider the impact of information disclosure decision on operational decisions (i.e., wholesale price determination and inventory ordering decision) but also consider its impact on the capital market evaluation (i.e., the interim stock price). To our best knowledge, our paper is the first study on such aspect. We show that when the firm faces the supplier and the capital market investor simultaneously, the optimal disclosure policy is quite different from the existing results. Our findings reveal the potentially conflicting effect of information disclosure on supplier and capital market decisions, which can provide a new explanation to firm's non-disclosure behaviors commonly observed in practice.

3. The model

We consider a game with three players: a firm, the firm's supplier, and a group of investors referred to as the capital market. We assume that all players are risk neutral and their objectives are to maximize their individual expected payoffs. We also assume that the firm uses *same* communication channel to disclose demand information to the capital market and the supplier, i.e., any disclosed information is equally accessible to both parties. We assume that the inverse demand function for the firm is:

$$p = \theta - q \tag{1}$$

where p is the market clearing price, q is the supply quantity, and θ is the market demand. θ is a generally distributed random variable in $[a, b]$, with expected value μ and standard deviation σ. The distribution of θ is common knowledge to all parties. Without loss of generality, the marginal production cost of the supplier is normalized to zero.

The sequence of events is as follows:

In the first stage, the manager of the firm acquires private information and observes the realization of demand θ, with probability λ. We call λ the *information endowment probability*. Similar to Guo (2009), we consider two important features of demand information acquisition and sharing: (i) there can be uncertainty about a firm's efforts to acquire information; (ii) a firm's information informational status can be unobservable to other parties. For instance, for the firm to collect data and convert the collected data into useful information, it usually require substantial human and technological resources, such as training or hiring specialists to process and analyze huge amount of raw data. The costs and difficulties in generating timely and meaningful information from collected data may result in substantial opportunity cost for information acquisition, and a firm may end up retrieving no useful information from its raw data. We assume that the supplier and investors do not know about market demand or the firm's informational status unless it is disclosed by the firm. This captures the asymmetry in the ability to acquire demand information, which can be justified by the fact that the firm usually has much better access to the market and its own sales data than the other parties.

The uninformed manager provides no disclosure; the informed manager decides whether to disclose the private demand information to the other parties. Consistent with many accounting literature (e.g., Dye, 1985 and numerous subsequent studies), we assume that the manager does not distort the information if he decides to provide a disclosure; however, the manager can withhold the information (e.g., pretend to be uninformed).

In the second stage, based on the observation of the firm's disclosure decision, the supplier and the capital market each determines the wholesale price w and the interim share price K. The interim share price reflects the capital market's short-term evaluation of the firm's profitability before it is finally realized. The firm then decides the order quantity q.

In the final stage, the customer demand is satisfied and the terminal cash flows $\pi(q, \theta)$ is realized. We assume that the manager's utility is a linear combination that assigns a weight of α to the firm's interim share price and a weight of $1 - \alpha$ to the terminal cash flows, where α is common knowledge. Such an assumption on the manager's utility has been widely used in the literature and is supported by the influential work of Holmstrom and Tirole (1993), where the optimal managerial incentive contract includes components that depend on short-term share prices and the terminal cash flows. The parameter α is usually called the *corporate myopia level* in the literature. A larger value of α means that the manager is more concerned about the interim share price.

We use backward induction to find the subgame-perfect equilibrium of the dynamic game discussed above. A summary of the key notation is provided in the Appendix (Table 6).

4. Information disclosure decision

In this section, we investigate the firm's decision regarding when it should disclose private information to the supplier and the capital market. Before we investigate the three-player interaction, we first examine two benchmark cases: (i) when the firm deals with the capital market investors only, and (ii) when the firm deals with its supplier only. The insights derived from these benchmark cases will help us better understand the underlying drivers of the disclosure decision and the conflicting impact of the firm's disclosure decisions on the supplier's wholesale price determination and the capital market investor's stock price evaluation.

The settings in the following three subsections are summarized in Table 1:

- Section 4.1 considers the case in which the firm is a publicly traded company that integrates with its supplier. The firm needs to decide the information disclosure strategy to the capital market only.
- Section 4.2 considers the case in which the firm is a private company that is not integrated with its supplier. The firm needs to decide the information disclosure strategy to the supplier only.
- Section 4.3 considers the case in which the firm is a publicly traded company that is not integrated with its supplier. The firm needs to decide the information disclosure strategy to both the capital market and the supplier.

Note that for the case in which the firm is a private company that integrates with its supplier, the firm does not need to disclose any information to the capital market or the supplier, therefore, it is not relevant to our study.

4.1. Case 1: the firm deals with the capital market only

We first consider the case when the firm deals with the capital market only. We denote the firm's information status by $s \in \{i, u\}$, where i means the firm is informed and u means uninformed. We

Table 1
Summary of disclosure cases.

	Privately owned	Publicly traded
Integrated	N/A	Section 4.1 (deal with the capital market only)
Non-integrated	Section 4.2 (deal with the supplier only)	Section 4.3 (deal with the capital market and the supplier)

Table 2
Events and probability update.

Event	Prior probability	Posterior probability	Terminal value π_1
A1: No information acquired	$1-\lambda$	$\frac{1-\lambda}{1-\lambda+\lambda F(t_1)}$	$\frac{\mu^2}{4}$
A2: Information acquired but withheld	$\lambda F(t_1)$	$\frac{\lambda F(t_1)}{1-\lambda+\lambda F(t_1)}$	$\frac{\theta^2}{4}$
A3: Information acquired and disclosed	$\lambda(1-F(t_1))$	0	$\frac{\theta^2}{4}$

denote the manager's disclosure decision by $m \in \{d, nd\}$: if $m = d$, the manager discloses private information; if $m = nd$, the manager withholds private information.

If the demand information is acquired and disclosed to the capital market, the firm's terminal profit and the interim share price respectively are:

$$\pi_1^i = (\theta - q)q, \quad K_1^d = (\theta - q)q,$$

where the superscript d represents disclosure and the subscript 1 represents the benchmark case 1. The manager maximizes the utility:

$$\Pi_1^d = (1-\alpha)\pi_1^i + \alpha K_1^d = (\theta - q)q.$$

This leads to an optimal order quantity of $\frac{\theta}{2}$. As a result, at the equilibrium, the payoffs of the firm manager and investors satisfy $\Pi_1^d = \pi_1^i = K_1^d = \frac{\theta^2}{4}$.

If no information is disclosed, the investors cannot verify whether the manager acquires no information or he acquires information but withholds it. Based on the prior belief about the potential demand, the capital market evaluate interim share price as K_1^{nd}, where nd represents nondisclosure. If the manager acquires but withholds the information, his utility is:

$$\Pi_1^{i,nd} = (1-\alpha)\pi_1^i + \alpha K_1^{nd} = (1-\alpha)(\theta - q)q + \alpha K_1^{nd}.$$

The optimal order quantity $q_1^{i*} = \frac{\theta}{2}$. As a result, $\pi_1^{i*} = \frac{\theta^2}{4}$ and $\Pi_1^{i,nd*} = (1-\alpha)\frac{\theta^2}{4} + \alpha K_1^{nd}$.

Clearly, the manager would disclose the received information if $\Pi_1^d > \Pi_1^{i,nd}$, which is equivalent to $\frac{\theta^2}{4} > K_1^{nd}$. We denote the threshold of the manager's voluntary disclosure policy as $t_1 = 2\sqrt{K_1^{nd}}$.

To calculate K_1^{nd}, the expected interim share price when no information is shared, we consider the probabilities of the three mutually exclusive events described in Table 2. Event A1 is that no information is acquired and no information is released by the manager. Event A2 is that information is acquired but not released by the manager. Event A3 is that information is both acquired and released by the manager. Conditional on no information being shared, the investors will revise the probability for each event according to Table 2 and assess the interim share price as follows:

$$K_1^{nd} = \frac{\mu^2(1-\lambda) + \lambda\int_a^{t_1}\theta^2 f(\theta)d\theta}{4(1-\lambda+\lambda F(t_1))}. \tag{2}$$

Lemma 1. *There exists a non-trivial information disclosure policy that is characterized by a unique threshold value t_1, such that if the private demand information is above (below) the threshold, the central planner discloses (withholds) the information. The threshold t_1 satisfies the following equation:*

$$t_1^2 = \frac{\mu^2(1-\lambda) + \lambda\int_a^{t_1}\theta^2 f(\theta)d\theta}{1-\lambda+\lambda F(t_1)}. \tag{3}$$

It can be shown that the threshold t_1 is always below the mean of the demand forecast.

