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# Supplier Diversification Under Buyer Risk

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**Abstract.** When should a firm diversify its supply base? Most extant theories attribute supplier diversification to supplier risk. Herein, we develop a new theory that attributes supplier diversification to buyer risk. When suppliers are subject to the risk of buyer default, buyers may take costly action to signal creditworthiness so as to obtain more favorable terms. But once signaling costs are sunk, buyers sourcing from a single supplier become vulnerable to future holdup. Although ex ante supply base diversification can be effective at alleviating the holdup problem, we show that it comes at the expense of higher up-front signaling costs. We resolve the ensuing trade-off and show that diversification emerges as the preferred strategy in equilibrium. Our theory can help explain sourcing strategies when risk in a trade relationship originates from the sourcing firm, for example, a small-to-medium enterprise or a start-up; a setting that has eluded existing theories so far.

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**Keywords:** supplier diversification • multisourcing • buyer default risk • signaling • information asymmetry

## 1. Introduction

When should a firm diversify its supply base? Most existing theories are based on the premise that buyers are subject to supplier risks such as capacity disruption, performance risk, yield uncertainty, and supplier default—see Tomlin and Wang (2010) and Section 2 for overviews. These theories rationalize multisourcing as a means for buyers to mitigate supply risks and can aptly explain why firms, such as Apple, for example, often choose to source input components (such as memory chips, high-resolution displays, etc.) from two or more suppliers (Li and Debo 2009).

But what if it is the suppliers who are subject to buyer risk, that is, the risk of buyer default? When risk exposure is reversed, theories based on supply risk are unable to explain sourcing strategies. Acknowledging that risk can originate on either side of the trade relationship exposes an important gap between theory and practice. A notable economic sector on which this gap impinges is small-to-medium enterprises (SMEs) and start-ups. Consider Meizu, an up-and-coming Chinese smartphone manufacturer that sources numerous components (CPUs, cameras, etc.) from well-established suppliers. To produce the Pro 6, one of its flagship devices, Meizu sourced the front camera entirely from Omnivision and the back camera entirely from Sony (Humrick 2016). This sourcing strategy from Sony and Omnivision, both of which can easily produce both camera types, cannot possibly be explained by supply risk theories. Worse, these theories would predict Meizu's to be a *bad* strategy: were either supplier to be disrupted, Meizu's phone assembly would halt.[1]

This paper provides a new rationale for supplier diversification based on buyer risk. To compensate for the risk of buyer default, suppliers command a premium, which incentivizes buyers to signal creditworthiness. But signaling often involves costs that, once sunk, could leave buyers vulnerable to holdup: because sourcing from new suppliers involves fresh signaling costs, an informed supplier could exploit its position to continue to extract a premium. Sourcing from (and thus signaling to) multiple suppliers, on the one hand, could alleviate this problem by establishing sustained, long-term competition among informed suppliers. On the other hand, we show that, by being potentially more attractive to all buyers, multisourcing increases the willingness of low-quality buyers to imitate and could, therefore, involve greater signaling costs. Our analysis shows that, in equilibrium, multisourcing emerges as a dominating strategy, which provides a possible explanation of why firms might benefit from a Meizu-type sourcing strategy.

The literature's emphasis on supply risk can be traced to the modus operandi of traditional supply chains. Many industries, including computer and car manufacturing, were historically dominated by large, vertically integrated firms, such as IBM and GM, which sourced large quantities of raw materials from smaller suppliers. As supply chains became more modular, firms increasingly wore both hats, becoming both upstream buyers and downstream suppliers (see, e.g., Stuckey and White 1993, Baldwin and Clark 2000, and Feng and Zhang 2014). The resulting exposure to risks on both sides creates a need for a deeper understanding of risk and sourcing strategies in modern trade relationships. By showing that a firm's *own* risk can drive its sourcing strategy, this paper fills an important gap in the existing literature and unifies the idea that diversification can help firms mitigate supply chain risks originating from either side of trade relationships.

Our theory is particularly relevant to start-ups and young firms, which, lacking a track record, tend to be viewed by suppliers as particularly risky. Take, for example, Xiaomi, founded in 2010 and now considered China's leading mobile phone company. One of the biggest challenges it faced in the beginning was to unlock access to the mature and competitive market for mobile phone components (Yoshida 2014). Chinese tech companies were, at the time, widely perceived to produce imitations, and a number of suppliers had had bad experiences with Chinese firms that had gone bankrupt (Yu 2014). Xiaomi's sourcing strategy from the get-go was to approach as many suppliers as early as possible. The company reached out to more than 100 and was initially rejected by 85 of the world's leading component suppliers. Some didn't want to provide capacity; others quoted prices "*five times higher than usual.*" In cofounder Bin Lin's words: "*That means no.*"

Of multiple mechanisms through which suppliers are exposed to buyer default risk, the most common, in practice, is arguably *trade credit*, whereby a buyer that purchases goods on account promises to pay the supplier at a later date. The World Trade Organization estimates 80%–90% of global merchandise trade flow relies on some type of trade credit. Trade credit being ubiquitous in practice, we include it in the model to capture supplier exposure to buyer risk. Similarly, of the multiple mechanisms through which buyers can signal to suppliers, following the growing literature on signaling in operations,[2] we consider signaling through the size of inventory orders. This endogenizes the firm's signaling costs and naturally ties them to the choice of the firm's sourcing strategy.

To develop our theory, we take the perspective of a manufacturing firm that operates over two production periods. In each, to produce its output, the firm needs to source inputs from a pool of homogeneous, perfectly competitive, and riskless suppliers. The firm can be one of two types, either high or low quality, which determines its default risk and constitutes its private information. The firm has no preexisting sourcing relationships, meaning all suppliers have the same prior regarding the firm's type. In each period, the firm decides whether to single-source or multisource and how much to order. Upon receipt of an order and based on all prior transactional information with the firm (if there is any), suppliers form a belief about the firm's quality, set the credit terms, and deliver the goods. The firm chooses its sourcing strategy and order quantities so as to maximize its expected payoff.

We find single-sourcing to incur severe informational holdup effects ex post. In particular, a high-quality firm that signals to a single supplier in the first period ends up forfeiting all potential benefits in the second: sure enough, the informed supplier sets future credit terms so as to leave the firm indifferent between continuing the relationship and starting anew. By broadcasting private information to multiple suppliers, multisourcing enables firms to sustain supplier competition and eliminates future holdup costs. But doing so is not without cost. Multisourcing, being potentially more attractive to both types of firms, inclines low-quality firms to imitate and thereby increases up-front signaling costs for high-quality firms.

We demonstrate that, in equilibrium, multisourcing emerges as the dominating strategy for high-quality firms. These findings are discussed in detail in Section 4. We preface the development of our model with a brief overview of the literature.

## 2. Literature

The existing literature on multisourcing has, for the most part, focused on supply base disruption risk. See Tomlin and Wang (2005), Tomlin (2006), Babich et al. (2007), Dada and Petruzzi (2007), Federgruen and Yang (2007), Tomlin (2009b), Babich et al. (2010), Wang et al. (2010), Kouvelis and Tang (2011), Dong and Tomlin (2012), and many others. As previously discussed, the risks considered usually involve bankruptcy, general disruption, yield uncertainty, etc. For example, Tomlin (2006) focuses on contracts with suppliers of different reliability levels; Federgruen and Yang (2007) study optimal supplier diversification with heterogeneous firms (in terms of yields, costs, and capacity). Wang et al. (2011) study trade regulations as a risk driver of supply chain strategy. More recently, Bimpikis et al. (2014) study optimal multitier supply chain networks in the presence of disruption risk. Ang et al. (2016) study disruption risk and optimal sourcing in a multitier setting; Bimpikis et al. (2018) study how nonconvexities of the production function affect supply chain risk. At a very high level, the general message of these papers is that multisourcing helps diversify away idiosyncratic upstream risk. Interestingly, recent empirical evidence put forth in Jain et al. (2015) shows that diversification may not be as effective in practice, compared with long-term relationships, when it comes to recovering from supply chain interruptions.

Of course, in many cases, supplier diversification represents a trade-off. For instance, Babich et al. (2007) study a trade-off between diversification and competition. Yang et al. (2012) extend this work by considering a more general competition framework and allowing the buyer to precommit to a sourcing strategy. They find that depending on how dual-sourcing is implemented, it could reduce supply base risk but may also lead to less competitive pricing. In our framework, multisourcing ensures competitive pricing but only if the competing suppliers are equally informed.

There is some literature on sourcing under information asymmetry, but unlike us, it focuses on settings in which buyers are the less informed party. For instance, Hasija et al. (2008) study outsourcing contracts assuming client firms have asymmetric information about vendors' worker productivity. Within this literature, several papers focus specifically on the issue of multisourcing when buyers have limited information about suppliers. Tomlin (2009b) develops a Bayesian updating model to describe how the buyer learns about the supplier's reliability. Yang et al. (2012) find that better information may increase or decrease the value of the dual-sourcing option. In particular, they highlight cases in which asymmetric information would cause buyers to refrain from diversifying even as the reliability of the supply base decreases. In our model, actions taken to alleviate asymmetric information have the potential to cause holdup over time, which strengthens buyer diversification incentives.

In contrast to our work, none of the aforementioned papers focuses on buyer default risk. To the best of our knowledge, we are not aware of any other work in the literature that studies how a firm's own riskiness impacts its sourcing diversification strategy.

That inventory can serve as a signal of firm prospects is relatively well established (Lai et al. 2012, Schmidt et al. 2015, Lai and Xiao 2016). Although this theory has been developed in the context of signaling to equity investors, only recently has there been an effort to extend it to the supplier–buyer setting (Chod et al. 2017). Yet this latter setting might be just as much, if not more, relevant given that suppliers observe order quantities on the fly, whereas equity investors rely on reported and often delayed information from financial statements. We extend and generalize this framework in several new directions that may be relevant to both settings: First, our focus is not on understanding whether firms over-order inventory but rather on understanding sourcing strategies. Second, we consider a dynamic setting, which unlocks new qualitative insights that existing static models cannot capture, such as the genesis of holdup effects. Third, we consider firms requiring multiple inputs to create their output. Fourth, we consider signaling to more than just one supplier. Finally, we also generalize firm production functions to a broader class and derive more fundamental conditions under which signaling to suppliers remains credible.

In the economics literature, signaling games have been studied extensively, most often, however, within single-period models (Kaya 2009). Among recent papers that consider repeated signaling, our work is most closely related to Kaya (2009). In every period of Kaya's model, the informed player takes an action, after which the uninformed player, who has observed the entire history of actions, makes an inference about the informed player's type and reacts. Among multiple pure strategy perfect Bayesian equilibria that could arise, Kaya studies least-cost separating equilibria (SE)[3] after ruling out other alternatives, such as non-least-cost SE or pooling equilibria, based on standard refinement techniques, for example, the Cho–Kreps intuitive criterion. Kaya also argues that the least-cost SE can involve signaling in every period or signaling "a lot" only in the first period. Other papers on multiperiod signaling focus on "constrained strategies," that is, they assume that either (a) agents are allowed to signal only once, for example, in the first period (see Alos-Ferrer and Prat 2012) or (b) high types precommit to their actions in every period (see Kreps and Wilson 1982).

Methodologically, our work is in line with Kaya (2009) in the sense that (a) we allow suppliers' beliefs to be updated based on current actions and past history, (b) we focus on least-cost SE (although we also consider pooling in the Extensions Section 7.4), and (c) we allow signaling to occur either once up front or repeatedly, whichever arises endogenously as less costly. By capturing important elements relevant to our sourcing context, our work departs from Kaya (2009) in several dimensions: First, we consider *multiple* uninformed players (suppliers). Second, we consider competition among the uninformed players. Third, we distinguish between privately observed signals, such as prior bilateral transactions between the firm and a supplier, and publicly observed signals, such as bankruptcy reorganization.

The literature on trade credit spans several areas, including operations management, finance, and economics. The main question raised in the finance and economics literatures is why trade credit is so ubiquitous in practice. After all, it is not obvious why suppliers systematically play the role of creditors. For a good overview, see Petersen and Rajan (1997), Burkart and Ellingsen (2004), and Giannetti et al. (2011). The operations literature has examined how trade credit affects inventory decisions (Luo and Shang 2015), whether trade credit can be used to improve supply chain efficiency (Kouvelis and Zhao 2012, Chod 2017), and whether trade credit and bank financing are complements or substitutes (Babich and Tang 2012, Chod et al. 2017). None of these papers has addressed supplier diversification or informational holdup.

The literature on holdup is vast and has been primarily developed from an economics and finance perspective, starting with the seminal work of Williamson (1971). A recent overview of the holdup literature can be found in Hermalin (2010). Within the topic of holdup, our paper focuses specifically on informational holdup. There is empirical evidence to support our premise that creditors can obtain an informational advantage through their relationship with firms over time, which allows them to hold up firms in later periods. For instance, using survey data from African trade credit relationships, Fisman and Raturi (2004) find that monopoly power is associated with less credit provision because of ex post holdup problems. Hale and Santos (2009) find evidence to suggest that banks' private information lets them hold up borrowers for higher interest rates in future periods. Similarly, Schenone (2010) finds a U-shaped relationship between borrowing rates and relationship length for pre-IPO firms. The underlying hypothesis is that when a private firm first approaches a lender, it bears high borrowing costs, reflecting the risk premium. These costs start decreasing as information asymmetry is alleviated over time but then increase again when holdup effects start manifesting. Although these papers provide empirical evidence supporting our premise that informational holdup can arise, they do not study whether and how it can be mitigated, which is the main focus of our work.

In the supply chain literature, holdup is usually studied from the perspective of a buyer holding up a supplier who needs to make buyer-specific investments at the genesis of the relationship (e.g., Taylor and Plambeck 2007). With respect to supplier opportunism, Babich and Tang (2012) show how product adulteration by suppliers can be mitigated via deferred payments and inspections. Similarly, Rui and Lai (2015) study a firm's procurement strategy in the presence of product adulteration risk. Li et al. (2014) study supplier encroachment in cases in which buyers are better informed than suppliers. None of these papers considers informational holdup.

Finally, many other papers study sourcing strategies while focusing on questions and/or contexts that depart from our own. Among these, Tunca and Wu (2009) and Pei et al. (2011) study procurement contract design, the former through option contracts and the latter through auctions. Wu and Zhang (2014) study the trade-off between efficient and responsive sourcing, characterizing conditions under which backshoring is optimal. Zhao et al. (2014) study optimal sourcing when competing suppliers are asymmetrically informed about the costs of fulfilling the buyer's order. Both Wu and Zhang (2014) and Zhao et al. (2014) consider single-sourcing only. In contrast, our work focuses on supplier diversification driven by buyer default risk.

## 3. Model

Consider an economy consisting of manufacturing firms (or simply "firms" for short) and suppliers that transact over two periods. In each period, firms decide how much input to source from suppliers to produce their output. Production requires multiple inputs, or components, and one unit of each is required to produce one unit of output (e.g., a phone module and a screen to produce a smartphone). For ease of exposition, we assume that exactly two inputs are required for production.[4] Let $\mathbf{Q} := [Q^1; Q^2]$ denote the procured input quantities or inventory, and let $\mathbf{c} := [c^1; c^2]$ be the associated unit purchasing costs. Given procured inventory $\mathbf{Q}$, the production quantity is then $Q := \min\{\mathbf{Q}\} = \min\{Q^1, Q^2\}$. We also let $c := c^1 + c^2$ be the total input cost for one unit of output.

