Efficient Supplier or Responsive Supplier? An Analysis of Sourcing Strategies under Competition

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Motivated by the recent trend of onshoring/backshoring, this paper studies a two-stage sourcing game where competing firms may choose between sourcing internationally (call this efficient sourcing strategy due to low production cost) and sourcing domestically (call this responsive sourcing strategy due to short lead time). We first characterize the equilibrium of the sourcing game. Then we examine how the equilibrium depends on various problem parameters. It has been found that more firms will shift from efficient sourcing to responsive sourcing in equilibrium if (1) the market size shrinks, (2) the demand is more volatile, or (3) the sourcing costs rise simultaneously. We also investigate how the information structure in the game affects the equilibrium outcome and the firms' profits. Interestingly, when the responsive sourcing firm can collect more demand signals, the firms may be less likely to use responsive sourcing in equilibrium under certain conditions. This is because obtaining more information that is also available to the competitor may actually hurt the profit of the responsive sourcing firm. Finally, we examine the impact of backshoring and a new entrant on other firms' profitability and sourcing strategies. We show that the backshoring trend will benefit the firms using efficient sourcing, but its impact on the responsive sourcing firms is ambiguous. We also find that adding a new entrant into the market will not affect the sourcing strategy of any existing firm.

1. Introduction

Driven by the pressure to control operating costs and focus on core competencies, outsourcing has been increasingly used by firms to maintain a competitive edge in the fast-changing, global market (Friedman 2005). In particular, the past few decades have witnessed the trend of manufacturing outsourcing, where firms move their production activities from in-house to third-party suppliers. A popular practice is the so-called offshoring, which refers to the migration of production from developed countries to emerging economies (Plunkett Research 2010 and Wilson 2010). It has been reported that in 2002-2003, about a quarter to half of the manufacturing companies in Western Europe were involved in production offshoring (Dachs et al. 2006). As of 2008, more than 50% of U.S. companies had a corporate offshoring strategy (Minter 2009).

The success of production outsourcing depends critically on the supplier selection process. One of the key factors in supplier selection is the location of the supplier. In making offshoring decisions, for instance, a firm essentially chooses between domestic sourcing and international sourcing. There

are many pros and cons for offshoring as widely discussed in the business media and the research literature (see Van Mieghem 2008 for a detailed discussion of the topics on capacity location, global network design and offshoring). The most-cited advantage of offshoring is the cost savings due to less expensive labor in emerging economies. In contrast, sourcing from a domestic supplier enables the firm to react quickly to market changes, improve customer service, and reduce inventory levels. Therefore, a major trade-off is between cost and flexibility (Farrell 2005, Anderson 2006, Ryley 2010). On one hand, a firm can enjoy the low production costs by sourcing internationally; on the other hand, due to the long production and transportation lead times, dealing with a supplier located far away decreases the firm's flexibility to respond to changing market conditions. The offshoring decision is debatable in many situations since it is not always clear whether the cost factor dominates the flexibility factor (De Treville and Trigeorgis 2010). Although there are certainly other important factors to consider (e.g., quality, currency exchange rates, political stability, etc.), this paper focuses on the trade-off between production cost and supply flexibility in studying firms' sourcing strategies.

The debate on offshoring has intensified in recent years. More voices have been heard that are skeptical about the offshoring trend for several reasons. First, the sourcing costs from emerging economies have been rising rapidly. For example, as of mid-2010, many Chinese firms were facing labor shortages and were forced to boost wages to attract qualified workers (Plunkett Research 2010). Second, the global commodity price index has risen significantly (Archstone Consulting 2009). This has led to more expensive transportation costs (higher oil prices) as well as higher production costs (higher raw material and component costs). Third, the economic recession that started at the end of 2007 has had a severe impact on the market. Consumers are more cautious in spending and firms are seeking various strategies to retain customers (Dodes 2011). Not surprisingly, "reshoring", "onshoring" and "backshoring" have frequently made headlines in the business press. That is, because of the unexpected high supply chain costs in offshoring, many firms are considering sourcing from domestic suppliers rather than international ones. To name a few examples: GE is moving some of its appliance manufacturing from China to Louisville, Kentucky (Davidson 2010). Vaniman Manufacturing, a dental equipment producer that outsourced most of its sheet metal fabrication to China in 2002, decided to bring its fabricated parts back to the U.S. because of the high offshoring costs associated with inventory, shipping, and traveling overseas (Collins 2010). NCR has started bringing all of its production of ATM machines from China, India, and Hungary back to a facility located in Columbus, Georgia in order to customize the products and move them to the market in a fast fashion (Davidson 2010). More discussions of the backshoring

trend can be found in Bussey (2011) and Zieminski (2011). As some of the U.S. firms move their production activities back home, similarly, an increasing number of Chinese firms begin to build factories in the U.S. to better serve the local market. In 2007, Yuncheng Plate Making, the world's largest manufacturer of gravure printing cylinders, established an operation in Spartanburg, South Carolina (Prasso 2010). All these firms emphasize that by being closer to the market, they can better understand the market and are able to respond quickly to market changes.

Outsourcing decisions based on the suppliers' location may bring distinctive advantages. However, as the above industry observations demonstrate, the trade-off between cost and flexibility can be quite involved and difficult to evaluate. It appears that the cost benefits gained from offshoring might not be sufficient to cover the lost flexibility under many circumstances. Firms at the crossroad of making offshoring decisions should not simply follow the trend. To make an intelligent decision, a firm needs to understand the business environment as well as the competitor's sourcing strategy. The purpose of this paper is to investigate the underlying factors that affect the sourcing trend and provide insights to firms on strategic sourcing decisions in a competitive setting. We develop a game-theoretic model where firms engage in quantity competition by selling substitutable products. Market demand is uncertain and each firm has a single ordering opportunity. There are two types of sourcing strategies from which the firms can choose. The first strategy is called efficient sourcing (e.g., offshoring), under which the procurement price is low but the delivery lead time is long. The second is called responsive sourcing (e.g., domestic sourcing), under which the procurement price is high but the delivery lead time is short. The responsive sourcing firm may observe better market signals when making the procurement quantity decision. In other words, the flexibility achieved from responsive sourcing is captured by accurate market demand information. The firms participate in a two-stage game: They first choose their sourcing strategy; then they compete by determining the quantity they want to sell in the market. With this model setup, we would like to address the following research questions.

First, what is the equilibrium outcome of the sourcing game where competing firms may choose to either source from an efficient supplier or source from a responsive supplier? Characterizing the equilibrium of the sourcing game is the first step to understand firms' behavior in a competitive setting. Second, how does the sourcing equilibrium depend on the market size, demand uncertainty, costs, and other parameters? We conduct sensitivity analysis to examine whether the recent market changes (e.g., the shrinking market size in recession, the increasing labor costs in emerging economies, and the rising global commodity prices) can be used to explain the backshoring trend mentioned above. Next, do firms have more incentives to use responsive sourcing if they can observe

more demand signals when making order quantity decisions (e.g., what if a responsive sourcing firm can also observe the competitor's demand signal)? Given the important role of information in supply chain management, we would like to study how the sourcing equilibrium depends on the information structure. Lastly, what is the impact of a certain change in the sourcing structure on other existing firms? For example, how does the backshoring trend affect other firms' performance as well as their sourcing strategies? What is the impact of a new firm entering the market on the incumbent firms?

The rest of the paper develops the model, presents the analysis, and provides answers to the above questions. The organization of the paper is as follows. Section 2 reviews the literature. Section 3 describes the model. Sections 4 to 6 analyze the model and derive the main insights. This paper concludes with Section 7. All proofs are given in the appendix.

2. Literature Review

This paper studies firms' sourcing decisions that take supply lead time and flexibility into consideration. Fast and flexible delivery performance is considered a common supplier selection criterion and has been extensively studied in the literature. A large group of papers in this literature focus on how to secure sufficient supply by designing appropriate contracts that maximize the entire supply chain's performance. Cachon (2003) provides a comprehensive review of these supply chain coordination contracts. Recently, there has been more research attention on how to incentivize the suppliers to invest in capacity/inventory and provide fast deliveries. Several papers study supply contract design problems under sole sourcing and asymmetric information (either on cost or demand), e.g., Cachon and Lariviere (2001), Özer and Wei (2006), Cachon and Zhang (2006), and Zhang (2010). There are also papers studying supplier competition design under multi-sourcing; see Cachon and Zhang (2007) and the references therein. A more general and detailed discussion of the incentives created by various sourcing strategies on supplier performance can be found in Elmaghraby (2000). Fisher (1997) proposes qualitative guidelines on how to design the supply process for products with different characteristics. Specifically, innovative products (i.e., products with short life cycles and highly uncertain demand) may require responsive supply chains (i.e., supply chains with flexible capacities and fast lead times), while functional products (i.e., products with long life cycles and predictable demand) match with efficient supply chains (i.e., supply chains that emphasize low production and logistics costs). The majority of studies in the above literature consider a single firm's sourcing problem; in contrast, our paper analyzes the firms' sourcing strategies in a competitive setting. In addition, the supply lead time is determined once the supplier is chosen and we do not consider the incentive issues.

An effective strategy that can be used to increase supply flexibility is the so-called quick response (QR). In quick response, a firm is allowed to place a second order after observing early demand information. Fisher and Raman (1996), Iyer and Bergen (1997), and Cachon and Swinney (2009) study the value of quick response in various settings. Caro and Martínez-de-Albéniz (2010) extend this important stream of research by studying quick response in a duopoly setting. They analyze a two-stage game: The firms make quick response related decisions in the first stage; then they engage in inventory competition in the second stage. Despite the similarity in the game structures, our paper differs from Caro and Martínez-de-Albéniz (2010) in several important aspects. First, in quick response a firm has two replenishment opportunities while in our model there is only a single ordering opportunity. Second, the second-stage game is formulated in different ways. Caro and Martínez-de-Albéniz (2010) consider inventory competition based on stockout substitution. Due to the lack of closed-form expressions, their qualitative insights rely on the numerical comparative statics. Instead, we use Cournot competition to model the second-stage game, which allows endogenous market price and is more amenable to analysis. This enables us to derive analytical results for more general settings such as multi-firm competition. Third, the purpose of our paper is to understand the offshoring/backshoring phenomenon, while Caro and Martínez-de-Albéniz (2010) focus on the value of quick response under competition. Accordingly, these papers present distinctive, but complementary sets of results and managerial insights.

There are numerous papers that study firm competition under exogenous supply characteristics. We highlight a few representative studies: Li (2002) proposes a production-inventory control model to investigate the role of inventory in competition. Several papers study competitive newsvendors with substitutable products, including Parlar (1988), Lippman and McCardle (1997), and Netessine and Rudi (2003). Netessine and Zhang (2005) study newsvendor competition with complementary products and compare it to the case of substitutable products. Li and Ha (2008) introduce reactive capacity into newsvendor competition. Bernstein and Federgruen (2004, 2005) study joint inventory and price decisions under retail competition. Deo and Corbett (2009), Federgruen and Yang (2009), and Kouvelis and Tang (2011) introduce supply uncertainties into firm competition. And most recently, Jiang et al. (2011) study newsvendor competition under asymmetric demand information. Our paper adds a new layer to these horizontal competition models, i.e., the firms first choose their sourcing strategies and then compete in the market.

We model firm competition under incomplete information since the firms observe different but correlated demand signals. Our modeling approach and equilibrium analysis are based on the earlier studies by Gal-Or (1985) and Li (1985). Similar paradigms have been applied in the supply

chain management literature to model information sharing/leaking/investment; see, for example, Li (2002), Li and Zhang (2008), Gal-Or et al. (2008), Anand and Goyal (2009), Shin and Tunca (2010), Taylor and Xiao (2010), and Ha et al. (2011). These studies have quite different model settings and none of them considers the location-based supplier selection decision as in our paper.

