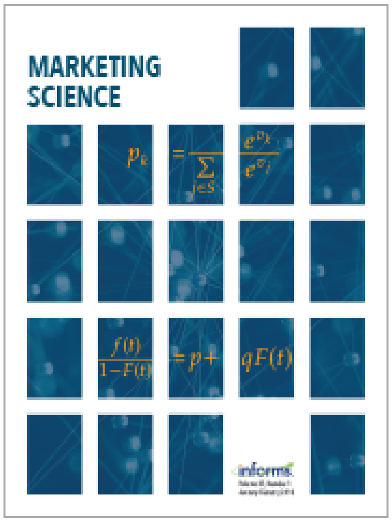


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# The Effects of Information Transparency on Suppliers, Manufacturers, and Consumers in Online Markets

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This paper looks into the effects of information transparency on market participants in an online trading environment. We study these effects in business-to-business electronic markets with firms competing in *both* upstream and downstream industries. The prior literature generally assumes that either the downstream firm (buyer) or the upstream firm (seller) is a monopoly. It is not clear whether information transparency would still create value if *both* buyers and sellers face oligopolistic competition, where the benefits of information transparency could be competed away. To answer this question, we first develop a simple two-echelon e-market model and then extend the model to more general settings. We find that information transparency can create value for the overall e-market, yet it affects buyers and sellers very *differently*: one side will be hurt, depending on the competition mode (Cournot or Bertrand) in the downstream. This suggests that a manufacturer-owned, a supplier-owned, and a neutral e-market will have different preferences for information transparency. Finally, we find that information transparency can hurt consumers when the downstream industry engages in Bertrand competition. This is a surprising result given the expectation that online markets create substantial value for consumers.

*Key words*: electronic markets; competition; uncertainty; market microstructure; information transparency; B2B marketing; game theory; analytical modeling
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## 1. Introduction

After the burst of the dot-com bubble in 2000, many electronic markets went out of business, yet many surviving markets, which built brand awareness and market share, kept growing and evolving. Alibaba, the largest business-to-business (B2B) online e-market in the world, has witnessed a revenue growth of 58% from 1,364 million yuan in 2006 to 2,163 million yuan in 2007. Its gross profit increased by 67% in 2007, and its operating profit increased by nearly 200%. The number of registered buyers and sellers of its online trading platform grew to 28 million (as of December 31, 2007), representing a 40% annual growth in user base.[1]

In the United States, online transactions were still small as a percentage of total retail sales ($31,708 million, about 3.5% of total retail sales in the first quarter of 2009), but they kept increasing steadily.[2] It was estimated that more than 94% of total online transactions were B2B trading.[3] The ups and downs of B2B e-markets motivate us to examine how a B2B market creates value for market participants. In this paper, we focus on an important feature of B2B: information transparency, which enables firms to share information online.

Information sharing has been shown to benefit trading partners. In reality, many industries are still in search of a platform that will facilitate information sharing while allowing firms to conduct transactions. B2B electronic markets (e-markets) have the promise of being one such transaction platform. B2B e-markets provide a digital environment with abundant data about products, prices, bids, quantities, and other transaction details. Hence, relative to traditional physical markets, e-markets offer a data-rich environment. Thus, information transparency, which is defined as the degree of visibility and accessibility of information, is a key feature of B2B e-markets (Zhu 2004).

Earlier studies show that information transparency benefits total supply chain (e.g., Lee et al. 2000, Cachon and Fisher 2000), but the information transparency in these studies generally refers to vertical information sharing about *demand* between an upstream firm (e.g., a supplier) and a downstream firm (e.g., a manufacturer). This is different from horizontal information transparency between competitors. Evidence shows that horizontal information

[1] See Alibaba (2008).

[2] See U.S. Census Bureau (2009).

[3] See U.S. Census Bureau.

transparency in electronic markets enables firms to use transaction data to infer the cost structure of competitors (Soh et al. 2006). This new feature is partly enabled by the data-rich environment of online markets (relative to traditional markets).

Information transparency is deemed socially desirable because it may help improve efficiency in resource allocation (Bakos 1997). On the other hand, market participants may want to conceal transaction data to protect their privacy (Kalvenes and Basu 2006). Prior economics literature has analyzed the effects of information sharing in a *one-level* market (e.g., Gal-Or 1985); however, it is not clear whether information transparency about competitors' cost would benefit a *two-level* e-market with oligopolistic competition existing in both upstream and downstream industries. In this paper, we focus on the following research questions:

- In such a market, will information transparency benefit both sellers and buyers, or will there be a conflict of interest?
- If such conflict of interest exists, under what conditions would buyers (or sellers) be hurt?
- How does information transparency affect consumers?

The real world offers examples on both sides: B2B e-markets with high information transparency and with low information transparency. Before 2000, auto manufacturers each had their own private exchanges in which their prequalified suppliers could do transactions with the dedicated auto manufacturer. That is, each of the "big three" auto manufacturers ran their own separate marketing channels.[4] In 2000, Covisint was created to provide a transparent shared platform on which bidding prices were visible to all participants, yet market participants were concerned about their privacy. Ariba, another B2B e-market, adopted a business model with lower information transparency than that of Covisint. WorldWide Retail Exchange (WWRE), another e-market, has two e-market structures with different levels of information transparency. First, WWRE's data pool service provides up-to-date and searchable information, with an objective to develop a "single platform that connects retailers, manufacturers and their business trading partners to more efficiently and effectively *share information* and manage work processes" (*Logistics Today* 2005, emphasis our own). Second, WWRE also provides private e-markets to those firms who want to customize their information exchange with selected suppliers, thus achieving better control over transaction data.

These real-world examples illustrate that neither the transparent e-market nor the opaque e-market is an all-encompassing solution in practice.[5] This can be related to multiform ownership structures of the B2B e-markets. Yoo et al. (2007) defined three ownership structures: (1) buyer-owned (manufacturer-owned) marketplaces where manufacturers jointly own the marketplace, (2) seller-owned (supplier-owned) marketplaces, and (3) neutral marketplaces that are owned by independent third parties. The ownership structure could affect the choice of transparency level of a B2B e-market. Intuitively, if the information transparency benefits manufacturers, then a manufacturer-owned marketplace would prefer a transparent market structure. The question is this: under what conditions will the information transparency be beneficial to a specific type of B2B e-market? The answer to such a question may generate useful insights about the role of information transparency in online markets and on the microstructure design of online markets. This in turn may be useful in understanding which structure worked and which structure failed.

To better understand these issues, we develop a two-level B2B e-market model. Buyers (manufacturers) in the downstream each have some prequalified suppliers in the upstream. Suppliers compete for the manufacturer's orders via bidding on the e-market platform; manufacturers in turn compete in the consumer market. Using this setting, we show that the information transparency affects manufacturers and suppliers very *differently*. We find that one side (either manufacturers or suppliers) is hurt by, whereas the other side benefits from, the information transparency enabled by the e-market. Interestingly, the competition mode of the downstream industry turns out to be a critical factor that determines which side is hurt. If manufacturers compete on quantity (i.e., Cournot competition), the information transparency helps them but hurts their upstream suppliers. That is, a manufacturer-owned B2B e-market may prefer a transparent e-market structure, whereas a supplier-owned B2B e-market may prefer an opaque market. Conversely, if manufacturers compete on price (i.e., Bertrand competition), they are hurt while suppliers benefit. These results show a conflict of interest regarding information transparency between manufacturers and suppliers.

Despite the conflict of interest, we find that information transparency always increases the overall welfare to *all* e-market participants regardless of the competition mode, implying that its benefit always dominates

[4] Exostar has a similar industry structure in the aerospace industry.

[5] Defined more precisely in the next section, a transparent e-market refers to an information structure in which a manufacturer is able to see the bids (prices) to other manufacturers in the online market, whereas an opaque e-market refers to an information structure in which a manufacturer is unable to see the bids to other manufacturers.

the loss. This suggests that a neutral B2B e-market may prefer a transparent e-market model.