This result shows that the manager with a strong demand forecast has the incentive to report to the capital market to increase the interim value of the firm. However, when the manager receives a weak demand forecast, he withholds it from the capital market to avoid a low stock evaluation.

Corollary 1. *The threshold t_1 decreases in the information endowment probability λ.*

Corollary 1 characterizes a monotone property of the threshold policy. It indicates that when investors are more certain about the firm's information endowment, the informed central planner is more likely to disclose the information. We can also show that the stock price if no information disclosure occurs (K_1^{nd}) decreases in λ.

Corollary 2. *When $\lambda = 1$, i.e., if the capital market knows that the manager always obtains demand information, then the manager will always disclose the information.*

Corollary 2 is consistent with the classical "unraveling" result in the accounting literature (e.g., Grossman, 1981; Grossman & Hart, 1980 and Milgrom, 1981). To illustrate, consider the case when the manager is certain to be endowed with the information but a disclosure is absent; the capital market would conjecture that the demand outlook is very bad, thus setting the interim share price close to $\frac{a^2}{4}$, the lowest possible interim value of the firm. This in turn will force the informed central planner to disclose the information to get a higher interim price.

4.2. Case 2: the firm deals with the supplier only

Now we consider the case when the firm interacts with its upstream supplier only. First, if the manager is uninformed, the firm's expected payoff is:

$$\pi_2^u = E[(\theta - q - w)q]. \tag{4}$$

It is easy to see that given the wholesale price w, the optimal order quantity and the resultant expected profit are:

$$q^{u*} = \frac{\mu - w}{2}, \quad \pi_2^{u*} = \frac{(\mu - w)^2}{4}.$$

If the manager is informed and the realized market demand is θ, then the optimal order quantity and the resultant expected profit become:

$$q^{i*} = \frac{\theta - w}{2}, \quad \pi_2^{i*} = (\theta - q)q - wq = \frac{(\theta - w)^2}{4}.$$

Next let us see how the supplier determines the wholesale price. If the firm manager discloses the demand information, it is

Table 3
Events and probability update.

Event	Prior probability	Posterior probability	Terminal value π_2
B1: No information acquired	$1-\lambda$	$\frac{1-\lambda}{1-\lambda+\lambda(1-F(t_2))}$	$(\frac{\mu-w_2^{nd}}{2})^2$
B2: Information acquired but withheld	$\lambda(1-F(t_2))$	$\frac{\lambda(1-F(t_2))}{1-\lambda+\lambda(1-F(t_2))}$	$(\frac{\theta-w_2^{nd}}{2})^2$
B3: Information acquired and disclosed	$\lambda F(t_2)$	0	$\frac{\theta^2}{16}$

straightforward to show that the optimal wholesale price set by the supplier is $\frac{\theta}{2}$. Next we denote the wholesale price *conditional on* the manager's non-disclosure as w_2^{nd}. Let $t_2 = 2w_2^{nd}$. It is easy to see that the manager would disclose the information if $\theta < t_2$, because it leads to a lower wholesale price.

To derive w_2^{nd}, we must analyze how the supplier responds to a non-disclosure. The supplier perceives ex ante that one of three mutually exclusive events, denoted by B1, B2, and B3 in Table 3, will occur during the game. Conditional on no information being shared, the supplier will revise the probability for events B1, B2, and B3 according to Table 3. The supplier's expected profit is:

$$R_2^{nd} = \frac{1-\lambda}{1-\lambda F(t_2)} \frac{w_2^{nd}\left(\mu - w_2^{nd}\right)}{2} + \frac{\lambda w_2^{nd}}{1-\lambda F(t_2)} \int_{t_2}^{b} \frac{\left(\theta - w_2^{nd}\right)}{2} f(\theta)d\theta. \tag{5}$$

R_2^{nd} is concave in w_2^{nd}, thus, we can use the first-order condition to obtain:

$$w_2^{nd} = \frac{\mu(1-\lambda) + \lambda \int_{t_2}^{b} \theta f(\theta)d\theta}{2(1-\lambda+\lambda\int_{t_2}^{b} f(\theta)d\theta)}. \tag{6}$$

Note that the supplier's pricing strategy depends on the manager's disclosure policy. At equilibrium, the manager's disclosure strategy needs to be consistent with the supplier's pricing strategy.

Lemma 2. *There exists a non-trivial information disclosure policy that is characterized by a unique threshold value t_2, such that if the private information is below (above) the threshold, the manager shares (withholds) the information with the supplier. The threshold t_2 satisfies the following equation:*

$$t_2 = \frac{\mu(1-\lambda) + \lambda \int_{t_2}^{b} \theta f(\theta)d\theta}{1-\lambda+\lambda\int_{t_2}^{b} f(\theta)d\theta}. \tag{7}$$

It can be shown that the threshold t_2 is always below the mean of the demand forecast.

This result shows that the informed manager has the incentive to withhold good news to avoid a high wholesale price. The following theorem characterizes the monotone property of the threshold policy.

Corollary 3. *The threshold value t_2 increases in the information endowment probability λ, so does the wholesale price w_2^{nd}.*

Corollary 3 suggests that when the supplier is more certain about the manager's information endowment, the informed manager is more likely to share the information, and the wholesale price when no information is disclosed (w_2^{nd}) becomes higher.

Corollary 4. *When $\lambda = 1$, i.e., when the supplier knows that the manager always obtains information, then the manager will always disclose information.*

The intuition for Corollary 4 is similar to that of Corollary 2. Consider the case when the manager is certain to be endowed with the information but does not disclose the information; the supplier would conjecture that the demand outlook must be good (because the manager discloses bad news only), thus the supplier would set the wholesale price to be around $b/2$ (i.e., the highest possible wholesale price that the supplier may charge). This, in turn, will force the manager to disclose the information to avoid the high wholesale price. Lemma 2 and Corollary 4 are also consistent with one of the findings in Guo et al. (2014) (Proposition 1).

4.3. Case 3: the firm deals with capital market and supplier simultaneously

Now we consider the game interaction among three players under supply chain and capital market interaction: the manager of a public traded firm, the supplier, and the capital market investor. In most countries, a publicly traded company should compile with laws and regulations to assure that stakeholders have equal access to the information. Selectively disclosing to some parties but not the others could result in unwelcome law suits or allegation of insider trading. Because of this, we adopt the equal accessibility assumption, i.e., both the supplier and the capital market investors have equal access to the information disclosed by the firm.

As shown in the previous two subsections, when the capital market or the supplier cannot verify whether the manager has obtained information or not, the manager's disclosure decision hinges on the impact of the information on the supplier's and investor's pricing decisions. The disclosure policies for the two special cases are summarized in Table 4. Specifically, we have shown that, if disclosing to the investor only, the manager will disclose good demand outlook only, (i.e., when demand is stronger than a threshold) in order to obtain a higher interim stock price; on the contrary, if disclosing to the supplier only, the manager will disclose bad demand outlook only, in order to induce a lower wholesale price. Next we want to examine the more interesting and complicated scenario: when should the manager disclose (withhold) information if he need to disclose to the supplier and the investor simultaneously?

We use backward induction to analyze this game. First, we examine the manager's ordering decision. Then we study the pricing decisions of the supplier and the investor. After that, we analyze the information disclosure decision with exogenous information acquisition probability.

First, we can show that the manager's ordering decision is as follows: the informed manager orders $(\theta - w_3^m)/2$, where w_3^m is the supplier's wholesale price conditional on m, the status of information disclosure. The uninformed manager always orders $(\mu - w_3^{nd})/2$.

Next we examine the decisions of wholesale price and capital market evaluation. When the demand information is disclosed, the supplier's profit $R_3^d = w_3^d q_3^d = w_3^d(\theta - w_3^d)/2$ and thus the supplier would set the wholesale price as $w_3^d = \theta/2$. Consequently, at equilibrium the manager's order size is $q_3^{d*} = \theta/4$. The utility of the firm $\Pi_3^{d*} = \theta^2/16$, the interim share price $K_3^{d*} = \theta^2/16$, and the profit of the supplier $R_3^{d*} = \theta^2/8$.

When no information is disclosed, the supplier and the capital market cannot tell whether the manager does not have information or he has information but chooses to withhold it. As a result, they need to calculate the probabilities of these two events to determine the appropriate interim share price and wholesale price. The calculation of the probabilities is based on updating the prior probabilities of three mutually exclusive events: Event C1 is that the

Table 4
Summary of disclosure policies for the two special cases.