Finally, this paper is related to the literature that deals with facility location decisions in a global context. See, for example, Lu and Van Mieghem (2009) and the references therein. This literature focuses on a single firm's facility network optimization problem where a major trade-off is between manufacturing costs and logistics costs. In contrast, we study a competitive setting with an emphasis on the trade-off between sourcing costs and supply responsiveness.

3. Model

Two firms (A and B) compete in the same market by selling substitutable products. Both firms need to source their product (or a critical input of the product) from external suppliers.[1] There are two types of suppliers: efficient and responsive. An efficient supplier incurs a low production cost, but the procurement lead time is also long; a responsive supplier has a short lead time, but the production cost is high. For example, the efficient type refers to the suppliers located overseas while the responsive suppliers are domestic ones. The notion of efficient and responsive suppliers is similar to that in Fisher (1997). We denote the efficient supplier type by S_l and the responsive supplier type by S_s, where the subscripts l and s stand for long and short lead times, respectively. Let w_l and w_s be the procurement prices associated with the two types of suppliers ($w_l < w_s$). These procurement prices represent the cost differential between the sourcing modes and are exogenously given. The firms may choose between the efficient sourcing mode (i.e., sourcing from an efficient supplier) and the responsive sourcing mode (i.e., sourcing from a responsive supplier). Sourcing from both types of suppliers is not a viable strategy for the firms. This might be because dual sourcing is prohibitively costly[2] or there are long-term relationship considerations.

The life cycle of the products is relatively short compared to the procurement lead time. As a result, the firms have to make their procurement decisions before the selling season starts, when the market demand is still uncertain. We assume that the firms have a single ordering opportunity and engage in Cournot (quantity) competition. The Cournot model is appropriate in our problem because we are interested in the firms' procurement quantity decisions under demand uncertainty. Specifically, given the firms' procurement quantities Q_i ($i = A, B$), the market clearing price is

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[1] Alternatively, the firms need to decide where to locate their production facilities (e.g., offshoring or not). For ease of exposition, we consider the firms' supplier selection decision rather than the offshoring decision.

[2] In the offshoring context, generally it is very costly to invest in production facilities at multiple locations.

$p = a - (Q_A + Q_B) + u$, where a is the intercept of the inverse demand function, and u is a random term that represents the firms' common prior belief of the demand uncertainty. One may view u as the aggregation of all random factors that may influence the market demand (e.g., economic and weather conditions). We assume u follows a normal distribution $N(0, \sigma)$ (σ is the variance of u). Since a is a measure of the expected market potential, later we will refer to a as the market size for simplicity.[3]

When choosing the sourcing mode, the firms face a trade-off between cost and flexibility. A responsive supplier charges a higher price, but the short lead time allows the firm to make a quantity decision at a time closer to the selling season. This means that the firm has more flexibility in reacting to uncertain market realization. We model such a flexibility as follows. If a firm sources from S_l, then she will observe a demand signal x_1 at time 1; if a firm sources from S_s, then she will observe both signals x_1 at time 1 and x_2 at time 2 before making the quantity decision. That is, the information from efficient sourcing $\{x_1\}$ is a subset of the information from responsive sourcing $\{x_1, x_2\}$. For now we assume the cost for signal collection is negligible. Section 5 considers an alternative scenario in which the responsive sourcing firm can only observe x_2 due to high signal collection cost. By comparing these two scenarios, we will investigate the impact of the information structure on the firms' sourcing strategies and performances. If the firms adopt the same sourcing mode, then they will observe exactly the same signal(s).

The demand signals satisfy $x_i = u + e_i$ ($i = 1, 2$), where e_i is an independent random variable following a normal distribution $N(0, m_i)$ (m_i is the variance of e_i). We assume that e_1 and e_2 are independent of each other since they represent the random noises at different times. The variance m_i indicates the accuracy of the signal (a higher m_i implies a less accurate signal). Clearly, there is $m_1 > m_2$ since time 2 is closer to the selling season.

We study the firms' sourcing strategy equilibrium under Cournot competition with uncertain demand. The timing of the events is shown in Figure 1. First, at time 0, the firms simultaneously choose their sourcing mode (i.e., either sourcing from S_l or S_s); second, at time 1, the firm(s) sourcing from S_l observes the signal x_1 and places her order; the firm(s) sourcing from S_s also observes x_1; then, at time 2, the firm(s) sourcing from S_s observes the other signal x_2 and places her order; finally, at time 3, the market demand is realized and the firms sell their products at the market-clearing price. Both firms are risk-neutral and aim at maximizing the expected profit. All information is common knowledge in our model except the firms' demand signals.

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[3] Note that by market size we do not mean the actual sales quantity in the market.
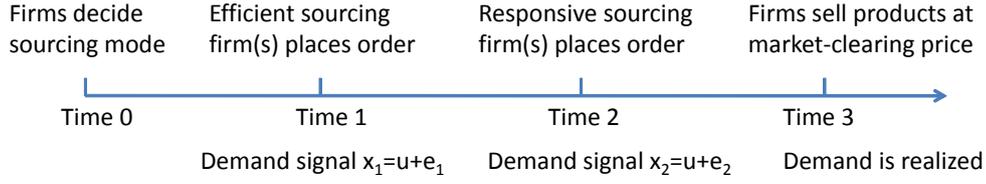
Figure 1   Timeline of Information and Decisions

$$
\begin{array}{c c}
 & \begin{array}{cc} S_l & S_s \end{array} \\
\begin{array}{c} S_l \\ S_s \end{array} &
\left[\begin{array}{cc}
\Pi_A^{ll}, \Pi_B^{ll} & \Pi_A^{ls}, \Pi_B^{ls} \\
\Pi_A^{ls}, \Pi_B^{ls} & \Pi_A^{ss}, \Pi_B^{ss}
\end{array} \right]
\end{array}
$$

Figure 2   Sourcing Game

Let (S_l, S_l), (S_s, S_s) and (S_l, S_s) denote the three possible equilibrium structures of the sourcing game.[4] We use superscripts ll, ss, and ls to refer to the above three sourcing structures, respectively. For instance, Π_A^{ll} denotes the expected profit of firm A under the sourcing structure (S_l, S_l). The above sourcing game can be characterized by the 2×2 matrix in Figure 2.

For future comparison, we first analyze a special case of the model with deterministic demand (i.e., $\sigma = 0$).

PROPOSITION 1. *Under deterministic demand (i.e., $\sigma = 0$), (S_l, S_l) is the unique sourcing equilibrium in which $Q_A^* = Q_B^* = \frac{a}{3} - \frac{1}{3}w_l$ and $\Pi_A^{ll} = \Pi_B^{ll} = \frac{1}{9}(a - w_l)^2$.*

Without demand uncertainty, both firms will choose to source from the low-cost supplier. The major benefit of sourcing from a responsive supplier is to obtain more accurate demand information, which does not exist if there is no demand uncertainty. As a result, the competitive advantage rests solely on cost efficiency and hence (S_l, S_l) is the only sourcing equilibrium. This result implies that for products with highly predictable demand, offshoring is still a useful strategy because firms compete mainly on cost. Later we will see how demand uncertainty may change the sourcing equilibrium.

4.   Equilibrium Analysis

This section presents the equilibrium analysis of the sourcing game. Since there is incomplete information (the firms may observe different private signals), we apply the Bayesian Nash Equilibrium

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[4] When one firm sources from S_l and the other from S_s, we assume without losing generality that firm A sources from S_l. The equilibrium structure of (S_s, S_l) is equivalent to (S_l, S_s) by symmetry.

(BNE) concept to characterize the outcome of the game. The Bayesian game can be solved backward. We first derive the equilibrium of the Cournot competition under each sourcing structure (ll, ss, and ls). This gives us the firms' profits in the 2×2 matrix in Figure 2. Then we compare the profits to determine the equilibrium of the sourcing game.

Proposition 2 shows there is a unique BNE under the sourcing structure ll (both firms source from S_l). We use Q_i^* to denote firm i's ($i = A, B$) equilibrium quantity in the Cournot competition. Note Q_i^* is a function of the signal the firm observes.

PROPOSITION 2. *Consider the sourcing structure ll, where both firms observe the common signal x_1 at time 1.*

(i) There is a unique BNE $(Q_A^*(x_1), Q_B^*(x_1))$ in the Cournot competition, where

$$Q_A^*(x_1) = Q_B^*(x_1) = \left(\frac{a}{3} - \frac{1}{3}w_l\right) + \frac{\sigma}{3(\sigma + m_1)}x_1.$$

(ii) The firms' expected profits in equilibrium are given by

$$\Pi_A^{ll} = \Pi_B^{ll} = \frac{1}{9}(a - w_l)^2 + \frac{\sigma^2}{9(\sigma + m_1)}.$$

We emphasize a few observations from this proposition. First, the firms' equilibrium strategies Q_i^* and profits Π_i^{ll} consist of two terms, each corresponding to an exclusive set of parameters. The first term is related to the market size (a) and the sourcing costs (w_l, w_s); the second term is composed of the demand information parameters (σ, m_i). Hereafter, we may refer to these two terms as the efficiency term and the information term, respectively. Second, the firms' profits are decreasing in m_1, i.e., they prefer to have more accurate demand signals. It is well-known that in a monopoly setting, accurate early demand information is beneficial because it helps the firm forecast market conditions and thus make better procurement decisions. Proposition 2 demonstrates that this intuitive result carries over to the Cournot setting where both firms observe a common demand signal. However, a less intuitive finding is that the firms' profits are increasing in σ, i.e., under Cournot competition, they actually prefer higher demand variability. In particular, both firms can make more profit with demand uncertainty ($\sigma > 0$) than without demand uncertainty ($\sigma = 0$). It is because highly uncertain demand may dampen the quantity competition: We know that firms will compete aggressively under strong demand signal(s) but will compete less aggressively under weak demand signal(s); due to demand uncertainty, on average the quantity competition will be less intense. This finding suggests that a more volatile market could be more profitable for the firms in a competitive setting. Note that m_1 (variance of e_1) and σ (variance of u) affect the firms' expected profits in different directions, which is unexpected. As $x_1 = u + e_1$ is observed by both

firms, one may conjecture that the random variables would have a similar effect on the firms' profits. Close scrutiny shows that there is a difference between u and e_1. Although both u and e_1 may influence the firms' quantity decisions through the signal x_1, only u has an impact on the price $p = a - (Q_A + Q_B) + u$. It can be shown that the firms' profits are convex in u but concave in e_1. Consequently, the firms' profits increase in σ and decrease in m_1.

Proposition 3 characterizes the Cournot competition outcome under the sourcing structure ss.

PROPOSITION 3. *Consider the sourcing structure ss, where both firms observe the signals x_1 at time 1 and x_2 at time 2.*

(i) There is a unique BNE $(Q_A^*(x_1, x_2), Q_B^*(x_1, x_2))$ in the Cournot competition, where

$$Q_A^*(x_1, x_2) = Q_B^*(x_1, x_2) = \left(\frac{a}{3} - \frac{1}{3} w_s \right) + \frac{\sigma(m_2 x_1 + m_1 x_2)}{3(\sigma m_1 + \sigma m_2 + m_1 m_2)}.$$

(ii) The firms' expected profits in equilibrium are given by

$$\Pi_A^{ss} = \Pi_B^{ss} = \frac{1}{9}(a - w_s)^2 + \frac{1}{9} \frac{\sigma^2(m_1 + m_2)}{(\sigma m_1 + \sigma m_2 + m_1 m_2)}.$$

The interpretation of this equilibrium is similar to that under the sourcing structure ll. In particular, the firms prefer higher market uncertainty; at the same time, they also benefit from more accurate common demand signal.