We further examine the effect of information transparency on consumers. We find that the information transparency can hurt consumers under certain conditions. This is a surprising result given the expectation that online markets could create substantial values to consumers (Hitt and Brynjolfsson 1996).

### 1.1. Related Literature

Our paper is related to the marketing literature on information economics in a distribution channel. Vertical information sharing was found to have two effects on an upstream manufacturer: (1) an efficiency effect, which helps the manufacturer to better manage its inventory; and (2) a strategic effect, which can hurt it by limiting its ability to extract profits from a downstream retailer (Iyer et al. 2007). In examining information acquisition and sharing in a distribution channel, it was shown that information acquisition benefits a downstream retailer, whereas vertical information sharing hurts the retailer but benefits an upstream wholesaler (Guo 2009). He et al. (2008) consider vertical information sharing in a channel setting where demand is highly volatile and firms engage in short-term trading relationships. Information asymmetry about demand can also be dealt with by using advertising and slotting allowances (Desai 2000, Chu 1992). The literature of operations management also examined the vertical information sharing in various settings (see, for example, Lee et al. 1997, 2000; Gavirneni et al. 1999; Cachon and Fisher 2000; Kulp et al. 2004).

Most of this prior literature focuses on vertical information sharing and considers the case where there is one firm in an upstream industry or in a downstream industry. Our paper differs from the prior literature in that we consider the case where competition exists in both the upstream and the downstream industries, and information is transferred horizontally between competitors via a market mechanism. There is a stream of economics literature that focuses on horizontal information sharing among competitors in a one-level market, where sourcing from upstream is not explicitly modeled (Vives 2002, Raith 1996, Shapiro 1986, Gal-Or 1985). Zhu (2004) examines the incentives for firms to join a transparent e-market. Our paper differs from this literature in that we model a two-level e-market, where both the upstream industry and downstream industry are explicitly modeled. Thus, our paper fills a gap in the literature and provides new business insight regarding the effects of information transparency on the upstream industry, the downstream industry, and the total e-market, respectively.

Our paper is also related to the marketing literature on vertical channel coordination (see, for example, Gerstner and Hess 1995, Iyer 1998, Coughlan 1985, Shaffer and Zettelmeyer 2004, Jeuland and Shugan 1983). In this paper, information transparency in the e-market can help downstream buyers to coordinate their strategies when the downstream industry engages in Cournot competition. The coordination occurs between competitors instead of between business partners. In our model, this is done by using supplier cost information to achieve better outcomes in the final consumer market.

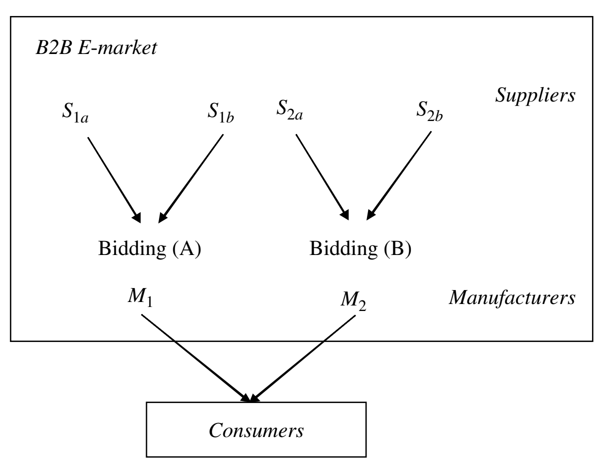
To illustrate the major result with mathematical simplicity, we present a simple base model, followed by an analysis of the overall effects on the total e-market and differential effects on suppliers and manufacturers, respectively. Then, we relax some of the assumptions and extend the base model to examine more general situations, incorporating (1) different competition modes (Cournot versus Bertrand), (2) overlapping suppliers, and (3) asymmetric procurement channels. We show that the major results in the base model also hold in more general settings. Most of the technical proofs are provided in the electronic companion, available as part of the online version that can be found at http://mktsci.pubs.informs.org/.

## 2. The Base Model

To illustrate the essence of the issue, we consider a simple two-level e-market with two manufacturers ($M_1$ and $M_2$) in the downstream industry. Each manufacturer has two prequalified upstream suppliers, where $M_i$'s suppliers are labeled as $S_{ia}$ and $S_{ib}$ ($i = 1, 2$), as shown in Figure 1. Built on related literature (Bakos and Brynjolfsson 1993, Pinker et al. 2003), we make several assumptions to model such a market.

Assumption 1. *A manufacturer procures from a limited number of prequalified suppliers.*

**Figure 1 The Base Model**



This setting captures some key features of B2B e-markets that are different from those of business-to-consumer (B2C) e-markets and is motivated by several real-world exchanges, such as Exostar and Covisint.[6] First, each manufacturer does business with a limited number of suppliers because business relation-specific investments in B2B e-markets are significantly higher than those in B2C e-markets. Bakos and Brynjolfsson (1993) argue that manufacturers often find it optimal to work with only a small number of suppliers. Second, transactions in B2B e-markets often involve mutual trust, integrating interorganizational information systems, quality requirements, product specification, and arrangements of shipments and payments. Before a manufacturer invites suppliers to bid on a contract, the manufacturer generally needs to prequalify suppliers who meet its requirements (Pinker et al. 2003). In a B2B e-market, it is often difficult or impractical to switch to a nonprequalified supplier in a short period of time.[7] These fundamental industry relationships remain important, even with the presence of an electronic market. We can think of the supplier selection problem as a two-stage process: first, manufacturers prequalify suppliers based on nonprice attributes (which we take as given in this model); second, prequalified suppliers bid for the manufacturers' business.

For mathematical simplicity, we assume that the prequalified suppliers of one manufacturer are different from those of the other manufacturer (i.e., manufacturers have different upstream suppliers). In §6, we will relax this assumption and allow overlapping suppliers (i.e., some suppliers can contract with both manufacturers).

Assumption 2. *Upstream suppliers' marginal costs are private information and independently follow a uniform distribution* $U(0, 1)$.

The cost structure of manufacturers consists of procurement cost and other costs. To simplify exposition, we assume that the sum of all other costs for each manufacturer remains a constant and is further normalized to zero.

Suppliers compete for contracts via a Vickrey second-bid auction. We make this assumption for two reasons. First, English auction is currently the dominant mechanism on the Internet (Pinker et al. 2003). Second, the outcome of the English auction can be achieved by the Vickrey auction, and it is customary to model an English auction as a Vickrey auction (Milgrom 1989).

Regarding the information structure, there are two possible informational schemes: transparent and opaque.[8] First, if the e-market is run as a transparent platform (i.e., bidding prices are revealed), suppliers' bids are visible to both manufacturers (see Figure 1), which means that both manufacturers can observe each other's procurement cost. Second, if the e-market is run as an opaque platform, suppliers' bids are visible only to the corresponding manufacturer, not to its competitor. That is, there are two separate auctions (similar to those private exchanges discussed in §1). In contrast to the transparent market, each manufacturer's procurement cost remains as private information. The following assumption summarizes the difference between the two information structures.

Assumption 3. *The transparent market enables manufacturers to share their cost information.*

Assumption 4. *A manufacturer-owned* (*or supplier-owned*) *B2B e-market seeks to maximize expected gains of manufacturers* (*or suppliers*), *whereas a neutral B2B e-market seeks to maximize the total expected gain of suppliers and manufacturers.*

Given the information structures defined above, the sequence of events is as follows. Prequalified upstream suppliers compete for downstream orders via bidding. After the bidding is closed, both manufacturers collect necessary information from the B2B e-market and then make decisions on their procurement quantities. After receiving purchased inputs from upstream suppliers, both manufacturers assemble final products and sell to consumers.

