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CONFLICT OF INTEREST REGARDING INFORMATION TRANSPARENCY IN A BUSINESS-TO-BUSINESS ELECTRONIC MARKET WITH TWO-SIDED COMPETITION

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Abstract

As a platform to facilitate information sharing, business-to-business (B2B) electronic markets allow buyers and sellers to conduct transactions in a digital environment with greater information transparency. Vertical information transparency about demand has been shown to be beneficial to supply chain management. Thus, information technology (EDI, B2B e-markets) is believed to offer great benefits. Yet, the literature generally assumes that either the downstream firm (retailer) or upstream firm (manufacturer) is a monopoly. Little is known whether this is still the case if both sides face competition. Built on the existing literature, this paper develops a simple two-level e-market model with upstream and downstream competition to study the effects of information transparency. We find that information transparency enabled by electronic markets can create value for the whole supply chain, yet it affects retailers and manufacturers very differently: one side will be hurt, depending on the competition mode (Cournot or Bertrand) in the downstream industry. Unfortunately, it never unanimously benefits the two sides; conflict of interest persists. Then, the theoretical benefits of information transparency recognized in the literature will not materialize. It illustrates a fundamental challenge with electronic markets and offers a possible explanation to the difficulty faced by many B2B e-markets. To deal with this issue, we propose a discriminatory pricing scheme for the e-market operator to internalize informational benefits among retailers and manufacturers so that the online market mechanism can be sustainable.

Key words: Electronic markets, competition, information transparency, IT-enabled supply chains.

1. Introduction

Information sharing has been shown to benefit supply chain management in academic literature. In reality, many industries are still in search of a platform that would facilitate information sharing while conducting transactions. As one such IT-enabled transaction platform and information hub (Lee and Whang 2000), business-to-business (B2B) electronic markets (e-markets) have been shown to increase information transparency (Zhu 2004). Here information transparency refers to a high degree of visibility and accessibility of information. For example, e-markets provide a digital environment with abundant data about products, prices, bids, trader information, and other transaction details. Hence, relative to traditional physical markets, electronic markets offer an information-rich environment (Kalvenes & Basu 2006). Along this line, infomediary is modeled as a key feature of B2B markets (Bhargava & Choudhary 2004).

It is widely believed that information transparency benefits the total supply chain (e.g., Lee et al. 2000, Cachon and Fisher 2000), but information transparency in the supply chain literature generally refers to vertical information sharing about *demand* or inventory between an upstream firm (e.g., a manufacturer) and a downstream firm (e.g., a retailer), not horizontal information sharing between competitors. Recent studies show that horizontal information transparency in B2B e-market enables firms to use transaction data to infer the cost structure of competitors (Soh et al. 2006).

Transaction data is generally considered as sensitive and private information of e-market participants. So B2B e-market operator should provide an option of revealing transaction information to participants if they want to protect their information privacy (Kalvenes & Basu 2006). On the other hand, information transparency is also deemed socially desirable because it generally believed to lead to more efficiency in resource allocation. If this intuition is true, it is still not clear whether the major benefits of information transparency are captured by end consumers or by B2B e-market participants. Prior economics literature (e.g. Gal-Or 1985) has shown that information sharing in a *one-level* market could intensify the competition or help competitors to coordinate their competing strategies. But the effects of information transparency about *cost* in a *two-level* B2B e-market remain unanswered. Motivated by these issues, we focus on the following research questions:

- About the value of information transparency, does it benefit the *whole* B2B e-market (such that the operator would find this worthwhile to pursue)?
- Does information transparency have the same effect on upstream sellers and downstream buyers, or will there be a conflict of interest?
- How to manage information transparency in B2B e-markets to make all participants better off?

The real world offers examples on both sides. For instance, Covisint provided a transparent platform on which information such as traders and prices was visible to all participants (Raisinghani and Hanebeck 2002). The auto-manufacturers used Covisint to find suppliers, but they conducted transactions offline partly due to the concern that their cost structures would be known by competitors (Day et al. 2003). It turned out that Covisint's transparent model did not work. In 2004, Covisint was sold to FreeMarkets (itself bought by Ariba) (Forbes 2004).