Firms can be one of two types: high quality and low quality, denoted by index $H$ and $L$, respectively. The firm's type is its private information. In each period, for given production quantity $Q$, a firm of type $i \in \{L, H\}$, or simply firm $i$, generates revenue $\pi_i(Q)$ if its product is a success, which occurs with probability $1 - b_i$. If its product is a failure, which occurs with probability $b_i$, the firm generates zero revenue. That is, the stochastic revenue that firm $i$ generates is given by

$$\tilde{\pi}_i(Q) := \begin{cases} \pi_i(Q) & \text{with probability } 1 - b_i, \\ 0 & \text{with probability } b_i. \end{cases} \tag{1}$$

We assume that $\pi_i(\cdot)$ is any generic differentiable, nondecreasing, and strictly concave function such that $\pi_i(0) = 0$ and $\lim_{Q\to\infty} \pi_i'(Q) = 0$ for $i \in \{L, H\}$.

High and low types differ in two ways. First, the high type is less likely to fail; that is, $b_H < b_L$. Therefore, if identified as high, a firm would secure more favorable trade credit terms from its suppliers, which provides both types with an incentive to signal "high." Second, conditional on success, the high type generates a higher revenue from each additional unit of output; that is, $\pi_H'(Q) > \pi_L'(Q)$. The reason we assume that a higher probability of success is associated with the ability to earn higher unit revenue is that both are likely to stem from superior management or operations capabilities. As we shall see, under this assumption firms signal by over-ordering inventory. If the reverse were true, that is, $\pi_H'(Q) < \pi_L'(Q)$, firms would signal by under-ordering. In Section 7.3, we analyze this alternative and show that our results continue to hold.

Firms start without any cash reserves and finance both inputs entirely through supplier trade credit. Suppliers are a priori homogeneous and each can produce both inputs without any disruption risk or capacity constraints. The supplier market is competitive, and suppliers engage in Bertrand competition, which has two implications. First, suppliers are price-takers with respect to $c^1$ and $c^2$. Second, trade credit is fairly priced; that is, suppliers charge a trade credit interest amount at which they expect to break even.[5] As we shall see, the nature of competition among suppliers may change throughout the game.

Consider now a supplier that receives in period $t$ an order for $\mathbf{Q} = [Q^1; Q^2]$ units of the two inputs from a firm. Because the supplier does not a priori know the firm's true type, it forms a belief $\beta_t$ based on the received order quantity $\mathbf{Q}$ and the entire firm history it has observed up to the beginning of period $t$. This history, which we denote with $\mathscr{F}_t$, comprises any previous orders placed by the firm with the supplier and information about whether the firm underwent bankruptcy reorganization at the end of the first period; we make the latter point precise when we discuss the sequence of events. Similar to Spence (1973), we posit the supplier's belief to be defined by an endogenous threshold $h_t$ and subsequently show its self-consistency in equilibrium:

$$\beta_t(\mathbf{Q}, \mathscr{F}_t) := \begin{cases} H & \text{if } Q^j \geq h_t(\mathscr{F}_t), \quad \forall j : Q^j > 0 \\ L & \text{otherwise} \end{cases}, \quad t \in \{1, 2\}. \tag{2}$$

In other words, the supplier believes the firm to be of the high type if and only if all input orders it receives from the firm are at or above some threshold.[6] The belief threshold $h_t$ is determined endogenously in equilibrium and depends on the time period and the observed history $\mathscr{F}_t$. To ease notation, we hereafter do not make the dependence of $h_t$ on the observed history explicit; that is, we write $h_t$ instead of $h_t(\mathscr{F}_t)$, but the reader should be cognizant of this dependence. In Section 7.1, we generalize our analysis by considering an arbitrary belief structure that is not necessarily threshold-type and show that our results continue to hold.

In each period, for any given inventory order $\mathbf{Q}$ and trade credit interest $r$, the expected payoff to firm $i$'s equity holders, or simply firm $i$'s payoff, is given by

$$v_i(\mathbf{Q}, r) := \mathbb{E}\max\{\tilde{\pi}_i(\min\{\mathbf{Q}\}) - \mathbf{c}^T\mathbf{Q} - r, 0\}, \tag{3}$$

where the max function captures limited liability.

Firms can follow one of two sourcing strategies. They can either procure both inputs from the same supplier (*single-sourcing*), or they can order each input from a different supplier (*multisourcing*). Firms choose their sourcing strategies, suppliers, and order quantities so as to maximize their equity value, that is, the sum of expected payoffs over the two periods. Let $\Pi_i^k$ be the equity value of a firm of type $i$ when it chooses to single-source ($k = S$) or multisource ($k = M$). To streamline exposition, we group equity values of high- and low-type firms under sourcing strategy $k \in \{M, S\}$ using vector notation $\mathbf{\Pi}^k := [\Pi_H^k; \Pi_L^k]$. Furthermore, we use the inequality operator "$\succ$" for vectors to denote Pareto dominance; that is, for vectors $\boldsymbol{x}$ and $\boldsymbol{y}$, $\boldsymbol{x} \succ \boldsymbol{y}$ means that $\boldsymbol{x}$ is component-wise greater than or equal to $\boldsymbol{y}$, $x_n \geq y_n$, and there is at least one component $n'$ for which $x_{n'} > y_{n'}$.

## Sequence of Events

The sequence of events is identical between the two sourcing modes, adjusting for singular or plural form with respect to supplier(s).

In period 1, the firm makes its sourcing decision and orders its two inputs. Upon observing the order, the firm's chosen suppliers update their beliefs about the firm type, set the trade credit interest accordingly, and deliver the goods. Finally, cash flows are realized, and if the firm succeeds, it repays its suppliers in full and distributes the residual revenue as dividends to equity holders. If the firm fails, it goes bankrupt.

In practice, bankrupt firms either reorganize their business and continue operating (Chapter 11, reorganization) or are liquidated (Chapter 7, liquidation). To capture both these outcomes and retain generality, we assume that conditional on bankruptcy at the end of period 1, the firm enters liquidation and leaves the market with probability $\eta \in (0, 1)$ or reorganizes and continues to operate in period 2 with probability $1 - \eta$. According to the American Bankruptcy Institute, Chapter 7 bankruptcies are generally more prevalent than Chapter 11 bankruptcies, implying that $\eta$ will be closer to one in practice. Because undergoing reorganization is part of a firm's public profile, we include it in the history $\mathscr{F}_2$ that suppliers use to form their beliefs.

In period 2, the firm either sources from its original suppliers, to whom it signaled its type in the first period, or approaches new, "uninformed" suppliers, and orders its inputs. Upon observing the order, the firm's chosen suppliers update their beliefs about the firm type, set the trade credit interest accordingly, and deliver the goods. Cash flows are realized, and trade credit is repaid if possible.

For convenience, we provide a summary of the events:

1. The firm observes its own type.

(First period begins.)

2. The firm chooses its suppliers and places its input orders.

3. The chosen suppliers observe the orders, update their beliefs, price trade credit accordingly, and deliver the goods. Note that this is equivalent to suppliers announcing up-front price schedules, in which prices include implicit interest and depend on the order being below or at/above a threshold, and firms choosing quantity.

4. The firm produces and sells output, and uncertainty is resolved:

(a) If the firm succeeds, it pays its suppliers, and shareholders, and continues to period 2.

(b) If the firm fails, with probability $\eta$, it is liquidated and exits the market; with probability $1-\eta$, it reorganizes and continues to period 2.

(Second period begins if the firm continues to operate.)

5. The firm either transacts with its original suppliers or chooses new, "uninformed" suppliers, and places its input orders.
6. The chosen suppliers observe the orders, update their beliefs (taking into account prior transactional history, if any), price trade credit accordingly, and deliver the goods.
7. The firm produces and sells output, uncertainty is resolved, and trade credit is repaid if possible.

Although the sequence of events is identical for the two sourcing strategies, the nature of supplier competition need not be. To make this precise, it is useful first to define the terms *informed* and *uninformed* supplier formally.

**Definition 1.** A supplier that forms the belief that the firm is of high type in period 1 is referred to as "informed" in period 2. A supplier that does not form this belief is referred to as "uninformed."

In period 1, suppliers' homogeneity leads to Bertrand competition as we argued previously. In period 2, however, the information gathered by some suppliers breaks this homogeneity. There are two cases: If the firm signaled its type to two suppliers in period 1, then both informed suppliers engage in Bertrand competition against each other in period 2, in addition to competing with the broader pool of uninformed suppliers. If the firm signaled its type to a single supplier in period 1, this informed supplier competes against the pool of uninformed suppliers in period 2.

In the latter case, when the firm transacts with the informed supplier in period 2, a bargaining game arises. Because our motivating context involves small start-up firms transacting with large well-established suppliers, it is natural to assume that bargaining power lies then with the supplier. We assume, for simplicity, that the supplier in this case has monopolistic bargaining power. In Section 7.5, we show that our results persist under any bargaining solution—including the Nash bargaining solution, the Kalai–Smorodinsky solution, and the egalitarian solution—except for the extreme case of the firm having monopolistic bargaining power, in which case there is no difference between single- and multisourcing.

Note that we assumed that any profits generated in the first period are distributed to equity holders via dividends and, thus, will not be used to finance inventory in the second period. This assumption ensures that suppliers play a dual role throughout both periods: they not only produce inputs, but also provide the necessary financing. The assumption can be relaxed without affecting our insights as long as the profit margin is relatively low so that the first-period proceeds are not sufficient to entirely finance the second-period inventory investment. This is reasonable given that a majority of B2B transactions are financed by trade credit as discussed earlier.

A couple of additional assumptions are made to simplify the exposition. First, regardless of the period, any inventory that is not used for production spoils and has no salvage value. Second, we assume that the low- and high-quality firms are not "excessively different," in which case the high type would be able to separate while following its first-best strategy, leading to a trivial equilibrium unaffected by information asymmetry. Formal statements will be made when necessary to make this assumption more precise.

Finally, we focus on characterizing least-cost pure-strategy perfect Bayesian separating equilibria (see relevant discussion in Section 2). We also study pooling equilibria in the Extensions Section 7.4.

Next, we define firms' first-best actions, which serve as a benchmark going forward.

### First Best Under Full Information

Absent information asymmetry, that is, when suppliers know each firm's type, the firms are indifferent between single- and multisourcing. It is clearly optimal for them to procure the same quantity of each input so that $Q^1 = Q^2 = Q$ in both periods. We refer to the inventory or production quantity that maximizes firm value in each period under full information as the *first-best* quantity and denote it with

$$Q_i^{fb} := \arg\max_{Q\geq 0}[\mathbb{E}\tilde{\pi}_i(Q) - cQ] \text{ for } i = L, H. \tag{4}$$

It is straightforward to show that the first-best quantity of the high type is larger; that is, $Q_H^{fb} > Q_L^{fb}$.

## 4. Main Result

We preface the formal analysis of our model with a summary of the paper's main findings and their underlying intuition.

High-quality firms, being less risky, can expect more favorable trade credit interest provided they credibly signal their type through their inventory orders. In turn, low-quality firms have an incentive to mimic the high types' order pattern so as to mislead suppliers into offering the same favorable interest. Because they extract higher value from each unit of inventory, high-quality firms are always able to signal their type in equilibrium, specifically by inflating their inventory orders to levels low-quality firms are not willing to imitate. Ideally, signaling in the first period serves as an "investment" that yields additional benefits in the form of lower signaling costs in the second period. As we discuss next, both the size and return of the signaling investment depend on the sourcing strategy.

Under single-sourcing, a high-quality firm entering the second period faces a single informed supplier that has an *informational monopoly* among suppliers. This leads to a holdup problem whereby the informed supplier is able to extract the entire value of the previously acquired information, leaving the firm with its reservation payoff (which the firm can obtain by contracting with new, uninformed suppliers). In other words, under single-sourcing, the first-period signaling investment does not yield any benefits in the second period, and the two periods decouple.

Under multisourcing, a high-quality firm entering the second period faces multiple informed suppliers competing with one another. This prevents the aforementioned informational monopoly and holdup. In other words, the first-period signaling now yields future benefits. However, it requires higher up-front investment. The reason is that the second-period competition between informed suppliers benefits *both* types. This provides the low type with a stronger incentive to mimic the high type's multisourcing strategy from the beginning, which, in turn, increases the high type's first-period signaling costs. In summary, high-quality firms face a trade-off between (a) higher initial signaling costs under multisourcing and (b) future holdup costs under single-sourcing.

Recall that $\Pi^M$ and $\Pi^S$ are the firms' equity values under multisourcing and single-sourcing, respectively. The main finding of our work, informally stated for now, is the following.

**Main Result.** Under buyer default risk, buyers prefer multisourcing over single-sourcing in equilibrium; that is,

$$\Pi^M \succ \Pi^S.$$

The next section presents a rigorous equilibrium analysis culminating in Theorem 1, which formalizes our main result.

Our finding identifies a new strategic dimension that buyers may want to consider when contemplating their long-term sourcing strategy. We argue that a firm's own riskiness, not just the riskiness of its suppliers, should be an important driver of its sourcing strategy. This finding complements the existing literature, which, up until now, has been debating the pros and cons of multisourcing primarily in the context of supplier risk.

The intuition behind our result is as follows. Under single-sourcing, because the two periods decouple, firms face the same signaling costs in both periods. Under multisourcing, firms are willing to incur higher signaling costs in the first period in exchange for lower signaling costs in the second. Whether this first-period signaling investment pays off is not obvious. Low-quality firms, being more prone to bankruptcy and, therefore, less likely to survive into the second period, put less weight on second-period outcomes. This allows high types to concentrate their signaling efforts in the first period, in which they are more effective at deterring the low types from mimicking. Therefore, under multisourcing, high-quality firms bear "somewhat" higher signaling costs in the first period in exchange for "much" lower signaling costs in the second. The net result is that multisourcing emerges as the preferred sourcing strategy in equilibrium.

## 5. Technical Analysis

Following backward induction, we start by analyzing the second-period subgame and then move on to characterizing the equilibrium of the full game.

### 5.1. Second Period Subgame

Depending on its first-period actions, a firm that continues its operations into the second period may have different sourcing options available. In particular, the firm may have access to either zero, one, or two informed suppliers. We analyze these cases separately.

**5.1.1. No Access to Informed Suppliers.** A firm that did not convince any suppliers of its high type in period 1 can only transact with uninformed suppliers in period 2. Although the firm can choose to either single-source or multisource, as we formally show in the proof of Lemma 1, these two sourcing modes are equivalent. Intuitively, this is because period 2 is the last period, and therefore, the firm cannot benefit from establishing relationships with multiple suppliers to avoid holdup in subsequent periods. For the ease of exposition, we continue the discussion assuming that the firm sources from a single supplier.

Because the two inputs are perfect complements, the firm orders the same quantity of each; that is, $Q^1 = Q^2 = Q$. After receiving the purchase order, the supplier delivers the goods, provides trade credit in the amount of $cQ$, and charges fair interest according to its belief regarding the firm type. In particular, if the supplier believes the firm to be of type $j$, it charges interest $r_j(Q)$, which is given by the break-even condition

$$\mathbb{E}\min\{cQ + r_j(Q), \tilde{\pi}_j(Q)\} = cQ. \tag{5}$$

Condition (5) ensures that the expected repayment to the supplier, which is the minimum of the amount due, $cQ + r_j(Q)$, and the firm's revenue, $\tilde{\pi}_j(Q)$, equals the credit amount $cQ$. Combining (5) with (1), we can write the fair interest explicitly as

$$r_j(Q) = \frac{b_j}{1 - b_j} cQ. \tag{6}$$

It is also useful to define the payoff of a firm of type $i$ sourcing input quantities $[Q; Q]$ from a supplier that believes the firm to be of type $j$ as

$$v_{ij}(Q) := v_i([Q; Q], r_j(Q)) = (1 - b_i)\left(\pi_i(Q) - \frac{cQ}{1 - b_j}\right). \quad (7)$$

Because $r_H(Q) < r_L(Q)$ for all $Q$, each firm, regardless of its true type, wants the supplier to believe that it is of high type and, thus, worth lower interest. As discussed earlier, the supplier forms its belief regarding the firm type based on the order quantity using a threshold decision rule (2). A separating equilibrium belief threshold used by uninformed suppliers in period 2, which we denote as $q$, is given by the following necessary and sufficient conditions:

$$\max_{Q<q} v_{HL}(Q) \le \max_{Q \ge q} v_{HH}(Q) \quad \text{and} \quad (8)$$

$$\max_{Q<q} v_{LL}(Q) \ge \max_{Q \ge q} v_{LH}(Q). \quad (9)$$

At a separating equilibrium, each type has to be identified correctly. Condition (8) ensures that a high-quality firm prefers to order a quantity at or above the threshold $q$ and be identified as high. Similarly, condition (9) ensures that a low-quality firm prefers to order a quantity below this threshold and be identified as low. Recall that according to (2), the equilibrium belief threshold $q$ could depend on whether the firm underwent bankruptcy reorganization or not. Thus, there are, in principle, two corresponding sets of equilibrium conditions (8) and (9). However, because the value to go of each type is independent of whether it underwent bankruptcy reorganization, the equilibrium conditions and, thus, the equilibrium belief threshold $q$ are identical in both cases. To simplify notation, we henceforth suppress dependence of $q$ on the reorganization event, and we do so subsequently for all other second-period thresholds. In addition, conditions (8) and (9) reveal that the equilibrium threshold $q$ is independent of the liquidation probability $\eta$.