Section	Scenarios	Prevailing disclosure strategy
4.1	Deal with the capital market only	Disclose **good**demand outlook only
4.2	Deal with the supplier only	Disclose **bad**demand outlook only
4.3	Deal with both simultaneously	?

Table 5
Events and probability update.

Event	Prior probability	Posterior probability	Terminal value π_3
C1: No information acquired	$1-\lambda$	$\frac{1-\lambda}{1-\lambda+\lambda\int_{\theta\in N}f(\theta)d\theta}$	$(\frac{\mu-w_3^{nd}}{2})^2$
C2: Information acquired but withheld	$\lambda\int_{\theta\in N}f(\theta)d\theta$	$\frac{\lambda\int_{\theta\in N}f(\theta)d\theta}{1-\lambda+\lambda\int_{\theta\in N}f(\theta)d\theta}$	$(\frac{\theta-w_3^{nd}}{2})^2$
C3: Information acquired and disclosed	$\lambda\int_{\theta\in D}f(\theta)d\theta$	0	$\frac{\theta^2}{16}$

manager is uninformed. Event C2 is that the manager is informed but withholds the information. Event C3 is that the manager is informed and discloses the information. The prior probability of each of these events are $1-\lambda$, $\lambda\int_{\theta\in N}f(\theta)d\theta$, and $\lambda\int_{\theta\in D}f(\theta)d\theta$, where λ is the prior probability that the manager is informed, N is the non-disclosure set (i.e., any $\theta\in N$ is not disclosed), and D is the complementary set of N, respectively. Conditional on no information being disclosed, the probabilities are updated as in Table 5.

As a result, when no information is disclosed, the expected profit of the supplier becomes

$$R_3^{nd}=\frac{(1-\lambda)}{1-\lambda+\lambda\int_{\theta\in N}f(\theta)d\theta}\frac{(\mu-w_3^{nd})w_3^{nd}}{2}+\frac{\lambda w_3^{nd}\int_{\theta\in N}\frac{\theta-w_3^{nd}}{2}f(\theta)d\theta}{1-\lambda+\lambda\int_{\theta\in N}f(\theta)d\theta}, \tag{8}$$

which is concave in w_3^{nd}. Solving the first order condition, we obtain the optimal wholesale price:

$$w_3^{nd}=\frac{\mu(1-\lambda)+\lambda\int_{\theta\in N}\theta f(\theta)d\theta}{2(1-\lambda+\lambda\int_{\theta\in N}f(\theta)d\theta)}. \tag{9}$$

The interim share price conditional on no information disclosure is:

$$K_3^{nd}=\frac{(1-\lambda)(\mu-w_3^{nd})^2+\lambda\int_{\theta\in N}(\theta-w_3^{nd})^2f(\theta)d\theta}{4(1-\lambda+\lambda\int_{\theta\in N}f(\theta)d\theta)}. \tag{10}$$

Consequently, the utility of the informed firm that withholds the information is:

$$\Pi_3^{i,nd}=(1-\alpha)\frac{(\theta-w_3^{nd})^2}{4}+\alpha K_3^{nd}. \tag{11}$$

Now we consider the manager's disclosure strategy. At equilibrium, the informed manager's disclosure strategy is consistent with the pricing strategies of the supplier and the capital market. This implies that the non-disclosure set N must satisfy Eqs. (9) and (10) simultaneously. We show how to derive N in the following.

If the manager discloses the acquired information, the utility is $\Pi_3^d=\theta^2/16$. If he does not disclose the information he acquired, the utility of the firm is shown in Eq. (11). Clearly, the manager would choose to disclose the information if and only if $\Pi_3^d>\Pi_3^{i,nd}$, i.e.,

$$\frac{\theta^2}{16}>(1-\alpha)\frac{(\theta-w_3^{nd})^2}{4}+\alpha K_3^{nd}. \tag{12}$$

Based on (12), we derive the following theorem.

Theorem 1. *Let* $\Delta=(1-\alpha)\left(w_3^{nd}\right)^2+4\alpha K_3^{nd}(4\alpha-3)$. *The manager's optimal disclosure policies are characterized as follows:*

1. *When* $\frac{3}{4}\le\alpha\le1$, *there exists a unique threshold* $t_{3,1}$,

$$t_{3,1}=\frac{2\sqrt{\Delta}-4(1-\alpha)w_3^{nd}}{4\alpha-3}, \tag{13}$$

such that if $\theta\ge t_{3,1}$, *the informed manager discloses* θ *to both the supplier and the capital market; if* $\theta<t_{3,1}$, *the informed manager withholds the information.*

2. *When* $\alpha=\frac{3}{4}$, *there exists a unique threshold:*

$$t_{3,2}=\frac{w_3^{nd}}{2}+\frac{6K_3^{nd}}{w_3^{nd}}, \tag{14}$$

such that if $\theta\ge t_{3,2}$, *the manager discloses the demand information; if* $\theta<t_{3,2}$, *the manager withholds the demand information. In the degenerating case where* $t_{3,2}\ge b$, *the manager withholds all the information.*

3. *When* $0<\alpha<\frac{3}{4}$ *and* $\Delta\le0$, *the manager always withholds the information.*
4. *When* $0<\alpha<\frac{3}{4}$ *and* $\Delta>0$, *there exist two thresholds:*

$$t_{3,3}=\frac{4(1-\alpha)w_3^{nd}-2\sqrt{\Delta}}{3-4\alpha}, t_{3,4}=\frac{4(1-\alpha)w_3^{nd}+2\sqrt{\Delta}}{3-4\alpha}, \tag{15}$$

such that if $t_{3,3}\le\theta\le t_{3,4}$, *the manager discloses the information and if* $\theta<t_{3,3}$ *or* $\theta>t_{3,4}$, *the manager withholds the demand information.*

Theorem 1 shows that given the supplier's wholesale price w and the capital market valuation K, the management's demand disclosure strategy is highly dependent on the corporate myopia level, α. For instance, when α is large, the manager tends to withhold low demand information and disclose high demand information.

Based on Theorem 1, we can denote the manager's disclosure strategy by using a non-disclosure set N, such that if $\theta\in N$ the informed manager withholds the demand information. Note that the threshold values (i.e., $t_{3,1},t_{3,2},t_{3,3},t_{3,4}$) which determine the set N are dependent on the wholesale price w and the interim share price K, thus we need to substitute the result in Theorem 1 back to Eqs. (9) and (10) to calculate the supplier's wholesale price and the interim share price, in order to derive the full equilibrium. Unfortunately, there is no closed-form solution for the set N when θ follows a general distribution.

To facilitate analysis, we assume that θ follows a binary distribution:

$$\theta=\begin{cases}a & \text{with probability } \rho;\\ b & \text{with probability } 1-\rho.\end{cases} \tag{16}$$

Here a represents low demand, while b represents high demand, $a<b$. The expected demand is $\mu=\rho a+(1-\rho)b$. Denote $\delta=b-a$. To facilitate analysis and avoid trivial cases in which the firm is not willing to place order, we assume that $\frac{b}{a}\le\frac{2-\rho}{1-\rho}$ which implies that the difference between the high and low state is not too large. The following theorem fully characterizes the manager's disclosure strategy in the binary demand case.

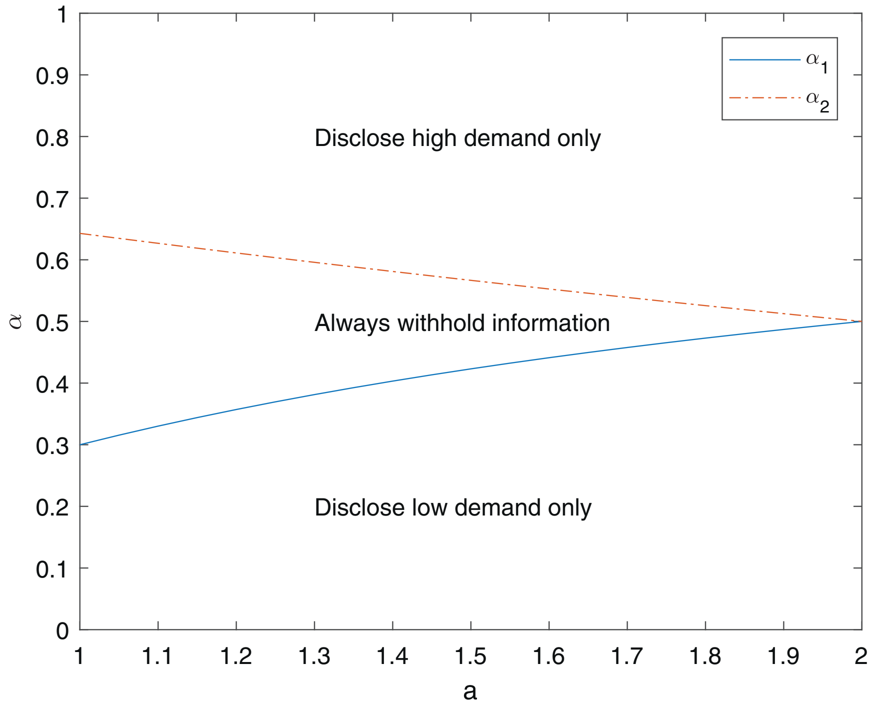

Fig. 1. Disclosure decision changes with *a*.