The fall of Covisint, along with many other public B2B exchanges, does not signify the end of transparent marketplaces. In fact, despite all the backlash about B2B exchanges, evidence shows that B2B transaction volumes are going up significantly: \$98 billion in 2006, a 24% growth over \$79 billion in 2005 (U.S. Census Bureau 2007). Regarding the information transparency, another B2B exchange, Alibaba, tells a story different from Covisint. The transaction data are publicly visible on Alibaba.com. It even provides historical data of closed transactions to participants. The transaction volume on Alibaba has been growing steadily (Forbes 2004). As another example, WorldWide Retail Exchange (WWRE) 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" (WWRE 2005). Second, WWRE also provides private exchanges to those firms who want to customize their information exchange with selected suppliers and customers, and want to have better control over transaction data and privacy.

These examples illustrate that although information transparency is one of the major concerns of B2B e-market participants, the transparent B2B e-market model can be successful in practice. But there are examples of

unsuccessful transparent B2B e-markets. A natural question is how to explain this phenomenon in practice. To answer this question, we need to understand whether the failure of some transparent B2B e-markets is caused by information transparency itself, or by mismanagement of information transparency. Answers to this question can generate useful insights into the role of information transparency in B2B e-markets and the optimal design of B2B e-markets.

To better understand these issues, we develop a simple model of a B2B e-market for a two-level supply chain. There are two buyers (retailers) in the downstream with each having two pre-qualified manufacturers in the upstream (which is later expanded to more retailers and manufacturers). Manufacturers compete for the retailer's demand via bidding on the e-market platform; then retailers compete in the end-consumer market.

Using this simple setting, we show that information transparency affects retailers and manufacturers very *differently*. We find that it is always the case that one side (either retailers or manufacturers) will be hurt by, while 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 the critical factor that determines which side will be hurt. If retailers compete on quantity (i.e., Cournot competition), information transparency helps them but hurts their upstream manufacturers. Conversely, if the retailers compete on price (i.e., Bertrand competition), retailers will be hurt while manufacturers will benefit. Unfortunately, we find that, in our research setting, information transparency never unanimously benefits the two sides; conflict of interest persists. Those who are hurt will be reluctant to participate in the transparent marketplace. The theoretical benefits of information sharing recognized in the literature will not materialize. This illustrates a fundamental challenge with information transparency in B2B e-markets.

Despite the conflict of interest, we find that information transparency always increases the overall welfare to e-market participants regardless of the competition mode, implying that the benefits generated by the information transparency always dominate the losses. To encourage information sharing, several studies in the literature proposed contract schemes (e.g., Cachon 2003, Corbett et al. 2004). We propose an alternative approach, namely, an electronic market uses a discriminatory pricing scheme to internalize the informational benefits between retailers and manufacturers so that both sides are better off. Comparing to the one-to-one contract scheme, our *market-based coordination mechanism* is more appropriate for a supply chain setting where *many* players are involved and affected.

Literature Review

This paper is built on a body of work in the information systems literature. The field has shown a steady interest in electronic marketplaces, interorganizational systems, and electronic data interchanges (EDIs). Bakos (1997) finds that B2B electronic marketplaces help reduce search costs and increase the ability of markets to optimally allocate resources. Bandyopadhyay et al. (2006) show that a move toward online B2B exchanges might trigger a wave of consolidation of higher-cost producers, resulting in a less fragmented industry. Kalvenes and Basu (2006) show that firms face serious tradeoffs between privacy and transparency. "Firms that set up electronic marketplaces to enhance their supply and/or distribution channels face challenges in attracting their competitors to participate" (Kalvenes and Basu 2006, p. 1721). To deal with this issue, they propose a marketplace design to protect a trader's identity. Banker et al. (2006) emphasize that IT facilitates buyers to economically monitor sellers' performance, and B2B e-markets may lead to a greater degree of completeness of buyer-supplier contracts. Wang and Seidmann (1995) use a "one-buyer, many-suppliers" EDI model to demonstrate that an additional supplier creates negative network externalities to other suppliers. To provide incentives for EDI adoption, the buyer should subsidize suppliers rather than mandate them to join an EDI network. While these prior papers study different aspects of B2B e-markets (or its predecessors), this paper focuses on a small piece of a large puzzle. We consider *the value of information transparency for competing buyers, competing sellers and the total welfare of B2B e-markets* while previous literature generally considers one side (buyers or sellers) or assumes that one side is a monopoly.