Manufacturers are engaged in Cournot competition with an inverse demand function from the consumer market,

$$p_{m1} = d - q_{m1} - \alpha q_{m2},$$
$$p_{m2} = d - q_{m2} - \alpha q_{m1},$$

where $q_{mi}$ is the quantity sold by manufacturer $i$ ($i = 1, 2$), $p_{mi}$ is the price set by manufacturer $i$ ($i = 1, 2$), and $d$ is the demand intercept. We further assume that $0 < \alpha < 1$, which means that the impact of a unit change of $q_{mi}$ on $p_{mi}$ is greater than that

[6] Examples of real-world B2B e-markets that partly resemble this feature (and the structure in Figure 1) include Covisint in the auto industry, Exostar in aerospace industry, and the Global Healthcare Exchange in health-care industry. They have a small number of downstream firms to do business with some prequalified upstream firms.

[7] For example, evidence shows that it is useful for auto manufacturers to procure from prequalified suppliers who get involved in collaborative new product development (Zirpoli and Caputo 2002). Price is not the only consideration when choosing suppliers. A manufacturer could procure car components from a dedicated supplier who offers a higher price than other nonprequalified suppliers.

[8] Given that we focus on comparing these two e-market structures, we do not consider the case that firms may trade off-line.

of $q_{mj}$ on $p_{mi}$ (that is, $|\partial p_{mi}/\partial q_{mi}| > |\partial p_{mi}/\partial q_{mj}|$, where $i \neq j$). To avoid degenerate solutions, we follow prior literature by assuming that the demand intercept is sufficiently large. Also, all firms are risk neutral. The notation used in this paper is given in the appendix.

## 3. The Effects of Information Transparency

Based on the above model setup, we study the effects of information transparency on the manufacturers, the suppliers, and the total e-market, respectively. Denote the cost to manufacturer $i$ by $c_{mi}$ ($i = 1, 2$), which is the best price that it can get from its prequalified supplier. Let the lowest cost of its upstream suppliers be $s_i^{l1}$ and the second-lowest cost be $s_i^{l2}$. The strategic variable for a supplier is its bidding price. In a Vickrey auction with endogenous quantity, a supplier's optimal bidding will reveal its true marginal cost, an equilibrium result established in standard auction theory (Hansen 1988, Milgrom 1989).[9] Thus, $c_{mi} = s_i^{l2}$ ($i = 1, 2$), manufacturer $i$'s cost is equivalent to the second-lowest cost of its prequalified suppliers. According to the information structure of the e-market, $c_{mi}$ is revealed to manufacturer $j$ ($j = 1, 2, j \neq i$) in a transparent e-market but remains private in an opaque e-market.

First, we consider the transparent e-market. After $c_{mj}$ is revealed to manufacturer $i$, its problem is

$$\max_{q_{mi}} \pi_{mi}^T = (d - q_{mi} - \alpha q_{mj} - c_{mi}) \cdot q_{mi}, \quad (i = 1, 2; i \neq j),$$

where $\pi_{mi}^T$, $c_{mi}$, and $q_{mi}$ are manufacturer $i$'s profit, cost, and quantity, respectively. As discussed above, $c_{mj}$ is observable to manufacturer $i$ through the e-market platform. Thus, manufacturer $i$ may use $c_{mj}$ to compute $q_{mj}$, indicating that $q_{mj}$ is known to $i$ by computation. Solving the two manufacturers' problems, we get the following results (see the appendix for details):

$$p_{mi}^T = \frac{1}{4 - \alpha^2}[d(2 - \alpha) + (2 - \alpha^2)c_{mi} + \alpha c_{mj}],$$
$$q_{mi}^T = \frac{1}{4 - \alpha^2}[d(2 - \alpha) - 2c_{mi} + \alpha c_{mj}],$$

where the superscript $T$ stands for a transparent market. It follows

$$E(\pi_{mi}^T) = \frac{1}{36}\left[\frac{1}{(2-\alpha)^2} + \frac{17 + 12d(3d - 4)}{(2+\alpha)^2}\right],$$
$$E(\pi_{si}^T) = \frac{6d(2-\alpha) + 4\alpha - 9}{18(4 - \alpha^2)}, \tag{1}$$

where $E(\pi_{mi}^T)$ is the expected profit of manufacturer $i$ in the transparent B2B e-market, and $E(\pi_{si}^T)$ is the expected profit of manufacturer $i$'s supplier who wins the auction. By symmetry, $E(\Pi^T)$, the total expected profit of all participants, is

$$E(\Pi^T) = 2E(\pi_{mi}^T) + 2E(\pi_{si}^T) = \frac{2d(3d + \alpha - 2)}{3(2+\alpha)^2} + \frac{2\alpha[\alpha(9 - 2\alpha) - 8]}{9(4 - \alpha^2)^2}. \tag{2}$$

Now, considering the opaque e-market, we get the following results (see the appendix for details):

$$p_{mi}^O = \frac{3d - \alpha - \alpha^2}{3(2+\alpha)} + \frac{1}{2}(c_{mi} + \alpha c_{mj}),$$
$$q_{mi}^O = \frac{1}{2(2+\alpha)}\left[2d + \frac{2\alpha}{3} - (2+\alpha)c_{mi}\right],$$
$$E(\pi_{mi}^O) = \frac{1}{(2+\alpha)^2}\left(d - \frac{2}{3}\right)^2 + \frac{1}{72},$$
$$E(\pi_{si}^O) = \frac{1}{72(2+\alpha)}(24d - 18 - \alpha), \tag{3}$$

$$E(\Pi^O) = 2E(\pi_{mi}^O) + 2E(\pi_{si}^O) = \frac{2(3d-2)(3d+\alpha)}{9(2+\alpha)^2}. \tag{4}$$

Comparing Equation (1) with Equation (3) and Equation (2) with Equation (4), we obtain the following result:

$$E(\pi_{mi}^T) - E(\pi_{mi}^O) = \alpha^2(12 - \alpha^2)/[72(4 - \alpha^2)^2] > 0,$$
$$E(\pi_{si}^T) - E(\pi_{si}^O) = -\alpha^2/[72(4 - \alpha^2)] < 0,$$
$$E(\Pi^T) - E(\Pi^O) = 2\alpha^2/[9(4 - \alpha^2)^2] > 0.$$

This shows that manufacturers will benefit from, and suppliers will be hurt by, information transparency. The overall effect is still positive.

Proposition 1. *When the downstream industry engages in Cournot competition, a manufacturer-owned and a neutral B2B e-market prefer a transparent e-market model, whereas a supplier-owned B2B e-market prefers an opaque e-market model.*

The prior literature has shown that vertical information sharing about demand creates value to a supply chain (e.g., Lee et al. 2000). Here, we obtain a consistent result but in an expanded setting where the information transparency is about cost rather than demand, and there are competing firms in both upstream and downstream—none is a monopoly. Thus, our result, based on a B2B e-market that makes this feasible, brings additional insights into the value of information in a more realistic two-level e-market setting.

[9] Here, we borrow a result from established literature in which the bidders' decision problem has been analyzed via game-theoretic models. Although we do not repeat the analysis, suppliers are still strategic.

It is easy to verify that $E(\pi_{mi}^b)=E[(q_{mi}^b)^2]=[E(q_{mi}^b)]^2+\text{var}(q_{mi}^b)$, where $b=T$ or $O$. Further,

$$E(q_{m1}^T)=E(q_{m1}^O)=\frac{3d-2}{3(2+\alpha)}.$$

Then $E(\pi_{mi}^T)-E(\pi_{mi}^O)=\text{var}(q_{mi}^T)-\text{var}(q_{mi}^O)$. When the downstream firm's decision variable is quantity (that is, Cournot competition in the downstream industry), a transparent B2B e-market makes the quantity more responsive to market conditions and thus makes it more volatile compared with that in an opaque B2B e-market. Thus, we have $\text{var}(q_{m1}^T)>\text{var}(q_{m1}^O)$, which leads to $E(\pi_{mi}^T)>E(\pi_{mi}^O)$. The intuition is that a transparent market helps manufacturers coordinate their quantity strategies, leading to more efficient production and thus greater expected profits for both.