Theorem 2. *Define*

$$\alpha_1 = \frac{2a - \delta(1-\rho)}{4(a+\delta\lambda\rho)},$$

$$\alpha_2 = \frac{2b + \rho\delta}{4(b - \delta\lambda(1-\rho))}.$$

The optimal disclosure strategy is as follows:

1. *When* $\alpha_1 \le \alpha \le \alpha_2$*, the manager always withholds the information;*
2. *When* $\alpha_2 < \alpha \le 1$*, the manager withholds low demand information and discloses high demand information;*
3. *When* $0 < \alpha < \alpha_1$*, the manager withholds high demand information and discloses low demand information.*

Corollary 5. $\alpha_1 < \frac{1}{2} < \alpha_2$*. Moreover,* α_1 *increases with* a *and decreases with* λ*,* b *and* δ*; on the other hand,* α_2 *decreases with* a *and increases with* λ*,* b *and* δ*. Neither* α_1 *nor* α_2 *has a monotone relationship with regard to* ρ*.*

Figs. 1–4 provide some numerical examples to further illustrate Theorem 2 and Corollary 5. We can see that the firm's disclosure strategy is highly dependent on the corporate myopia level α. When α is small or large, the firm tends to disclose low or high demand information; when α is medium, the firm tends to withhold information. Furthermore, when the low demand (a) increases and approaches to the high demand (b), or when b decreases and approaches to a, or when δ (the difference between a and b) decreases, the firm would be more likely to disclose the acquired information, because the capital market and the supplier can anticipate more accurately about the demand. Finally, Fig. 4 shows that even when $\lambda = 1$, the firm would choose to withhold information when α is medium, which is in sharp contrast to the results in benchmark case 1 and 2 (i.e., Corollaries 2 and 4). It is due to the conflicting effect of information disclosure on the supplier's and capital market's responses. This provides a novel plausible explanation to firms' non-disclosure behaviors commonly observed in practice.

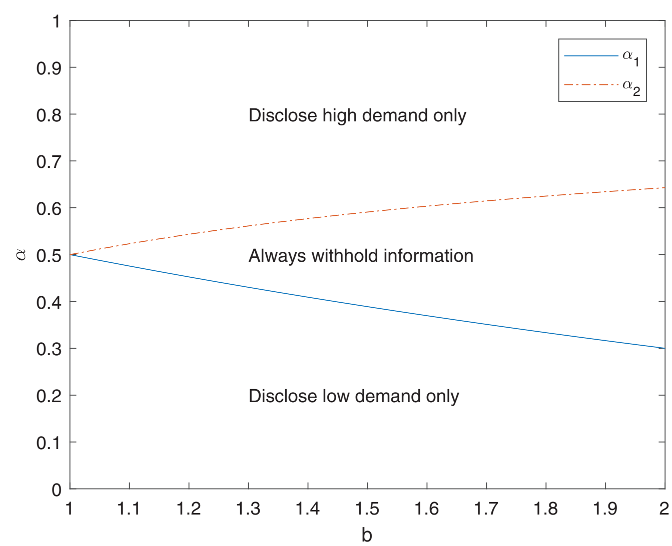

Fig. 2. Disclosure decision changes with *b*.

We also conduct further numerical studies for the cases in which θ is generally distributed and we have the similar findings:

1. When α is large, the manager would disclose high demand information only. The reason is that when α is large, which means that the capital market evaluation is much more important, the manager would choose to disclose high demand information to raise the firm's valuation and withhold low demand information to prevent a low pricing of the firm.
2. When α is small, the manager would disclose low demand information only. The reason is that the manager is much more concerned about the wholesale price rather than the stock price when α is small, and thus he withholds high forecast demand information to prevent a high wholesale price and discloses low forecast demand information to induce a low wholesale price.

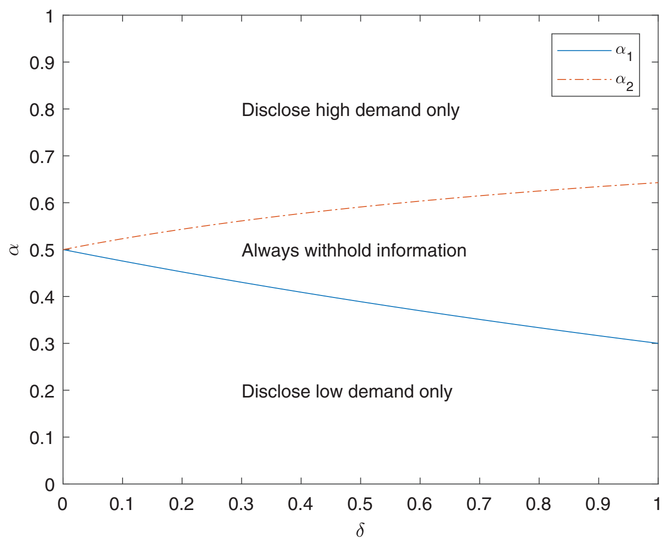

Fig. 3. Disclosure decision changes with δ.

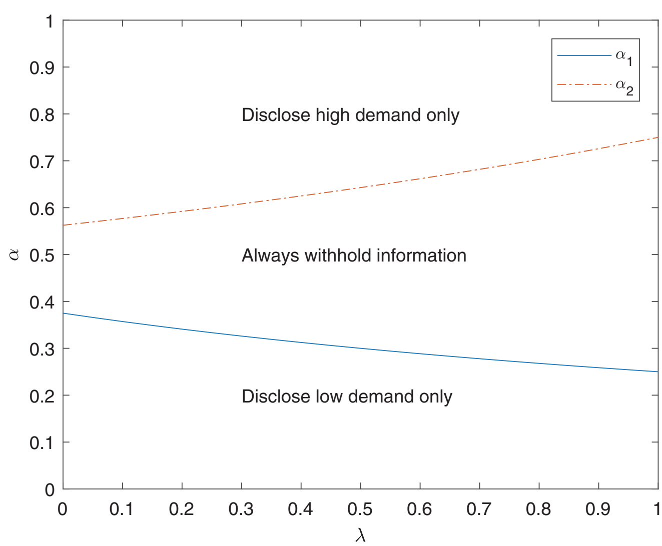

Fig. 4. Disclosure decision changes with λ.

3. When α is medium, the manager would always withhold the demand information, due to the conflicting pressure from both sides of the supply chain partner and the capital market.

We can also derive the equilibrium wholesale price and the interim share price conditional on no information disclosure, which are shown in Theorem 3.

Theorem 3. *The pricing strategies in the binary demand case are as follows:*

1. *When* $\alpha_1 \le \alpha \le \alpha_2$,

$$w^{nd}_{3,1} = \frac{\mu}{2},$$
$$K^{nd}_{3,1} = \frac{1}{16}\mu^2 + \frac{1}{4}\lambda\rho(1-\rho)\delta^2;$$

2. *When* $\alpha_2 < \alpha \le 1$,

$$w^{nd}_{3,2} = \frac{b}{2} - \frac{\rho\delta}{2(1-\lambda+\lambda\rho)},$$
$$K^{nd}_{3,2} = \frac{1}{16}\left(b - \frac{\rho\delta}{1-\lambda+\lambda\rho}\right)^2 + \frac{\lambda(1-\lambda)\rho(1-\rho)^2\delta^2}{4(1-\lambda+\lambda\rho)^2};$$

3. *When* $0 < \alpha < \alpha_1$,

$$w^{nd}_{3,3} = \frac{a}{2} + \frac{(1-\rho)\delta}{2(1-\lambda\rho)}$$
$$K^{nd}_{3,3} = \frac{1}{16}\left(a + \frac{(1-\rho)\delta}{1-\lambda\rho}\right)^2 + \frac{\lambda(1-\lambda)\rho^2(1-\rho)\delta^2}{4(1-\lambda\rho)^2}.$$

Theorem 3 characterizes the supplier's wholesale price decision and the capital market interim price decision at the equilibrium when no demand information is disclosed. It shows that the pricing decisions are also highly affected by the corporate myopia level α. For instance, when α is medium, the wholesale price ($w^{nd}_{3,1}$) is dependent on the mean of the demand only, since the firm always withholds the demand information. However, when α is large or small, the wholesale price depends on not only the demand distribution but also the information endowment probability λ. When α is large, the wholesale price ($w^{nd}_{3,2}$) decreases with λ since the firm is more likely to withhold low demand information. On the other hand, when α is small, the wholesale price ($w^{nd}_{3,3}$) increases with λ since the firm is more likely to withhold high demand information.