Information sharing has been studied in the supply chain and economics literature in various settings. The supply chain literature has focused on sharing information on demand vertically with supply chain partners. This has been found beneficial as transparent information helps upstream and downstream partners to coordinate, and thus gains more efficiency for the supply chain by reducing bullwhip effects (Lee et al. 1997) and inventory costs (e.g., Gavirneni et al. 1999, Lee et al. 2000, Cachon and Fisher 2000). Yet, the literature generally assumes that either buyer or seller is a monopoly. Further, most studies focused on sharing *demand* information while *cost* information is the primary concern in our setting. This may bring different effects, as cost is a firm-specific, private parameter, while demand is an industry-wide common parameter (Gal-Or 1986). Comparing with this stream of literature, our paper considers a different two-level supply chain model where competition exists in *both* upstream and downstream

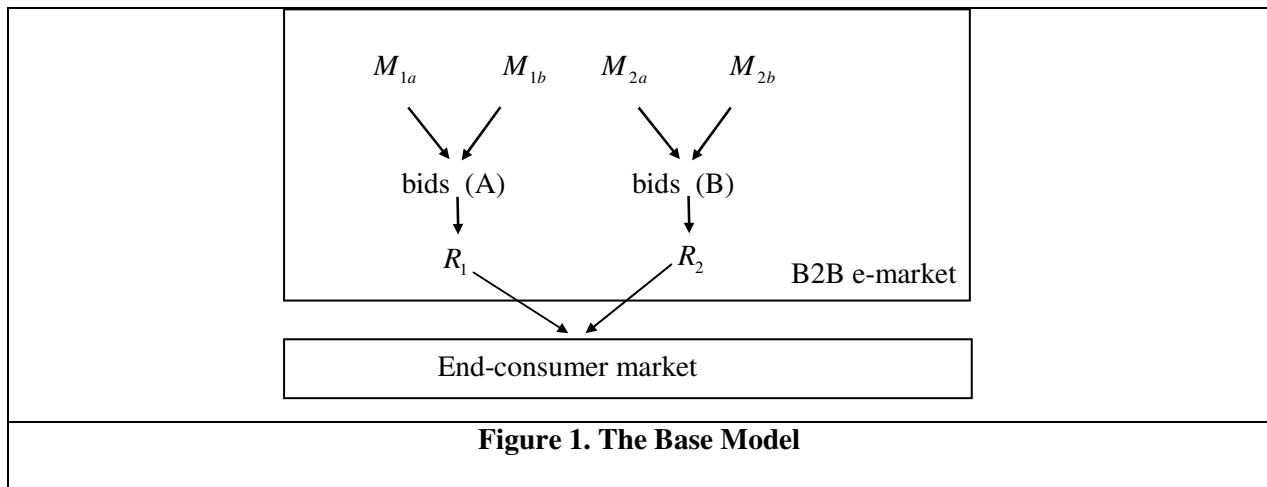
industries, and firms are influenced by the horizontal effects of cost information rather than vertical effects of demand information.

The economics literature has studied horizontal information sharing about costs with competitors at a *one-level* market. This is found to have mixed effects. It can make competing firms better or worse off. The net effects are found to be sensitive to the competition mode (Bertrand vs. Cournot), degree of product differentiation (substitute vs. complement), and the nature of the information (demand vs. cost) (e.g., Clarke 1983, Gal-Or 1985, 1986, Shapiro 1986, Vives 2002, Raith 1996). This stream of literature does not model a *two-level* B2B e-market where both manufacturers and retailers are affected by the information transparency. Thus, the effects of information transparency on upstream manufacturers and on the total B2B e-market remain unanswered in prior economics literature. In a two-level B2B e-market, both sides of manufacturers and retailers are important to the B2B e-market operator. The reason is that if any side is hurt and then leaves the B2B e-market, then the B2B e-market will not sustain any more. Our paper explicitly models both sides (manufacturers and retailers) in a B2B e-market and then shows a conflict of interests regarding information transparency between both sides. To our best knowledge, our B2B e-market model with two-sided competition is not considered in the prior economics literature.