It can be shown that $E(\pi_{si}^b)=E[q_{mi}^b(s_i^{l2}-s_i^{l1})]+\text{cov}(q_{mi}^b, s_i^{l2}-s_i^{l1})$, where $b=T$ or $O$. Further,

$$E\big[q_{mi}^T(s_i^{l2}-s_i^{l1})\big]=E\big[q_{mi}^O(s_i^{l2}-s_i^{l1})\big].$$

Then $E(\pi_{si}^T)-E(\pi_{si}^O)=\text{cov}(q_{mi}^T, s_i^{l2}-s_i^{l1})-\text{cov}(q_{mi}^O, s_i^{l2}-s_i^{l1})$. Consider a supplier (say, $S_{1a}$) who wins the bid. Supplier $S_{1a}$ hopes that $q_{m1}$ and $(s_1^{l2}-s_1^{l1})$ have a more positive correlation. That is, when $S_{1a}$'s profit margin $(s_1^{l2}-s_1^{l1})$ is large, $q_{m1}$ is also large. However, $s_1^{l2}-s_1^{l1}$ in a transparent e-market tends to be more negatively associated with $q_{m1}$ than in an opaque market. This can be illustrated by

$$\text{cov}(q_{m1}^T, s_1^{l2}-s_1^{l1})=-1/[18(4-\alpha^2)]<\text{cov}(q_{m1}^O, s_1^{l2}-s_1^{l1})=-1/72.$$

It means that a high-cost manufacturer is less likely to "incorrectly" order a large quantity in a transparent e-market than in an opaque market, but such a "mistake" is desirable to suppliers. In this sense, information transparency works against suppliers.

Proposition 1 has important managerial implications to e-market operators. The first business implication is that the ownership structure of an e-market affects the choice between transparency and opaqueness. Second, regarding the information transparency, a conflict of interest between suppliers and manufacturers exists in a setting where both sides engage in competition, whereas the prior literature generally does not consider the competition within both levels.

# 4. Bertrand Competition in Downstream Industry

The above analysis assumes that manufacturers compete on quantity. In this section, we consider Bertrand competition where manufacturers compete on price. Manufacturer $i$'s demand function is

$$q_{mi}=d-p_{mi}+\alpha p_{mj}, \quad (i=1,2; i\neq j),$$

where $p_{mi}$ and $p_{mj}$ are prices charged by manufacturers $i$ and $j$, respectively. Again, $0<\alpha<1$, which means that the impact of $M_i$'s price change on $M_i$'s demand is greater than the impact of $M_j$'s price change (that is, $|\partial q_{mi}/\partial p_{mi}|>|\partial q_{mi}/\partial p_{mj}|$). Using a similar process as that in the previous section, we derive the following results.

In a transparent e-market,

$$p_{mi}^T=\frac{1}{4-\alpha^2}[d(2+\alpha)+2c_{mi}+\alpha c_{mj}],$$

$$q_{mi}^T=\frac{1}{4-\alpha^2}[d(2+\alpha)-(2-\alpha^2)c_{mi}+\alpha c_{mj}],$$

$$E(\pi_{mi}^T)=\frac{1}{6(2-\alpha)^2}[6d^2-8d(1-\alpha)+3(1-\alpha)^2]+\frac{\alpha(2-\alpha^2)}{9(4-\alpha^2)^2}, \tag{5}$$

$$E(\pi_{si}^T)=\frac{1}{6-3\alpha}d-\frac{1}{36(4-\alpha^2)}[18-(8+9\alpha)\alpha], \tag{6}$$

$$E(\Pi^T)=2E(\pi_{mi}^T)+2E(\pi_{si}^T)=\frac{2d^2}{(2-\alpha)^2}-\frac{2d(2-3\alpha)}{3(2-\alpha)^2}+\frac{\alpha[3\alpha^2(8+3\alpha)-32]}{18(4-\alpha^2)^2}. \tag{7}$$

In an opaque e-market,

$$p_{mi}^O=\frac{3d+\alpha}{3(2-\alpha)}+\frac{1}{2}c_{mi},$$

$$q_{mi}^O=\frac{3d-\alpha(1-\alpha)}{3(2-\alpha)}-\frac{1}{2}(c_{mi}-\alpha c_{mj}),$$

$$E(\pi_{mi}^O)=\frac{d^2}{(2-\alpha)^2}-\frac{4d(1-\alpha)}{3(2-\alpha)^2}+\frac{36+\alpha(33\alpha-68)}{72(2-\alpha)^2}, \tag{8}$$

$$E(\pi_{si}^O)=\frac{d}{3(2-\alpha)}-\frac{18-17\alpha}{72(2-\alpha)}, \tag{9}$$

$$E(\Pi^O)=2E(\pi_{mi}^O)+2E(\pi_{si}^O)=\frac{2(3d+\alpha)(3d+2\alpha-2)}{9(2-\alpha)^2}. \tag{10}$$

These equations represent the expected profits for the manufacturers, the suppliers, and the total e-market under transparent and opaque markets, respectively. Comparing Equation (5) with Equation (8), Equation (6) with Equation (9), and Equation (7) with Equation (10), we obtain the following result:

$$E(\pi_{mi}^T)-E(\pi_{mi}^O)=-\alpha^2(4-3\alpha^2)/[72(4-\alpha^2)^2]<0,$$
$$E(\pi_{si}^T)-E(\pi_{si}^O)=\alpha^2/(288-72\alpha^2)>0,$$
$$E(\Pi^T)-E(\Pi^O)=\alpha^4/[18(4-\alpha^2)^2]>0.$$

It shows that information transparency hurts manufacturers but benefits suppliers and the whole e-market.

**Table 1** **Impact of Information Transparency on Price, Quantity, and Profit**

| | $c_{m1}=\bar{c}+\varepsilon, c_{m2}=\bar{c}$ | $c_{m1}=\bar{c}-\varepsilon, c_{m2}=\bar{c}$ |
|---|---|---|
| $p$ | $p_{m1}\uparrow$, $p_{m2}\uparrow$ | $p_{m1}\downarrow$, $p_{m2}\downarrow$ |
| $\pi$ | $\pi_{m1}\uparrow$, $\pi_{m2}\uparrow$ | $\pi_{m1}\downarrow$, $\pi_{m2}\downarrow$ |

Proposition 2. *When the downstream industry engages in Bertrand competition, a supplier-owned and a neutral B2B e-market prefer a transparent e-market model, whereas a manufacturer-owned B2B e-market prefers an opaque e-market model.*

Recall that information transparency benefits downstream manufacturers when they compete on quantity, but here it turns to be against them under Bertrand competition. Following a similar analysis as that for the Cournot competition, we can show that $E(\pi_{mi}^T) - E(\pi_{mi}^O) = \mathrm{var}(q_{mi}^T) - \mathrm{var}(q_{mi}^O)$. Again, a transparent e-market makes the decision variable, which is price in Bertrand competition, more responsive to market conditions. However, price absorbs most of the market uncertainties, leading to a reduction of the variance of quantity and thus a reduction of the expected profits of manufacturers. Another way of illustrating the intuition is showing how prices and profits are affected by the information transparency under different scenarios.