5. Value of information acquisition

In this section, we analyze the value of information acquisition and show when it is most beneficial for the manager to acquire private demand information. Let U^i be the ex-ante utility if the firm is informed and U^u be the ex-ante utility if the firm is uninformed. Given λ and α, the ex-ante utility of the informed firm is:

$$U^i = \int_{\theta\in N} (\Pi^{i,nd}_3) f(\theta)d\theta + \int_{\theta\in D} (\Pi^d_3) f(\theta)d\theta$$
$$= \int_{\theta\in N} \left(\frac{(1-\alpha)(\theta - w^{nd}_3)^2}{4} + \alpha K^{nd}_3\right) f(\theta)d\theta + \int_{\theta\in D} \frac{\theta^2}{16} f(\theta)d\theta. \quad (17)$$

The ex-ante utility of the unformed firm is:

$$U^u = \int_a^b (\pi^u_3) f(\theta)d\theta = \int_a^b \left(\frac{(1-\alpha)(\mu - w^{nd}_3)^2}{4} + \alpha K^{nd}_3\right) f(\theta)d\theta. \quad (18)$$

The difference between the two indicates the value of information acquisition.

Fig. 5 shows how the value of information acquisition changes with respect to the CML (α) and the information endowment probability (λ), where demand θ is assumed to be uniformly distributed between 1 and 2. Here we demonstrate the cases when α takes on the value of $0.1, 0.5, 0.9$ respectively. We also add the case when $\alpha = 0$ which essentially is the benchmark case when the firm deals with the supplier only (Section 4.2). We can see that the value of information acquisition increases as λ increases, which is intuitive. More interestingly, it is also shown that information acquisition is more valuable when the CML is either low or high (e.g., when $\alpha = 0$, 0.1 or 0.9) than when it is intermediate (e.g., when $\alpha = 0.5$). The reason is as follows: When the CML is low, the manager can potentially disclose low demand information to lower the wholesale price. When the CML is high, the manager can potentially disclose high demand information to raise his firm's stock valuation. When the CML is medium, the manager is torn by the conflicting pressure from both the capital market and the supplier and he always withholds the demand information even if he acquires it, and thus information acquisition becomes less beneficial to the manager.

Figs. 6 and 7 show how the value of information acquisition changes with respect to parameters a and b. The observation is that the value of information acquisition decreases with the low

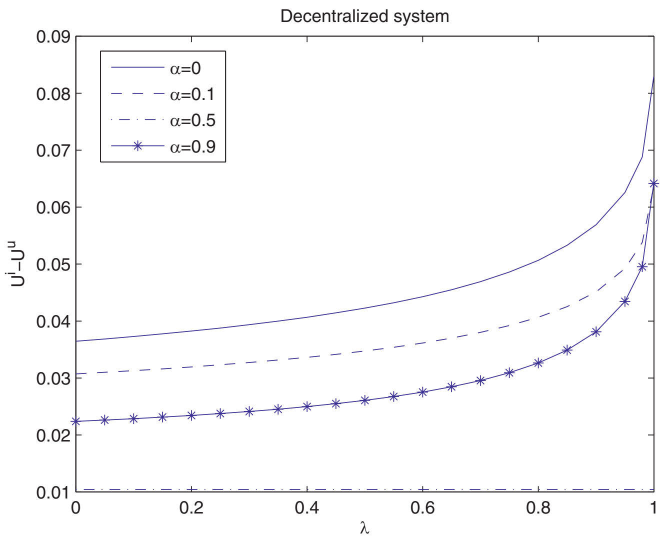

Fig. 5. Value of information acquisition with different corporate myopia levels.

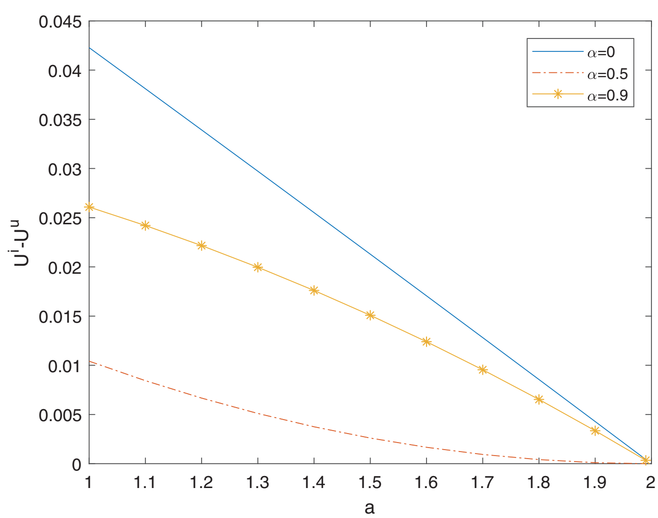

Fig. 6. Value of information acquisition with a.

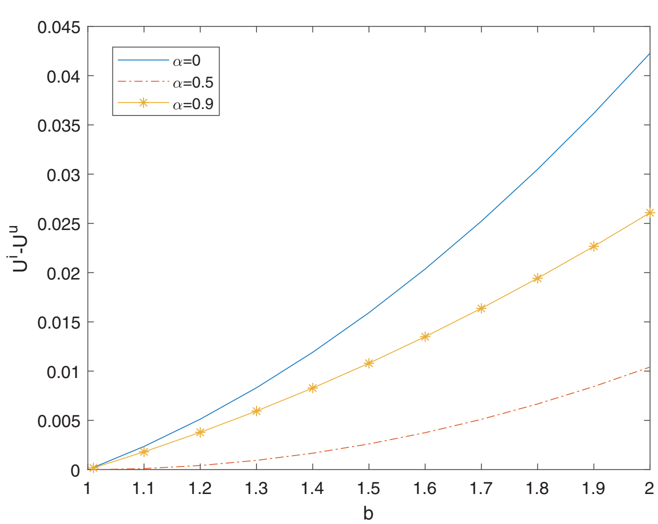

Fig. 7. Value of information acquisition with b.

demand a and increases with the high demand b. The reason is as follows: when a increases and approaches to b, or b decreases and approaches to a, the capital market and the supplier can anticipate more accurately about the demand, thus the information acquisition is less valuable.

6. Conclusions

We study a firm's information acquisition and voluntary disclosure decision when it deals with supply chain partner and capital market investors simultaneously and the latter parties cannot verify whether the firm possess private demand information. We show that, due to the conflicting effect of the disclosed information on the wholesale price and interim share price, the manager need to carefully evaluate the tradeoff of disclosure decision.

We show that the optimal information disclosure strategy is highly dependent on the corporate myopia level. More specifically, when the corporate myopia level is low, the manager would disclose demand information only if it is lower than a certain threshold; when the corporate myopia level is high, the manager would disclose demand information only if it is higher than a certain threshold; and when the corporate myopia level is medium, the manager would always withhold the demand information. Our result provides an alternative explanation to the firm's non-disclosure behavior commonly observed in real practice and highlights the importance of considering the effect of supply chain and capital market interaction.

We also evaluate the benefit of information acquisition and show when it is most beneficial for the firm to acquire demand information. Our results show that information acquisition is more valuable when the CML is either low or high than when it is medium. We also observe that the value of information acquisition decreases with the lower bound of the demand and increases with the upper bound of demand.

Acknowledgments

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Appendix

Key notation table.