More specifically, among these studies in the literature, Zhu (2004) examined the incentives of firms to join a transparent e-market. His model shows that such incentives are divided between high-cost firms and low-cost firms. We extend his model from a one-level e-market (where only informational effects on suppliers are considered) to a two-level supply chain which operates on a B2B e-market that provides a transaction platform and information hub (Lee and Whang 2000). Built on but going beyond Zhu (2004), our paper considers informational effects on manufacturers, retailers, and the total B2B e-market. We also analyze the optimal discriminatory pricing strategies for B2B e-market operator while Zhu did not consider such a pricing scheme.

To illustrate the major result without being burdened by mathematical complexity, we will present a simple base model first, followed by an analysis about the overall effects on the supply chain and differential effects on manufacturers and retailers. Then, we extend the base model to examine the informational effects when multiple manufacturers and multiple retailers are involved. Necessary technical proofs are provided in the appendix while some proofs that are relatively brief are presented in the main text.

2. The Base Model



To illustrate the essence of the issue, we first consider a simple two-level e-market with two retailers (R_1 and R_2) in downstream industry. Each retailer has two pre-qualified manufacturers in the upstream, where R_i 's manufacturers are labeled as M_{ia} and M_{ib} ($i=1,2$). This simple setting captures two key features of B2B e-markets that are different from those of B2C e-markets. First, each retailer does business with a limited number of manufacturers. This is because the business-relation specific investments in B2B e-markets are significantly higher than those in B2C e-markets. Bakos and Brynjolfsson (1993) argue that retailers often find it more profitable to work with only a small number of manufacturers when closer business relationships give manufacturers higher incentives to invest in their product quality, innovation and other noncontractible items. Second, each retailer chooses prequalified manufacturers before transactions. This is because transactions in B2B e-markets often involve mutual trust,

integrating interorganizational information systems, streamlining data exchanges, quality requirements, specification of product features, arrangements of shipments and payments. Typically a retailer needs to choose prequalified manufacturers that meet its requirements and trusted by it before inviting them to bid for contracts (Pinker et al. 2003, Dai and Kauffman 2002). Thus, price is the last factor to be considered after screening potential business partners. In a B2C e-market, the transaction volume and the total price are small, such prequalification process is not critical to buyers. But in a B2B e-market, it is so risky to do business with non-prequalified suppliers that it is impractical to switch to a non-prequalified supplier in a short period of time. For simplicity, we do not model complicated processes of a retailer's decision of deciding optimal number of suppliers and choosing prequalified suppliers. Instead, our paper only focuses on the informational effects of information transparency. Built on prior B2B e-market literature (Bakos and Brynjolfsson 1993, Pinker et al. 2003, Dai and Kauffman 2002), we use the following assumptions to model the B2B e-market.

Assumption 1: A retailer does business with a limited number of prequalified manufacturers.

The procurement cost reflects the retailer's cost structure, which consists of procurement cost and other costs. To simplify exposition, we assume that the sum of all other costs for each retailer is a constant known to the industry and is normalized to zero. Manufacturers compete for contracts via the 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 English auction can be achieved by the Vickrey auction (Milgrom 1989). And it is customary to model an English auction as a Vickrey auction (Milgrom 1989).

The marginal cost of each manufacturer independently follows a uniform distribution $U(0, 1)$, which implies that manufacturers have a positive probability to win the bid. Apparently, a manufacturer will not be chosen as a retailer's prequalified business partner if that manufacturer always lose the bid (i.e. the cost of that manufacturer is always higher than the costs of other manufacturers).

There are two possible informational schemes with the B2B e-market: transparent B2B e-market and opaque B2B e-market. The design of a transparent B2B e-market is as follows. Both retailers can observe the participants and the winner's bid of an auction. But they do not know who wins the bid. Such design has two advantages. First, it enables both retailers to share the information about their procurement costs (see Figure 1, the winner's bid in auction A and auction B are visible to both retailers). Second, it does not disclose all information of a successful transaction and thus is acceptable to B2B e-market participants.