Because there are generally multiple SEs, we adopt the Cho and Kreps (1987) intuitive criterion refinement, which eliminates any Pareto-dominated equilibria. We refer to any equilibria that survive as least-cost separating equilibria (LCSE). In our analysis, we limit our attention only to LCSE.[7] In the next lemma, we characterize firms' actions and payoffs in period 2 when sourcing from uninformed supplier(s).

**Lemma 1.** *When sourcing from uninformed suppliers in period 2,*

(i) *the low type orders its first best, that is, $Q_L^{fb}$ units of each input, and earns a payoff of $v_{LL}(Q_L^{fb})$;*

(ii) *the high type inflates its order to $q$ units of each input and earns a payoff of $v_{HH}(q)$, where $q$ is the larger of the two roots of*

$$v_{LH}(q) = v_{LL}(Q_L^{fb}). \quad (10)$$

The belief threshold $q$ is the order quantity such that the low type is indifferent between inflating its input orders up to $q$ units each and being perceived as high, and ordering its first best while being perceived as low. In equilibrium, the low type follows its first best whereas the high type needs to over-order up to $q$ units of each input to separate. Thus, it is the high type that bears the costs of information asymmetry as is usually the case in signaling games (Spence 1973).[8]

Note that regardless of how many informed suppliers a firm has access to, it has always the option to transact with new and, hence, uninformed suppliers in period 2. Therefore, sourcing from uninformed suppliers serves as an *outside option* for any firm in period 2, and we shall accordingly refer to a firm's payoff under this option as its *reservation payoff*.

**5.1.2. Access to One Informed Supplier.** Next, we turn our attention to a firm that has access to one and only one informed supplier in period 2. This would be the case if in period 1 the firm sourced from a single supplier to which it credibly signaled "high." Apart from sourcing both inputs from the informed supplier, the firm has its outside option as discussed previously.[9]

When transacting with the firm in period 2, the informed supplier may reaffirm or change the "high" belief it formed in period 1, depending on whether the firm takes actions consistent with being of high type in period 2. To this end, let $s_2$ be the order threshold for the firm to retain its characterization as high type in the second period. (Letter $s$ is mnemonic for *single*-sourcing and subscript 2 denotes period 2.) Thus, if the firm orders at or above $s_2$ in the second period, the informed supplier confirms its belief whereas, if the firm orders below $s_2$, the informed supplier updates its belief to "low." Because the threshold $s_2$ is determined jointly with the first-period belief threshold, we take $s_2$ as given for now and endogenize it once we analyze period 1. Because it is unnatural for a supplier to have a stricter rule for simply confirming high type than for identifying high type for the first time, we assume $s_2 \le q$.[10]

Importantly, the informed supplier has an informational advantage over its peers in the sense that it is no longer part of the perfectly competitive, uninformed, market. Rather, it can act as a "monopolist," dealing with a firm that has the uninformed market as its outside option. As such, upon receiving an order $Q \ge s_2$, the informed supplier charges the interest at which a high-quality firm earns its reservation payoff or fair interest, whichever is higher. Let $r_M(Q)$ be this "monopolistic" interest. Formally, $r_M(Q)$ is the maximum of the fair interest $r_H(Q)$ and the interest $r$ that satisfies

$$v_H([Q;Q], r) = v_{HH}(q). \tag{11}$$

Let us now discuss how a high-quality firm would transact with the informed supplier. Even if the firm reaffirms its high type by ordering at or above $s_2$, the supplier charges the monopolistic interest that extracts any value above the firm's reservation payoff (if there is any). Thus, the high type can never earn a payoff exceeding its reservation payoff $v_{HH}(q)$ by ordering from the informed supplier. This is the *informational holdup* effect.

We now switch our attention to the actions of a low-quality firm that managed to deceive its supplier in period 1 by signaling high.[11] The firm can deceive the informed supplier once again, this time by ordering $Q \geq s_2$. If it does, the supplier charges the monopolistic interest $r_M(Q)$. However, because the monopolistic interest is set as to extract all surplus from the high type, the firm (being of low type) may be able to retain some surplus despite paying this interest. Whether this is the case or not depends on the threshold $s_2$ as shown in the next lemma.

**Lemma 2.** *When having access to one and only one informed supplier in period 2,*

(i) *the high type is "held up," that is, it does not extract any benefit from having signaled "high" in period 1 and earns its reservation payoff $v_{HH}(q)$;*

(ii) *the low type earns a payoff*

$$\bar{v}_{LH} = \begin{cases} \max\limits_{Q \geq s_2} v_L([Q,Q], r_M(Q)) > v_{LL}(Q_L^{fb}) & \text{if } s_2 < q, \\ v_{LL}(Q_L^{fb}) & \text{otherwise.} \end{cases}$$

In summary, when having access to only one informed supplier in period 2, the high type fails to benefit from having established itself as high in period 1. This is because of the holdup problem, whereby the first-period supplier extracts the entire benefit of the acquired information. The low type would enjoy a second-period benefit of being identified as high in the first period if and only if the order quantity required to confirm one's high type, $s_2$, were lower than the order quantity required to signal high for the first time, $q$.

**5.1.3. Access to Two Informed Suppliers.** Consider a firm that has access to two informed suppliers because it multisourced and signaled high in period 1. An informed supplier may again reaffirm or change its belief formed in period 1, depending on the firm's second-period order quantity. Let $m_2$ be the order threshold required for an informed supplier to confirm its first-period belief. (Letter $m$ is mnemonic for *multi*sourcing and subscript 2 denotes period 2.) For now, we take $m_2$ as given and assume without any loss of generality that $m_2 \leq q$.[12]

In the second period, there is no difference between sourcing from one or two informed suppliers. The mere existence of two informed suppliers competing with one another eliminates the holdup problem and ensures that each of them offers fair credit terms. Let's suppose that the firm continues to source from both informed suppliers.[13] If the firm fails to reaffirm its high type by ordering $Q < m_2$, it is considered low type and earns a payoff that cannot exceed its reservation payoff. If the firm reaffirms its high type by ordering $Q \geq m_2$, it is charged fair interest as a high type, $r_H(Q)$, and it earns a payoff of

$$\max_{Q \geq m_2} v_{iH}(Q), \tag{12}$$

where $i$ is the firm's true type. Because signaling to informed suppliers is not more onerous than signaling to uninformed suppliers, that is, $m_2 \leq q$, this payoff is at least as good as the firm's reservation payoff. This leads to the following result.

**Lemma 3.** *When having access to two informed suppliers in period 2, a firm of type $i$, $i \in \{L, H\}$, earns a payoff of* $\max_{Q \geq m_2} v_{iH}(Q)$.

## 5.2. First Period

The sourcing strategy that a firm follows in period 1 determines the number of informed suppliers that are available to it in period 2. The number of informed suppliers available to a firm in period 2 then determines the firm's second-period payoff as discussed in Lemmas 1–3 and summarized in Table 1.

A firm realizes its second-period payoff given in Table 1 only if it continues to operate in the second period. Recall that a firm discontinues operations and leaves the market after period 1 if two events take place: the firm defaults in period 1, which happens with probability $b_i$ for type $i \in \{L, H\}$, and it is subsequently liquidated (according to Chapter 7 bankruptcy), which happens with probability $\eta$. Therefore, the probability that a firm of type $i$ continues to operate in period 2 is $1 - \eta b_i$. The firm's objective in period 1 is to maximize its equity value, which is the sum of its expected payoff in period 1 and its expected payoff in period 2.

**Table 1.** Summary of Firms' Period 2 Payoffs

| # Informed suppliers | High type | Low type |
|---|---|---|
| 0 | $v_{HH}(q)$ | $v_{LL}(Q_L^{fb})$ |
| 1 | $v_{HH}(q)$ | $\bar{v}_{LH} \geq v_{LL}(Q_L^{fb})$ |
| 2 | $\max\limits_{Q \geq m_2} v_{HH}(Q)$ | $\max\limits_{Q \geq m_2} v_{LH}(Q)$ |

In period 1, all suppliers are equally uninformed and, therefore, have the same belief thresholds. We denote suppliers' first-period belief thresholds under single-sourcing and multisourcing as $s_1$ and $m_1$, respectively. This means that a supplier uses belief threshold $s_1$ whenever it receives orders for both inputs, and it uses belief threshold $m_1$ whenever it receives an order for only one of the inputs. With this, we are ready to analyze firms' first-period actions under each sourcing strategy. We start with single-sourcing.

**5.2.1. Single-Sourcing.** Suppose the firm chooses to single-source in period 1. A separating equilibrium of the full two-period game under single-sourcing consists of the optimal input quantities that each type orders in each period and consistent belief thresholds $s_1$ and $s_2$ that satisfy the following necessary and sufficient conditions:

$$\max_{Q<s_1} v_{HL}(Q) \le \max_{Q\ge s_1} v_{HH}(Q) \quad \text{and} \tag{13}$$

$$\max_{Q<s_1} v_{LL}(Q) + (1-\eta b_L)v_{LL}(Q_L^{fb}) \ge \max_{Q\ge s_1} v_{LH}(Q) + (1-\eta b_L)\bar{v}_{LH}. \tag{14}$$

Condition (13) ensures that, in period 1, the high type is identified as high by ordering $Q \ge s_1$. Note that the high type's ordering decision in period 1 does not take into account period 2. This is because of the holdup problem, which eliminates any potential second-period benefits of being identified as high in period 1 by a *single* supplier. In other words, the high type's second-period payoff is the same whether it signals or not in period 1.

Condition (14) ensures that, in period 1, the low type is identified as low by ordering $Q < s_1$. Unlike the high type, the low type needs to take into account period 2 when choosing how much to order in period 1. This is because, for the low type, there is a potential second-period benefit of being misidentified as high in period 1 provided $s_2 < q$.

**Proposition 1.** *Under single-sourcing, there exists a unique LCSE under which in both periods*

(i) *the low type orders its first best $Q_L^{fb}$,*

(ii) *the high type inflates its orders to $q$ units, where $q$ is given in Lemma 1,*

*and the consistent belief thresholds are $s_1 = s_2 = q$. The firms' LCSE equity values are*

$$\Pi_L^S = (2-\eta b_L)v_{LL}(Q_L^{fb}) \quad \text{and} \quad \Pi_H^S = (2-\eta b_H)v_{HH}(q). \tag{15}$$

This equilibrium outcome reflects the informational holdup that arises under single-sourcing: establishing creditworthiness with only one supplier does not afford firms any advantage in future transactions because the informed supplier will use its unique position to extract the entire value of the acquired information. As a result, the two periods completely decouple, and firms interact in each period as if it were a single-period game.

**5.2.2. Multisourcing.** Suppose the firm chooses to source from two suppliers in period 1. A SE under multisourcing consists of the optimal quantities that each type orders in each period and consistent belief thresholds $m_1$ and $m_2$ that satisfy the following necessary and sufficient conditions:

$$\max_{Q<m_1} v_{HL}(Q) + (1-\eta b_H)v_{HH}(q) \le \max_{Q\ge m_1} v_{HH}(Q) + (1-\eta b_H)\max_{Q\ge m_2} v_{HH}(Q) \quad \text{and} \tag{16}$$

$$\max_{Q<m_1} v_{LL}(Q) + (1-\eta b_L)v_{LL}(Q_L^{fb}) \ge \max_{Q\ge m_1} v_{LH}(Q) + (1-\eta b_L)\max_{Q\ge m_2} v_{LH}(Q). \tag{17}$$

Condition (16) ensures that, in the first period, the high type signals by ordering $Q \ge m_1$, whereas condition (17) guarantees that the low type does not imitate and orders $Q < m_1$. Note that, in contrast to the single-sourcing game, under multisourcing the high type's decision to signal in the first period affects its payoff in the second period. This is because competition between the two informed suppliers in the second period allows the high type to reap the benefits of being identified as high in the first period. In other words, multisourcing eliminates informational holdup. The next proposition characterizes the LCSE.

**Proposition 2.** *Under multisourcing, there exists a LCSE under which*

(i) *the low type orders its first best $Q_L^{fb}$ in both periods,*

(ii) *the high type inflates its orders to $m_1$ units in period 1 and $m_2$ units in period 2,*

*and the consistent belief thresholds $m_1$ and $m_2$ satisfy*

$$m_1, m_2 \in \arg\max_{m_1,m_2\le q} [v_{HH}(m_1) + (1-\eta b_H)v_{HH}(m_2)]$$
$$\text{subject to} \quad (2-\eta b_L)v_{LL}(Q_L^{fb}) = v_{LH}(m_1) + (1-\eta b_L)v_{LH}(m_2). \tag{18}$$

*The firms' LCSE equity values are*

$$\Pi_L^M = (2-\eta b_L)v_{LL}(Q_L^{fb}) \quad \text{and}$$
$$\Pi_H^M = v_{HH}(m_1) + (1-\eta b_H)\,v_{HH}(m_2). \tag{19}$$

According to (18), the LCSE thresholds $(m_1, m_2)$ maximize the high type's equity value while ensuring that the low type is not willing to imitate. Although the optimization in (18) leaves open the possibility that there may be multiple LCSEs, by definition of the *least-cost* SE, all of these equilibria must result in the same firm equity values. In the next section, we compare firm equity values under single- and multisourcing.

### 5.3. Preferred Sourcing Mode

A firm's choice between single- and multisourcing comes down to a choice between the equilibrium equity values given in (15) and (19), respectively. In either case, the low-quality firm achieves first best and is, therefore, indifferent between the two sourcing modes. In contrast, the high-quality firm has to distort its order quantities to separate, incurring different signaling costs under each sourcing mode. Whether these costs are higher under single- or multisourcing depends on how the suppliers' equilibrium belief threshold under single-sourcing, $s_1 = s_2 = q$, compares with the equilibrium thresholds under multisourcing, $m_1$ and $m_2$. These thresholds determine how much the high type needs to over-order beyond its first best to signal. Therefore, the higher these thresholds, the higher the signaling costs, and the lower the high type's equity value.

Although we know that multisourcing eliminates holdup, it is not obvious that it is the preferred sourcing mode for the high type. The reason is that second-period competition between informed suppliers potentially benefits *both* types. This means that, under multisourcing, the low type is more eager to imitate in period 1, increasing the high type's first-period signaling cost. This reduces the attractiveness of multisourcing for the high type. The high type will be better off under multisourcing only if it can internalize greater benefit in period 2 than what it has to pay in higher signaling cost in period 1. As we show in Theorem 1, this is indeed the case.