Next we consider the Cournot competition outcome under the sourcing structure ls. In this case, firm A sources from S_l, so she observes only the signal x_1 when placing her order at time 1; firm B can observe both signals x_1 and x_2 when placing her order at time 2. When placing her order, firm A knows that firm B has also observed the same signal x_1 and will observe an additional signal x_2 at time 2. Although firm A cannot observe x_2, she can update her belief of x_2 based on x_1. When making her ordering decision at time 2, firm B does not know firm A's exact order quantity placed at time 1. Therefore, even though the firms place their orders at different times, they essentially engage in a simultaneous-move game rather than a Stackelberg game. Proposition 4 presents the equilibrium of such a Cournot game with incomplete information.

PROPOSITION 4. *Consider the sourcing structure ls, where both firms observe the signal x_1 at time 1 and firm B also observes the signal x_2 at time 2.*

(i) There is a unique BNE $(Q_A^*(x_1), Q_B^*(x_1, x_2))$ in the Cournot competition, where

$$\begin{aligned}
Q_A^*(x_1) &= \left(\frac{a}{3} - \frac{2}{3} w_l + \frac{1}{3} w_s \right) + \frac{\sigma}{3(\sigma + m_1)} x_1, \\
Q_B^*(x_1, x_2) &= \left(\frac{a}{3} + \frac{1}{3} w_l - \frac{2}{3} w_s \right) + \frac{\sigma}{6} \left(\frac{(2m_2(\sigma + m_1) - \sigma m_1) x_1 + 3m_1(m_1 + \sigma) x_2}{(m_1 + \sigma)(m_1 m_2 + \sigma m_1 + \sigma m_2)} \right).
\end{aligned}$$

(ii) The firms' expected profits in equilibrium are given by

$$\Pi_A^{ls} = \frac{1}{9} \left(a - 2w_l + w_s \right)^2 + \frac{\sigma^2}{9 \left(\sigma + m_1 \right)},$$
$$\Pi_B^{ls} = \frac{1}{9} \left(a - 2w_s + w_l \right)^2 + \frac{\sigma^2}{9 \left(\sigma + m_1 \right)} + \frac{\sigma^2 m_1^2}{4(\sigma + m_1) \left(m_1 m_2 + \sigma m_1 + \sigma m_2 \right)}.$$

It can be readily shown that in firm A's equilibrium profit, the efficiency term is greater than its counterpart in firm B's profit, and the information term is smaller than its counterpart in firm B's profit. This is not surprising because firm A sources from a more efficient supplier while firm B obtains more accurate demand information from responsive sourcing. Again both firms' expected profits increase in σ, implying that both firms would benefit from a more uncertain market demand under asymmetric sourcing structure as well.

From Proposition 4, we can see that firm A's equilibrium order quantity is independent of signal x_2 because it is not observable at time 1, when firm A makes the quantity decision. Firm B's order quantity is dependent on both signals x_1 and x_2; however, it is not always increasing in x_1. Specifically, if $m_2 < \frac{m_1 \sigma}{2(m_1 + \sigma)}$, i.e., signal x_2 is sufficiently more accurate than x_1, then firm B would order less when she receives a strong demand signal at time 1. This is an interesting finding because without competition, a firm's optimal order quantity shall increase in the demand signal. Note that increasing x_1 has two effects on firm B's ordering decision. On one hand, a higher x_1 indicates a stronger market demand, so firm B has more incentives to procure a large quantity; on the other hand, a higher x_1 leads to a higher quantity Q_A^* at firm A (firm A observes x_1 only), so firm B should procure less due to product substitutability. The relationship between Q_B^* and x_1 depends on these two counteracting effects. When $m_2 < \frac{m_1 \sigma}{2(m_1 + \sigma)}$ (x_2 is sufficiently more accurate than x_1), signal x_1 as a market condition indicator is less important for firm B. Consider the extreme case with $m_2 = 0$, i.e., x_2 provides perfect demand information. Then firm B does not have to rely on x_1 to infer demand information at all; and in this case, the first effect does not exist and only the second effect plays the role. Similarly, with $0 < m_2 < \frac{m_1 \sigma}{2(m_1 + \sigma)}$, the second effect dominates the first one, yielding the result that Q_B^* decreases in x_1. The opposite is true if $m_2 > \frac{m_1 \sigma}{2(m_1 + \sigma)}$. Therefore, we have shown that in a competitive market with demand uncertainty, the firms do not necessarily order more when observing stronger demand signals.

As to the firms' equilibrium profits, firm A has a greater efficiency term but a smaller information term than firm B. Comparing to the *ll* sourcing structure (Proposition 2), we can see that by sourcing from S_s, firm B earns an additional profit term $\frac{\sigma^2 m_1^2}{4(\sigma+m_1)(m_1 m_2 + \sigma m_1 + \sigma m_2)}$, which is achieved at the expense of a lower efficiency term $\frac{1}{9} \left(a - 2w_s + w_l \right)^2$. The trade-off between these terms will determine whether firm B has incentives to deviate from S_l to S_s. There is another difference

between the sourcing structures ll and ls. In Proposition 2, both firms prefer a more accurate signal x_1. In Proposition 4, by contrast, firm B does not always prefer a more accurate signal x_1. It can be shown that when m_2 is sufficiently small, i.e., signal x_2 is accurate enough, the information term of Π_B^{ls} decreases in the accuracy of x_1. This is because x_1 is observed by firm A, so an accurate x_1 will help firm A compete against firm B. From firm B's perspective, she does not have to rely heavily on x_1 since she also observes x_2, and this is especially so when x_2 is very accurate.

4.1. Sourcing Equilibrium

Given the equilibrium profits derived in the above three propositions, we are now ready to present the equilibrium of the sourcing game in Figure 2. Define

$$\Gamma_1^1 = \frac{\sigma^2 m_1^2}{4\left(m_1+\sigma\right)\left(m_2\sigma+m_1m_2+m_1\sigma\right)} \text{ and } \Gamma_2^1 = \frac{\sigma^2 m_1^2}{9(m_1+\sigma)(m_2\sigma+m_1m_2+m_1\sigma)},$$

$$T_1^1 = w_l + \frac{9}{4}\frac{\Gamma_2^1}{w_s-w_l} \text{ and } T_2^1 = w_s + \frac{9}{4}\frac{\Gamma_1^1}{w_s-w_l},$$

where the superscript 1 refers to the base scenario where responsive sourcing firm(s) observes both signals x_1 and x_2 (later we will use superscript 2 for the alternative scenario). It is clear that $\Gamma_1^1 > \Gamma_2^1$ and $T_1^1 < T_2^1$.

> PROPOSITION 5. *The equilibria of the sourcing game are given as follows:*
> *(i) If $a < T_1^1$, then (S_s, S_s) is the unique Nash equilibrium;*
> *(ii) If $a = T_1^1$, then both (S_s, S_s) and (S_l, S_s) are the Nash equilibria;*
> *(iii) If $T_1^1 < a < T_2^1$, then (S_l, S_s) is the unique Nash equilibrium;*
> *(iv) If $a = T_2^1$, then both (S_l, S_l) and (S_l, S_s) are the Nash equilibria;*
> *(v) If $a > T_2^1$, then (S_l, S_l) is the unique Nash equilibrium.*

In contrast with the deterministic demand case, Proposition 5 shows that there is a larger set of possible equilibria under the presence of demand uncertainty. The equilibrium is not necessarily unique (e.g., both (S_s, S_s) and (S_l, S_s) are equilibria if $a = T_1^1$). Also, the symmetric sourcing game may have an asymmetric equilibrium (i.e., when $T_1^1 \leq a \leq T_2^1$). The equilibria characterized in Proposition 5 enables us to investigate how different problem parameters affect the outcome of the sourcing game. First, we consider the impact of the demand uncertainty. It is straightforward to show that both thresholds T_1^1 and T_2^1 increase in σ, i.e., both threshold values will be larger as the market demand becomes more variable. The increase in T_2^1 means that (S_l, S_l) will be less likely to happen because it is the equilibrium of the sourcing game only if $a \geq T_2^1$. In addition, the increase in T_1^1 means that (S_s, S_s) will be a more likely equilibrium outcome. Thus, we conclude that a more volatile market demand drives firms to source more often from S_s.

Second, the market size plays a critical role in determining the equilibrium of the sourcing game. When the market is relatively small ($a < T_1^1$), both firms will adopt the responsive sourcing mode; when the market size is intermediate ($T_1^1 < a < T_2^1$), the firms will diversify their sourcing strategies (i.e., one sources from an efficient supplier while the other uses a responsive supplier); when the market is relatively large ($a > T_2^1$), both firms will adopt the efficient sourcing mode. That is, as the market size shrinks, firms are more likely to use responsive sourcing in equilibrium. There are two explanations for this observation. First, when the firms compete in a small market, the competition is more intense and the firms' selling quantities are also low, so accurate demand information is more valuable; on the other hand, when the market size is large, the firms' selling quantities are large too, which implies that a low procurement cost can bring in more benefits. Second, recall that a is the expected market potential. All else being equal, a smaller a implies a more variable market (the coefficient of variation of the demand increases as a decreases). This result suggests that different competitive weapons might have different values depending on the market condition: In a small niche market, firms should give higher priority to responsiveness when choosing their suppliers; however, in a large mass market focusing on efficiency and cost reduction through offshoring would be a more effective strategy.

Lastly, it is worth noting how the sourcing equilibrium varies with the sourcing costs. As w_l increases, (S_l, S_l) will be less likely to be the equilibrium because T_2^1 increases in w_l. As a result, (S_l, S_s) and (S_s, S_s) are more likely to be the equilibrium outcome. This is an intuitive result: Sourcing from an overseas supplier will become less attractive if the unit sourcing cost increases. However, this result rests upon the assumption that w_s is held constant. What if w_l and w_s rise simultaneously? Note that the rising raw material prices in the global market would affect a supplier's cost regardless of his location. Hence the sourcing costs for both the efficient supplier (e.g., located in Asia) and the responsive supplier (e.g., located in the U.S.) may inflate at the same time. Suppose w_l and w_s increase by the same amount, i.e., $w_s - w_l$ is held constant. Under this condition, it is clear that both T_1^1 and T_2^1 increase in the sourcing cost w_l (or w_s). The increase in T_2^1 and T_1^1 leads (S_l, S_l) to occur less likely and (S_s, S_s) to occur more likely. Therefore, even if the cost differential between the two sourcing modes remains constant, a universal cost increase will drive more firms to source from S_s. This corroborates the recent "onshoring" and "backshoring" trend, which has been taking place when the raw materials prices in the global market increase rapidly.

5. Alternative Scenario: Single Signal in Responsive Sourcing

The previous analysis is based on the premise that the responsive sourcing firm can observe both signals x_1 and x_2. This applies to situations where the cost for collecting and processing information is insignificant. When the cost for obtaining a signal is non-negligible, the firm may not be able to observe two signals. This section studies an alternative scenario in which the firm sourcing from S_s can only observe x_2 at time 2 (it is optimal for a responsive sourcing firm to observe x_2 if she can choose between the two signals). We first derive the sourcing equilibrium and investigate whether the earlier observations hold in this alternative scenario. Then we examine the impact of the additional demand signal on the firms' sourcing decisions by comparing the equilibria from the above two scenarios.

Since the demand information for efficient sourcing does not change in the alternative scenario, the outcome of the Cournot competition under the sourcing structure ll will be the same as before (see Proposition 2). Proposition 6 characterizes the Cournot competition outcome under the sourcing structure ss for the alternative scenario.