If the e-market is run as an opaque platform, then each retailer's procurement costs would remain as private information (manufacturer bids are visible to the corresponding retailer only, not to its competitor). In this case, retailers will need to estimate competitor's cost based on available information. We explicitly express our assumption as follows.

Assumption 2: The transparent B2B e-market enables retailers to share their cost information.

Retailers are engaged in Cournot competition with an inverse demand function from the end-consumer market,

$$p = d - q_{r1} - q_{r2},$$

where q_{ri} is the quantity sold by retailer i ($i=1,2$), p is the price in consumer market, and d is the demand intercept. We assume that the products are perfect substitutes. To avoid degenerated solutions and to simplify the analysis, we follow prior literature (Li 2002) by assuming that the demand intercept is sufficiently large and that each manufacturer is able to fill the quantity ordered by the retailer. Also, all firms are risk-neutral.

3. The Effects of Information Transparency

Based on the above model setup, we study the effects of information transparency on retailers, manufacturers, and the total e-market participants respectively. Denote the cost of retailer i by c_{ri} ($i=1,2$), which equals to the second lowest bid that retailer i obtains from its pre-qualified manufacturers. According to the information structure of the e-market, c_{ri} is revealed to retailer j ($j=1,2; j \neq i$) in a transparent e-market but remains private in an opaque e-market.

Transparent e-market

First, we analyze the transparent e-market. Retailer i 's problem is:

$$\max_{q_{ri}} \pi_{ri}(q_{ri}) = (d - q_{ri} - q_{rj} - c_{ri})q_{ri} \quad (i = 1, 2; i \neq j)$$

where $\pi_{ri}(q_{ri})$, c_{ri} and q_{ri} are retailer i 's profit, cost and quantity, respectively. As discussed above, retailer i 's cost is observable to retailer j ($i, j = 1, 2; i \neq j$) through the e-market platform. Thus, retailer j may use c_{ri} to compute q_{ri} , indicating that q_{ri} is also known to retailer j by expectation. Solving the first-order condition and noting that the second-order condition is satisfied, we have:

$$q_{ri}^T = \frac{1}{3}(d - 2c_{ri} + c_{rj}), \quad \pi_{ri}^T = \frac{1}{9}(d - 2c_{ri} + c_{rj})^2,$$

where the superscript "T" stands for "transparent" market.

Now consider the manufacturers, the strategic variable of a manufacturer is its bidding price. In a Vickrey auction with endogenous quantity, a manufacturer's optimal bidding will truly reveal its marginal cost (Hansen 1988, Milgrom 1989). Thus, c_{ri} ($i = 1, 2$) is equivalent to the second-lowest manufacturer's marginal cost, and follows a cumulative distribution function (CDF)¹ $\Pr(c_{ri} \leq x) = F(x) = x^2$. It follows that $f(x) = 2x$, $E(c_{ri}) = 2/3$, and $\text{var}(c_{ri}) = 1/18$. Since the two retailers procure from different manufacturers, and the manufacturers' marginal costs are independent of each other, we have $\text{cov}(c_{r1}, c_{r2}) = 0$. Then the retailer's expected profit can be computed as:

$$E(\pi_{ri}^T) = \frac{1}{9}[d - E(c_{ri})]^2 + \frac{5}{9}\text{var}(c_{ri}) = \frac{1}{162}(18d^2 - 24d + 13). \quad (1)$$

Next we derive the total expected profit of all manufacturers. Apparently, the manufacturer who loses the bidding obtains zero profit. Now, consider R_1 's manufacturers whose marginal costs are m_{1a} and m_{1b} . Without losing generality, we assume that $m_{1b} \geq m_{1a}$, meaning that M_{1a} will win the order from R_1 , and that $c_{r1} = m_{1b}$. The expected profit of M_{1a} is

$$E(\pi_m^T) = E[q_{r1}^T \cdot (m_{1b} - m_{1a})],$$

where m_{1b} is the price R_1 pays to M_{1a} , and m_{1a} is the marginal cost of M_{1a} . To derive $E(\pi_m^T)$, we use the following results. First, $\text{cov}(m_{1a}, c_{r2}) = \text{cov}(m_{1b}, c_{r2}) = 0$ because m_{1a} and m_{1b} are independent of c_{r2} . Second, the CDF of m_{1b} is $F(x) = x^2$ ($x \in [0, 1]$), the conditional CDF of m_{1a} , given m_{1b} , is $H(x|m_{1b}) = x/m_{1b}$ ($x \in [0, m_{1b}]$), and the CDF of m_{1a} is $G(x) = 1 - (1 - x)^2$. Using these results, we have