**Theorem 1.** *Equilibrium firm values under multisourcing Pareto-dominate equilibrium firm values under single-sourcing; that is,*

$$\mathbf{\Pi}^M > \mathbf{\Pi}^S. \tag{20}$$

*Furthermore, the equilibrium belief thresholds satisfy* $m_1 > s_1 = q = s_2 > m_2$.

According to Theorem 1, the high type is able to enjoy the second-period benefits of multisourcing—no informational holdup—despite the higher efforts needed to deter the low type from imitating this strategy in period 1. This is possible because of the different weights that the two types put on the second period. The low-quality firms are more prone to bankruptcy and, therefore, less likely to survive into the second period. Whereas this has no effect on single-sourcing, under which the two periods decouple, it impacts multisourcing, under which the low type discounts second-period payoff more heavily than the high type. Consequently, the high type prefers to concentrate its signaling efforts into the first period, in which it is more effective at deterring the low type from mimicking. The result is the multisourcing belief structure in which $m_1 > q > m_2$: *the high type bears somewhat higher signaling cost in one period in exchange for much lower signaling cost in the next.*

Finally, note that it is conceivable that, in practice, compared with the high type, the low type could be more likely to liquidate following bankruptcy. This would affect the supplier's prior at the beginning of period 2 and how the two types discount the second-period payoffs. Whereas the former effect does not influence separating equilibria outcomes (see our discussion prior to Lemma 1), the low type being even less likely to continue into the second period would further weaken its incentive to imitate the high type's multisourcing strategy. The implication would be lower signaling costs and, thus, stronger preference for multisourcing by the high type.

## 6. Numerical Examples and Comparative Statics

In this section, we quantify the benefits of multisourcing using a series of numerical experiments. The firm equity values under each sourcing strategy are summarized in Table 2. Recall that, in equilibrium, it is only the high type who bears signaling costs and is, thus, affected by the choice of sourcing strategy. As can be seen from Table 2, the effect of sourcing strategy on the high type's equity value is driven by the equilibrium thresholds $q$, $m_1$, and $m_2$ (recall that these thresholds determine how much the high type needs to over-order to signal and, therefore, the magnitude of the signaling costs). Threshold $q$ can be obtained from (10), and $m_1$ and $m_2$ are given by (18). The latter two thresholds can be obtained by solving the following first-order conditions:

$$v'_{HH}(m_1) = \frac{(1-\eta b_H)v'_{LH}(m_1)}{(1-\eta b_L)v'_{LH}(m_2)} v'_{HH}(m_2),$$

$$\text{and} \quad (2-\eta b_L)v_{LL}(Q_L^{fb}) = v_{LH}(m_1) + (1-\eta b_L)v_{LH}(m_2).$$

**Table 2.** Summary of Firms' Equity Values

| Sourcing strategy | High type | Low type |
|---|---|---|
| Single-sourcing | $\Pi_H^S = (2-\eta b_H)v_{HH}(q)$ | $\Pi_L^S = (2-\eta b_L)v_{LL}(Q_L^{fb})$ |
| Multisourcing | $\Pi_H^M = v_{HH}(m_1) + (1-\eta b_H)v_{HH}(m_2)$ | $\Pi_L^M = (2-\eta b_L)v_{LL}(Q_L^{fb})$ |

Our model so far has considered only abstract operational differences between the two types, keeping the revenue function $\pi_i$ as general as possible. To quantify the performance differential between the two sourcing strategies, we need to adopt a specific functional form for $\pi_i$. We assume that when firm $i$'s product is a success, it is sold at price $P_i(Q)$, resulting in total revenue $\pi_i(Q) = QP_i(Q)$. We further assume that each firm's selling price is given by an isoelastic demand curve, that is, $P_i(Q) = \alpha_i Q^{-1/e}$, where $e > 1$ is demand elasticity, $\alpha_i$ measures demand level, and $\alpha_H \geq \alpha_L$. In this case, firm $i$'s revenue is

$$\pi_i(Q) = \alpha_i Q^{-1/e+1}.$$

Our numerical experiments are then based on the following base-case parameter values: $c = 1$, $a_L = 2.50$, $a_H = 2.54$, $e = 2$, $b_L = 0.5$, $b_H = 0.1$, and $\eta = 1$.

Figures 1 and 2 illustrate the effect of the high type's bankruptcy probability $b_H$ varying from 0% to 25% in increments of 1%. Figure 1 shows the high type's equilibrium order quantity (for each input) in the first and second periods and in aggregate. Dashed black is reserved for the single-sourcing threshold $q$, and solid black is reserved for the multisourcing thresholds, $m_1$ in period 1 and $m_2$ in period 2. These thresholds represent the firm's equilibrium order quantities. The first-best order quantity is represented by a dotted black line and always lies below the equilibrium orders. In other words, whether the firm decides to single-source or multisource, it needs to over-order compared with its first best to separate itself from the low type.

As can be seen in all subfigures of Figure 1, order quantities are decreasing with $b_H$, which is expected. In the first period, $q < m_1$; that is, firms that are multisourcing need to over-order comparatively more initially and, hence, incur larger up-front costs. In period 2, however, $m_2$ is not only below $q$, it is very close to the first best. In other words, having made a significant investment to signal to multiple suppliers in the first period, the high type can reap large benefits in the second period, in which it attains nearly its first best. Finally, the aggregate two-period order quantity under multisourcing is significantly lower than under single-sourcing. Specifically, multisourcing allows the high type to reduce the overall inventory distortion resulting from information asymmetry by approximately 21.2% on average. As shown in Figure 2, this leads to a considerably higher equity value. Namely, multisourcing enables the high-quality firm to increase value by approximately 13.7% on average.

Recall that the benefit of multisourcing hinges on the low type "caring less about future payoffs" because of its higher bankruptcy probability. The magnitude of this effect obviously depends the probability with which bankrupt firms are being liquidated, $\eta$. As the liquidation probability $\eta$ decreases, that is, bankrupt firms are more likely to be reorganized and continue operating in the second period, the discount factors of the two types become more similar, and the advantage of multisourcing becomes smaller. This is illustrated in Figures 3 and 4, which show the high type's equilibrium order quantities and equity value, respectively, as a function of the liquidation probability $\eta$. As $\eta$ approaches zero, the benefit of multisourcing fades. As $\eta$ varies between zero and one, we observe a 13.9% average reduction in operational distortions and a 6.2% average increase in equity value of the high-quality firm.

## 7. Model Extensions

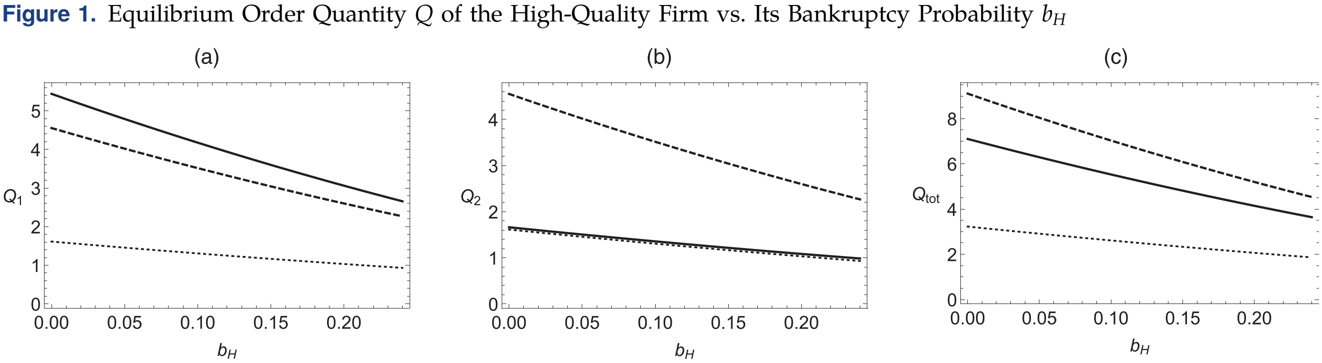
In this section, we verify the robustness of our results by considering several extensions and generalizations of the model we have studied thus far.

### 7.1. General Belief Structure

In Section 3, we assumed that suppliers' beliefs about their buyers' types were threshold-based. Under this belief structure, we showed that multisourcing yields a lower cost equilibrium than single-sourcing. In this section, we confirm that this result holds true even if we allow a general belief structure that is not necessarily threshold-based.

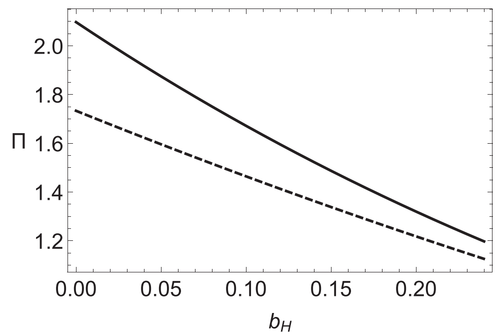
Consider a supplier that receives an order $\mathbf{Q}$ in period $t$. Recall that $\mathscr{F}_t$ is the set containing all information observed by the supplier up to that point, which

**Figure 1.** Equilibrium Order Quantity $Q$ of the High-Quality Firm vs. Its Bankruptcy Probability $b_H$




*Note.* (a) First period, (b) second period, and (c) total order; dotted: first best, solid: multisourcing, dashed: single-sourcing.

**Figure 2.** Equilibrium Equity Value of the High-Quality Firm $\Pi_H$ vs. Its Bankruptcy Probability $b_H$




*Note.* Solid: multisourcing, dashed: single-sourcing.

comprises prior order quantities and a record of reorganization or the lack thereof. We assume that the supplier forms a belief

$$\beta_t(\mathbf{Q}, \mathcal{F}_t) = \begin{cases} H & \text{if } \mathbf{Q} \in \mathcal{H}_t(\mathcal{F}_t) \\ L & \text{otherwise,} \end{cases}$$

where $\mathcal{H}_t(\mathcal{F}_t) \subset \mathbb{R}^2, t \in \{1, 2\}$ are arbitrary sets to which we shall refer as *belief sets*. All other elements of our model remain the same. In particular, we maintain our focus on pure-strategy separating equilibria, in which, by definition, the supplier is able to perfectly distinguish between the high and the low type; that is, it believes the firm to be of either high type or low type with probability one.

Let $\widetilde{\Pi}_i^k$ be the equity value of a firm of type $i$ when it chooses to single-source ($k = S$) or multisource ($k = M$) under an LCSE. We have the following result for this more general setting:

**Theorem 2.** *Equilibrium firm values under multisourcing Pareto-dominate equilibrium firm values under single-sourcing; that is,*

$$\widetilde{\mathbf{\Pi}}^M \succ \widetilde{\mathbf{\Pi}}^S.$$

### 7.2. Single Input

Multisourcing results in sustained competition among informed suppliers only if these suppliers are aware of the firm's sourcing strategy. In the base-case model, we assumed that production requires two complementary inputs. This gives rise to one mechanism through which a firm's suppliers could *infer* its sourcing strategy—for example, a supplier receiving an order for phone modules can infer that the firm sources the same quantity of screens from another supplier.

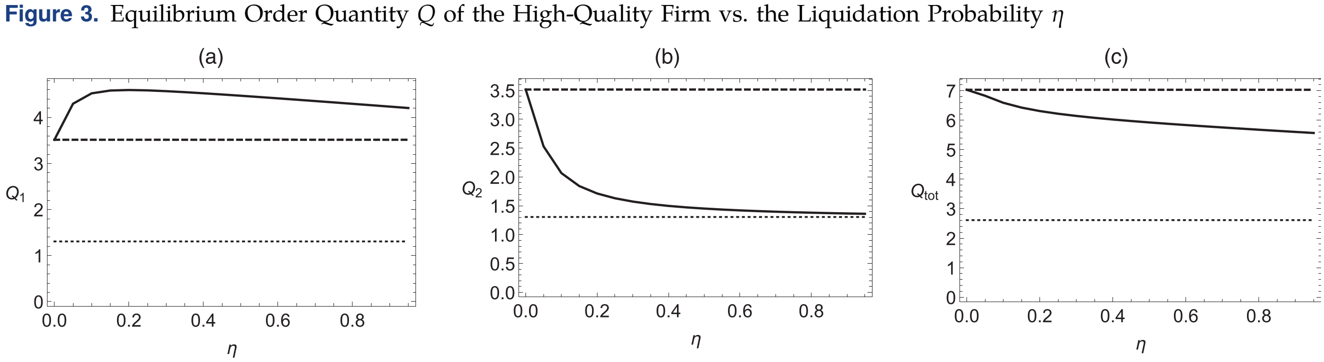
When a firm multisources a single input, that is, when it splits the order for a single input between two suppliers, inference of the firm's sourcing strategy through input complementarity is no longer possible. However, inference of sourcing strategy could still be possible as suppliers usually learn about the buyer's debt obligations in the process of extending trade credit. Indeed, to be able to assess risk in practice, creditors usually require information about the borrower's other debt obligations; see, for example, the guidelines of the U.S. Small Business Administration federal agency to borrowers, SBA (2017) or p. 84 in Buchheit (2000). By verifying the firm's debt obligations, which include accounts payable, that is, orders from other suppliers financed by trade credit, suppliers could then infer the firm's sourcing strategy. (Of course, only a supplier that receives a nonzero order is entitled to verify the buyer's other debt obligations.) Suppose that this is indeed the case; that is, suppliers of a multisourcing firm can infer each other's current-period sales to the firm. In this situation, our main result continues to hold even when production requires a single input as formally shown next.

**Proposition 3.** *If production requires a single input, equilibrium firm values under multisourcing Pareto-dominate equilibrium firm values under single-sourcing; that is,*

$$\mathbf{\Pi}^M \succ \mathbf{\Pi}^S.$$

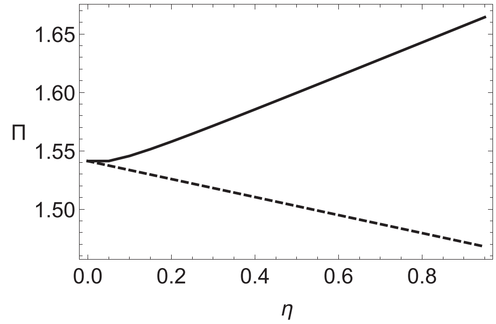
We remark that multiple least-cost separating equilibria could emerge here, in which a high-quality firm signals

**Figure 3.** Equilibrium Order Quantity $Q$ of the High-Quality Firm vs. the Liquidation Probability $\eta$




*Note.* (a) First period, (b) second period, and (c) total order; dotted: first best, solid: multisourcing, dashed: single-sourcing.

**Figure 4.** Equilibrium Equity Value of the High-Quality Firm $\Pi_H$ vs. the Liquidation Probability $\eta$




*Note.* Solid: multisourcing, dashed: single-sourcing.

to $N \geq 2$ suppliers by splitting its total order arbitrarily into $N$ individual orders. However, sourcing from more than two suppliers provides no additional benefit because the existence of two informed suppliers is enough to sustain price competition and eliminate the holdup problem.

## 7.3. Signaling by Under-ordering

In the base-case model, we assumed that the two types differ in two ways. First, the high type is less likely to fail, that is, $b_H < b_L$, and second, the high type generates a higher revenue from each additional unit of output conditional on success, that is, $\pi'_H(Q) > \pi'_L(Q)$. A higher probability of success could be associated with the ability to earn a higher unit revenue when both are a result of superior management or operations capabilities for example.

However, it is also conceivable that the reverse could be true, for example, when there exist two production technologies with the newer one being more efficient but also more prone to failure. In this case, a high type, that is, a firm that faces a lower risk of failure, would earn a lower net revenue on each unit produced conditional on success; that is, we have $b_H < b_L$ and $\pi'_H(Q) < \pi'_L(Q)$. Suppose further that the difference in marginal revenues is such that the first-best quantity of the high type falls below that of the low type; that is, $Q_H^{fb} < Q_L^{fb}$. We can show that as long as a firm's suppliers can observe each other's sales to the firm (see our discussion in Section 7.2), the high type can, in this case, signal by *under-ordering*. Observability is required to ensure that the low type cannot costlessly imitate the high type's under-ordering strategy by splitting its order for a given input among multiple suppliers.