In Table 1, we fix $M_2$'s cost to be the expected cost $\bar{c}$ and let $M_1$'s cost be slightly higher (or lower) than $\bar{c}$. Table 1 shows that when $M_1$'s cost is slightly higher than $\bar{c}$, then the information transparency increases $M_1$'s price and profit. This is because when $M_2$ realizes that $M_1$ is a less competitive firm than expected ($c_{m1} > \bar{c}$), $M_2$ increases its price ($p_{m2}\uparrow$). Consequently, $M_1$ faces a softened price competition and thus is able to increase its price as well. In this case, the information transparency helps $M_1$. However, when $M_1$'s cost is a little bit lower than $\bar{c}$, then the information transparency works against $M_1$. The reason is that $M_2$ reduces its price when it realizes that it faces a more competitive firm than expected ($c_{m1} < \bar{c}$). Such reaction causes $M_1$ to reduce its price as well, resulting in an intensified price competition, which hurts both manufacturers. It can be verified that $M_1$'s gain from the first case is less than its loss from the second case:

$$\triangle\pi_{m1}(c_{m1}=\bar{c}+\varepsilon, c_{m2}=\bar{c})+\triangle\pi_{m1}(c_{m1}=\bar{c}-\varepsilon, c_{m2}=\bar{c})<0.$$

Thus, the information transparency reduces a manufacturer's expected profit.

Following a similar analysis as that for the Cournot competition, we find that a winning supplier (say, $S_{1a}$) hopes that $q_{m1}$ and $(s_1^{l2} - s_1^{l1})$ have a more positive correlation, and it can be shown that $\mathrm{cov}(q_{m1}^T, s_1^{l2} - s_1^{l1}) > \mathrm{cov}(q_{m1}^O, s_1^{l2} - s_1^{l1})$. That is, when $S_{1a}$'s profit margin $(s_1^{l2} - s_1^{l1})$ is large, $q_{m1}$ in a transparent e-market tends to be larger than that in an opaque e-market. The intuition is that a transparent e-market enables a manufacturer to adjust its price according to its competitors' cost. In Bertrand competition, both manufacturers can raise their prices without losing too much demand, especially when $\alpha$ is close to 1 (noting that the demand of $M_1$ is $q_1 = d - p_1 + \alpha p_2$). This suggests that when $(s_1^{l2} - s_1^{l1})$ is large in a transparent e-market, $q_{m1}^T$ still can be large as a result of price adjustments by manufacturers. Thus, a transparent e-market benefits suppliers.

### 4.1. Conflict of Interest Regarding Information Transparency

As a quick summary of the analysis so far, we have found that the effect of information transparency on the upstream is always *opposite* to the effect on the downstream. Table 2 summarizes these effects. It means that information transparency can benefit one side but at the cost of the other side, indicating an inherent conflict of interest regarding information transparency. The competition mode in the downstream industry determines which side will be hurt.

We have shown that a neutral e-market prefers a transparent e-market model. However, if manufacturers or suppliers have an alternative choice to establish an opaque e-market by themselves, then the operator of a neutral e-market could lose its customers. For example, when the downstream is Cournot competition, manufacturers could establish an opaque manufacturer-owned e-market when these manufacturers have more market power than suppliers. The conflict of interest between buyers and sellers in such an e-market has been conceptually addressed in the prior literature (e.g., Sairamesh et al. 2002). This paper uses an analytical model to illustrate such conflict of interest regarding information transparency in a neutral e-market. This result offers an important managerial insight to a neutral e-market operator. It suggests that the operator may need to reallocate the informational benefits between buyers and sellers (e.g., charging one side while compensating the other side) so that both sides have no incentives to establish their own private e-markets.

**Table 2** **The Effects of Information Transparency in B2B E-market**

| Downstream competition | Manufacturers | Suppliers | Overall effect |
|---|---|---|---|
| Cournot | + | − | + |
| Bertrand | − | + | + |

## 5. The Effects on Consumers

Our above analysis focuses on the informational effects on business participants. Now we consider the broader effects on consumers (the lowest tier in Figure 1). If the downstream industry engages in Cournot competition, the consumer surplus (CS) can be expressed as

$$\begin{aligned} \mathrm{CS} &= \sum_{i=1}^{2}\left[\int_0^{q_i}(d-q_i-\alpha q_{3-i})\,dq_i-(d-q_i-\alpha q_{3-i})q_i\right]\\ &= \tfrac{1}{2}(q_{m1}^2+q_{m2}^2). \end{aligned}$$

If the e-market is transparent, then $\mathrm{CS}^T=\frac{1}{2}[(q_{m1}^T)^2+(q_{m2}^T)^2]$. If the e-market is opaque, then $\mathrm{CS}^O=\frac{1}{2}[(q_{m1}^O)^2+(q_{m2}^O)^2]$. Using the results established earlier, it can be shown that

$$E(\mathrm{CS}^T)-E(\mathrm{CS}^O)=\alpha^2(12-\alpha^2)/[72(4-\alpha^2)^2]>0,$$

meaning that consumer surplus in the transparent e-market is higher than that in the opaque e-market.

The intuition is as follows: $E(\mathrm{CS}^T)-E(\mathrm{CS}^O)=E[(q_{m1}^T)^2]-E[(q_{m1}^O)^2]$ by symmetry. It can be shown that $E(q_{m1}^T)=E(q_{m1}^O)=(3d-2)/(3(2+\alpha))$. Then $E(\mathrm{CS}^T)-E(\mathrm{CS}^O)=[E(q_{m1}^T)]^2+\mathrm{var}(q_{m1}^T)-[E(q_{m1}^O)]^2-\mathrm{var}(q_{m1}^O)=\mathrm{var}(q_{m1}^T)-\mathrm{var}(q_{m1}^O)$. This shows that $E(\mathrm{CS}^T)>E(\mathrm{CS}^O)$ because $\mathrm{var}(q_{m1}^T)>\mathrm{var}(q_{m1}^O)$. As discussed earlier, when downstream firms engage in Cournot competition, their quantities are more responsive to market conditions than those in an opaque e-market. Thus, we have $\mathrm{var}(q_{m1}^T)>\mathrm{var}(q_{m1}^O)$ and $E(\mathrm{CS}^T)>E(\mathrm{CS}^O)$. This shows that a higher variance of quantity makes consumers better off.

As shown in Table 2, the information transparency benefits the e-market as a whole. It follows that the information transparency increases the social welfare (SW) when the downstream competition is Cournot competition. That is,

$$E(\mathrm{SW}^T)>E(\mathrm{SW}^O),$$

where $\mathrm{SW}^T=\Pi^T+\mathrm{CS}^T$ and $\mathrm{SW}^O=\Pi^O+\mathrm{CS}^O$.

Now, consider the Bertrand competition in the downstream industry. We follow a similar derivation process to arrive at

$$\begin{aligned} &E(\mathrm{CS}^T)-E(\mathrm{CS}^O)\\ &\quad=-\alpha^2(20-11\alpha^2+\alpha^4)/[72(4-\alpha^2)^2]<0,\\ &E(\mathrm{SW}^T)-E(\mathrm{SW}^O)\\ &\quad=-\alpha^2(20-15\alpha^2+\alpha^4)/[72(4-\alpha^2)^2]<0. \end{aligned}$$

We find that $E(\mathrm{CS}^T)<E(\mathrm{CS}^O)$ because $\mathrm{var}(q_{m1}^T)<\mathrm{var}(q_{m1}^O)$. As discussed earlier, when downstream firms engage in Bertrand competition, a transparent e-market increases the variance of the decision variable (that is, price). However, it reduces the variance of quantity because the decision variable has absorbed most of the market uncertainties. This explains $\mathrm{var}(q_{m1}^T)<\mathrm{var}(q_{m1}^O)$ in Bertrand competition, and this hurts consumers.

**Table 3** **The Effects of Information Transparency**

| Downstream competition | Consumers | E-market | Social welfare |
|---|---|---|---|
| Cournot | + | + | + |
| Bertrand | − | + | − |

Proposition 3. *When the downstream industry engages in Cournot competition, information transparency benefits end consumers and increases the total social welfare. When the downstream industry engages in Bertrand competition, information transparency hurts end consumers and reduces the total social welfare.*

Interestingly, when the downstream industry engages in Cournot competition, there is no conflict of interest between consumers and upstream firms. However, when the downstream industry engages in Bertrand competition, a conflict of interest between end consumers and upstream firms arises. This is summarized in Table 3.