Proof of Lemma 1. The condition (3) can be re-arranged as

$$(1-\lambda)\mu^2 = t^2[1-\lambda+\lambda F(t)] - \lambda\int_a^t \theta^2 f(\theta)d\theta. \tag{19}$$

Let

$$g(t) = t^2[1-\lambda+\lambda F(t)] - \lambda\int_a^t \theta^2 f(\theta)d\theta, \tag{20}$$

$g(t)$ is continuous in t.

Using Leibniz rule, when $\lambda \in (0,1)$, one can find that the first derivative of $g(t)$ with respect to t is $g'(t) = 2t[1-\lambda+\lambda F(t)] > 0$. This means that $g(t)$ is monotonically increasing in t. It is easy to see that $\lim_{t\to a} g(t) = a^2(1-\lambda) < (1-\lambda)\mu^2$ and $\lim_{t\to\mu} g(t) = \mu^2(1-\lambda) + \lambda\int_a^\mu(\mu^2-\theta^2)f(\theta)d\theta > (1-\lambda)\mu^2$. Hence, there is a unique solution $a < t_1 < \mu$ such that $(1-\lambda)\mu^2 = g(t_1)$.

When $\lambda = 1$, the left side of Eq. (19), $(1-\lambda)\mu^2 = 0$, and the right side $g(t) = t^2F(t) - \int_a^t \theta^2 f(\theta)d\theta$. Then, $g'(t) = 2tF(t) > 0$ for $t > a$, and $g'(t) = 0$ for $t = a$. This means that $g(t)$ is monotonically increasing in t. It is easy to see that $\lim_{t\to a} g(t) = a^2(1-\lambda) = 0$ and $\lim_{t\to\mu} g(t) = \int_a^\mu(\mu^2-\theta^2)f(\theta)d\theta > 0$. Therefore, when $\lambda = 1$, $t_1 = a$. □

Proof of Corollary 1. Using the implicit function theorem, one can find that

$$\frac{\partial t_1}{\partial \lambda} = \frac{t^2[1-F(t)] + \int_a^t \theta^2 f(\theta)d\theta - \mu^2}{2t[1-\lambda+\lambda F(t)]}. \tag{21}$$

The denominator of the above equation is positive. The numerator $n(t) = t^2[1-F(t)] + \int_a^t \theta^2 f(\theta)d\theta - \mu^2$ is monotonically increasing in t, since the first derivative $n'(t) = 2t[1-F(t)] > 0$. According to Lemma 1, $t_1 \in [a, \mu)$. We also note that $n(a) = a^2 - \mu^2 < 0$ and $\lim_{t\to\mu} n(t) = \int_a^\mu (\theta^2 - \mu^2) f(\theta)d\theta < 0$. Therefore, $\frac{\partial t_1}{\partial \lambda} < 0$, i.e., t_1 is decreasing in λ when $\lambda \in (0, 1]$. Because $t_1 = 2\sqrt{K_1^{nd}}$, K_1^{nd} is also decreasing in λ. □

Proof of Corollary 2. As shown in the proof of Lemma 1, when $\lambda = 1$, $t_1 = a$, which means that the firm would always disclose information. □

Proof of Lemma 2. The condition (7) can be re-arranged as

$$(1-\lambda)\mu = t(1-\lambda) + \lambda \int_t^b (t-\theta)f(\theta)d\theta. \tag{22}$$

Let

$$k(t) = t(1-\lambda) + \lambda \int_t^b (t-\theta)f(\theta)d\theta. \tag{23}$$

Note that $k(t)$ is continuous in t. Using Leibniz rule, when $\lambda \in (0,1)$, one can find that the first derivative of $k(t)$ with respect to t is $k'(t) = 1 + \lambda \int_t^b f(\theta)\, d\theta - \lambda > 0$. This means that $k(t)$ is monotonically increasing in t. It is easy to see that $\lim_{t\to\mu} k(t) = \mu(1-\lambda) + \lambda \int_\mu^b (\mu-\theta)f(\theta)d\theta < (1-\lambda)\mu$ and $\lim_{t\to b} k(t) = (1-\lambda)b > (1-\lambda)\mu$. Hence, there is a unique solution $\mu < t_2 < b$ such that $(1-\lambda)\mu = k(t_2)$.

When $\lambda = 1$, $(1-\lambda)\mu = 0$ and $k(t) = \int_t^b (t-\theta)f(\theta)d\theta$. Then, $k'(t) = \int_t^b f(\theta)\, d\theta > 0$ for $t < b$, and $k'(t) = 0$ for $t = b$. This means that $k(t)$ is monotonically increasing in t. It is easy to see that $\lim_{t\to\mu} k(t) = \int_\mu^b (\mu-\theta)f(\theta)d\theta < 0$ and $\lim_{t\to b} k(t) = 0$. Hence, there is a unique solution $t_2 = b$ which means the manager will always disclose information when $\lambda = 1$. ■ □

Proof of Corollary 3. Using the implicit function theorem, one can find that

$$\frac{\partial t_2}{\partial \lambda} = \frac{t - \int_t^b (t-\theta)f(\theta)\, d\theta - \mu}{1 + \lambda \int_t^b f(\theta)\, d\theta - \lambda}. \tag{24}$$

The denominator of the above equation is positive. The numerator $m(t) = t - \int_t^b (t-\theta)f(\theta)\, d\theta - \mu$ is monotonically increasing in t, as $m'(t) = 1 - \int_t^b f(\theta)\, d\theta = F(t) > 0$. Since $\mu < t_2 \le b$, $\lim t \to \mu m(t) = \int_\mu^b (\theta-\mu)f(\theta)d\theta > 0$ and $m(b) = b - \mu > 0$ We find that $m(t) > 0$ for all $t \in (\mu, b]$, which implies that $\frac{\partial t_2}{\partial \lambda} > 0$. Because $w_2^{nd} = \frac{t_2}{2}$, w_2^{nd} is also increasing in λ. □

Proof of Corollary 4. As shown in the proof of Lemma 2, when $\lambda = 1$, $t_2 = b$, which means that the firm would always disclose information. □

Proof of Theorem 1. Let $G(\theta)$ denote the difference between the utility of the manager when he has received the demand information but withheld it and that when the manager disclosed his acquired information.

$$\begin{aligned} G(\theta) &= \Pi_3^{i,nd} - \Pi_3^d \\ &= (1-\alpha)\frac{(\theta - w_3^{nd})^2}{4} + \alpha K_3^{nd} - \frac{\theta^2}{16}. \end{aligned} \tag{25}$$

The analysis is divided into three cases. First, we consider the case of $\frac{3}{4} < \alpha \le 1$. Second, we consider the case of $\alpha = \frac{3}{4}$. Finally, we consider the case of $0 < \alpha < \frac{3}{4}$.

Case 1, when $\frac{3}{4} < \alpha \le 1$:

Let $\Delta = (1-\alpha)\left(w_3^{nd}\right)^2 + 4\alpha K_3^{nd}(4\alpha - 3)$, then

$$G(\theta) = -\frac{4\alpha-3}{16}(\theta + \frac{4(1-\alpha)w_3^{nd}}{(4\alpha-3)})^2 + \frac{\Delta}{4(4\alpha-3)}. \tag{26}$$

It can be easily derived that $G(\theta)$ is concave and Δ is always positive in this case. Since the demand forecast information θ is positive, then, $G(\theta) > 0$ if and only if $\theta < \frac{2\sqrt{\Delta} - 4(1-\alpha)w_3^{nd}}{4\alpha-3}$. Hence, there is a unique threshold:

$$t_{3,1} = \frac{2\sqrt{\Delta} - 4(1-\alpha)w_3^{nd}}{4\alpha - 3}. \tag{27}$$

Case 2, when $\alpha = \frac{3}{4}$:

In this case, $G(\theta) = \frac{1}{16}\left(12K_3^{nd} + \left(w_3^{nd}\right)^2 - 2w_3^{nd}\theta\right)$. Obviously, $G(\theta) > 0$ if and only if $\theta < \frac{w_3^{nd}}{2} + \frac{6K_3^{nd}}{w_3^{nd}}$. Hence, there is also a unique threshold:

$$t_{3,2} = \frac{w_3^{nd}}{2} + \frac{6K_3^{nd}}{w_3^{nd}}. \tag{28}$$

Case 3, when $0 < \alpha < \frac{3}{4}$:

In this case, $G(\theta)$ can be rewritten as

$$G(\theta) = \frac{3-4\alpha}{16}(\theta - \frac{4(1-\alpha)w_3^{nd}}{(3-4\alpha)})^2 - \frac{\Delta}{4(3-4\alpha)}. \tag{29}$$

Different from case 1, $G(\theta)$ is convex and Δ is not always positive in this case. Therefore, we examine the disclosure policy in two situations: $\Delta \le 0$ and $\Delta > 0$.