Most important, we can show that our main result continues to hold. In particular, let $\widehat{\Pi}_i^k$ be the equity value of a firm of type $i$ when it chooses to single-source ($k = S$) or multisource ($k = M$) under an LCSE in this setting.

**Proposition 4.** *Equilibrium firm values under multisourcing Pareto-dominate equilibrium firm values under single-sourcing; that is,*

$$\widehat{\boldsymbol{\Pi}}^M > \widehat{\boldsymbol{\Pi}}^S.$$

As a closing remark, if the two types were precisely equally productive in the sense that $\pi'_H(Q) = \pi'_L(Q)$, signaling with inventory would no longer be possible; simply having a lower failure probability would not be enough to incent the high type to order more inventory under information asymmetry. To see this, note that, by Equation (7), the firms' objective in the second period boils down to maximizing payoff in the nonbankruptcy state, whose first derivative would be equal for both types in this case.

## 7.4. Pooling Equilibria

So far, we have restricted our attention to separating equilibria (SE), leaving aside any discussion of possible pooling outcomes. Here, we study equilibria that involve pooling and find that they are always dominated by least-cost SE as long as the proportion of low-quality firms is not "too small."

It is straightforward to show that any pooling outcome in the second period cannot survive the intuitive criterion refinement of Cho and Kreps (1987). However, we cannot eliminate the possibility that firms pool in the first period and separate in the second. Let $\ell$ be the proportion of low-quality firms in the economy, which is also suppliers' prior that a firm is of low type in period 1. Intuitively, if $\ell$ is very small, the fair interest under pooling, $r_P(Q)$, is not much different from the fair interest charged to a high type, $r_H(Q)$. In this case, the high type may prefer pooling to incurring the signaling cost, which is independent of $\ell$. If firms indeed pool in period 1, sourcing strategy is irrelevant because pooling is not informative and the number of first-period suppliers has no effect on a firm's payoff in period 2. Most important, we can show that when $\ell$ is sufficiently large, the high type is better off separating from the outset and, therefore, has a strict preference for multisourcing. We formalize the result in the next proposition.

**Proposition 5.** *There exists $\bar{\ell} \in (0,1)$ such that, if $\ell > \bar{\ell}$, the high type strictly prefers to separate from the low type in both periods and use multisourcing over any other equilibrium that survives the intuitive criterion.*

## 7.5. Bargaining Power

Recall that under a single-sourcing strategy, when the firm transacts with the single informed supplier in period 2, a bargaining game arises between them. Because our focus is on small, risky firms dealing with large, established suppliers, our base-case model assumed that, in this situation, the supplier has monopolistic bargaining power and extracts the maximum possible surplus. In this extension, we relax this assumption and show that our main result holds true for any bargaining solution—including the Nash bargaining solution, the Kalai–Smorodinsky solution, and the egalitarian solution—except for the extreme case of the firm having monopolistic bargaining power.

In particular, let $B$ be the firm's extracted surplus from the aforementioned bargaining game as a proportion of the firm's maximum possible surplus from bargaining. Loosely speaking, $B$ is a measure of the firm's bargaining power. The case of the supplier having monopolistic bargaining power, assumed in the base-case model, corresponds to $B = 0$. The Nash bargaining solution, the Kalai-Smorodinsky solution, and the egalitarian solution all correspond to values of $B \in (0, 1)$. We have the following result.

**Proposition 6.** *For any $0 \le B < 1$, equilibrium firm values under multisourcing Pareto-dominate equilibrium firm values under single-sourcing; that is,*

$$\mathbf{\Pi}^M \succ \mathbf{\Pi}^S.$$

Note that single-sourcing becomes equivalent to multisourcing if $B = 1$, that is, when the firm has monopolistic bargaining power. However, this case is incompatible with our intention of studying small, risky buyers sourcing from large, well-established suppliers.

## 8. Conclusion

Existing theories of supplier diversification are based on the premise that the bulk of the risk in trade relationships originates from suppliers. In this context, diversification is put forth as a means to hedge against supply-side risks. This view is well suited for situations in which large buyers source from smaller, riskier, or less well-established suppliers and has roots in the way traditional supply chains used to operate. But this setting is inadequate to describe sourcing strategies when the premise is reversed, for instance, when risky firms, such as SMEs or startups, are dealing with well-established suppliers. What's more, this alternative setting is increasingly relevant in modern modular supply chains, in which firms operate both as buyers and suppliers and can be exposed to risks on either side.

This paper argues that a firm's own risk can drive its sourcing strategy. Inspired by some of the difficulties that start-up firms often encounter in practice, we start from the premise that a firm's risk can represent an obstacle in its attempt to access a competitive supply market. In such situations, the firm has the incentive to make an up-front investment (i.e., take costly actions) to convince suppliers of its quality so as to unlock fair access to the market. So doing, however, could leave the firm exposed to supplier opportunism, which, in our model, takes the form of informational holdup. Supplier diversification can then be put forth as a means to alleviate this opportunism. By arguing that a firm's own riskiness, not just the riskiness of its suppliers, should be an important driver of its sourcing strategy, our work identifies a new strategic dimension that young firms and, in particular, start-ups, may want to consider when contemplating their long-term sourcing strategy.

There are some immediate extensions that would make our model more realistic but would not affect qualitative insights. For example, one may reflect the increased cost of complexity when dealing with multiple suppliers. Clearly, if this cost is high enough, it will eventually overcome the advantage of multisourcing identified here. More involved extensions that may provide potentially interesting insights could consider supplier heterogeneity (cost, quality, risk), different competitive structures of the supplier industry (e.g., oligopoly), alternative signaling mechanisms, and different types of buyer risk or supplier opportunism. Finally, there could be other channels through which buyer risk could motivate supplier diversification, which could be explored in future research.

## Appendix A. Proofs

### A.1. Proof of Lemma 1

We first prove that the expected payoffs of the two types satisfy the single crossing property; that is,

$$v_{LL}(Q_1) \le v_{LH}(Q_2) \Rightarrow v_{HL}(Q_1) < v_{HH}(Q_2) \tag{A.1}$$

for any $Q_2 > Q_1$. Suppose $Q_2 > Q_1$. Using (7), statement (A.1) can be written as

$$\frac{cQ_2}{1-b_H} - \frac{cQ_1}{1-b_L} \le \pi_L(Q_2) - \pi_L(Q_1)$$
$$\Rightarrow \frac{cQ_2}{1-b_H} - \frac{cQ_1}{1-b_L} < \pi_H(Q_2) - \pi_H(Q_1). \tag{A.2}$$

Thus, to prove (A.2), it is enough to prove

$$\pi_L(Q_2) - \pi_L(Q_1) < \pi_H(Q_2) - \pi_H(Q_1) \quad \Leftrightarrow \tag{A.3}$$

$$\int_{Q_1}^{Q_2} \pi_L'(Q)dQ < \int_{Q_1}^{Q_2} \pi_H'(Q)dQ, \tag{A.4}$$

which follows from the assumption $\pi_H'(Q) > \pi_L'(Q)$.

Next, we prove the desired result separately for sourcing from a single supplier and for sourcing from two suppliers.

#### A.1.1. Sourcing from a Single Supplier.

Because $v_{LH}(Q)$ is continuous and concave, $v_{LH}(0) = 0$, $v_{LH}(Q_L^{fb}) > v_{LL}(Q_L^{fb})$, and $\lim_{Q\to\infty} v_{LH}(Q) = -\infty$, Equation (10) has two roots, the larger of which satisfies $q > Q_L^{fb}$. To exclude trivial equilibria in which the high type can separate while ordering its first-best quantity, we assume $q > Q_H^{fb}$. Next, we show that, independent of whether the firm underwent reorganization, $q$ satisfies conditions (8) and (9), starting with the latter. Because $Q_L^{fb} < q$, the LHS of (9) is $v_{LL}(Q_L^{fb})$. Because $v_{LH}(Q)$ is decreasing for $Q \geq q$, the RHS of (9) is equal to $v_{LH}(q)$, and condition (9) is satisfied as equality.

Next, we prove that $q$ satisfies condition (8) by showing that $v_{HL}(Q) \leq v_{HH}(q)$ for any $Q < q$. Given (A.1), it is enough to show that $v_{LL}(Q) \leq v_{LH}(q)$ for any $Q < q$. This follows from (10) and the definition of $Q_L^{fb}$. Thus, we proved that $q$ satisfies both (8) and (9). This, the fact that $Q_L^{fb} < Q_H^{fb} < q$, and the concavity of $v_{HH}(Q)$ together imply that order quantities $[Q_L^{fb}, q]$ with the belief threshold $q$ are an SE.

To prove that this is an LCSE, we need to show that there is no SE in which the high type is better off. Because $v_{HH}(Q)$ is decreasing for $Q > q > Q_H^{fb}$, such an equilibrium would have to have a threshold belief $\bar{q} < q$. However, a threshold $\bar{q} < q$ cannot be an SE belief because, if it were, the low type could order $q - \varepsilon$, in which case it would be perceived as the high type and $v_{LH}(q - \varepsilon) > v_{LH}(q) = v_{LL}(Q_L^{fb})$.

#### A.1.2. Sourcing from Two Suppliers.

We first show, by contradiction, that a strategy profile in which either type orders $Q^1 \neq Q^2$ cannot be an SE. Suppose the high type chooses $Q^1 \neq Q^2$ at an SE. At any SE, the high type needs to choose $Q^1 \geq q$ and $Q^2 \geq q$. Because the inputs are perfect complements, the high type can always improve its payoff by simply reducing the larger of the two quantities. Thus, $Q^1 \neq Q^2$ cannot be the high type's SE quantities and similarly for the low type.

When a firm chooses $Q^1 = Q^2$, its payoff is the same as under single-sourcing. Thus, to prove that the order quantities and belief threshold characterized in Lemma 1 are a unique LCSE under multisourcing, it is enough to show that neither type can improve its payoff by deviating from this strategy profile to some $[Q^1, Q^2]$ such that $Q^1 \neq Q^2$. This follows again from the perfect complementarity of the two inputs. ∎

### A.2. Proof of Lemma 2

We consider the payoffs of the two types one by one.

#### A.2.1. High Type.

If the high type orders $Q < s_2$ from the informed supplier, it is considered low, and its payoff is necessarily below its reservation payoff.

If the high type orders $Q \geq s_2$ from the informed supplier, it is considered high, but the supplier charges interest $r_M(Q)$ that extracts any value above the firm's reservation payoff (if there is any).

Thus, in either case, the high type cannot earn more than its reservation payoff by ordering from the informed supplier. Therefore, its second-period payoff is always equal to its reservation payoff $v_{HH}(q)$.

#### A.2.2. Low Type.

To derive the low type's payoff, we consider two cases.

Case 1: $s_2 < q$. If the low type orders $Q < s_2$ from the informed supplier, it is recognized as low type and its payoff cannot exceed $v_{LL}(Q_L^{fb})$. Now suppose that the low type orders $Q \geq s_2$ from the informed supplier. It is considered a high type and charged the monopolistic interest $r_M(Q)$. Because the firm chooses the *optimal* order quantity, its payoff is $\max_{Q \geq s_2} v_L([Q,Q], r_M(Q))$. To prove that $\max_{Q \geq s_2} v_L([Q,Q], r_M(Q)) > v_{LL}(Q_L^{fb})$, we show that there exists a feasible order quantity $Q = q - \varepsilon \geq s_2$ such that $v_L([q-\varepsilon, q-\varepsilon], r_M(q-\varepsilon)) > v_{LL}(Q_L^{fb})$. Because $v_L([Q,Q], r_M(Q))$ is continuous, it is enough to show that (a) $v_L([q,q], r_M(q)) = v_{LL}(Q_L^{fb})$ and (b) $v_L([Q,Q], r_M(Q))$ is strictly decreasing in $Q \in [q-\varepsilon, q)$. To show (a), note that $r_M(q) = r_H(q)$, and so $v_L([q,q], r_M(q)) = v_{LH}(q) = v_{LL}(Q_L^{fb})$. To show (b), note that for any $Q \in [q-\varepsilon, q)$, we have $v_H([Q,Q], r_H(Q)) > v_{HH}(q)$, and so $r_M(Q)$ is given by (11). Thus,

$$r_M(Q) = \pi_H(Q) - cQ - \pi_H(q) + \frac{cq}{1-b_H} \text{ and, thus,} \tag{A.5}$$

$$v_L([Q,Q], r_M(Q)) = (1-b_L)\Big(\pi_L(Q) - \pi_H(Q) + \pi_H(q) - \frac{cq}{1-b_H}\Big), \text{ and} \tag{A.6}$$

$$\frac{d}{dQ} v_L([Q,Q], r_M(Q)) = (1-b_L)(\pi_L'(Q) - \pi_H'(Q)) < 0. \tag{A.7}$$

Thus, the low type orders $Q \geq s_2$ from the informed supplier and earns $\max_{Q \geq s_2} v_L([Q,Q], r_M(Q)) > v_{LL}(Q_L^{fb})$.

Case 2: $s_2 = q$. If the belief threshold of the informed supplier is as high as the belief threshold of uninformed suppliers, the low type cannot earn a payoff above its reservation payoff $v_{LL}(Q_L^{fb})$. ∎

### A.3. Proof of Lemma 3

The result follows directly from the discussion preceding Lemma 3. ∎

### A.4. Proof of Proposition 1

To establish the result, we consider two cases.

Case 1: $s_2 = q$. Using Lemma 2, the firms' second-period payoffs become independent of their first-period actions, the equilibrium conditions (13) and (14) simplify into (8) and (9), and the first period is thus equivalent to a single-period game in the absence of informed suppliers. Invoking Lemma 1, the only first-period order quantities and belief threshold that can be an LCSE are $(Q_L^{fb}, q)$ and $s_1 = q$, and they result in first-period payoffs $v_{HH}(q)$ and $v_{LL}(Q_L^{fb})$ for the two types, respectively. In the second period, the high type orders $q$ units from either the informed supplier or an uninformed supplier, in each case earning $v_{HH}(q)$. The low type orders its first best and earns $v_{LL}(Q_L^{fb})$.

Case 2: $s_2 < q$. It follows from Lemma 2 and condition (14) that $\max_{Q < s_1} v_{LL}(Q) > \max_{Q \geq s_1} v_{LH}(Q)$. Invoking (10), this inequality implies $s_1 > q$, which, in turn, implies that the high type's first-period payoff is below $v_{HH}(q)$. Because the high type's second-period payoff is always $v_{HH}(q)$ and the low type's payoff in each period is $v_{LL}(Q_L^{fb})$, any SE with $s_2 < q$ is Pareto-dominated by the SE where $s_2 = q$.

Thus, the SE where $s_2 = q$ is the unique LCSE. ∎

### A.5. Proof of Proposition 2

We first prove the existence of an SE by verifying that the low type ordering $Q_L^{fb}$ and the high type ordering $q$ in each period and belief thresholds $m_1 = m_2 = q$ is an SE. If we substitute $q$ for both $m_1$ and $m_2$, the equilibrium conditions (16) and (17) simplify into (8) and (9), which are satisfied by the definition of $q$. Under this belief structure, the two-period problem decouples into two single-period problems, and we know from Lemma 1 that the order quantities $Q_L^{fb}$ and $q$, and belief threshold $q$ are indeed an SE.