The finding that when the downstream competition is Bertrand-type, information transparency hurts consumers is a rather surprising, and perhaps unintended, consequence of electronic markets. The common belief about the Internet-enabled e-markets has been that they are largely positive for consumers (Bakos 1997, Hitt and Brynjolfsson 1996). Our results indicate that this is not always the case.

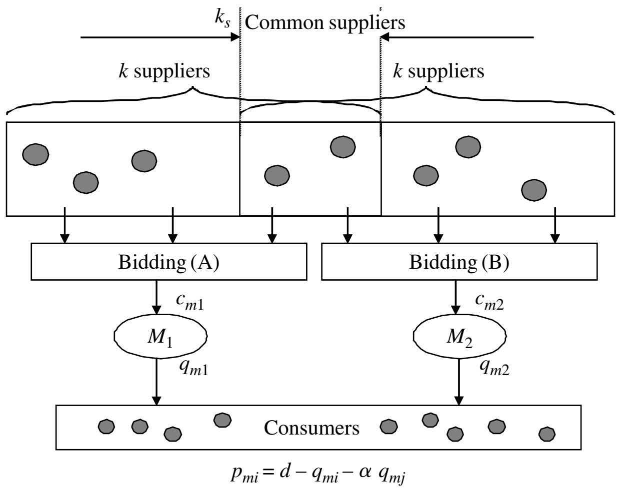
## 6. Extensions

Our results thus far were obtained under certain assumptions, and we realize that some of them may seem restrictive. In this section, we attempt to relax some of the assumptions and extend the base model in several dimensions. We will see that the simple base model is in fact able to demonstrate the major result, whereas the extended model confirms its robustness.

### 6.1. Overlapping Suppliers in Upstream Channel

The base model assumes that each downstream manufacturer has its own dedicated supplier base in the upstream. Now we relax this assumption by allowing manufacturers to have common suppliers; i.e., a supplier may trade with both manufacturers, who in turn compete on quantity in the consumer market. Thus, it becomes possible that both manufacturers may procure from the same supplier (as illustrated in Figure 2). In fact, this is becoming increasingly common as the outsourcing trend continues.

**Figure 2** **Expanded Model with Overlapping Upstream Suppliers**




We assume that each manufacturer has $k$ prequalified suppliers, among which $k_s$ suppliers are commonly shared by both manufacturers ($k \geq k_s \geq 0$, $k \geq 2$, $k, k_s \in N$). Sharing common suppliers may have two effects on manufacturers. First, it increases the cost correlation between manufacturers as they tend to get similar prices from the upstream industry. That is, $\mathrm{cov}(c_{m1}, c_{m2})$ is no longer zero. Second, information spillover may arise even in an opaque e-market when $k_s \geq 1$. This is because $M_i$ may observe the bidding prices of common suppliers. This information may be used to infer $M_j$'s cost, even in an opaque market structure. These two effects introduce new complexities. Albeit a tedious process, it can be shown that

$$\Delta\pi_{mi} = E(\pi_{mi}^T) - E(\pi_{mi}^O) \geq 0,$$
$$\Delta\pi_{si} = E(\pi_{si}^T) - E(\pi_{si}^O) \leq 0,$$
$$\Delta\Pi = E(\Pi^T) - E(\Pi^O) \geq 0.$$

This is consistent with what we have established in Proposition 1. Moreover,

$$\Delta\pi_{mi}(k_s+1) - \Delta\pi_{mi}(k_s) < 0,$$
$$\Delta\pi_{si}(k_s+1) - \Delta\pi_{si}(k_s) > 0,$$
$$\Delta\Pi(k_s+1) - \Delta\Pi(k_s) < 0.$$

This establishes the following result.

Proposition 4. *If upstream suppliers are allowed to trade with both manufacturers who engage in Cournot competition, the value of information transparency to the total e-market* ($\Delta\Pi$) *and to a manufacturer* ($\Delta\pi_{mi}$) *and a supplier's loss caused by information transparency* ($|\Delta\pi_{si}|$) *decrease as the number of overlapping suppliers increases.*

This proposition shows that the benefits of information transparency go down when the number of overlapping suppliers goes up. The key reason is that information spillover via overlapping suppliers partly substitutes the value of information transparency. To see why, suppose that both manufacturers share a completely overlapping set of suppliers ($k = k_s$); then it no longer matters whether the B2B e-market is opaque or transparent because a manufacturer would know the competitor's cost in both types of information structures. In this extreme case, the informational value of the transparent e-market would be neutralized.

As shown in §3, information transparency benefits the manufacturers and the total e-market. This section shows that information transparency can be achieved in two ways: (1) adopting a transparent e-market structure, and (2) sharing common suppliers. A natural question then arises: Which way would be more beneficial (a) to manufacturers, (b) to suppliers, and (c) to consumers? The following proposition provides an answer.

Proposition 5. *Compared to adopting a transparent e-market, sharing common suppliers hurts manufacturers and end consumers, but it benefits suppliers.*

It can be shown that

$$E(\pi_{mi}^T) \geq E(\pi_{mi}^O \mid k_s = k),$$
$$E(\pi_{si}^T) \leq E(\pi_{si}^O \mid k_s = k),$$

which indicates that sharing common suppliers is suboptimal to achieve information transparency. Using common suppliers increases the information transparency on the one hand, but it has an unintended consequence on the other hand: increasing manufacturer cost correlation $\mathrm{cov}(c_{mi}, c_{mj})$. The first effect benefits manufacturers and the second hurts them because manufacturers would be more likely to have the same cost (or less differentiated), which may intensify head-to-head competition between them. Proposition 5 suggests that the net effect is negative to manufacturers. It also shows that upstream suppliers can take advantage of the intensified competition between downstream manufacturers.

This result warns managers to be mindful about the *mechanism* of information transparency. The increasing reliance on common contract suppliers may have unintentional consequences of information spillover despite the growing trend of outsourcing.

Last, but important to note, consumers are hurt by this kind of information transparency because sharing suppliers reduces the variance of quantity (when both manufacturers have the same suppliers, then their quantities are the same). Following a similar analysis as that shown in §5, we show that

$$E(\mathrm{CS}^T) - E(\mathrm{CS}^O \mid k_s = k) = \mathrm{var}(q_{m1}^T) - \mathrm{var}(q_{m1}^O \mid k_s = k)$$
$$= \mathrm{var}(q_{m1}^T) > 0.$$

Thus, a reduction in quantity variance reduces consumer surplus.

### 6.2. Asymmetric Upstream Channels

The base model assumes that each of the two manufacturers has two prequalified upstream suppliers. This assumption can be relaxed by allowing each manufacturer, $M_i$, to have an arbitrary number, $k_i$, of suppliers, and without losing generality, let $k_2 \geq k_1 \geq 2$, $k_i \in N$. Manufacturers could have an asymmetric number of prequalified suppliers. We derive the expected manufacturer profit and supplier profit as in the appendix. It follows that

$$\Delta\pi_{mi} = E(\pi_{mi}^T) - E(\pi_{mi}^O) > 0,$$
$$\Delta\pi_{si} = E(\pi_{si}^T) - E(\pi_{si}^O) < 0,$$
$$\Delta\Pi = E(\Pi^T) - E(\Pi^O) > 0.$$

This is the same result as in Proposition 1. Hence, the result established earlier with the simple base model carries over to a setting when more suppliers are involved. It can be shown that

$$\Delta\pi_{m1} \geq \Delta\pi_{m2} \quad \text{and} \quad |\Delta\pi_{s1}| \geq |\Delta\pi_{s2}|.$$

Thus we have the following result.

Proposition 6. *If manufacturers engage in Cournot competition and have different numbers of upstream suppliers, the manufacturer who has fewer suppliers obtains more value from information transparency than its competitor* ($\Delta\pi_{m1} \geq \Delta\pi_{m2}$). *The expected loss of that manufacturer's winning supplier is more than that of the other manufacturer's winning supplier* ($|\Delta\pi_{s1}| \geq |\Delta\pi_{s2}|$).