PROPOSITION 6. *Consider the sourcing structure ss in the alternative scenario, where both firms observe the common signal x_2 at time 2.*

(i) There is a unique BNE $(Q_A^*(x_2), Q_B^*(x_2))$ in the Cournot competition, where

$$Q_A^*(x_2) = Q_B^*(x_2) = \left(\frac{a}{3} - \frac{1}{3}w_s \right) + \frac{\sigma}{3(\sigma + m_2)}x_2.$$

(ii) The firms' expected profits in equilibrium are given by

$$\Pi_A^{ss} = \Pi_B^{ss} = \frac{1}{9}(a - w_s)^2 + \frac{\sigma^2}{9(\sigma + m_2)}.$$

It can be shown that the firms' equilibrium profit increases in σ but decreases in m_1 and m_2, which is consistent with the observations in the base scenario. Proposition 7 characterizes the unique BNE under the sourcing structure ls (firm A sources from S_l but firm B sources from S_s).

PROPOSITION 7. *Consider the sourcing structure ls in the alternative scenario, where firm A observes a signal x_1 at time 1 and firm B observes a signal x_2 at time 2.*

(i) There is a unique BNE $(Q_A^*(x_1), Q_B^*(x_2))$ in the Cournot competition, where

$$Q_A^*(x_1) = \left(\frac{a}{3} - \frac{2}{3}w_l + \frac{1}{3}w_s \right) + \frac{\sigma(2m_2 + \sigma)}{4m_1m_2 + 4m_1\sigma + 4m_2\sigma + 3\sigma^2}x_1,$$
$$Q_B^*(x_2) = \left(\frac{a}{3} - \frac{2}{3}w_s + \frac{1}{3}w_l \right) + \frac{\sigma(2m_1 + \sigma)}{4m_1m_2 + 4m_1\sigma + 4m_2\sigma + 3\sigma^2}x_2.$$

(ii) The firms' expected profits in equilibrium are given by

$$\Pi_A^{ls} = \frac{1}{9}\left(a - 2w_l + w_s\right)^2 + \frac{\sigma^2\left(m_1 + \sigma\right)\left(2m_2 + \sigma\right)^2}{\left(4m_1 m_2 + 4\sigma\left(m_1 + m_2\right) + 3\sigma^2\right)^2},$$

$$\Pi_B^{ls} = \frac{1}{9}\left(a - 2w_s + w_l\right)^2 + \frac{\sigma^2\left(m_2 + \sigma\right)\left(2m_1 + \sigma\right)^2}{\left(4m_1 m_2 + 4\sigma\left(m_1 + m_2\right) + 3\sigma^2\right)^2}.$$

Similar to the results from the base scenario, firm A's equilibrium profit has a larger efficiency term but a smaller information term, compared to firm B's profit. Under the sourcing structure ls in the alternative scenario, each firm observes a distinct private signal. We can show that each firm's profit increases in the accuracy of her own signal and decreases in the accuracy of the competitor's signal. In particular, now firm B always prefers the signal x_1 to be less accurate because it is only observable to firm A. This is different from the base scenario where firm B may or may not benefit from a less accurate x_1 (see the discussion after Proposition 4). In the base scenario, signal x_1 is observed by both firms A and B, so firm B's preference for the accuracy of x_1 depends on how accurate her other signal x_2 is.

5.1. Sourcing Equilibrium

In this subsection we present the sourcing equilibrium for the alternative scenario. Again the sourcing game is defined by the 2×2 matrix in Figure 2. Define

$$\Gamma_1^2 = \frac{\sigma^2\left(m_2 + \sigma\right)\left(2m_1 + \sigma\right)^2}{\left(4m_1 m_2 + 4\sigma\left(m_1 + m_2\right) + 3\sigma^2\right)^2} - \frac{\sigma^2}{9\left(\sigma + m_1\right)},$$

$$\Gamma_2^2 = \frac{\sigma^2}{9\left(\sigma + m_2\right)} - \frac{\sigma^2\left(m_1 + \sigma\right)\left(2m_2 + \sigma\right)^2}{\left(4m_1 m_2 + 4\sigma\left(m_1 + m_2\right) + 3\sigma^2\right)^2}.$$

The superscript 2 denotes the alternative scenario in which the responsive sourcing firm only observes the signal x_2 at time 2. It can be shown that $\Gamma_1^2 > 0$, $\Gamma_2^2 > 0$, and $\Gamma_1^2 > \Gamma_2^2$. Define

$$T_1^2 = w_l + \frac{9}{4}\frac{\Gamma_2^2}{w_s - w_l} \text{ and } T_2^2 = w_s + \frac{9}{4}\frac{\Gamma_1^2}{w_s - w_l},$$

where $T_1^2 < T_2^2$.

PROPOSITION 8. *The equilibria of the sourcing game under the alternative scenario are given as follows:*

(i) If $a < T_1^2$, then (S_s, S_s) is the unique Nash equilibrium;

(ii) If $a = T_1^2$, then both (S_s, S_s) and (S_l, S_s) are the Nash equilibria;

(iii) If $T_1^2 < a < T_2^2$, then (S_l, S_s) is the unique Nash equilibrium;

(iv) If $a = T_2^2$, then both (S_l, S_l) and (S_l, S_s) are the Nash equilibria;

(v) If $a > T_2^2$, then (S_l, S_l) is the unique Nash equilibrium.

The structure of the sourcing equilibrium for the alternative scenario is the same as that for the base scenario. Although the equilibrium regions characterized by the T_i^j's ($i, j = 1, 2$) could be different, the qualitative observations from Proposition 5 in the base scenario continue to hold in the alternative scenario. That is, more firms will shift from efficient sourcing to responsive sourcing if the demand is more variable, the market size becomes smaller, or the procurement costs for both supplier types simultaneously rise. Therefore, the results on the comparative statics are quite robust under different information structures.

5.2. Impact of Additional Signal

So far we have derived the sourcing equilibria under two different information scenarios. The responsive sourcing firm can observe an additional signal x_1 in the base scenario than in the alternative scenario. Several natural questions may arise: Does the responsive sourcing firm always benefit from this additional signal? Will the equilibrium outcome (S_s, S_s) occur more often in the base scenario than in the alternative scenario? What will happen if the responsive sourcing firm can choose whether to observe this additional signal? This subsection aims to address these questions. To this end, we compare the equilibrium in Proposition 8 with that in Proposition 5.

LEMMA 1. *There exist thresholds $\hat{m}_{2i} \in \left[0, \frac{m_1 \sigma}{2(m_1 + \sigma)}\right]$ ($i = 1, 2$) such that $\Gamma_i^1 < \Gamma_i^2$ for $m_2 < \hat{m}_{2i}$, $\Gamma_i^1 = \Gamma_i^2$ for $m_2 = \hat{m}_{2i}$, and $\Gamma_i^1 > \Gamma_i^2$ for $m_2 > \hat{m}_{2i}$. In addition, $\hat{m}_{22} < \hat{m}_{21} = \frac{m_1 \sigma}{2(m_1 + \sigma)}$.*

Lemma 1 defines the two thresholds $\hat{m}_{2i}$ ($i = 1, 2$) for comparing the equilibrium regions under the two scenarios. Based on this lemma, we have the following proposition.

PROPOSITION 9. *Consider the two information scenarios where the responsive sourcing firm observes one and two signals, respectively.*

(i) For $m_2 < \hat{m}_{22}$, the equilibrium (S_l, S_l) occurs within a larger range of the market size a while (S_s, S_s) occurs within a smaller range of the market size a in the base scenario than in the alternative scenario.

(ii) For $\hat{m}_{22} < m_2 < \hat{m}_{21}$, both the equilibria (S_l, S_l) and (S_s, S_s) occur within a larger range of the market size a in the base scenario than in the alternative scenario.

(iii) For $m_2 > \hat{m}_{21}$, the equilibrium (S_l, S_l) occurs within a smaller range of the market size a while (S_s, S_s) occurs within a larger range of the market size a in the base scenario than in the alternative scenario.

This proposition deserves some discussion. One observation worth highlighting is that for $m_2 < \hat{m}_{21} = \frac{m_1 \sigma}{2(m_1 + \sigma)}$, the parameter range for (S_l, S_l) to arise is larger in the base scenario than in the

alternative scenario; see Proposition 9(i) and (ii). In other words, although the responsive sourcing firm can observe more demand signals in the base scenario, the equilibrium involving at least one firm sourcing from S_s is less likely to happen. Close examination shows that under the sourcing structure ls, firm B (who sources from S_s) will be worse off by observing one more signal at time 1 if $m_2 < \frac{m_1\sigma}{2(m_1+\sigma)}$ (i.e., the signal at time 2 is accurate enough). By comparing firm A's equilibrium order quantities (Q_A^*) in Propositions 7 and 4, we find that for $m_2 < \frac{m_1\sigma}{2(m_1+\sigma)}$, the coefficient of x_1 in Proposition 4 is greater than its counterpart in Proposition 7. That is, when firm B can observe a very accurate signal at time 2, then firm A will order more aggressively if firm B can also observe the signal at time 1. Thus, more information may make firm B worse off in the competitive setting: Under the sourcing structure ls and $m_2 < \frac{m_1\sigma}{2(m_1+\sigma)}$, firm B's expected profit under the base scenario is less than that under the alternative scenario. This gives rise to the result that the equilibrium involving at least one firm sourcing from S_s ((S_l, S_s) or (S_s, S_s)) will be less likely to occur in the base scenario as long as $m_2 < \frac{m_1\sigma}{2(m_1+\sigma)}$. However, for $m_2 > \frac{m_1\sigma}{2(m_1+\sigma)}$, firm A would not act too aggressively and in this case, firm B will benefit from observing the time 1 signal x_1. As a result, the equilibrium involving at least one firm sourcing from S_s will be more likely to occur in the base scenario.

There is another important implication from the above proposition. Suppose the firms have already chosen their sourcing structure ls, i.e., firm A sources from an international supplier while firm B sources from a domestic supplier. What if we endogenize firm B's decision on obtaining the additional signal x_1? To answer this question, we need to study a new Cournot game under the sourcing structure ls. This Cournot game is the same as the one depicted in Figure 1 except that now firm B also decides whether to collect the signal x_1 at time 1. As a benchmark for discussion, let us assume that there is no cost for collecting the signal and firm B's signal-collecting decision at time 1 is not verifiable. Consider firm B's ordering decision at time 2 in such a game. Since firm A's order quantity has already been fixed at time 1 (firm A's ordering quantity might be a function of her signal x_1), firm B will never be worse off if an additional signal x_1 is available (firm B's strategy space will be larger with two signals than with only one signal). This means that firm B will choose to collect the signal x_1 at time 1 in any subgame-perfect Nash equilibrium of the new Cournot game. When making her quantity decision at time 1, firm A should be able to correctly anticipate firm B's action at time 2. As a result, the Cournot game with an endogenous signal-collecting decision reduces to the Cournot game studied in the base scenario, where both firms know that firm B will obtain two demand signals. However, according to the previous discussion, having an additional signal x_1 may hurt firm B's profit when signal x_2 is sufficiently accurate ($m_2 < \frac{m_1\sigma}{2(m_1+\sigma)}$).

This leads to an interesting situation: When signal x_2 is accurate enough, firm B may wish to have the ability to credibly commit *not* to collecting signal x_1, while firm A may wish to voluntarily share signal x_1 with firm B. Therefore, in our model setting, a high signal-collecting cost is not necessarily detrimental because it may help the responsive firm achieve credible commitment that only a single signal will be collected.

Investment decisions to improve demand forecast have received considerable attention in the literature. With a single firm setting, a better forecasting ability should be beneficial because it helps the firm better match supply with demand. The above analysis demonstrates that such an intuition may not hold under horizontal competition.[5] Specifically, obtaining more demand information (e.g., early demand signals) may hurt a firm when that information is also available to competitors. This is because the competitors will react strategically depending on the information structure of the game. Therefore, achieving more accurate demand information may not be desirable even if doing so has no cost. Consequently, responsive sourcing is not necessarily more attractive if it allows a firm to obtain more demand information. These insights may be helpful for managers when making sourcing and forecast investment decisions.