$$E(m_{1b}) = 2/3, \quad \text{var}(m_{1b}) = 1/18, \quad E(m_{1a}) = 1/3, \quad \text{var}(m_{1a}) = 1/6,$$

$$\text{cov}(m_{1a}, m_{1b}) = \int_0^1 \int_0^{m_{1b}} m_{1a} \cdot m_{1b} dH(m_{1a}|m_{1b}) dF(m_{1b}) - \int_0^1 m_{1b} dF(m_{1b}) \cdot \int_0^1 m_{1a} dG(m_{1a}) = 1/36,$$

and thus

$$= \frac{1}{3}(d - 2/3) \cdot \frac{1}{3} + \frac{2}{3}[\text{cov}(m_{1a}, m_{1b}) - \text{var}(m_{1b})] = \frac{1}{54}(6d - 5). \quad (2)$$

¹ There are two manufacturers. Thus, the probability that the second-lowest manufacturer marginal cost is lower than x is equivalent to the probability that the marginal costs of *both* manufacturers are lower than x .

By symmetry, the total profit of all participants in a transparent e-market is

$$E(\Pi^T) = 2E(\pi_{r1}^T) + 2E[q_{r1}^T \cdot (m_{1b} - m_{1a})] = \frac{2}{81}(9d^2 - 3d - 1).$$

(3)

Opaque e-market

Now, we turn to the opaque B2B e-market. Retailer i 's problem is

$$\max_{q_{ri}} E[\pi_{ri}^O] = [d - q_{ri} - E(q_{rj}) - c_{ri}]q_{ri}, \quad (i = 1, 2; i \neq j)$$

where the superscript ‘‘O’’ stands for ‘‘opaque’’ market and $E(q_{rj})$ is R_i 's expectation about R_j 's quantity (not directly observable to R_i). Solving the first-order condition yields $q_{ri}^O = \frac{1}{2}[d - E(q_{rj}^O) - c_{ri}]$. Retailers are rational, so it must follow that $E(q_{ri}^O) = \frac{1}{2}[d - E(q_{rj}^O) - E(c_{ri})]$. By symmetry, $E(q_{ri}^O) = E(q_{rj}^O) = Eq$, which leads to $Eq = \frac{1}{3}[d - E(c_{ri})]$. Thus,

$$q_{ri}^O = \frac{1}{6}[2d + E(c_{ri}) - 3c_{ri}] = \frac{1}{18}(6d - 9c_{ri} + 2),$$

$$\pi_{ri}^O = [d - q_{ri} - q_{rj} - c_{ri}]q_{ri} = \frac{1}{324}(6d - 9c_{ri} + 2)(6d - 9c_{ri} + 9c_{rj} - 4),$$

$$E(\pi_{ri}^O) = \frac{1}{324}[6d - 9E(c_{ri}) + 2](6d - 4) + \frac{1}{4}\text{var}(c_{ri}) = \frac{1}{648}[9 + 8(3d - 2)^2].$$

(4)

Following a similar argument, we have

$$E(\pi_m^O) = E[q_{r1}^O \cdot (m_{1b} - m_{1a})] = \frac{1}{216}(24d - 19)$$

(5)

Then, the total profit of all participants in an opaque e-market is

$$E(\Pi^O) = 2E(\pi_{r1}^O) + 2E[q_{r1}^O \cdot (m_{1b} - m_{1a})] = \frac{2}{81}(9d^2 - 3d - 2).$$

(6)

Comparing (3) with (6), we find that $E(\Pi^T) > E(\Pi^O)$, which leads to the following result.

Proposition 1: The overall effect of information transparency on the whole B2B e-market is positive.

It is well known 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 competition exists in both upstream and downstream (both retailers and manufacturers face competition – 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 sharing (about costs) in a more realistic two-level supply chain setting.