When $\Delta \le 0$, $G(\theta)$ is always positive, which means that the manager always withhold the information.

When $\Delta > 0$, there exist two thresholds:

$$t_{3,3} = \frac{4(1-\alpha)w_3^{nd} - 2\sqrt{\Delta}}{3-4\alpha}, \text{ and } t_{3,4} = \frac{4(1-\alpha)w_3^{nd} + 2\sqrt{\Delta}}{3-4\alpha}. \tag{30}$$

where $0 < t_{3,3} < t_{3,4}$. In this case $G(\theta) > 0$ if and only if $\theta < t_{3,3}$ *or* $\theta > t_{3,4}$. □

Proof of Theorem 2. In the special case that the market demand follows a binary distribution, we have the following 4 strategies as described in Table 7 which lists the wholesale price and the interim share price conditional on no information shared, and the utilities of the manager when he receives different demand information θ. To simplify notation, here we simply w_3^{nd} to w^{nd}.

Then, we find the disclosure strategy is a prisoner's dilemma problem as showed in Table 8.

According to Tables 7 and 8, we derive the Nash Equilibrium solutions in the order presented.

1. When should the manager withholds the information a? There are two situations:

1.1. The manager keeps silence when he receives b. It leads that $N = \{a, b\}$ and $D = \phi$. Correspondingly, the wholesale price determined by the supplier conditional on no information shared is $w_{S1}^{nd} = \frac{\rho a + (1-\rho)b}{2}$, and the interim share price is $K_{S1}^{nd} = (1-\lambda)\frac{(\mu - w^{nd})^2}{4} + \lambda(\frac{\rho(a-w^{nd})^2}{4} + \frac{(1-\rho)(b-w^{nd})^2}{4})$.

Let $G(\theta)$ denote the difference between the utilities of the manager when he has received the demand information θ, but withheld it and that when the manager disclosed his acquired information.

$$G_{S1}(a) = \Pi_{S1}(a) - \Pi^d(a) = \frac{(1-\alpha)(a - w_{S1}^{nd})^2}{4} + \alpha K_{S1}^{nd} - \frac{a^2}{16}$$

In this situation, the manager receives a and keeps silence only when $\Pi_{S1}(a) \ge \Pi^d(a)$. Therefore, one sufficient condition of the

Table 6
Summary of key notation.

Notation	Explanation
θ	Market demand, generally distributed in [a,b] with cdf F(.), pdf f(.), meanμ, and standard deviationσ
α	The corporate myopia level
p	Market clearing price
s	The manager's information state ($s \in \{i, u\}$); $i(u)$ means being informed(uninformed)
λ	Information endowment probability
m	The manager's disclosure decision ($m \in \{d, nd\}$); $d(nd)$ means disclosure(non-disclosure)
ρ	The probability that demand equals a in a binary distribution
z	$z \in \{1, 2, 3\}$ represents three different cases: benchmark case 1, benchmark case 2, general case.
q_z^s	The firm's order quantity for $s \in \{i, u\}$ under case $z \in \{1, 2, 3\}$
w_z^m	The wholesale price conditional on $m \in \{d, nd\}$under case $z \in \{1, 2, 3\}$
R_z^m	The supplier's profit conditional on $m \in \{d, nd\}$ under case $z \in \{1, 2, 3\}$
$\pi_z^{s,m}$	The firm's terminal cash flow conditional on $s \in \{i, u\}$ and $m \in \{d, nd\}$ under case $z \in \{1, 2, 3\}$
K_z^m	The interim share price conditional on $m \in \{d, nd\}$ under case $z \in \{1, 2, 3\}$
$\Pi_z^{s,m}$	The firm's utility conditional on $s \in \{i, u\}$ and $m \in \{d, nd\}$ under case $z \in \{1, 2, 3\}$
U_z^s	The firm's ex-ante utility for $s \in \{i, u\}$ under case $z \in \{1, 2, 3\}$
t_z	Disclosure threshold under case $z \in \{1, 2, 3\}$

Table 7
Pricing strategies and utility functions under different disclosure strategy.

	N	D	w^{nd}	K^{nd}
S1	a, b	ϕ	$\frac{\mu}{2}$	$(1-\lambda)\frac{(\mu-w^{nd})^2}{4} + \lambda(\frac{\rho(a-w^{nd})^2}{4} + \frac{(1-\rho)(b-w^{nd})^2}{4})$
S2	a	b	$\frac{\mu(1-\lambda)+\lambda\rho a}{2(1-\lambda+\lambda\rho)}$	$\frac{1-\lambda}{1-\lambda+\lambda\rho}\frac{(\mu-w^{nd})^2}{4} + \frac{\lambda\rho}{1-\lambda+\lambda\rho}\frac{(a-w^{nd})^2}{4}$
S3	b	a	$\frac{\mu(1-\lambda)+\lambda(1-\rho)b}{2(1-\lambda\rho)}$	$\frac{1-\lambda}{1-\lambda\rho}\frac{(\mu-w^{nd})^2}{4} + \frac{\lambda(1-\rho)}{1-\lambda\rho}\frac{(b-w^{nd})^2}{4}z$
S4	ϕ	a, b	$\frac{\mu}{2}$	$\frac{\mu^2}{16}$
	N	D	$\Pi(a)$	$\Pi(b)$
S1	a, b	ϕ	$(1-\alpha)\frac{(a-w^{nd})^2}{4} + \alpha K^{nd}$	$(1-\alpha)\frac{(b-w^{nd})^2}{4} + \alpha K^{nd}$
S2	a	b	$(1-\alpha)\frac{(a-w^{nd})^2}{4} + \alpha K^{nd}$	$\frac{b^2}{16}$
S3	b	a	$\frac{a^2}{16}$	$(1-\alpha)\frac{(b-w^{nd})^2}{4} + \alpha K^{nd}$
S4	ϕ	a, b	$\frac{a^2}{16}$	$\frac{b^2}{16}$

Table 8
The manager's utility on different disclosure strategies.

$\theta = a \backslash \theta = b$	Non-disclose	Disclose
Non-disclose	$\Pi_{S1}(a), \Pi_{S1}(b)$	$\Pi_{S2}(a), \Pi_{S2}(b)$
Disclose	$\Pi_{S3}(a), \Pi_{S3}(b)$	$\Pi_{S4}(a), \Pi_{S4}(b)$

strategy $N = \{a, b\}$ and $D = \phi$ is that $G_{S1}(a) \geq 0$, i.e. $\alpha \geq \alpha_1$, where $\alpha_1 \triangleq \frac{3a-b+(b-a)\rho}{4(a+(b-a)\lambda\rho)}$. Furthermore, $0 < \alpha_1 < 0.5$.

1.2. The manager discloses the demand information b. It leads that $N = a$ and $D = b$. Correspondingly, the wholesale price determined by the supplier conditional on no information shared is $w_{S2}^{nd} = \frac{b(1-\lambda+\lambda\rho)-(b-a)\rho}{2(1-\lambda+\lambda\rho)}$, and the interim share price is $K_{S2}^{nd} = \frac{1-\lambda}{1-\lambda+\rho\lambda}(\frac{\mu-w_{S2}^{nd}}{2})^2 + \frac{\rho\lambda}{1-\lambda+\rho\lambda}(\frac{a-w_{S2}^{nd}}{2})^2$. The difference of the utilities is

$$G_{S2}(a) = \Pi_{S2}(a) - \Pi^d(a) = \frac{(1-\alpha)(a-w_{S1}^{nd})^2}{4} + \alpha K_{S1}^{nd} - \frac{a^2}{16}.$$

In this situation, the manager receives a and keeps silence only when $\Pi_{S2}(a) \geq \Pi^d(a)$. Therefore, one sufficient condition of the strategy $N = a$, and $D = b$ is that $G_{S2}(a) \geq 0$, i.e. $\alpha \geq \alpha_1'$, where $\alpha_1' \triangleq \frac{(3a-b)(1-\lambda+\lambda\rho)+(b-a)\rho}{4(a-a\lambda+a\lambda\rho^2+b\lambda\rho(1-\rho))}$. Furthermore, $\alpha_1' < 0.5$.