6.   Multiple Firms

This section extends the basic model in the previous sections to $N \geq 2$ firms. There is a two-fold purpose. First, we examine the robustness of the results from the basic model; second, we derive additional insights about the firms' sourcing strategies in a more general setting. Throughout this section we focus on the base scenario, i.e., the responsive sourcing firm(s) can observe both x_1 and x_2. The alternative scenario yields similar qualitative results and is therefore omitted.

For convenience, we use (N, K) to denote the sourcing structure where K $(0 \leq K \leq N)$ firms source from S_l and $N - K$ firms source from S_s. Since there may be more than two firms, it is no longer appropriate to use subscripts A, B for the firms. Instead, we use subscript l, s to stand for firms sourcing from S_l and S_s, respectively. For instance, $Q_l^*(x_1)$ refers to the equilibrium quantity for a firm sourcing from S_l, and $\Pi_s(N, K)$ is the profit for a firm using responsive sourcing under the structure (N, K). Proposition 10 presents the equilibrium outcome for the sourcing structure (N, K).

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[5] Several studies have studied the value of better forecasting capability in a supply chain setting, i.e., when there is vertical interaction between firms. It has been shown that a better demand forecast does not necessarily benefit all supply chain members. For example, Taylor and Xiao (2010) find that a manufacturer may be worse off when selling to a retailer with more accurate demand forecast. Similarly, Shin and Tunca (2010) demonstrate that a retailer's overinvestment in forecasting may hurt the efficiency of the supply chain.

PROPOSITION 10. *Consider N competing firms under the sourcing structure (N, K).*

(i) There is a unique BNE $(Q_l^*(x_1), Q_s^*(x_1, x_2))$ in the Cournot competition, where

$$Q_l^* = \frac{a - (N - K + 1)w_l + (N - K)w_s}{N + 1} + \frac{\sigma}{(m_1 + \sigma)(1 + N)}x_1,$$

$$Q_s^* = \frac{a + Kw_l - (K + 1)w_s}{N + 1} + \frac{\sigma((N - K + 1)(m_2\sigma + m_1 m_2) - Km_1\sigma)}{(N - K + 1)(N + 1)(m_1 + \sigma)(m_1 m_2 + m_1\sigma + m_2\sigma)}x_1$$

$$+ \frac{m_1\sigma}{(N - K + 1)(m_1 m_2 + m_1\sigma + m_2\sigma)}x_2.$$

(ii) The firms' expected profits in equilibrium are given by

$$\Pi_l(N, K) = \left(\frac{a - (N + 1 - K)w_l + (N - K)w_s}{N + 1}\right)^2 + \frac{\sigma^2}{(N + 1)^2(m_1 + \sigma)},$$

$$\Pi_s(N, K) = \left(\frac{a + Kw_l - (K + 1)w_s}{N + 1}\right)^2 + \frac{\sigma^2}{(N + 1)^2(m_1 + \sigma)}$$

$$+ \frac{m_1^2\sigma^2}{(N - K + 1)^2(m_1 + \sigma)(m_1 m_2 + m_1\sigma + m_2\sigma)}.$$

Note that Proposition 10 reduces to Proposition 2 if we set $N = K = 2$, to Proposition 3 if we set $N = 2$ and $K = 0$, and to Proposition 4 if we set $N = 2$ and $K = 1$. When $K = 0$, Q_l^* and $\Pi_l(N, K)$ are not relevant; similarly, when $K = N$, Q_s^* and $\Pi_s(N, K)$ are not relevant anymore.

6.1. Impact of Backshoring

The recent onshoring/backshoring trend means that some firms are switching from S_l to S_s. How does such switching behavior affect other firms' profits? To answer this question, we first derive some properties of the firms' equilibrium profit functions $\Pi_l(N, K)$ and $\Pi_s(N, K)$.

PROPOSITION 11. *In the Cournot equilibrium under the sourcing structure (N, K):*

(i) Both $\Pi_l(N, K)$ and $\Pi_s(N, K)$ decrease in N.

(ii) $\Pi_l(N, K)$ decreases in K. Specifically, the efficiency term in $\Pi_l(N, K)$ decreases in K while the information term is independent of K.

(iii) $\Pi_s(N, K)$ is unimodal in K, i.e., there exists $\hat{K}$ $(0 \leq \hat{K} \leq N)$ such that $\Pi_s(N, K)$ is decreasing in K for $K \leq \hat{K}$, and increasing in K for $K \geq \hat{K}$. Specifically, the efficiency term in $\Pi_s(N, K)$ decreases in K while the information term increases in K.

Proposition 11(i) indicates that the firms make lower profits when there are more competitors in the market, which is not surprising. Given a fixed number of firms, since $\Pi_l(N, K)$ decreases in K (Proposition 11(ii)), we know that the firms sourcing from S_l prefer to have more firms sourcing from S_s. That is, all else being equal, the backshoring trend will benefit the firms that stick with efficient sourcing. However, the same preference may not hold for the firms sourcing from S_s. Based on Proposition 11(iii), the firms sourcing from S_s prefer to have either many or few

firms also sourcing from S_s. So the firms that are already sourcing from S_s may either benefit from the backshoring trend (if the current K is smaller than $\hat{K}$), or first suffer from this trend and then benefit from it (if the current K is greater than $\hat{K}$). Therefore, if the number of firms sourcing from S_s exceeds a threshold, then all the firms sticking to their original sourcing mode will benefit from any firm backshoring.

To better understand the above result, we may examine how the efficiency and information terms in the firms' profit functions vary in K. We find that the efficiency terms in both $\Pi_l(N,K)$ and $\Pi_s(N,K)$ are decreasing in K. This means that more firms sourcing from S_l increases the competition intensity on the sourcing cost dimension, so all firms are worse off without considering the information term. It can be shown that the expected procurement quantity of the firms sourcing from S_l is always greater than that of the firms sourcing from S_s, i.e., $E(Q_l^*) - E(Q_s^*) = w_s - w_l > 0$. Further, the total expected output $KE(Q_l^*) + (N - K)E(Q_s^*)$ equals $\frac{K(w_s - w_l)}{N+1} + \frac{N}{N+1}(a - w_s)$, which is increasing in K. This explains why the efficiency terms in both types of firms' profit functions are decreasing in K.

As to the information term, it is independent of K for firms sourcing from S_l. However, the information term is increasing in K for firms sourcing from S_s. The aggregate impact of increasing K on $\Pi_s(N,K)$ depends on the trade-off between the efficiency term and the information term. Proposition 11 demonstrates that when a firm deviates from S_l to S_s, for the other firms sourcing from S_s, the loss in the information term is less than the gain in the efficiency term if there are enough firms sourcing from S_s ($K \leq \hat{K}$); the opposite is true if there are enough firms sourcing from S_l ($K \geq \hat{K}$).

6.2. Sourcing Equilibrium

We proceed to derive the sourcing equilibrium when there are N firms competing in the market. Define the following threshold values:

$$T_l(K,N) = \frac{(2K - N)w_s + (N - 2K + 2)w_l}{2}$$
$$+ \frac{(N+1)^2 m_1^2 \sigma^2}{2N(N + 2 - K)^2(w_s - w_l)(m_1 + \sigma)(m_1 m_2 + m_1 \sigma + m_2 \sigma)},$$
$$T_s(K,N) = \frac{(N - 2K + 2)w_s + (2K - N)w_l}{2}$$
$$+ \frac{(N+1)^2 m_1^2 \sigma^2}{2N(K+1)^2(w_s - w_l)(m_1 + \sigma)(m_1 m_2 + m_1 \sigma + m_2 \sigma)},$$

Note that we use (K,N) to differentiate from the sourcing structure (N,K). As shown next, these two thresholds are critical in determining the structure of the sourcing equilibrium.

PROPOSITION 12. *Consider the sourcing game with N firms.*

(i) If $a \geq T_l(K, N)$, there will be at least K firms sourcing from S_l in the sourcing equilibrium; if $a \leq T_s(K, N)$, there will be at least K firms sourcing from S_s in the sourcing equilibrium.

(ii) $T_l(K, N)$ decreases in N and increases in K; $T_s(K, N)$ increases in N and decreases in K.

(iii) If there is a K^* satisfying $T_l(K^*, N) < a < T_l(K^* + 1, N)$, then K^* firms sourcing from S_l (the rest sourcing from S_s) is the unique equilibrium of the sourcing game. If there is a K^* satisfying $a = T_l(K^*, N)$, then $K^* - 1$ and K^* firms sourcing from S_l are both equilibria of the sourcing game.

Given the sourcing equilibrium K^*, if the current number of efficient sourcing firms is greater than K^*, then one may expect to observe the backshoring phenomenon, i.e., some firms switching from S_l to S_s. The opposite would be true if the current number of efficient sourcing firms is less than K^*. Next we check whether the previous results from the basic model continue to hold with general N firms.

First, from Proposition 12(ii) and (iii), we know that K^* increases in a. That is, a larger market size will lead to more firms sourcing from S_l. This is consistent with the earlier result that a shrinking market may drive the backshoring phenomenon. Second, holding $w_s - w_l$ constant, we can show that both $T_l(K, N)$ and $T_s(N - K, N)$ increase in the sourcing cost w_l (or w_s). By Proposition 12, all else being equal, increasing $T_l(K, N)$ and $T_s(N - K, N)$ yields a smaller K^*. Thus a simultaneous cost increase for both sourcing modes may also cause the backshoring phenomenon, as has been shown in the basic model. Third, it can be readily shown that $T_l(K, N)$ is increasing in σ, which implies that K^* is decreasing in σ. So with a higher demand variability, we expect fewer firms sourcing from S_l, or more firms sourcing from S_s. This confirms the earlier observation that more firms may choose backshoring if the market demand becomes more variable.

Therefore, we have shown that previous results based on the two-firm case are robust. Based on Proposition 12, we may also study the impact of a new entrant on the sourcing equilibrium. The result is summarized in the next proposition.

PROPOSITION 13. *Consider N incumbent competing firms and the equilibrium where K^* firms source from S_l and the rest $N - K^*$ firms source from S_s. When a new entrant, the $(N + 1)$th firm, enters the market:*

(i) All the incumbent firms will stay with their original sourcing strategy.

(ii) If $a > T_l(K^* + 1, N + 1)$, then the new entrant will source from S_l; if $a < T_l(K^* + 1, N + 1)$, the new entrant will source from S_s; if $a = T_l(K^* + 1, N + 1)$, the new entrant is indifferent between sourcing from S_l and sourcing from S_s.

Proposition 13(i) asserts that the incumbent firms' sourcing strategies will not be affected by the new entrant. This is because $T_l(K^*, N) < a < T_s(N - K^*, N)$ implies $T_l(K^*, N+1) < a < T_s(N - K^*, N+1)$. Thus there will still be at least K^* firms sourcing from S_l and at least $N - K^*$ firms sourcing from S_s. The new entrant's sourcing strategy depends on the market size a, as shown in Proposition 13(ii). In particular, the higher the a value, the more likely the new entrant will choose efficient sourcing.

7.   Concluding Remarks

Motivated by the boom of outsourcing in the past few decades and also the recent new trend of onshoring/backshoring, this paper develops a theoretical model to study the driving forces underlying the industry observations and derive managerial insights for firms making sourcing decisions. Given the increasing competition in the global market, we focus on a competitive setting where multiple firms may choose between efficient sourcing (e.g., sourcing internationally from S_l) and responsive sourcing (e.g., sourcing domestically from S_s). Specifically, we study a two-stage game: In the first stage, firms decide where to source from; then in the second stage, firms compete by determining the quantity they sell in the market. A key feature of the game is that depending on the sourcing strategy, a firm may observe different signals about the uncertain market demand. That is, they may possess different amounts of information when making their quantity decisions. The principal findings from this paper can be summarized as follows.