Next we examine the effects of information transparency on retailers and manufacturers separately. The results we established earlier turn out to be quite useful. Comparing (1) with (4), and (2) with (5), we obtain: $E(\pi_m^T) < E(\pi_m^O)$, and $E(\pi_{ri}^T) > E(\pi_{ri}^O)$, which lead to our next result:

Proposition 2: Information transparency benefits retailers but hurts manufacturers.

The intuition is as follows. When retailers engage in Cournot competition, information transparency helps them make more accurate decisions on quantity. For example, consider retailer i with $c_{ri} > E(c_{rj})$. If it is in a transparent e-market and retailer i finds that the realized c_{rj} is actually greater than c_{ri} , it would order more from its

manufacturers than otherwise if it is in an opaque market. Thus, a transparent market helps both retailers to coordinate their quantity strategies, leading to greater expected profit for both.

Intuitively, manufacturers would take advantages of retailers if they make mistakes. Now, if the information transparency helps retailers better coordinate their strategies and reduce their miscalculations, manufacturers would be worse off. To see this, consider a manufacturer (say, M_{1a}) who wins the bid. Its profit is $q_{r1} \cdot (m_{1b} - m_{1a})$. Manufacturer M_{1a} hopes that when m_{1b} is large (or M_{1a} 's profit margin $(m_{1b} - m_{1a})$ is large), q_{r1} is as large as possible. But in a transparent e-market, m_{1b} tends to be more negatively associated with q_{r1} than in an opaque market. This can be illustrated by

$$\text{cov}(m_{1b}, q_{r1}^T) = -1/27 > \text{cov}(m_{1b}, q_{r1}^O) = -1/36.$$

It means that a high-cost retailer is less likely to "incorrectly" order large quantity in a transparent e-market than in an opaque market. But such retailer's mistake is desirable to manufacturers. Therefore, information transparency works against manufacturers.

Propositions 1 and 2 offer important managerial implications to B2B e-market operators. The first business implication is that the B2B e-market operator should adopt a transparent B2B e-market. Second, the e-market operator also faces a managerial dilemma: i.e., how to reconcile these two opposing effects of information transparency on retailers and on manufacturers. Otherwise, manufacturers would not participate in the e-market. To resolve the incentive problem, we propose a *discriminatory pricing scheme* for the e-market operator to redistribute informational benefits among retailers and manufacturers to make both sides better off. Denote by f_{ri} the fees charged to retailer i by the B2B e-market operator. And denote by f_{mi} the fees charged to the manufacturer who wins retailer i 's order. We describe the B2B e-market operator's problem as follows.

$$(7) \quad \begin{aligned} & \max_{f_{ri}, f_{mi}} \sum_{i=1}^2 (f_{ri} + f_{mi}) \\ & \text{s.t. } E(\pi_{ri}^T) - f_{ri} \geq E(\pi_{ri}^O) \text{ and } E(\pi_{mi}^T) - f_{mi} \geq E(\pi_{mi}^O) \end{aligned}$$

The constraints of e-market operator's problem ensure that both retailers and manufacturers are at least indifferent between a transparent B2B e-market and an opaque B2B e-market. Otherwise either retailers or manufacturers would leave the transparent B2B e-market and thus the e-market is not sustainable any more. The optimal strategy of the B2B e-market operator is straightforward and is summarized in the following Proposition.

Corollary 1: The B2B e-market operator should adopt a transparent e-market mechanism, charge $f_{ri} = E(\pi_{ri}^T) - E(\pi_{ri}^O)$ on retailers and $f_{mi} = E(\pi_{mi}^T) - E(\pi_{mi}^O)$ on winning manufacturers.

f_{ri} is the maximum fees can be charged on retailers while f_{mi} is the minimum compensations given to manufacturers in order to retain them in the B2B e-market. Apparently, f_{ri} and f_{mi} given in Corollary 1 is the optimal strategy of the B2B e-market operator. Given $f_{ri} + f_{mi} > 0$, the discriminatory pricing scheme is feasible and is profitable to the B2B e-market operator. Even though information transparency might hurt one side, the losses of this side could be compensated by the gains of the other side. In such a case, charging a transaction fee on one side and subsidizing the other side may help internalize incentives of both sides.