Next, we characterize an LCSE. Suppose $m_1 \le Q_H^{fb}$. Because $Q_H^{fb} < q$, this implies $m_1 < q$. This together with $m_2 \le q$ means that (17) cannot be satisfied. Hence, we must have $m_1 > Q_H^{fb}$, and conditions (16) and (17) simplify into

$$\max_Q v_{HL}(Q) + (1-\eta b_H)v_{HH}(q) \le v_{HH}(m_1) + (1-\eta b_H)\max_{Q\ge m_2} v_{HH}(Q) \quad \text{and} \tag{A.8}$$

$$v_{LL}(Q_L^{fb}) + (1-\eta b_L)v_{LL}(Q_L^{fb}) \ge v_{LH}(m_1) + (1-\eta b_L)\max_{Q\ge m_2} v_{LH}(Q). \tag{A.9}$$

Now suppose $m_2 < Q_H^{fb}$. This cannot correspond to an LCSE because any SE under this belief structure is strictly Pareto-dominated by the same SE with $m_2$ being replaced by $Q_H^{fb}$. (This is because replacing $m_2$ with $Q_H^{fb}$ will not change the second-period payoff of the high type, but it will strictly reduce the second-period payoff of the low type that signals in the first period. This will, in turn, decrease the low type's willingness to signal in the first period captured by $m_1$. Because $m_1 > Q_H^{fb}$, reducing $m_1$ will reduce the high type's first-period signaling cost.) Thus, at any LCSE, we must have $m_2 \ge Q_H^{fb}$.

The fact that $m_2 \ge Q_H^{fb}$ implies that both $v_{HH}(Q)$ and $v_{LH}(Q)$ are decreasing for $Q \ge m_2$ and, therefore, conditions (A.8) and (A.9) simplify into

$$\max_Q v_{HL}(Q) + (1-\eta b_H)v_{HH}(q) \le v_{HH}(m_1) + (1-\eta b_H)v_{HH}(m_2) \text{ and} \tag{A.10}$$

$$v_{LL}(Q_L^{fb}) + (1-\eta b_L)v_{LL}(Q_L^{fb}) \ge v_{LH}(m_1) + (1-\eta b_L)v_{LH}(m_2). \tag{A.11}$$

The LCSE belief structure is one that maximizes the high type's total equilibrium payoff, which is the RHS of (A.10), while ensuring that the low type does not imitate; that is, condition (A.11) holds.

Finally, suppose condition (A.11) is satisfied as a strict inequality for some SE belief structure $(m_1, m_2)$. If this is the case, there must be some $(m_1 - \varepsilon, m_2)$ that also satisfies condition (A.11) but results in a strictly larger RHS of (A.10). Thus, $(m_1, m_2)$ cannot be an LCSE. Therefore, at any LCSE condition, (A.11) must be satisfied as an equality, and the desired result follows. ∎

### A.6. Proof of Theorem 1

Note that $m_1 = m_2 = q$ satisfies conditions (16) and (17); that is, $m_1 = m_2 = q$ is an SE under multisourcing. Furthermore, firm equity values at this particular multisourcing SE are the same as those under the single-sourcing LCSE.

Next, we show that, under multisourcing, this particular SE is not an LCSE; that is, we show that $m_1 = m_2 = q$, which is clearly a feasible solution of problem (18), is not its optimal solution. To do that, we reformulate (18) as

$$m_1 \in \arg\max_{m_1 \ge q}\left[v_{HH}(m_1) + (1-\eta b_H)v_{HH}(m_2(m_1))\right], \tag{A.12}$$

where function $m_2(m_1)$ is given implicitly by the larger root of

$$(2-\eta b_L)v_{LL}(Q_L^{fb}) = v_{LH}(m_1) + (1-\eta b_L)v_{LH}(m_2). \tag{A.13}$$

Taking the total derivative of the objective function in (A.12) w.r.t. $m_1$ yields

$$v'_{HH}(m_1) - \frac{(1-\eta b_H)v'_{LH}(m_1)}{(1-\eta b_L)v'_{LH}(m_2)}v'_{HH}(m_2). \tag{A.14}$$

Evaluating this derivative at $m_1 = q$ gives

$$v'_{HH}(q)\left(1 - \frac{(1-\eta b_H)}{(1-\eta b_L)}\right) > 0. \tag{A.15}$$

Thus, $m_1 = q$ cannot be the optimal solution of (A.12); that is, $m_1 = m_2 = q$ cannot be the optimal solution of (18) even though it is clearly feasible. Therefore, the optimal solution of (18) must provide a larger value of the objective than $m_1 = m_2 = q$ does. This means that, under multisourcing, the LCSE must result in a larger payoff for the high type than the SE where $m_1 = m_2 = q$, which gives the same payoffs as the LCSE under single-sourcing.

Finally, note that according to (18), $m_2 = q$ implies $m_1 = q$. Because this is not an LCSE under multisourcing, an LCSE must have $m_2 < q$, which, according to (18), requires $m_1 > q$. This, together with Proposition 1, implies that the LCSE thresholds satisfy $m_1 > s_1 = q = s_2 > m_2$. ∎

### A.7. Proof of Theorem 2

To introduce some notation first, we denote the information available to a supplier at the beginning of the second period with $\mathcal{F}_2 = (\mathbf{Q}, I)$, where $\mathbf{Q}$ and $I$ are interpreted as follows. If the supplier transacted with the firm before, $\mathbf{Q}$ is the prior order it received; otherwise, we write $\mathbf{Q} = \emptyset$. The signal $I$ equals $R$ or $NR$, depending on whether the firm went through reorganization or not. We can then write the second-period belief set $\mathcal{H}_2(\mathcal{F}_2)$ also as $\mathcal{H}_2(\mathbf{Q}, I)$. Because no information is available at the beginning of the first period, we write the first-period belief set simply as $\mathcal{H}_1$.

Consider some belief sets $\mathcal{H}_t(\mathcal{F}_t)$ for $t \in \{1, 2\}$ and all possible $\mathcal{F}_t$'s that are consistent with a separating equilibrium. The existence of such a collection of sets is guaranteed by our analysis in Section 5 that identified interval sets of the form $[h, \infty)$, which formed a threshold-type SE belief system. Because under an SE the low type orders its first-best quantity and no order below that quantity is credible in either period, we have

$$\mathcal{H}_t(\mathcal{F}_t) \subset (Q_L^{fb}, \infty) \times (Q_L^{fb}, \infty), \quad \forall \mathcal{F}_t, \quad t \in \{1, 2\}. \tag{A.16}$$

We analyze the single-sourcing strategy first. Consider a firm in period 2. There are two cases: the firm has access to either one informed supplier or none. Let $\tilde{v}_i(1, \mathcal{F}_2)$ be the second-period payoff of type $i$ if it has access to one informed supplier that has observed $\mathcal{F}_2 = (\mathbf{Q}, I)$. Let also $\tilde{v}_i(0, \mathcal{F}_2)$ be the second-period payoff of type $i$ if it has access only to uniformed suppliers that have observed $\mathcal{F}_2 = (\emptyset, I)$. (We are assuming without a loss that the firm will never source from a supplier to which it signaled low in period 1.) These payoffs are generalizations of the payoffs we derived in Lemmata 1–3. We can characterize these second-period payoffs as follows:

- When having access to no informed suppliers, the firm transacts with a new supplier, and $\mathcal{F}_2 = (\emptyset, I)$. The firm can then can signal high or low, and if its true type is $i$, its payoff is given by

$$\tilde{v}_i(0,(\emptyset,I)) = \max\left\{\max_{[Q;Q]\in\mathcal{H}_2(\emptyset,I)} v_{iH}(Q), \max_{[Q;Q]\notin\mathcal{H}_2(\emptyset,I)} v_{iL}(Q),\right\}, \quad i\in\{L,H\}, \tag{A.17}$$

where $v_{ij}(\cdot)$ was defined in (7).

- When having access to one informed supplier, using similar arguments as in the proof of Lemma 2, it can be readily seen that a firm of high type is "held up" and, therefore,

$$\tilde{v}_H(1,(\mathbf{Q},I)) = \tilde{v}_H(0,(\emptyset,I)), \quad \forall(\mathbf{Q},I). \tag{A.18}$$

A firm of low type always has the option of transacting with an uninformed supplier and, thus,

$$\tilde{v}_L(1,(\mathbf{Q},I)) \ge \tilde{v}_L(0,(\emptyset,I)), \quad \forall(\mathbf{Q},I). \tag{A.19}$$

Consider now the full two-period game. At an SE, the low type signals its true type in both periods and obtains its first-best payoff, $v_{LL}(Q_L^{fb})$. Therefore, in the second period, it has no access to informed suppliers. Combining these two facts and (A.17), we get that

$$v_{LL}(Q_L^{fb}) = \tilde{v}_L(0,(\emptyset,I)) \ge \max_{[Q;Q]\in\mathcal{H}_2(\emptyset,I)} v_{LH}(Q), \quad \forall I. \tag{A.20}$$

Consider now the critical quantity $q$ we introduced in Lemma 1. As we showed in the proof of that Lemma, we have that $v_{LH}(Q) > v_{LL}(Q_L^{fb})$ for all $Q_L^{fb} < Q < q$. Therefore, we conclude that

$$\mathcal{H}_2(\emptyset,I) \subset [q,\infty)\times[q,\infty), \quad \forall I. \tag{A.21}$$

To derive the SE conditions for the first period, let's consider first the off-equilibrium path in which the low type orders a quantity $Q\in\mathcal{H}_1$ and imitates the high type. Its expected payoff is then given by

$$v_{LH}(Q) + \mathbb{E}[\tilde{v}_L(1,([Q;Q],I)\mathbf{1}_C],$$

where $\mathbf{1}_C$ is the indicator of the firm continuing into the second period, and the expectation is taken over bankruptcy and reorganization. Under an SE, the low type shall be better off revealing its true type rather than imitating the high type. That is,

$$\max_{[Q;Q]\in\mathcal{H}_1}\{v_{LH}(Q) + \mathbb{E}[\tilde{v}_L(1,([Q;Q],I)\mathbf{1}_C]\} \le (2-\eta b_L)v_{LL}(Q_L^{fb}), \tag{A.22}$$

where the right-hand side of the inequality is the low-type's expected payoff under an SE (cf. Proposition 1).

Suppose now that there exists a $\overline{\mathbf{Q}} = [\overline{Q};\overline{Q}]\in\mathcal{H}_1$ such that $v_{LH}(\overline{Q}) > v_{LL}(Q_L^{fb})$. That leads to the following contradiction:

$$\begin{aligned}
&\max_{[Q;Q]\in\mathcal{H}_1}\{v_{LH}(Q) + \mathbb{E}[\tilde{v}_L(1,([Q;Q],I)\mathbf{1}_C]\}\\
&\quad\ge v_{LH}(\overline{Q}) + \mathbb{E}[\tilde{v}_L(1,(\overline{\mathbf{Q}},I)\mathbf{1}_C] \ge v_{LH}(\overline{Q}) + \mathbb{E}[\tilde{v}_L(0,(\emptyset,I)\mathbf{1}_C]\\
&\quad= v_{LH}(\overline{Q}) + \mathbb{E}[v_{LL}(Q_L^{fb})\mathbf{1}_C] > v_{LL}(Q_L^{fb}) + (1-\eta b_L)v_{LL}(Q_L^{fb})\\
&\quad= (2-\eta b_L)v_{LL}(Q_L^{fb}),
\end{aligned}$$

where the second inequality follows from (A.19), the first equality from the equality in (A.20), and the final inequality from evaluating the continuation probability and our assumption above. Given that $v_{LH}(Q) \le v_{LL}(Q_L^{fb})$ for all $[Q;Q]\in\mathcal{H}_1$, we conclude that

$$\mathcal{H}_1 \subset [q,\infty)\times[q,\infty). \tag{A.23}$$

We now switch our attention to the high type. In the second period, as we remarked previously, the high type is "held up," and therefore, we can assume without a loss that under an SE it transacts with an uninformed supplier. Consequently, we get

$$\tilde{v}_H(0,(\emptyset,I)) = \max_{[Q;Q]\in\mathcal{H}_2(\emptyset,I)} v_{HH}(Q) \le v_{HH}(q), \quad \forall I, \tag{A.24}$$

where the equality follows from (A.17) and the fact that the high type signals its type under an SE and the inequality from (A.21) and the fact that $v_{HH}$ is decreasing in $[q,\infty)$. Suppose that, in the first period under an SE, the high type orders $\widetilde{\mathbf{Q}} = [\widetilde{Q};\widetilde{Q}]\in\mathcal{H}_1$. Then, its payoff is given by

$$\begin{aligned}
v_{HH}(\widetilde{Q}) + \mathbb{E}[\tilde{v}_H(1,(\widetilde{\mathbf{Q}},I)\mathbf{1}_C] &= v_{HH}(\widetilde{Q}) + \mathbb{E}[\tilde{v}_H(0,(\emptyset,I)\mathbf{1}_C]\\
&\le v_{HH}(\widetilde{Q}) + \mathbb{E}[v_{HH}(q)\mathbf{1}_C]\\
&= v_{HH}(\widetilde{Q}) + (1-\eta b_H)v_{HH}(q)\\
&\le v_{HH}(q) + (1-\eta b_H)v_{HH}(q)\\
&= (2-\eta b_H)v_{HH}(q),
\end{aligned}$$

where the first equality follows from (A.18), the first inequality from (A.24), and the second inequality from (A.23) and the fact that $v_{HH}$ is decreasing in $[q,\infty)$. Given that the belief system and $\widetilde{\mathbf{Q}}$ were arbitrarily chosen so as to only satisfy necessary conditions for an SE, we get that

$$\widetilde{\Pi}_H^S \le (2-\eta b_H)v_{HH}(q).$$

To complete the proof, note that the LCSE equity value of a multisourcing high type under this more general game, $\widetilde{\Pi}_H^M$, is greater than or equal to the LCSE equity value of a multisourcing high type under the original game, $\Pi_H^M$. Thus,

$$\widetilde{\Pi}_H^M \ge \Pi_H^M > (2-\eta b_H)v_{HH}(q) \ge \widetilde{\Pi}_H^S,$$

where the strict inequality follows from Theorem 1. ■

### A.8. Proof of Proposition 3

We prove the result by showing that our base-case two-input model and a model in which production requires a single input with a unit cost $c = c^1 + c^2$ are equivalent; that is, they result in the same payoffs for both types as functions of production quantity $Q$ and thresholds $q, s_1, s_2, m_1, m_2$. Under single-sourcing, the number of inputs is clearly irrelevant as one can think of the two inputs as a single input with cost $c = c^1 + c^2$.

Next, consider multisourcing in either period. For any given production quantity $Q$, value of type $i$ is $v_i(Q,r) := \mathbb{E}\max\{\tilde{\pi}_i(Q) - cQ - r(Q), 0\}$ in both two-input and single-input scenarios. Thus, it is enough to show that for any given production quantity $Q$ and belief threshold $t$, each type is charged the same total interest $r(Q)$ in both scenarios. We characterize this interest in the two scenarios next.