We derive the equilibrium outcome of the sourcing game in two steps. First we analyze the quantity competition between the firms for each given sourcing structure. There are three possible structures: both sourcing from S_l, both sourcing from S_s, and diversified sourcing (one from S_l and the other from S_s). It has been shown that there is a unique Bayesian Nash equilibrium for each sourcing structure. By comparing the firms' profits in different sourcing structures, we are able to characterize the equilibrium outcome of the sourcing game.

Since the equilibrium outcome of the sourcing game depends on the problem parameters, we proceed to examine how the equilibrium varies with several key parameters. Three results are worth highlighting. First, when there is *no* demand uncertainty, both firms will use efficient sourcing in the equilibrium. As demand uncertainty (measured by the variance of demand) increases, the equilibrium may shift from (S_l, S_l) to either (S_l, S_s) or (S_s, S_s). This indicates that we may observe more responsive sourcing for products with highly uncertain market demand (e.g., innovative and short-life-cycle products). Second, the market size plays a critical role in determining the equilibrium sourcing structure. In particular, when the market is relatively small, both firms will adopt

responsive sourcing; when the market size is intermediate, the firms will diversify their sourcing strategies; when the market is relatively large, both firms will use efficient sourcing. That is, a shrinking market will make firms value the flexibility from responsive sourcing more. This may partly explain why the backshoring phenomenon became prominent during the recent recession. Third, a change in the suppliers' cost structure may also affect the equilibrium sourcing structure. When the production cost at the efficient supplier rises, firms are more likely to switch to responsive sourcing, which is intuitive. Interestingly, when there is an equal cost increase for both sourcing modes (e.g., due to soaring global commodity prices), there will be more firms using responsive sourcing in equilibrium. Thus our research suggests that rising global commodity prices might be another contributing factor to the recent backshoring trend.

In our model, the flexibility from responsive sourcing is captured by the quality of the demand signal observed by the firms. A natural question to ask is: Does a firm have more incentives to use responsive sourcing if she is able to observe more demand signals? To address this question, we compare two demand signal scenarios: In the base scenario, the responsive sourcing firm can observe both signals at time 1 and time 2; in the alternative scenario, she can observe only the signal at time 2. We find that, contrary to our intuition, the firms may be less likely to use responsive sourcing in the base scenario than in the alternative scenario. That is, allowing the responsive firm to observe more demand signals may lead more firms to source from S_l. In particular, the responsive sourcing firm's profit may be lower in the base scenario than in the alternative scenario under certain circumstances. So in a competitive setting, collecting more demand signals (thus having more accurate demand information) may hurt a firm's profit because competitors may react strategically according to the information structure of the game. These counterintuitive results are in contrast with the common beliefs that a firm always benefits from more accurate demand information in a monopolistic setting.

We also investigate impacts of backshoring and a new entrant on other firms' profits and sourcing strategies. We show that the backshoring trend would benefit the firms that stick to sourcing from S_l, but would either hurt or benefit the firms that are sourcing from S_s. If the number of firms sourcing from S_s exceeds a threshold, then all the firms sticking to their original sourcing mode will benefit from any firm backshoring. Further, when a new firm enters the market, the existing firms' sourcing strategy will remain the same. The new firm will use efficient sourcing only if the market size is greater than a certain threshold.

The firms are restricted to sole sourcing in this paper. One potential direction for future research is to allow firms to use both responsive and efficient sourcing simultaneously. In addition, this paper

focuses on Cournot (quantity) competition. It would be interesting to study whether the results continue to hold under other competition modes (e.g., price competition). Finally, it has been assumed that both domestic and international suppliers have ample capacity. What will happen if there are capacity constraints at suppliers is also an open question for future research.

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Appendix: Proofs of Lemmas and Propositions

To save space, we only present the proofs for selected results. The rest of the proofs are either similar or straightforward and therefore omitted.

Proof of Proposition 5 The equilibrium of the game is determined by comparing the profit functions in the 2×2 matrix in Figure 2. For (S_l, S_l) to be an equilibrium, we need $\Pi_B^{ll} \geq \Pi_B^{ls}$ and $\Pi_A^{ll} \geq \Pi_B^{ls}$. Since $\Pi_B^{ll} = \Pi_A^{ll}$ (Proposition 2), $\Pi_B^{ll} \geq \Pi_B^{ls}$ if and only if (iff) $\Pi_A^{ll} \geq \Pi_B^{ls}$. Since

$$\Pi_B^{ll} - \Pi_B^{ls} = \frac{1}{9}(a - w_l)^2 + \frac{1}{9}\frac{\sigma^2}{\sigma + m_1} = \frac{4}{9}(w_s - w_l)(a - w_s) - \Gamma_1^1, \tag{1}$$

we know $\Pi_B^{ll} \geq \Pi_B^{ls}$ iff $a \geq w_s + \frac{9}{4}\frac{\Gamma_1^1}{w_s - w_l} = T_2^1$. Thus (S_l, S_l) is an equilibrium if $a \geq T_2^1$.

For (S_l, S_s) to be an equilibrium, we need $\Pi_B^{ls} \geq \Pi_B^{ll}$ and $\Pi_A^{ls} \geq \Pi_A^{ss}$. By Equation (1), $\Pi_B^{ls} \geq \Pi_B^{ll}$ iff $a \leq T_2^1$. Since

$$\begin{aligned}
\Pi_A^{ls} - \Pi_A^{ss} &= \frac{1}{9}(a - 2w_l + w_s)^2 + \frac{\sigma^2}{9(\sigma + m_1)} - \frac{1}{9}(a - w_s)^2 - \frac{1}{9}\frac{\sigma^2(m_1 + m_2)}{(\sigma m_1 + \sigma m_2 + m_1 m_2)} \\
&= \frac{4}{9}(w_s - w_l)(a - w_l) - \Gamma_2^1,
\end{aligned} \tag{2}$$

we know $\Pi_A^{ls} \geq \Pi_A^{ss}$ iff $a \geq w_l + \frac{9}{4}\frac{\Gamma_2^1}{w_s - w_l} = T_1^1$. Thus (S_l, S_s) is an equilibrium if $T_1^1 \leq a \leq T_2^1$.

For (S_s, S_s) to be an equilibrium, we need $\Pi_B^{ls} \leq \Pi_B^{ss}$ and $\Pi_A^{ls} \leq \Pi_A^{ss}$. By Proposition 3, $\Pi_B^{ss} = \Pi_A^{ss}$. Thus $\Pi_A^{ls} \leq \Pi_B^{ss}$ iff $\Pi_A^{ls} \leq \Pi_A^{ss}$. By Equation (2), $\Pi_A^{ls} \leq \Pi_A^{ss}$ iff $a \leq T_1^1$. Thus (S_s, S_s) is an equilibrium if $a \leq T_1^1$. This completes the proof. $\square$

Proof of Proposition 8 This proof is similar to that of Proposition 5, except it is for the alternative scenario instead of the base scenario. Thus, we need to use Π_A^{ls}, Π_B^{ls}, Π_A^{ss} and Π_B^{ss} for the alternative scenario in this proof.

The equilibrium of the game is determined by comparing the profit functions in the 2×2 matrix in Figure 2. For (S_l, S_l) to be an equilibrium, we need $\Pi_B^{ll} \geq \Pi_B^{ls}$ and $\Pi_A^{ll} \geq \Pi_B^{ls}$. Since $\Pi_B^{ll} = \Pi_A^{ll}$ (Proposition 2), $\Pi_B^{ll} \geq \Pi_B^{ls}$ iff $\Pi_A^{ll} \geq \Pi_B^{ls}$. Since

$$\begin{aligned}
\Pi_B^{ll} - \Pi_B^{ls} &= \frac{1}{9}(a - w_l)^2 + \frac{1}{9}\frac{\sigma^2}{\sigma + m_1} - \frac{1}{9}(a - 2w_s + w_l)^2 - \frac{\sigma^2(m_2 + \sigma)(2m_1 + \sigma)^2}{(4m_1 m_2 + 4\sigma(m_1 + m_2) + 3\sigma^2)^2} \\
&= \frac{4}{9}(w_s - w_l)(a - w_s) - \Gamma_1^2,
\end{aligned} \tag{3}$$

we know $\Pi_B^{ll} \geq \Pi_B^{ls}$ iff $a \geq w_s + \frac{9}{4}\frac{\Gamma_1^2}{w_s - w_l} = T_2^2$. Thus (S_l, S_l) is an equilibrium if $a \geq T_2^2$.

For (S_l, S_s) to be an equilibrium, we need $\Pi_B^{ls} \geq \Pi_B^{ll}$ and $\Pi_A^{ls} \geq \Pi_A^{ss}$. By Equation (3), $\Pi_B^{ls} \geq \Pi_B^{ll}$ iff $a \leq T_2^2$. Since

$$\begin{aligned}
\Pi_A^{ls} - \Pi_A^{ss} &= \frac{1}{9}(a - 2w_l + w_s)^2 + \frac{\sigma^2(m_1 + \sigma)(2m_2 + \sigma)^2}{(4m_1 m_2 + 4\sigma(m_1 + m_2) + 3\sigma^2)^2} - \frac{1}{9}(a - w_s)^2 - \frac{1}{9}\frac{\sigma^2}{\sigma + m_2} \\
&= \frac{4}{9}(w_s - w_l)(a - w_l) - \Gamma_2^2,
\end{aligned} \tag{4}$$

we know $\Pi_A^{ls} \geq \Pi_A^{ss}$ iff $a \geq w_l + \frac{9}{4}\frac{\Gamma_2^2}{w_s - w_l} = T_1^2$. Thus (S_l, S_s) is an equilibrium if $T_1^2 \leq a \leq T_2^2$.

For (S_s, S_s) to be an equilibrium, we need $\Pi_A^{ls} \leq \Pi_B^{ss}$ and $\Pi_A^{ls} \leq \Pi_A^{ss}$. By Proposition 6, $\Pi_B^{ss} = \Pi_A^{ss}$. Thus $\Pi_A^{ls} \leq \Pi_B^{ss}$ iff $\Pi_A^{ls} \leq \Pi_A^{ss}$. By Equation (4), $\Pi_A^{ss} \geq \Pi_A^{ls}$ iff $a \leq T_1^2$. Thus, (S_s, S_s) is an equilibrium if $a \leq T_1^2$. This completes the proof. $\square$

Proof of Lemma 1 We prove the following two results here. The rest of the proof is straightforward and omitted.

(1) $\Gamma_1^1 < \Gamma_1^2$ if $m_2 < \hat{m}_{21} = \frac{m_1\sigma}{2(m_1+\sigma)}, \Gamma_1^1 > \Gamma_1^2$ if $m_2 > \hat{m}_{21}$, and $\Gamma_1^1 = \Gamma_1^2$ otherwise.