2. When should the manager disclose the information a? There are two situations:

2.1. The manager keeps silence when he receives b. It leads that $N = b$ and $D = a$. In this situation, the manager receives a and discloses it only when $\Pi_{S3}(a) > \Pi_{S1}(a)$ which is converse to Case 1.1 due to $\Pi_{S3}(a) = \Pi^d(a)$. Therefore, one sufficient condition of the strategy $N = b$ and $D = a$ is that $G_{S1}(a) < 0$, $\alpha < \alpha_1$.

2.2, The manager discloses the demand information b. It leads that $N = \phi$, and $D = \{a, b\}$.In this situation, the manager receives a and discloses it only when $\Pi_{S4}(a) > \Pi_{S2}(a)$ which is converse to Case 1.2 due to $\Pi_{S4}(a) = \Pi^d(a)$. Therefore, one sufficient condition of the strategy $N = \phi$, and $D = \{a, b\}$ is that $G_{S2}(a) < 0$, $\alpha < \alpha_1'$.

3. When should the manager withhold the information b? There are two situations:

3.1. The manager keeps silence when he receives a. It leads that $N = \{a, b\}$ and $D = \phi$. Correspondingly, the wholesale price conditional on no information shared and the interim share price is the same as the first situation. In this situation, the difference of the utilities is

$$G_{S1}(b) = \Pi_{S1}(b) - \Pi^d(b) = \frac{(1-\alpha)(b-w_{S1}^{nd})^2}{4} + \alpha K_{S1}^{nd} - \frac{b^2}{16}$$

and the manager receives b and keeps silence only when $\Pi_{S1}^{nd}(b) \geq \Pi^d(b)$. Therefore, one sufficient condition of the strategy $N = \{a, b\}$ and $D = \phi$ is that $G_{S3}(b) \geq 0$, i.e. $\alpha \leq \alpha_2$, where $\alpha_2 \triangleq \frac{2b+\rho(b-a)}{4(b(1-\lambda+\lambda\rho)+a\lambda(1-\rho))}$. Furthermore, $0.5 < \alpha_2 < 1$.

3.2. The manager discloses the demand information a. It leads that $N = b$ and $D = a$. Correspondingly, the wholesale price determined by the supplier conditional on no information shared is $w_{S3}^{nd} = \frac{1}{2}\frac{b+a\rho-b\rho-a\lambda\rho}{1-\lambda\rho}$, the interim share price is $K_{S3}^{nd} = \frac{1-\lambda}{1-\lambda+(1-\rho)\lambda}(\frac{\mu-w_{S3}^{nd}}{2})^2 + \frac{(1-\rho)\lambda}{1-\lambda+(1-\rho)\lambda}(\frac{b-w_{S3}^{nd}}{2})^2$, and the difference of the utilities is

$$G_{S3}(b) = \Pi_{S3}(b) - \Pi^d(b) = \frac{(1-\alpha)(b-w_{S3}^{nd})^2}{4} + \alpha K_{S3}^{nd} - \frac{b^2}{16}$$

In this situation, the manager receives b and keeps silence only when $\Pi_{S3}(b) \geq \Pi^d(b)$. Therefore, one sufficient condition of the strategy $N = b$ and $D = a$ is that $G_{S3}(b) \geq 0$, i.e. $\alpha \leq \alpha_2'$, where $\alpha_2' \triangleq \frac{2b-a\rho+b\rho+a\lambda\rho-3b\lambda\rho}{4(b+a\lambda\rho-2b\lambda\rho-a\lambda\rho^2+b\lambda\rho^2)}$. Furthermore, $\alpha_2' > 0.5$.

4. When should the manager disclose the information b? There are two situations:

Table 9
Pricing strategy conditional on no information disclosed.

α	Strategy	w^{nd}	K^{nd}
$\alpha_1 \le \alpha \le \alpha_2$	$N = \{a, b\}, D = \phi$	$\frac{\mu}{2}$	$\frac{1}{16}\mu^2 + \frac{1}{4}\lambda\rho(1-\rho)\delta^2$
$\alpha_2 < \alpha \le 1$	$N = a, D = b$	$\frac{b}{2} - \frac{\rho\delta}{2(1-\lambda+\lambda\rho)}$	$\frac{1}{16}\left(b - \frac{\rho\delta}{1-\lambda+\lambda\rho}\right)^2 + \frac{\lambda(1-\lambda)\rho(1-\rho)^2\delta^2}{4(1-\lambda+\lambda\rho)^2}$
$0 < \alpha < \alpha_1$	$N = b, D = a$	$\frac{a}{2} + \frac{(1-\rho)\delta}{2(1-\lambda\rho)}$	$\frac{1}{16}\left(a + \frac{(1-\rho)\delta}{1-\lambda\rho}\right)^2 + \frac{\lambda(1-\lambda)\rho^2(1-\rho)\delta^2}{4(1-\lambda\rho)^2}$

4.1. The manager keeps silence when he receives a. It leads that $N = a$ and $D = b$. In this situation, the manager receives b and discloses it only when $\Pi_{S2}(b) > \Pi_{S1}(b)$ which is converse to Case 3.1 due to $\Pi_{S2}(b) = \Pi^d(b)$. Therefore, one sufficient condition of the strategy $N = b$ and $D = a$ is that $G_{S1}(b) < 0$, $\alpha > \alpha_2$.

4.2. The manager discloses the demand information a. It leads that $N = \phi$, and $D = \{a, b\}$.In this situation, the manager receives b and discloses it only when $\Pi_{S4}(b) > \Pi_{S3}(b)$ which is converse to Case 3.2 due to $\Pi_{S4}(b) = \Pi^d(b)$. Therefore, one sufficient condition of the strategy $N = \phi$, and $D = \{a, b\}$ is that $G_{S3}(b) < 0$, $\alpha > \alpha_2'$.

As a result, we obtain the disclosure strategies from the intersection of the previous situations.

1. According to Cases 1.1 and 3.1, the sufficient and necessary condition of strategy $N = \{a, b\}$ and $D = \phi$ is $\alpha_1 \le \alpha \le \alpha_2$.
2. According to Cases 1.2 and 4.1, the sufficient and necessary condition of strategy $N = a$ and $D = b$ is $\alpha > \max\{\alpha_2, \alpha_1'\} = \alpha_2$.
3. According to Cases 2.1 and 3.2, the sufficient and necessary condition of strategy $N = b$ and $D = a$ is $\alpha < \min\{\alpha_1, \alpha_2'\} = \alpha_1$.
4. According to Cases 2.2 and 4.2, the sufficient and necessary condition of strategy $N = \phi$ and $D = \{a, b\}$ is $\alpha_2' < \alpha < \alpha_1'$. However, $\alpha_1' < 0.5 < \alpha_2'$, which is contradiction. Therefore, the full-disclosure strategy is impossible. □

Proof of Corollary 5. $\alpha_1 - \frac{1}{2} = -\frac{(1-\rho+2\lambda\rho)(b-a)}{4(a+(b-a)\lambda\rho)} < 0$, $\alpha_2 - \frac{1}{2} = \frac{(2\lambda(1-\rho)+\rho)(b-a)}{4(b-(b-a)\lambda(1-\rho))} > 0$ as $b - (b-a)\lambda(1-\rho) = b(1-\lambda) + a\lambda(1-\rho) + b\lambda\rho > 0$. Therefore, $\alpha_1 < \frac{1}{2} < \alpha_2$.

We have $\frac{\partial\alpha_1}{\partial a} = \frac{b(1-\rho+2\lambda\rho)}{4(a+(b-a)\lambda\rho)^2} > 0$, $\frac{\partial\alpha_1}{\partial b} = -\frac{a(1-\rho+2\lambda\rho)}{4(a+(b-a)\lambda\rho)^2} < 0$, $\frac{\partial\alpha_1}{\partial\delta} = -\frac{a(1-\rho+2\lambda\rho)}{4(a+\lambda\delta\rho)^2} < 0$; $\frac{\partial\alpha_2}{\partial a} = -\frac{b(2\lambda(1-\rho)+\rho)}{4(b-(b-a)\lambda(1-\rho))^2} < 0$, $\frac{\partial\alpha_2}{\partial b} = \frac{a(2\lambda(1-\rho)+\rho)}{4(b-(b-a)\lambda(1-\rho))^2} > 0$, $\frac{\partial\alpha_2}{\partial\delta} = \frac{b(2\lambda(1-\rho)+\rho)}{4(b-\lambda\delta(1-\lambda))^2} > 0$. □

Proof of Theorem 3. According to Table 7 and $\delta \triangleq b - a$, we have the pricing strategies as described in Table 9. □

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