**A.8.1. Total Interest in the Base-case Two-input Scenario.** Recall that a multisourcing firm orders $Q$ units of one input from one supplier and $Q$ units of the other input from another supplier. If supplier of input $i$ believes the firm to be of type $j$, it charges fair interest $r_j^i(Q)$ that satisfies the break-even condition

$$(1-b_j)(c^iQ + r_j^i(Q)) = c^iQ,$$

where the RHS is the input cost and the LHS is the expected payment. Thus, this interest can be written explicitly as $r_j^i(Q) = \frac{b_j}{1-b_j}c^iQ$. Because each supplier forms its belief by comparing the order quantity $Q$ and threshold $t$, the total interest faced by the firm is

$$r(Q) = \begin{cases} r_H^1(Q) + r_H^2(Q) = \dfrac{b_H}{1-b_H}cQ & \text{if } Q \geq t, \\[2ex] r_L^1(Q) + r_L^2(Q) = \dfrac{b_L}{1-b_L}cQ & \text{otherwise.} \end{cases} \tag{A.25}$$

**A.8.2. Total Interest in the Single-input Scenario.** Suppose that a firm splits the total input order $Q$ between two suppliers in arbitrary proportions $\gamma_1 \in (0,1)$ and $\gamma_2 = 1-\gamma_1$. If supplier $i$ believes the firm to be of type $j$, it charges fair interest that satisfies the break-even condition

$$(1-b_j)(c\gamma_iQ + r_j^i(\gamma_iQ)) = c\gamma_iQ,$$

and is, thus, equal to $r_j^i(\gamma_iQ) = \frac{b_j}{1-b_j}c\gamma_iQ$. Because each of the two suppliers forms its belief by comparing the total order quantity $Q$ and threshold $t$, the firm faces total interest

$$r(Q) = \begin{cases} r_H^1(\gamma_1Q) + r_H^2(\gamma_2Q) = \dfrac{b_H}{1-b_H}cQ & \text{if } Q \geq t, \\[2ex] r_L^1(\gamma_1Q) + r_L^2(\gamma_2Q) = \dfrac{b_L}{1-b_L}cQ & \text{otherwise.} \end{cases} \tag{A.26}$$

Because the two scenarios lead to the same trade credit interests and, thus, the same firm values, they also result in the same equilibrium payoffs. Therefore, Theorem 1 continues to hold in the single-input scenario. ∎

## A.9. Proof of Proposition 4

Suppose without loss of generality that production requires two inputs and the suppliers' belief structure is

$$\beta := \begin{cases} H & \text{if } Q \leq t, \\ L & \text{otherwise,} \end{cases} \quad j \in \{1,2\}, \tag{A.27}$$

for some endogenous threshold $t$. We first consider the second period.

**A.9.1. No Access to Informed Suppliers.** This situation is equivalent to a single-period game, so there is no difference between single- and multisourcing, We assume for simplicity that firms source from a single supplier. The only difference from our base-case is that the conditions for a separating equilibrium belief threshold $q$ change as follows:

$$\max_{Q>q} v_{HL}(Q) \leq \max_{Q\leq q} v_{HH}(Q) \quad \text{and} \tag{A.28}$$

$$\max_{Q>q} v_{LL}(Q) \geq \max_{Q\leq q} v_{LH}(Q). \tag{A.29}$$

Next, we prove that, analogously to Lemma 1, the low type orders its first best, $Q_L^{fb}$, of each input and earns $v_{LL}(Q_L^{fb})$ whereas the high type reduces its order to $q$ units of each input and earns $v_{HH}(q)$, where $q$ is the smaller of the two roots of

$$v_{LH}(q) = v_{LL}(Q_L^{fb}). \tag{A.30}$$

We first show that the expected payoffs of the two types satisfy the following property; that is,

$$v_{LL}(Q_2) \leq v_{LH}(Q_1) \Rightarrow v_{HL}(Q_2) < v_{HH}(Q_1) \tag{A.31}$$

for any $Q_2 > Q_1$. Suppose $Q_2 > Q_1$. Using (7), statement (A.31) can be written as

$$\frac{cQ_1}{1-b_H} - \frac{cQ_2}{1-b_L} \leq \pi_L(Q_1) - \pi_L(Q_2)$$

$$\Rightarrow \frac{cQ_1}{1-b_H} - \frac{cQ_2}{1-b_L} < \pi_H(Q_1) - \pi_H(Q_2). \tag{A.32}$$

Thus, to prove (A.32), it is enough to prove

$$\pi_L(Q_1) - \pi_L(Q_2) < \pi_H(Q_1) - \pi_H(Q_2) \Leftrightarrow \tag{A.33}$$

$$\pi_L(Q_2) - \pi_L(Q_1) > \pi_H(Q_2) - \pi_H(Q_1) \Leftrightarrow \tag{A.34}$$

$$\int_{Q_1}^{Q_2} \pi_L'(Q)dQ > \int_{Q_1}^{Q_2} \pi_H'(Q)dQ, \tag{A.35}$$

which follows from the assumption $\pi_L'(Q) > \pi_H'(Q)$.

Because $v_{LH}(Q)$ is continuous and concave, $v_{LH}(0) = 0$, $v_{LH}(Q_L^{fb}) > v_{LL}(Q_L^{fb})$, and $\lim_{Q\to\infty} v_{LH}(Q) = -\infty$, Equation (A.30) has two roots, the smaller of which satisfies $q < Q_L^{fb}$. To exclude trivial equilibria in which the high type can separate while ordering its first-best quantity, we assume $q < Q_H^{fb}$. Next, we show that $q$ satisfies conditions (A.28) and (A.29), starting with the latter. Because $Q_L^{fb} > q$, the LHS of (A.29) is $v_{LL}(Q_L^{fb})$. Because $v_{LH}(Q)$ is increasing for $Q \leq q$, the RHS of (A.29) is equal to $v_{LH}(q)$, and condition (A.29) is satisfied as an equality.

Next, we prove that $q$ satisfies condition (A.28) by showing that $v_{HL}(Q) \leq v_{HH}(q)$ for any $Q > q$. Given (A.31), it is enough to show that $v_{LL}(Q) \leq v_{LH}(q)$ for any $Q > q$. This follows from (A.30) and the definition of $Q_L^{fb}$. Thus, we proved that $q$ satisfies both (A.28) and (A.29). This, the fact that $q < \min\{Q_L^{fb}, Q_H^{fb}\}$, and the concavity of $v_{HH}(Q)$ together imply that order quantities $[Q_L^{fb}, q]$ with the belief threshold $q$ are an SE.

To prove that this is an LCSE, we need to show that there is no SE in which the high type is better off. Because $v_{HH}(Q)$ is increasing for $Q < q < Q_H^{fb}$, such an equilibrium would have to have a threshold belief $\bar{q} > q$. However, a threshold $\bar{q} > q$ cannot be an SE belief because, if it were, the low type could order $q+\varepsilon$, in which case it would be perceived as the high type and $v_{LH}(q+\varepsilon) > v_{LH}(q) = v_{LL}(Q_L^{fb})$.

**A.9.2. Access to One Informed Supplier.** Analogously to the base case, we assume without any loss of generality that $s_2 \geq q$. We prove that analogously to Lemma 2, the high type earns its reservation payoff $v_{HH}(q)$ whereas the low type earns a payoff

$$\bar{v}_{LH} = \begin{cases} \max_{Q \leq s_2} v_L([Q,Q], r_M(Q)) > v_{LL}(Q_L^{fb}) & \text{if } s_2 > q, \\ v_{LL}(Q_L^{fb}) & \text{otherwise.} \end{cases}$$

Consider the high type first. If the high type orders $Q > s_2$ from the informed supplier, it is considered low, and its payoff is necessarily below its reservation payoff. If the high type orders $Q \leq s_2$ from the informed supplier, it is considered high, but the supplier charges interest $r_M(Q)$ that extracts any potential value above the firm's reservation payoff. Thus, the high type cannot earn more than its reservation payoff by ordering from the informed supplier. Therefore, its second-period payoff is always equal to its reservation payoff $v_{HH}(q)$.

To derive the low type's payoff, we consider two cases.

Case 1: $s_2 > q$. If the low type orders $Q > s_2$ from the informed supplier, it is recognized as low type, and its payoff cannot exceed $v_{LL}(Q_L^{fb})$. Now suppose that the low type orders $Q \leq s_2$ from the informed supplier. It is considered a high type and charged the monopolistic interest $r_M(Q)$. Because the firm chooses the *optimal* order quantity, its payoff is $\max_{Q \leq s_2} v_L([Q,Q], r_M(Q))$. To prove that $\max_{Q \leq s_2} v_L([Q,Q], r_M(Q)) > v_{LL}(Q_L^{fb})$, we show that there exists a feasible order quantity $Q = q + \varepsilon \leq s_2$ such that $v_L([q+\varepsilon, q+\varepsilon], r_M(q+\varepsilon)) > v_{LL}(Q_L^{fb})$. Because $v_L([Q,Q], r_M(Q))$ is continuous, it is enough to show that (a) $v_L([q,q], r_M(q)) = v_{LL}(Q_L^{fb})$ and (b) $v_L([Q,Q], r_M(Q))$ is strictly increasing in $Q \in (q, q+\varepsilon]$. To show (a), note that $r_M(q) = r_H(q)$, and so $v_L([q,q], r_M(q)) = v_{LH}(q) = v_{LL}(Q_L^{fb})$. To show (b), note that for any $Q \in (q, q+\varepsilon]$, we have $v_H([Q,Q], r_H(Q)) > v_{HH}(q)$, and so $r_M(Q)$ is given by (11). Thus,

$$r_M(Q) = \pi_H(Q) - cQ - \pi_H(q) + \frac{cq}{1-b_H} \text{ and, thus,} \tag{A.36}$$

$$v_L([Q,Q], r_M(Q)) = (1-b_L)\left(\pi_L(Q) - \pi_H(Q) + \pi_H(q) - \frac{cq}{1-b_H}\right), \text{ and} \tag{A.37}$$

$$\frac{d}{dQ} v_L([Q,Q], r_M(Q)) = (1-b_L)(\pi_L'(Q) - \pi_H'(Q)) > 0. \tag{A.38}$$

Thus, the low type orders $Q \leq s_2$ from the informed supplier and earns $\max_{Q \leq s_2} v_L([Q,Q], r_M(Q)) > v_{LL}(Q_L^{fb})$.

Case 2: $s_2 = q$. If the belief threshold of the informed supplier is as low as the belief threshold of uninformed suppliers, the low type cannot earn a payoff above its reservation payoff $v_{LL}(Q_L^{fb})$.

**A.9.3. Access to Two Informed Suppliers.** Analogously to the base case, we assume without any loss of generality that $m_2 \geq q$. If a firm fails to reaffirm its high type by ordering $Q > m_2$, it is considered low type and earns a payoff that cannot exceed its reservation payoff. If a firm reaffirms its high type by ordering $Q \leq m_2$, it is charged fair interest as a high type, $r_H(Q)$, and it earns a payoff of

$$\max_{Q \leq m_2} v_{iH}(Q), \tag{A.39}$$

where $i$ is the firm's true type. Because $m_2 \geq q$, this payoff is at least as good as the firm's reservation payoff. This leads to a result analogous to Lemma 3; that is, a firm of type $i$, $i \in \{L, H\}$, earns a payoff of $\max_{Q \leq m_2} v_{iH}(Q)$.

We are ready to consider the full two-period game.

***Single-Sourcing.*** Under single-sourcing, the SE belief thresholds $s_1$ and $s_2$ are given by

$$\max_{Q > s_1} v_{HL}(Q) \leq \max_{Q \leq s_1} v_{HH}(Q) \quad \text{and} \tag{A.40}$$

$$\max_{Q > s_1} v_{LL}(Q) + (1-\eta b_L) v_{LL}(Q_L^{fb}) \geq \max_{Q \leq s_1} v_{LH}(Q) + (1-\eta b_L)\bar{v}_{LH}. \tag{A.41}$$

We prove that, analogously to Proposition 1, there exists an LCSE under which in both periods the low type orders its first best $Q_L^{fb}$, the high type reduces its orders to $q$ units, $s_1 = s_2 = q$, and the equity values are

$$\Pi_L^S = (2-\eta b_L) v_{LL}(Q_L^{fb}) \quad \text{and} \quad \Pi_H^S = (2-\eta b_H) v_{HH}(q). \tag{A.42}$$

We do so by considering two cases.

Case 1: $s_2 = q$. The firms' second-period payoffs are independent of their first-period actions, the equilibrium conditions (A.40) and (A.41) simplify into (A.28) and (A.29), and the first period is equivalent to a single-period game in the absence of informed suppliers. Therefore, it has an LCSE order quantities $(Q_L^{fb}, q)$ and a consistent belief threshold $s_1 = q$, resulting in first-period payoffs $v_{HH}(q)$ and $v_{LL}(Q_L^{fb})$ for the two types, respectively. In the second period, the high type orders $q$ units from either the informed supplier or an uninformed supplier, in each case earning $v_{HH}(q)$. The low type orders its first best and earns $v_{LL}(Q_L^{fb})$.

Case 2: $s_2 > q$. The fact that $\bar{v}_{LH} > v_{LL}(Q_L^{fb})$ together with condition (A.41) implies that $\max_{Q > s_1} v_{LL}(Q) > \max_{Q \leq s_1} v_{LH}(Q)$. This implies that $s_1 < q$, and the high type's first-period payoff is below $v_{HH}(q)$. Because the high type's second-period payoff is always $v_{HH}(q)$ and the low type's payoff in each period is $v_{LL}(Q_L^{fb})$, any SE with $s_2 > q$ is Pareto-dominated by the SE where $s_2 = q$.

***Multisourcing.*** Under multisourcing, the SE belief thresholds $m_1$ and $m_2$ are given by

$$\max_{Q > m_1} v_{HL}(Q) + (1-\eta b_H) v_{HH}(q) \leq \max_{Q \leq m_1} v_{HH}(Q) + (1-\eta b_H) \max_{Q \leq m_2} v_{HH}(Q) \quad \text{and} \tag{A.43}$$

$$\max_{Q > m_1} v_{LL}(Q) + (1-\eta b_L) v_{LL}(Q_L^{fb}) \geq \max_{Q \leq m_1} v_{LH}(Q) + (1-\eta b_L) \max_{Q \leq m_2} v_{LH}(Q). \tag{A.44}$$

We prove that analogously to Proposition 2, there exists an LCSE under which the low type orders its first best $Q_L^{fb}$ in both periods, the high type reduces its orders to $m_1$ units in period 1 and $m_2$ units in period 2, $m_1$ and $m_2$ satisfy

$$m_1, m_2 \in \arg\max_{m_1,m_2\geq q}\left[v_{HH}(m_1) + (1-\eta b_H)v_{HH}(m_2)\right]$$
$$\text{subject to } (2-\eta b_L)v_{LL}(Q_L^{fb}) = v_{LH}(m_1) + (1-\eta b_L)v_{LH}(m_2), \quad \text{(A.45)}$$

and the equity values are

$$\Pi_L^M = (2-\eta b_L)v_{LL}(Q_L^{fb}) \quad \text{and}$$
$$\Pi_H^M = v_{HH}(m_1) + (1-\eta b_H)v_{HH}(m_2). \quad \text{(A.46)}$$

Similar to the base case, we can verify that the low type ordering $Q_L^{fb}$ and the high type ordering $q$ in each period and $m_1 = m_2 = q$ is an SE. Next, we characterize an LCSE. Suppose $m_1 \geq Q_H^{fb}$. Because $Q_H^{fb} > q$, this implies $m_1 > q$. This together with $m_2 \geq q$ means that (A.44) cannot be satisfied. Hence, we must have $m_1 < Q_H^{fb} < Q_L^{fb}$, and conditions (A.43) and (A.44) simplify into

$$\max_{Q>m_1} v_{HL}(Q)+(1-\eta b_H)v_{HH}(q) \leq v_{HH}(m_1) + (1-\eta b_H)\max_{Q\leq m_2} v_{HH}(Q) \quad \text{and} \quad \text{(A.47)}$$
$$v_{LL}(Q_L^{fb}) + (1-\eta b_L)v_{LL}(Q_L^{fb}) \geq v_{LH}(m_1) + (1-\eta b_L)\max_{Q\leq m_2} v_{LH}(Q). \quad \text{(A.48)}$$

Now suppose $m_2 > Q_H^{fb}$. This cannot correspond to an LCSE because any SE under this belief structure is strictly Pareto-dominated by the same SE with $m_2$ being replaced by $Q_H^{fb}$. (This is because replacing $m_2$ with $Q_H^{fb}$ will not change the second-period payoff of the high type, but it will strictly reduce the second-period payoff of the low type that signals in the first period. This will, in turn, decrease the low type's willingness to signal in the first period captured by $m_1$. Because $m_1 < Q_H^{fb}$, increasing $m_1$ will reduce the high type's first-period signaling cost.) Thus, at any LCSE, we must have $m_2 \leq Q_H^{fb}$. This implies that both $v_{HH}(Q)$ and $v_{LH}(Q)$ are increasing for $Q \leq m_2$, and therefore, conditions (A.47) and (A.48) simplify into

$$\max_{Q>m_1} v_{HL}(Q) + (1-\eta b_H)v_{HH}(q) \leq v_{HH}(m_1) + (1-\eta b_H)v_{HH}(m_2) \quad \text{and} \quad \text{(A.49)}$$

$$v_{LL}(Q_L^{fb}) + (1-\eta b_L)v_{LL}(Q_L^{fb}) \geq v_{LH}(m_1) + (1-\eta b_L)v_{LH}(m_2). \quad \text{(A.50)}$$

The LCSE belief structure is one that maximizes the high type's total equilibrium payoff, which is the RHS of (A.49) while ensuring that conditions (A.49) and (A.50) hold. Suppose condition (A.50) is satisfied as a strict inequality for some SE belief structure $(m_1, m_2)$. If this is the case, there must be some $(m_1 + \varepsilon, m_2)$ that also satisfies condition (A.50) but results in a strictly larger RHS of (A.49). Thus, $(m_1, m_2)$ cannot be an LCSE. Therefore, at any LCSE condition, (A.50) must be satisfied as an equality.