We examine the sign of $\Gamma_1^2 - \Gamma_1^1$ by examining its numerator, as the common denominator is positive. Let $\Lambda\left(\Gamma_1^2 - \Gamma_1^1\right)$ denote the numerator of $\Gamma_1^2 - \Gamma_1^1$. Since $\frac{d^2\left(\Lambda\left(\Gamma_1^2 - \Gamma_1^1\right)\right)}{d(m_2)^2} < 0$, $\Lambda\left(\Gamma_1^2 - \Gamma_1^1\right)$ is concave in m_2. We can show that

$$\Lambda\left(\Gamma_1^2 - \Gamma_1^1\right)|_{m_2=0} > 0, \ \Lambda\left(\Gamma_1^2 - \Gamma_1^1\right)|_{m_2=m_1} < 0, \ \frac{d\left(\Lambda\left(\Gamma_1^2 - \Gamma_1^1\right)\right)}{dm_2}|_{m_2=0} > 0.$$

Thus, given $\Gamma_1^1 = \Gamma_1^2$ for $m_2 = \frac{m_1\sigma}{2(m_1+\sigma)}$, we have $\Gamma_1^2 - \Gamma_1^1 > 0$ for $m_2 < \frac{m_1\sigma}{2(m_1+\sigma)}$ and $\Gamma_1^2 < \Gamma_1^1$ for $m_2 > \frac{m_1\sigma}{2(m_1+\sigma)}$.

(2) $\Gamma_2^1 < \Gamma_2^2$ if $m_2 < \hat{m}_{22}$, $\Gamma_2^1 > \Gamma_2^2$ if $m_2 > \hat{m}_{22}$, and $\Gamma_2^1 = \Gamma_2^2$ otherwise.

We examine the sign of $\Gamma_2^2 - \Gamma_2^1$ by examining its numerator, as the common denominator is positive. Let $\Lambda\left(\Gamma_2^2 - \Gamma_2^1\right)$ denote the numerator of $\Gamma_2^2 - \Gamma_2^1$. From

$$\frac{d^2\left(\Lambda\left(\Gamma_2^2 - \Gamma_2^1\right)\right)}{d\left(m_2\right)^2} < 0, \ \Lambda\left(\Gamma_2^2 - \Gamma_2^1\right)|_{m_2=0} > 0, \ \Lambda\left(\Gamma_2^2 - \Gamma_2^1\right)|_{m_2=m_1} < 0,$$

we know there exists $0 < \hat{m}_{22} < m_1$, such that $\Gamma_2^2 - \Gamma_2^1 > 0$ for $m_2 < \hat{m}_{22}$ and $\Gamma_2^2 - \Gamma_2^1 < 0$ for $m_2 > \hat{m}_{22}$. Since $\Lambda\left(\Gamma_2^2 - \Gamma_2^1\right)|_{m_2=\hat{m}_{21}=\frac{m_1\sigma}{2(m_1+\sigma)}} < 0$, there is $\hat{m}_{22} < \hat{m}_{21} = \frac{m_1\sigma}{2(m_1+\sigma)}$. $\square$

Proof of Proposition 9 (i) If $m_2 < \hat{m}_{22}$, then by Lemma 1, we have $\Gamma_2^1 < \Gamma_2^2$ and $\Gamma_1^1 < \Gamma_1^2$, which imply $T_1^1 < T_1^2$ and $T_2^1 < T_2^2$. Together with $T_2^1 > T_1^1$ and $T_2^2 > T_1^2$, we have $T_2^2 > (T_2^1, T_1^2) > T_1^1$, where the order of T_2^1 and T_1^2 depends on w_l, w_s, Γ_2^2 and Γ_1^1. Based on Propositions 5 and 8, below we summarize the equilibria for different market size a under both the base and alternative scenarios. We divide the discussion into two cases: $T_1^1 > T_2^2$ and $T_2^2 > T_1^1$. Let $\underline{a}$ and $\bar{a}$ denote the lower and upper bounds of market size a, respectively.

For $T_1^2 > T_2^1$, we have the following equilibrium results:

Market size a	$(\underline{a}, T_1^1)$	(T_1^1, T_2^1)	(T_2^1, T_1^2)	(T_1^2, T_2^2)	$(T_2^2, \bar{a})$
Base scenario	(S_s, S_s)	(S_l, S_s)	(S_l, S_l)	(S_l, S_l)	(S_l, S_l)
Alternative scenario	(S_s, S_s)	(S_s, S_s)	(S_s, S_s)	(S_l, S_s)	(S_l, S_l)

For $T_2^1 > T_1^2$, we have the following equilibrium results:

Market size a	$(\underline{a}, T_1^1)$	(T_1^1, T_1^2)	(T_1^2, T_2^1)	(T_2^1, T_2^2)	$(T_2^2, \bar{a})$
Base scenario	(S_s, S_s)	(S_l, S_s)	(S_l, S_s)	(S_l, S_l)	(S_l, S_l)
Alternative scenario	(S_s, S_s)	(S_s, S_s)	(S_l, S_s)	(S_l, S_s)	(S_l, S_l)

We can see that in both cases, (S_l, S_l) arises as the equilibrium within a larger range of a under the base scenario, while (S_s, S_s) arises within a smaller range of a under the base scenario.

(ii) If $\hat{m}_{22} < m_2 < \hat{m}_{21}$, then by Lemma 1, we have $\Gamma_2^1 > \Gamma_2^2$ and $\Gamma_1^1 < \Gamma_1^2$, which together with $T_2^1 > T_1^1$ and $T_2^2 > T_1^2$ imply $T_2^2 > T_2^1 > T_1^1 > T_1^2$. The equilibrium results are summarized as follows:

Market size a	$(\underline{a}, T_1^2)$	(T_1^2, T_1^1)	(T_1^1, T_2^1)	(T_2^1, T_2^2)	$(T_2^2, \bar{a})$
Base scenario	(S_s, S_s)	(S_s, S_s)	(S_l, S_s)	(S_l, S_l)	(S_l, S_l)
Alternative scenario	(S_s, S_s)	(S_l, S_s)	(S_l, S_s)	(S_l, S_s)	(S_l, S_l)

We can see that both (S_s, S_s) and (S_l, S_l) occur within a larger range of a under the base scenario.

(iii) If $\frac{m_1\sigma}{2(m_1+\sigma)} < m_2$, then by Lemma 1, we have $\Gamma_1^1 > \Gamma_1^2$ and $\Gamma_2^1 > \Gamma_2^2$, which imply $T_2^1 > T_2^2$ and $T_1^1 > T_1^2$. Together with $T_2^2 > T_1^1$ and $T_2^2 > T_1^2$, we have $T_2^1 > (T_1^1, T_2^2) > T_1^2$. Similarly to (i), we consider two cases: $T_1^1 > T_2^2$ and $T_1^1 < T_2^2$.

For $T_1^1 > T_2^2$, we have the following equilibrium results:

Market size a	$(\underline{a}, T_1^2)$	(T_1^2, T_2^2)	(T_2^2, T_1^1)	(T_1^1, T_2^1)	$(T_2^1, \bar{a})$
Base scenario	(S_s, S_s)	(S_s, S_s)	(S_s, S_s)	(S_l, S_s)	(S_l, S_l)
Alternative scenario	(S_s, S_s)	(S_l, S_s)	(S_l, S_l)	(S_l, S_l)	(S_l, S_l)

For $T_1^1 < T_2^2$, we have the following equilibrium results:

Market size a	$(\underline{a}, T_1^2)$	(T_1^2, T_1^1)	(T_1^1, T_2^2)	(T_2^2, T_2^1)	$(T_2^1, \bar{a})$
Base scenario	(S_s, S_s)	(S_s, S_s)	(S_l, S_s)	(S_l, S_s)	(S_l, S_l)
Alternative scenario	(S_s, S_s)	(S_l, S_s)	(S_l, S_s)	(S_l, S_l)	(S_l, S_l)

We can see that in both cases, (S_l, S_l) arises as the equilibrium within a smaller range of a under the base scenario, while (S_s, S_s) occurs within a larger range of a under the base scenario. $\square$

Proof of Proposition 10 Suppose the firms sourcing from S_l adopt strategies $Q_l^i(x_1)$, $i = 1, 2, \cdots, K$, and the firms sourcing from S_s adopt strategies $Q_s^i(x_1, x_2)$, $i = K+1, K+2, \cdots, N$. The expected profit of any firm i $(i = 1, 2, \cdots, K)$ sourcing from S_l given signal x_1 is

$$\pi_l(x_1) = Q_l^i E\left[a - \left(Q_l^i + \sum_{j=1, j\neq i}^{K} Q_l^j + \sum_{j=K+1}^{N} Q_s^j\right) + u - w_l \,\middle|\, x_1\right].$$

The first-order condition yields

$$2Q_l^i = a - \sum_{j=1, j\neq i}^{K} Q_l^j - E\left(\sum_{j=K+1}^{N} Q_s^j \,\middle|\, x_1\right) + E(u|x_1) - w_l. \tag{5}$$

From Equation (5) we know the K firms that source from S_l adopt symmetric strategies in any equilibrium, i.e. $Q_l^j = Q_l^k$, for $j \neq k$ and $j, k \leq K$.

Similarly, the expected profit of any firm j $(j = K+1, K+2, \cdots, N)$ sourcing from S_s given signals x_1 and x_2 is

$$\pi_s(x_1, x_2) = Q_s^j E\left[a - \left(Q_s^j + \sum_{i=1}^{K} Q_l^i + \sum_{i=K+1, i\neq j}^{N} Q_s^i\right) + u - w_s \,\middle|\, x_1, x_2\right],$$

which leads to

$$2Q_s^j = a - \left(\sum_{i=1}^{K} Q_l^i + \sum_{i=K+1, i\neq j}^{N} Q_s^i\right) + E(u|x_1, x_2) - w_s. \tag{6}$$

From Equation (6) we know the $N - K$ firms that source from S_s adopt symmetric strategies in any equilibrium, i.e. $Q_s^i = Q_s^k$, for $i \neq k$ and $i, k > K$. Then Equations (5) and (6) can be respectively written as

$$(K+1)Q_l^i = a - (N-K)E\left(Q_s^j|x_1\right) + E(u|x_1) - w_l, \tag{7}$$

$$(N-K+1)Q_s^j = a - KQ_l^i + E(u|x_1, x_2) - w_s. \tag{8}$$

Define

$$\tilde{Q}_l^i = A_1 x_1 + B_1 w_l + C_1 w_s + D_1, \ i \leq K,$$
$$\tilde{Q}_s^j = A_2 x_2 + B_2 x_1 + C_2 w_s + D_2 w_l + E_2, \ j > K.$$

Let

$$g(x_1) = Q_l^i - \tilde{Q}_l^i = Q_l^i - (A_1 x_1 + B_1 w_l + C_1 w_s + D_1),$$
$$g(x_1, x_2) = Q_s^j - \tilde{Q}_s^j = Q_s^j - (A_2 x_2 + B_2 x_1 + C_2 w_s + D_2 w_l + E_2).$$

Then Equations (7) and (8) become

$$(K+1)g(x_1) = -(N-K)E(g(x_1,x_2)|x_1) \tag{9}$$

$$(N-K+1)g(x_1,x_2) = -KE(g(x_1)|x_1,x_2), \tag{10}$$

with the following nine simultaneous conditions:

$$\frac{\sigma}{\sigma+m_1} - (K+1)A_1 = (N-K)(A_2 \frac{\sigma}{\sigma+m_1} + B_2), \tag{11}$$
$$-1-(K+1)B_1 = (N-K)C_2,$$
$$-(K+1)C_1 = (N-K)D_2,$$
$$a-(K+1)D_1 = (N-K)E_2,$$
$$\frac{m_1\sigma}{(m_1+m_2)\sigma+m_1m_2} = (N-K+1)A_2, \tag{12}$$
$$\frac{m_2\sigma}{(m_1+m_2)\sigma+m_1m_2} = (N-K+1)B_2 + KA_1, \tag{13}$$
$$-1-(N-K+1)D_2 = KC_1,$$
$$-(N-K+1)C_2 = KB_1,$$
$$a-(N-K+1)E_2 = KD_1.$$

Note that Equations (11),(12) and (13) are derived by applying the results $E(u|x_1) = E(x_2|x_1) = \frac{\sigma}{\sigma+m_1}x_1$, and $E(u|x_1,x_2) = \frac{m_1\sigma x_2 + m_2\sigma x_1}{(m_1+m_2)\sigma+m_1m_2}$.