As discussed earlier, information transparency tends to help Cournot manufacturers coordinate their quantity strategies. Because $k_2 \geq k_1 \geq 2$, $M_2$ is more likely to obtain a lower procurement price than that obtained by $M_1$ and thus is more competitive than $M_1$. Information transparency reduces $M_1$'s cost uncertainty in $M_2$'s eyes and makes $M_2$ less aggressive than otherwise in an opaque e-market. This is the source of informational benefits to $M_1$. Given the fact that $M_2$ is more competitive than $M_1$ in terms of cost advantage, a decrease in the agressiveness of $M_2$ is certainly more valuable to $M_1$ than a decrease in the aggressiveness of $M_1$ to $M_2$, all else being equal.

On the other hand, information transparency makes suppliers worse off because a high-cost manufacturer in a transparent e-market is less likely to "incorrectly" order a large quantity than in an opaque market. Note that $M_1$ is more likely to be a higher-cost manufacturer than $M_2$. This suggests that the negative effect of information transparency would have a stronger impact on $M_1$'s winning supplier than on $M_2$'s winning supplier.

## 7. Discussion and Conclusions

This paper studies marketing channels and associated information transparency in an e-market where suppliers compete for orders from downstream manufacturers in a B2B e-market and then manufacturers compete for consumers in a B2C market. Based on a model different from the literature, our study sheds light on several important questions about the effects of information transparency on market participants. Along the way, it makes several contributions to the literature.

### 7.1. Major Findings and Contributions

First, we find that the information transparency enabled by online trading benefits the overall marketing channel. Prior literature has shown that information sharing about *demand* benefits the total supply chain. In this paper, our result is obtained in an expanded setting in which we take competition into account (where the informational benefits would have to be divided among market participants). Also, information transparency in this paper refers to transparency about a competitor's *cost* rather than market demand. Thus this paper takes another step further toward understanding the important but subtle effects of information transparency in an online environment.

Second, although the information transparency benefits the total marketing channel, the effect on one side is always in conflict with the other side. The competition mode in the downstream e-market determines which side is benefited (or hurt) by the information transparency. Prior literature has shown that the key difference between Cournot and Bertrand competition critically depends on production capacity (Kreps and Scheinkman 1983, Haskel and Martin 1994). The Cournot model is appropriate when firms are capacity constrained, whereas the Bertrand model fits the case where firms have the capacity to serve the market gained. The auto industry in the United States can be considered a Cournot industry. We find that when the downstream firms engage in Cournot competition, a manufacturer-owned B2B e-market prefers a transparent structure. This finding seems to be consistent with Covisint, which was a transparent B2B platform owned by the big three auto manufacturers. In contrast, the retailing industry in the United States can be considered a Bertrand industry. We find that when the downstream firms engage in Bertrand competition, then an opaque structure is preferred by downstream firms. This finding seems to be consistent with the fact that major U.S. retailers tend to use their own private exchanges to source goods from their suppliers.

It is commonly believed in the post-bubble era that a lack of overall value creation may kill a neutral

B2B e-market. However, this paper suggests information transparency can actually create overall value for a neutral e-market's participants. However, its market operator may need to reallocate informational benefits between sellers and buyers so as to resolve their conflict of interest regarding information transparency. A mismanagement of value reallocation may also cause a problem. Our theoretical model seems to be supported by empirical evidence presented in Soh et al. (2006), which shows that buyers and sellers have conflicting interests regarding price transparency.

Finally, we consider the effects on consumers and the total social welfare. It was believed that the Internet-enabled e-markets have been largely positive for consumers. We show that this is not always the case. When the downstream firms engage in Bertrand competition, the consumers are worse off with information transparency. Another surprising result is that information transparency can reduce the total social welfare under certain conditions (that is, when downstream competition is Bertrand-type). These findings suggest that a more transparent e-market is not necessarily socially desirable. Even when it is socially desirable, it may come at a cost to end consumers.

More broadly, the results of this paper can be applied to other settings where the downstream firms source inputs from upstream suppliers via open bidding and then sell the products to consumers. Also, there may be uncertainty about the costs of the procurement. The transaction platform is not necessarily a B2B e-market. It can be an electronic data integration (EDI), a teleconference bidding system, or a quote via phone or fax, for example.

### 7.2. Future Research

This paper leaves several issues open for further research. First, our results are obtained under several assumptions about costs, demand, and market structure. We have relaxed some of these assumptions (and the results seem robust). Other assumptions can also be relaxed. For example, one could use more general demand functions and cost distribution and test if our results still hold in more general settings. Second, one could introduce uncertainty in demand functions (e.g., the intercept $d$ is not a constant) and then examine the effects of information transparency. Third, our e-market model can be used to study not only information transparency but also other interesting issues such as the consequences of the increased use of common contract suppliers due to outsourcing. These questions are left for further analysis. We hope that the initial results reported herein will motivate more research in this area.

## 8. Electronic Companion

An electronic companion to this paper is available as part of the online version that can be found at http://mktsci.pubs.informs.org/.

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## Appendix

**Notation**

| | |
|---|---|
| $d$ | Demand intercept in demand function |
| $c_{mi}$ | Marginal cost of manufacturer $i$, also the best price offered by its prequalified suppliers |
| $\pi_{mi}$ | Profit of manufacturer $i$ |
| $\pi_{si}$ | Profit of manufacturer $i$'s supplier who wins the auction |
| $q_{mi}$ | Quantity of manufacturer $i$ ordered from suppliers |
| $p_{mi}$ | Price of manufacturer $i$ charged to end consumers |
| $s_i^{l1}$ | The lowest marginal cost of manufacturer $i$'s prequalified suppliers |
| $s_i^{l2}$ | The second-lowest marginal cost of manufacturer $i$'s prequalified suppliers |
| $M_i$ | Manufacturer $i$ |
| $S_{ia}$, $S_{ib}$ | Manufacturer $i$'s prequalified suppliers |
| $T$ | A supperscript denoting a transparent B2B e-market |
| $O$ | A supperscript denoting an opaque B2B e-market |
| $\Pi$ | The total profit of all participants in B2B e-market |
| $k_i$ | The number of manufacturer $i$'s prequalified suppliers (see §6.2) |
| $k_s$ | The number of shared common suppliers (see §6.1) |
| $k$ | The number of manufacturer's prequalified suppliers (see §6.1) |
| CS | Consumer surplus of end consumers |
| SW | Social welfare |

**Cournot Competition (Proposition 1)**

**Transparent E-market.** Manufacturer $i$'s problem is

$$\max_{q_{mi}} \pi_{mi}^T = (d - q_{mi} - \alpha q_{mj} - c_{mi}) \cdot q_{mi}, \quad (i = 1, 2; i \neq j).$$

Solving the first-order condition and noting that the second-order condition is satisfied, we have

$$q_{mi}^T = \frac{d(2-\alpha) - 2c_{mi} + \alpha c_{mj}}{4 - \alpha^2}, \quad (i = 1, 2; i \neq j), \tag{11}$$

where the superscript "$T$" stands for transparent market. We will substitute this back to the profit function to get

$E(\pi_{mi}^T)$, the expected profit for manufacturer $i$. Before computing $E(\pi_{mi}^T)$, we need to obtain the expected value of $c_{mi}$, $E(c_{mi})$, and its variance, $\mathrm{var}(c_{mi})$.