It remains to show that $m_1$ and $m_2$ given in (A.45) satisfy condition (A.49). Because $m_1 = m_2 = q$ is a feasible solution to (A.45), the optimal solution to (A.45) satisfies

$$v_{HH}(m_1) + (1-\eta b_H)v_{HH}(m_2) \geq v_{HH}(q) + (1-\eta b_H)v_{HH}(q).$$

Thus, to show that the optimal solution to (A.45) satisfies condition (A.49), it is enough to show that it satisfies the following:

$$\max_{Q>m_1} v_{HL}(Q) + (1-\eta b_H)v_{HH}(q) \leq v_{HH}(q) + (1-\eta b_H)v_{HH}(q).$$

Thus, it is enough to show that $v_{HL}(Q) \leq v_{HH}(q)$ for any $Q$. We have already shown previously that this is true for any $Q > q$. Now suppose that $Q \leq q$. The fact that $q < Q_H^{fb}$ implies $v_{HH}(Q) \leq v_{HH}(q)$, which, in turn, implies. $v_{HL}(Q) \leq v_{HH}(q)$.

**A.9.4. Preferred Sourcing Mode.** Having characterized the separating equilibria under both single- and multisourcing, it remains to show $\boldsymbol{\Pi}^M > \boldsymbol{\Pi}^S$. Note that $m_1 = m_2 = q$ satisfies conditions (A.43) and (A.44); that is, $m_1 = m_2 = q$ is an SE under multisourcing. Furthermore, firm equity values at this particular multisourcing SE are the same as those under the single-sourcing LCSE. Next, we show that under multisourcing, this particular SE is not an LCSE; that is, we show that $m_1 = m_2 = q$, which is clearly a feasible solution of problem (A.45), is not its optimal solution. To do that, we reformulate (A.45) as

$$m_1 \in \arg\max_{m_1\leq q}\left[v_{HH}(m_1) + (1-\eta b_H)v_{HH}(m_2(m_1))\right], \quad \text{(A.51)}$$

where function $m_2(m_1)$ is given implicitly by the smaller root of

$$(2-\eta b_L)v_{LL}(Q_L^{fb}) = v_{LH}(m_1) + (1-\eta b_L)v_{LH}(m_2). \quad \text{(A.52)}$$

Taking the total derivative of the objective function in (A.51) w.r.t. $m_1$ yields

$$v'_{HH}(m_1) - \frac{(1-\eta b_H)v'_{LH}(m_1)}{(1-\eta b_L)v'_{LH}(m_2)}v'_{HH}(m_2). \quad \text{(A.53)}$$

Evaluating this derivative at $m_1 = q$ gives

$$v'_{HH}(q)\left(1 - \frac{(1-\eta b_H)}{(1-\eta b_L)}\right) < 0. \quad \text{(A.54)}$$

Thus, $m_1 = q$ cannot be the optimal solution of (A.51); that is, $m_1 = m_2 = q$ cannot be the optimal solution of (A.45) even though it is clearly feasible. Therefore, the optimal solution of (A.45) must provide a larger value of the objective than $m_1 = m_2 = q$ does. This means that, under multisourcing, the LCSE must result in a larger payoff for the high type than the SE where $m_1 = m_2 = q$, which gives the same payoffs as the LCSE under single-sourcing. ■

### A.10. Proof of Proposition 5

We first show that no equilibrium in which firms pool in period 2 can survive the intuitive criterion. Consider an equilibrium in which in period 2 both types order $Q^P$ units of each input. (It is immaterial whether a firm uses one or two suppliers in the last period.) Let $r_P(Q)$ and $v_{iP}(Q) := v_i([Q,Q], r_P(Q))$ be the fair interest and value of type $i$, respectively, when suppliers cannot distinguish between the two types. We define $\hat{Q}$ as the largest quantity to which the low type would be willing to deviate in period 2 if it meant being perceived as high. Formally, $\hat{Q}$ is the larger root of

$$\begin{aligned} &v_{LP}(Q^P) = v_{LH}(\hat{Q}) \\ &\Leftrightarrow (1-b_L)(\pi_L(Q^P) - cQ^P - r_P(Q^P)) = (1-b_L)(\pi_L(\hat{Q}) - c\hat{Q} - r_H(\hat{Q})) \\ &\Leftrightarrow c\hat{Q} + r_H(\hat{Q}) - cQ^P - r_P(Q^P) = \pi_L(\hat{Q}) - \pi_L(Q^P). \end{aligned} \tag{A.55}$$

Next, we show that the high type would strictly prefer deviating to $\hat{Q}$ if it meant being perceived as high; that is,

$$\begin{aligned} &v_{HP}(Q^P) < v_{HH}(\hat{Q}) \\ &\Leftrightarrow (1-b_H)(\pi_H(Q^P) - cQ^P - r_P(Q^P)) < (1-b_H) \\ &\qquad \cdot (\pi_H(\hat{Q}) - c\hat{Q} - r_H(\hat{Q})). \end{aligned} \tag{A.56}$$

Using (A.55), inequality (A.56) is equivalent to

$$\pi_L(\hat{Q}) - \pi_L(Q^P) < \pi_H(\hat{Q}) - \pi_H(Q^P). \tag{A.57}$$

Inequality (A.57) follows from the proof of Lemma 1 and the fact that $\hat{Q} > Q^P$. Because the low type would not deviate to $\hat{Q} + \varepsilon$ even if it meant being perceived as high whereas the high type would, associating $\hat{Q} + \varepsilon$ with $\beta = L$ would violate the intuitive criterion. Associating $\hat{Q} + \varepsilon$ with $\beta = H$ cannot be an equilibrium belief at all because the high type would deviate. Thus, there is no equilibrium in which firms pool in period 2 that would survive the intuitive criterion.

It remains to consider an equilibrium in which the two types pool in period 1 and separate in period 2. (Because pooling is not informative, it is immaterial whether firms single- or multisource.) Because there are no informed suppliers in period 2, the high type's equity value under this equilibrium is

$$\Pi_H^P = v_{HP}(Q^P) + (1-\eta b_H)v_{HH}(q),$$

where $Q^P$ is the first-period order quantity of either type. We define

$$\bar{\Pi}_H^P := \max_{Q \geq 0} v_{HP}(Q) + (1-\eta b_H)v_{HH}(q).$$

Thus, $\bar{\Pi}_H^P$ is an upper bound on the high type's equity value under any equilibrium in which the two types pool in period 1. To prove the desired result, it is enough to show that there exists $\bar{\ell} \in (0,1)$ such that if $\ell > \bar{\ell}$, then $\Pi_H^M > \bar{\Pi}_H^P$. Because $\Pi_H^M$ is independent of $\ell$ and $\bar{\Pi}_H^P$ is continuous in $\ell$, it is enough to show that $\Pi_H^M > \lim_{\ell \to 1} \bar{\Pi}_H^P$. Using Theorem 1, it is enough to show

$$\begin{aligned} &\Pi_H^S \geq \lim_{\ell \to 1} \bar{\Pi}_H^P \\ &\Leftrightarrow v_{HH}(q) + (1-\eta b_H)v_{HH}(q) \geq \lim_{\ell \to 1} [\max_{Q \geq 0} v_{HP}(Q) \\ &\qquad + (1-\eta b_H)v_{HH}(q)] \\ &\Leftrightarrow v_{HH}(q) \geq \lim_{\ell \to 1} [\max_{Q \geq 0} v_{HP}(Q)] \\ &\Leftrightarrow v_{HH}(q) \geq \max_{Q \geq 0} v_{HL}(Q). \end{aligned}$$

The last inequality follows directly from the proof of Lemma 1. ■

### A.11. Proof of Proposition 6

Under single-sourcing in period 2, the high type's reservation payoff is $v_{HH}(q)$ whereas the supplier's reservation payoff is zero. If a firm reaffirms its high type by ordering at/above $s_2$, the supplier believes that the total expected payoff of the two parties is $v_{HH}(s_2)$, resulting in total gain of $v_{HH}(s_2) - v_{HH}(q)$. Thus, the supplier charges an interest $r_B(Q)$ so that the firm, which the supplier believes to be high type, receives fraction $B$ of this gain; that is,

$$v_H([Q,Q], r_B(Q)) = v_{HH}(q) + B(v_{HH}(Q) - v_{HH}(q)). \tag{A.58}$$

It is straightforward to show that, in an LCSE under single-sourcing, we must have $s_1 \geq q \geq s_2$, and the high type's payoff is

$$\begin{aligned} \Pi_H^S = &\max_{s_1, s_2 \leq q} [v_{HH}(s_1) + (1-\eta b_H)v_H([s_2,s_2], r_B(s_2))] \\ &\text{subject to } (2-\eta b_L)v_{LL}(Q_L^{fb}) \\ &\quad = v_{LH}(s_1) + (1-\eta b_L)v_L([s_2,s_2], r_B(s_2)). \end{aligned} \tag{A.59}$$

Using (A.58) and the definition of $v_i([Q,Q],r) = (1-b_i)(\pi_i(Q) - cQ - r)$, this is equivalent to

$$\begin{aligned} \Pi_H^S = &\max_{s_1, s_2 \leq q} [v_{HH}(s_1) + (1-\eta b_H)((1-B)v_{HH}(q) + Bv_{HH}(s_2))] \\ &\text{subject to } (2-\eta b_L)v_{LL}(Q_L^{fb}) \\ &\quad = v_{LH}(s_1) + (1-\eta b_L)(1-b_L) \\ &\qquad \cdot \left(\pi_L(s_2) - \pi_H(s_2) + \frac{(1-B)v_{HH}(q) + Bv_{HH}(s_2)}{(1-b_H)}\right). \end{aligned} \tag{A.60}$$

This can be equivalently thought of as

$$\Pi_H^S = \max_{s_1} [v_{HH}(s_1) + (1-\eta b_H)((1-B)v_{HH}(q) + Bv_{HH}(s_2(s_1)))], \tag{A.61}$$

where function $s_2(s_1)$ is given implicitly by the larger root of

$$\begin{aligned} (2-\eta b_L)v_{LL}(Q_L^{fb}) = &v_{LH}(s_1) + (1-\eta b_L)(1-b_L) \\ &\cdot \left(\pi_L(s_2) - \pi_H(s_2) + \frac{(1-B)v_{HH}(q) + Bv_{HH}(s_2)}{(1-b_H)}\right). \end{aligned} \tag{A.62}$$

Because $\Pi_H^M = \Pi_H^S(B=1)$, we can prove the desired result by showing that $\Pi_H^S$ given in (A.61) strictly increases in $B$. We show that by proving that the objective of (A.61), which we denote by $\Psi$, strictly increases in $B$ for any $s_1 \geq q$. We have

$$\frac{d\Psi}{dB} = \frac{\partial \Psi}{\partial B} + \frac{\partial s_2}{\partial B}\frac{\partial \Psi}{\partial s_2},$$

where $\frac{\partial s_2}{\partial B}$ is given by implicit differentiation of (A.62). We have

$$\begin{aligned} \frac{d\Psi}{dB} = &(1-\eta b_H)(-v_{HH}(q) + v_{HH}(s_2)) \\ &+ \frac{\partial s_2}{\partial B}(1-\eta b_H)Bv'_{HH}(s_2), \end{aligned}$$

$$\text{where } \frac{\partial s_2}{\partial B} = \frac{\dfrac{v_{HH}(q) - v_{HH}(s_2)}{(1-b_H)}}{\pi'_L(s_2) - \pi'_H(s_2) + \dfrac{Bv'_{HH}(s_2)}{(1-b_H)}}.$$

Thus, $\frac{d\Psi}{dB} > 0$ if and only if

$$-v_{HH}(q) + v_{HH}(s_2) + \frac{\dfrac{v_{HH}(q) - v_{HH}(s_2)}{(1-b_H)}}{\pi_L'(s_2) - \pi_H'(s_2) + \dfrac{Bv_{HH}'(s_2)}{(1-b_H)}} Bv_{HH}'(s_2) > 0. \tag{A.63}$$

We know that the desired result holds when $s_2 = q$, in which case the two periods decouple, so we can assume without any loss of generality that $s_2 < q$. Using the fact that $v_{HH}(s_2) > v_{HH}(q)$, inequality (A.63) is equivalent to

$$1 - \frac{\dfrac{1}{(1-b_H)}}{\pi_L'(s_2) - \pi_H'(s_2) + \dfrac{Bv_{HH}'(s_2)}{(1-b_H)}} Bv_{HH}'(s_2) > 0.$$

This follows directly from the facts that $\pi_L'(s_2) < \pi_H'(s_2)$ and $v_{HH}'(s_2) < 0$. ■

## Endnotes

[1] Similarly, a volume discount argument would predict Meizu to be better off sourcing both components from a single supplier. To add to the puzzle, smartphone components having largely been commoditized (Cheng 2016), alternative explanations based on price, yield, and/or quality differences between suppliers would likely also fall short at rationalizing this type of diversification strategy.

[2] See, for example, Lai et al. (2012), Schmidt et al. (2015), and Lai and Xiao (2016).

[3] A separating equilibrium is one in which the uninformed player's belief is degenerate, or a singleton, after any equilibrium path history. A least-cost SE is an SE that maximizes the high type's payoff.

[4] In Section 7.2, we show under what conditions our results extend if the firm sources a single input.

[5] Without loss of generality, we normalize suppliers' cost of capital and the risk-free rate to zero.

[6] Associating a higher order quantity with the high-type firm is reasonable given that, in the absence of information asymmetry, the optimal order quantity of the high type exceeds that of the low type.

[7] In Section 7.4, we also discuss pooling equilibria.

[8] We are assuming here that $q$ given by (10) satisfies $q > Q_H^{fb}$. Otherwise, the game has a trivial equilibrium in which both types order their first-best quantities and information asymmetry plays no role as discussed earlier.

[9] It can be easily shown that the firm will never source one input from the informed supplier and the other input from an uninformed supplier, or source different quantities of the two inputs.

[10] This is without any loss of generality because, in the presence of the outside option, any value of $s_2 > q$ leads to the same actions and payoffs as $s_2 = q$.

[11] Although this is an off-equilibrium action, it is relevant for establishing the LCSE of the full two-period game.

[12] There is no loss of generality because any value of $m_2 > q$ results in the same actions and payoffs as $m_2 = q$. We endogenize $m_2$ once we analyze period 1.

[13] Given the input complementarity, it is straightforward to show that the firm orders the same quantity of each.

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