Equations (9) and (10) can be reorganized as

$$g(x_1) = -(N-K)E(g(x_1,x_2) + \frac{K}{N-K}g(x_1)|x_1), \tag{14}$$
$$g(x_1,x_2) = -KE(g(x_1) + \frac{N-K}{K}g(x_1,x_2)|x_1,x_2). \tag{15}$$

Multiplying Equation (14) by $g(x_1)$ and taking expectation, we obtain

$$E(g^2(x_1)) = -E((N-K)g(x_1,x_2)g(x_1) + Kg^2(x_1)). \tag{16}$$

Multiplying Equation (15) by $g(x_1,x_2)$ and taking expectations, we obtain

$$E(g^2(x_1,x_2)) = -E(Kg(x_1,x_2)g(x_1) + (N-K)g^2(x_1,x_2)). \tag{17}$$

Summing Equations (16) and (17) yields

$$E(g^2(x_1) + g^2(x_1,x_2)) = -E((N-K+K)g(x_1,x_2)g(x_1) + Kg^2(x_1) + (N-K)g^2(x_1,x_2)). \tag{18}$$

Next, we show that the right-hand side (RHS) of Equation (18) is non-positive.

If $g(x_1, x_2)$ and $g(x_1)$ have the same sign, then

$$(N - K + K)g(x_1, x_2)g(x_1) \geq 2\sqrt{(N-K)}\sqrt{K}g(x_1, x_2)g(x_1).$$

Hence $RHS \leq -E\left((\sqrt{(N-K)}g(x_1, x_2) + \sqrt{K}g(x_1))^2\right) \leq 0$.

If $g(x_1, x_2) > (<)0$ and $g(x_1) < (>)0$, then $E(g(x_1, x_2)) > (<)0$ and $E(g(x_1)) < (>)0$. Taking expectation of Equations (14) and (15), we have $E((N-K)g(x_1, x_2) + Kg(x_1)) > (<)0$ and $E(Kg(x_1) + (N-K)g(x_1, x_2)) < (>)0$. Multiplying the former inequality by $g(x_1, x_2)$ and the latter inequality by $g(x_1)$, and then summing the two inequalities gives $RHS \leq 0$.

The fact that the right-hand side of Equation (18) is less than or equal to 0, together with the fact that the left-hand side of Equation (18) is greater than or equal to 0, leads to $g(x_1, x_2) = g(x_1) = 0$, i.e.

$$Q_l^{i*} = \tilde{Q}_l^i = A_1 x_1 + B_1 w_l + C_1 w_s + D_1, \; i = 1, 2, \cdots, K,$$

$$Q_s^{j*} = \tilde{Q}_s^j = A_2 x_2 + B_2 x_1 + C_2 w_s + D_2 w_l + E_2, \; j = K+1, K+2, \cdots, N.$$

Therefore, the Cournot competition under the sourcing structure (N, K) has a unique equilibrium in the linear form. Solving the above nine simultaneous equations gives

$$A_1 = \frac{\sigma}{(m_1 + \sigma)(N+1)}, \; A_2 = \frac{m_1 \sigma}{(N-K+1)(m_1 m_2 + m_1 \sigma + m_2 \sigma)},$$

$$B_1 = \frac{-(N-K+1)}{N+1}, \; B_2 = \frac{\sigma(-(N-K+1)(m_2 \sigma + m_1 m_2) + K m_1 \sigma)}{-(N-K+1)(N+1)(m_1 + \sigma)(m_1 m_2 + m_1 \sigma + m_2 \sigma)},$$

$$C_1 = \frac{N-K}{N+1}, \; C_2 = \frac{K}{N+1},$$

$$D_1 = \frac{a}{N+1}, \; D_2 = \frac{-(K+1)}{N+1}, \; E_2 = \frac{a}{N+1}.$$

Substituting all the coefficients (A_1 to E_2) into the profit functions and then taking expectation give $\Pi_l(N, K)$ and $\Pi_s(N, K)$. This completes the proof. $\square$

Proof of Proposition 11 The profit functions can be written as

$$\Pi_l(N, K) = I_l^e(N, K) + I_l^i(N, K),$$

$$\Pi_s(N, K) = I_s^e(N, K) + I_s^i(N, K),$$

where

$$I_l^e(N, K) = \frac{(a - (N+1-K)w_l + (N-K)w_s)^2}{(N+1)^2}, \; I_l^i(N, K) = \frac{\sigma^2}{(N+1)^2(m_1 + \sigma)},$$

$$I_s^e(N, K) = \frac{(a + Kw_l - (K+1)w_s)^2}{(N+1)^2},$$

$$I_s^i(N, K) = \frac{\sigma^2}{(N+1)^2(m_1 + \sigma)} + \frac{m_1^2 \sigma^2}{(N-K+1)^2(m_1 + \sigma)(m_1 m_2 + m_1 \sigma + m_2 \sigma)}.$$

(i) Taking derivative gives

$$\frac{dI_l^e(N, K)}{dN} = -\frac{2(a - K(w_s - w_l) - w_s)(a + (N-K)(w_s - w_l) - w_l)}{(N+1)^3}.$$

The non-negativity of the market price requires $a - K(w_s - w_l) - w_s > 0$ and $a + (N - K)(w_s - w_l) - w_l > 0$. Under these conditions, we have $\frac{dI_l^e(N,K)}{dN} < 0$. Note $I_l^i(N,K)$ also decreases in N. Therefore, $\Pi_l(N,K) = I_l^e(N,K) + I_l^i(N,K)$ decreases in N. The result that $\Pi_s(N,K)$ decreases in N is by observation.

(ii) Observe that $I_l^i(N,K)$ is independent of K. Taking derivative gives

$$\frac{dI_l^e(N,K)}{dK} = \frac{-2(w_s - w_l)(a + (N - K)(w_s - w_l) - w_l)}{(N+1)^2} < 0.$$

(iii) Note

$$I_s^e(N,K) = \frac{(a + Kw_l - (K+1)w_s)^2}{(N+1)^2} = \frac{(a - K(w_s - w_l) - w_s)^2}{(N+1)^2}.$$

Given $a - K(w_s - w_l) - w_s > 0$, we know $I_s^e(N,K)$ decreases in K. It is straightforward to show that $I_s^i(N,K)$ increases in K. Taking derivative gives

$$\frac{d\Pi_s(N,K)}{dK} = \frac{H}{(N+1)^2(N+1-K)^3(m_1 + \sigma)(m_1 m_2 + m_1 \sigma + m_2 \sigma)},$$

where

$$H = 2m_1^2\sigma^2(N+1)^2 + 2(w_l - w_s)(a - w_s + K(w_l - w_s))(N+1-K)^3(m_1 + \sigma)(m_1 m_2 + m_1 \sigma + m_2 \sigma)$$

is increasing in K since $a - K(w_s - w_l) - w_s > 0$. Thus, there exists a $\hat{K}$ such that $\frac{d\Pi_s(N,K)}{dK} \leq 0$ for $K \leq \hat{K}$ and $\frac{d\Pi_s(N,K)}{dK} \geq 0$ for $K \geq \hat{K}$. This proves the unimodality of $\Pi_s(N,K)$. $\square$

Proof of Proposition 12 (i) Given there are already $K - 1$ firms sourcing from S_l and $N - K$ firms sourcing from S_s, if the Nth firm sources from S_l (S_s), she will obtain an expected profit of $\Pi_l(N,K)$ ($\Pi_s(N, K-1)$). She will choose to source from S_l if $\Pi_l(N,K) > \Pi_s(N, K-1)$. If $\Pi_l(N,K) = \Pi_s(N, K-1)$, she is indifferent between sourcing from S_l and sourcing from S_s. Note

$$\Pi_l(N,K) - \Pi_s(N, K-1) = \frac{N(w_s - w_l)}{(N+1)^2}(2a + (2K - N - 2)w_l + (N - 2K)w_s)$$
$$- \frac{m_1^2\sigma^2}{(N + 2 - K)^2(m_1 + \sigma)(m_1 m_2 + m_1 \sigma + m_2 \sigma)},$$

which is decreasing in K. Thus, $\Pi_l(N,K) - \Pi_s(N, K-1) > 0$ implies $\Pi_l(N, i-1) - \Pi_s(N, i-2) > 0$ for all $i \leq K - 1$. This means that there will be at least K firms sourcing from S_l if $\Pi_l(N,K) > \Pi_s(N, K-1)$. Such a condition is equivalent to $a > T_l(K, N)$.

Given there are already $K - 1$ firms sourcing from S_s, $N - K$ firms sourcing from S_l, if the Nth firm sources from S_s (S_l), she will obtain an expected profit of $\Pi_s(N, N - K)$ ($\Pi_l(N, N - K + 1)$). She will choose to source from S_s if $\Pi_s(N, N - K) > \Pi_l(N, N - K + 1)$. Note

$$\Pi_s(N, N - K) - \Pi_l(N, N - K + 1) = \frac{N(w_l - w_s)(2a + (N - 2K)w_l + (2K - N - 2)w_s)}{(N+1)^2}$$
$$+ \frac{m_1^2\sigma^2}{(K+1)^2(m_1 + \sigma)(m_1 m_2 + m_1 \sigma + m_2 \sigma)},$$

which is decreasing in K. By the same argument, there will be at least K firms sourcing from S_s if $\Pi_s(N, N - K) > \Pi_l(N, N - K + 1)$, a condition that is equivalent to $a < T_s(K, N)$.

(ii) The proof is straightforward and omitted.

(iii) From (i), there are at least K firms sourcing from S_l if $a > T_l(K, N)$; there are at least $N - K$ firms sourcing from S_s if $a < T_s(N - K, N)$. Therefore, if $T_l(K, N) < a < T_s(N - K, N)$, there are exactly K firms sourcing from S_l, and $N - K$ firms sourcing from S_s. It can be shown that $T_s(N - K, N) = T_l(K + 1, N)$, so $T_l(K, N) < a < T_s(N - K, N)$ is equivalent to $T_l(K, N) < a < T_l(K + 1, N)$.

Note that $a = T_l(K, N)$ implies $\Pi_l(N, K) = \Pi_s(N, K - 1)$, i.e., the firm is indifferent between sourcing from S_l and sourcing from S_s; so in equilibrium, there are either K or $K - 1$ firms sourcing from S_l.$\square$

Proof of Proposition 13 (i) Since out of the N incumbent firms, there are exactly K firms sourcing from S_l, we have $T_l(K, N) \leq a \leq T_s(N - K, N)$. By Proposition 12(ii), we have $T_s(N - K, N) < T_s(N - K, N + 1)$ and $T_l(K, N) > T_l(K, N + 1)$. Hence, $T_l(K, N + 1) < T_l(K, N) \leq a \leq T_s(N - K, N) < T_s(N - K, N + 1)$. By Proposition 12(i), with $N + 1$ firms in the market, there will still be at least K firms sourcing from S_l and $N - K$ firms sourcing from S_s.

(ii) If $a > T_l(K + 1, N + 1)$, there will be at least $K + 1$ firms sourcing from S_l by Proposition 12(i). As in (i), with $N + 1$ firms, there will still be at least $N - K$ firms sourcing from S_s. Therefore, the new entrant sources from S_l under the condition $a > T_l(K + 1, N + 1)$ and there will be exactly $K + 1$ firms sourcing from S_l. By Proposition 12(iii), if $a = T_l(K + 1, N + 1)$, the new entrant will be indifferent between sourcing from S_l and sourcing from S_s; if $a < T_l(K + 1, N + 1)$, the new entrant prefers to source from S_s. $\square$