Noting that $c_{mi} = s_i^{l2}$, we get the cumulative distribution function (CDF) of $c_{mi}$ as follows: $F(x) = \Pr(c_{mi} \le x) = \Pr(s_i^{l2} \le x) = x^2$. The last equality holds because manufacturer $i$ has two prequalified suppliers, and thus the probability that the second-lowest supplier cost is lower than $x$ is equivalent to the probability that the costs of both suppliers are lower than $x$. It follows that $f(x) = 2x$, $E(c_{mi}) = 2/3$, and $\mathrm{var}(c_{mi}) = 1/18$. Because the two manufacturers procure from different suppliers, and the suppliers' marginal costs are independent of each other, we have $\mathrm{cov}(c_{m1}, c_{m2}) = 0$. The manufacturer's expected profit can be computed as $E(\pi_{mi}^T) = E[q_{mi}^T \cdot (d - q_{mi}^T - \alpha q_{mj}^T - c_{mi})] = E\{[d(2-\alpha) - 2c_{mi} + \alpha c_{mj}]^2/(4-\alpha^2)^2\}$. By symmetry, we have

$$E(c_{mj}) = E(c_{mi}) = 2/3, \quad \mathrm{var}(c_{mi}) = \mathrm{var}(c_{mj}) = 1/18. \tag{12}$$

It follows that

$$E(\pi_{mi}^T) = \frac{1}{36}\left[\frac{1}{(2-\alpha)^2} + \frac{17 + 12d(3d-4)}{(2+\alpha)^2}\right].$$

Next, we derive the expected profit of the suppliers. It is apparent that, the supplier who loses the bidding obtains zero profit. Now consider the supplier who wins the order from $M_i$. The cost of this supplier is $s_i^{l1}$, and the price paid to it by $M_i$ is $s_i^{l2}$, where $s_i^{l1} \le s_i^{l2}$. The expected profit of the winning supplier is $E(\pi_{si}^T) = E[q_{mi}^T \cdot (s_i^{l2} - s_i^{l1})]$, where

$$\begin{aligned} q_{mi}^T &= 1/(4-\alpha^2)[d(2-\alpha) - 2c_{mi} + \alpha c_{mj}] \\ &= 1/(4-\alpha^2)[d(2-\alpha) - 2s_i^{l2} + \alpha c_{mj}]. \end{aligned}$$

To derive $E(\pi_{si}^T)$, we need to derive the following results. First, $\mathrm{cov}(s_i^{l1}, c_{mj}) = \mathrm{cov}(s_i^{l2}, c_{mj}) = 0$ because $s_i^{l1}$ and $s_i^{l2}$ are independent of $c_{mj}$. Second, the CDF of $s_i^{l2}$ is $F(x) = x^2$ ($x \in [0,1]$), the conditional CDF of $s_i^{l1}$, given $s_i^{l2}$, is $H(x \mid s_i^{l2}) = x/s_i^{l2}$ ($x \in [0, s_i^{l2}]$), and the CDF of $s_i^{l1}$ is $G(x) = 1-(1-x)^2$. Using these results, we have

$$E(s_i^{l2}) = 2/3, \mathrm{var}(s_i^{l2}) = 1/18, E(s_i^{l1}) = 1/3, \mathrm{var}(s_i^{l1}) = 1/6, \tag{13}$$

$$\begin{aligned} \mathrm{cov}(s_i^{l1}, s_i^{l2}) &= E(s_i^{l2} \cdot s_i^{l1}) - E(s_i^{l2}) \cdot E(s_i^{l1}) \\ &= \int_0^1 \int_0^{s_i^{l2}} s_i^{l1} \cdot s_i^{l2}\, dH(s_i^{l1} \mid s_i^{l2})\, dF(s_i^{l2}) - \tfrac{2}{3} \cdot \tfrac{1}{3} \\ &= \tfrac{1}{36}. \end{aligned} \tag{14}$$

Thus, $E(\pi_{si}^T) = E[q_{mi}^T \cdot (s_i^{l2} - s_i^{l1})] = E(q_{mi}^T) \cdot E(s_i^{l2} - s_i^{l1}) + \mathrm{cov}(q_{mi}^T, s_i^{l2} - s_i^{l1})$. Inserting Equation (11) in $E(\pi_{si}^T)$ and noting that $c_{mi} = s_i^{l2}$, we have

$$\begin{aligned} E(\pi_{si}^T) &= E[1/(4-\alpha^2)[d(2-\alpha) - 2c_{mi} + \alpha c_{mj}]] \cdot E(s_i^{l2} - s_i^{l1}) \\ &\quad + \mathrm{cov}[1/(4-\alpha^2)[d(2-\alpha) - 2s_i^{l2} + \alpha c_{mj}], s_i^{l2} - s_i^{l1}]. \end{aligned}$$

Using the results obtained above, we have

$$E(\pi_{si}^T) = \frac{3d-2}{3(2+\alpha)} \cdot \frac{1}{3} + \frac{2}{4-\alpha^2}\left(\frac{1}{36} - \frac{1}{18}\right) = \frac{6d(2-\alpha) + 4\alpha - 9}{18(4-\alpha^2)}.$$

By symmetry, the total expected profit of all participants $E(\Pi^T)$ in a transparent e-market is

$$\begin{aligned} E(\Pi^T) &= 2E(\pi_{mi}^T) + 2E(\pi_{si}^T) \\ &= \frac{2d(3d+\alpha-2)}{3(2+\alpha)^2} + \frac{2\alpha[\alpha(9-2\alpha) - 8]}{9(4-\alpha^2)^2}. \end{aligned}$$

**Opaque E-market.** Now, we turn to the opaque B2B e-market in which firms have less information relative to the transparent market design. Manufacturer $i$'s problem is

$$\max_{q_{mi}} E(\pi_{mi}^O) = [d - q_{mi} - \alpha E(q_{mj}) - c_{mi}] \cdot q_{mi}, \quad (i = 1, 2; i \ne j),$$

where the superscript $O$ stands for opaque market, and $E(q_{mj})$ represents manufacturer $i$'s expectation about manufacturer $j$'s quantity (not directly observable to manufacturer $i$). Following prior literature (Vives 1984, 2002), we derive the Bayesian Nash equilibrium (Harsanyi 1967), which is defined by a pair of strategies and a pair of conjectures such that (a) each firm's strategy is a best response to its conjecture about the behavior of the rival, and (b) the conjectures are unbiased.

Solving the first-order condition, we have $q_{mi}^O = 1/2[d - \alpha E(q_{mj}^O) - c_{mi}]$. This satisfies the first requirement of the Bayesian Nash equilibrium. The second requirement implies that $E(q_{mi}^O) = 1/2[d - \alpha E(q_{mj}^O) - E(c_{mi})]$. By symmetry, $E(q_{mi}^O) = E(q_{mj}^O) = Eq$, which leads to $Eq = 1/(2+\alpha)[d - E(c_{mi})] = 1/(2+\alpha)[d - 2/3]$. Thus,

$$q_{mi}^O = \frac{1}{2(2+\alpha)}\left[2d + \frac{2\alpha}{3} - (2+\alpha)c_{mi}\right]. \tag{15}$$

Substituting it back to the profit function yields the expected profit for the manufacturer:

$$E(\pi_{mi}^O) = \frac{1}{(2+\alpha)^2}\left(d - \frac{2}{3}\right)^2 + \frac{1}{72}.$$

Manufacturer $i$'s price is determined by $p_{mi}^O = d - q_{mi}^O - \alpha q_{mj}^O$. Using Equation (15), we get

$$p_{mi}^O = \frac{1}{3(2+\alpha)}[3d - \alpha(1+\alpha)] + \frac{1}{2}(c_{mi} + \alpha c_{mj}).$$

Following a similar process as above, we can derive the expected profit for the winning supplier:

$$E(\pi_{si}^O) = E[q_{mi}^O \cdot (s_i^{l2} - s_i^{l1})] = \frac{1}{72(2+\alpha)}(24d - 18 - \alpha).$$

Then, the total profit of all participants, $E(\Pi^O)$, in an opaque e-market is

$$E(\Pi^O) = 2E(\pi_{mi}^O) + 2E(\pi_{si}^O) = \frac{2(3d-2)(3d+\alpha)}{9(2+\alpha)^2}.$$

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