4. Bertrand Competition in Downstream Industry

The above analysis assumes that retailers compete on quantity. In this section, we consider the case where retailers compete on price (Bertrand competition). Retailer i 's demand function is $q_{ri} = d - p_{ri} + p_{rj}$, ($i, j = 1, 2; i \neq j$), where p_{ri} , the price charged by retailer i , is retailer i 's strategic variable. Using a similar argument as that in the previous section, we proceed to obtain the following results.

In a transparent e-market,

$$p_{ri}^T = \frac{1}{3}(3d + 2c_{ri} + c_{rj}), \quad q_{ri}^T = \frac{1}{3}(3d - c_{ri} + c_{rj}), \quad \pi_{ri}^T = \frac{1}{9}(3d - c_{ri} + c_{rj})^2,$$

$$E(\pi_{ri}^T) = d^2 + \frac{2}{9} \text{var}(c_{ri}) = d^2 + \frac{1}{81},$$

(8)

$$E(\pi_m^T) = \frac{1}{3}d - \frac{1}{3}[\text{var}(m_{1b}) - \text{cov}(m_{1a}, m_{1b})] = \frac{1}{3}d - \frac{1}{108},$$

$$(9) E(\Pi^T) = 2E(\pi_{r1}^T) + 2E[q_{r1}^T \cdot (m_{1b} - m_{1a})] = 2d^2 + \frac{2}{3}d + \frac{1}{162}$$

(10)

Similarly, in an opaque market,

$$p_{ri}^o = \frac{1}{6}(6d + 3c_{ri} + 2), \quad q_{ri}^o = \frac{1}{2}(2d - c_{ri} + c_{rj}), \quad \pi_{ri}^o = \frac{1}{12}(2d - c_{ri} + c_{rj})(6d - 3c_{ri} + 2),$$

$$E(\pi_{ri}^o) = d^2 + \frac{1}{4} \text{var}(c_{ri}) = d^2 + \frac{1}{72},$$

(11)

$$E(\pi_m^o) = \frac{1}{3}d - \frac{1}{2}[\text{var}(m_{1b}) - \text{cov}(m_{1a}, m_{1b})] = \frac{1}{3}d - \frac{1}{72},$$

$$(12) E(\Pi^o) = 2E(\pi_{r1}^o) + 2E[q_{r1}^o \cdot (m_{1b} - m_{1a})] = 2d^2 + \frac{2}{3}d.$$

(13)

Comparing (10) with (13), (9) with (12), and (8) with (11), we have the following result:

Proposition 3: *If downstream retailers engage in price competition, the overall effect of information transparency on the total B2B e-market is still positive. But information transparency hurts retailers while benefits manufacturers.*

Recall that information transparency benefits retailers when they compete on quantity, but here information transparency turns to be against them under Bertrand competition. To the best of our knowledge, prior literature did not consider competing manufacturers in the upstream. Hence, it is worthwhile to explain the effects. Information transparency tends to intensify price competition (Zhu 2004). That is, price competition is more intense when firms know each other's costs. On average, the prices the retailers charge will be lower with information transparency, which leads to lower profit for the retailers. However, since lower prices means higher demand, the manufacturers can sell a greater quantity under information transparency, which leads to greater profits for the manufacturers.

Comparison with Prior Economics Literature

To the best of our knowledge, prior economics literature of information sharing did not considered a two-level B2B e-market model with competing retailers in downstream and competing manufacturers in upstream. Instead, prior economics literature only focused on the informational effects in a one-level market without upstream industry. Thus, prior economics literature did not answer two important questions face by B2B e-market operators: (1) Is it worthwhile for the B2B e-market operator to pursue the information transparency? and (2) If so, will both sides of buyers and sellers be better off with information transparency? If any side is hurt, then which side is hurt, under what conditions? Our paper answers these questions based on a two-level e-market model different from those used in prior economics literature.

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 manufacturers is always opposite to the effect on retailers. It means that information transparency can always benefit one side, but at the cost of the other side. That is,

Corollary 2: *Information transparency always hurts one side (either retailers or manufacturers), indicating an inherent conflict of interest regarding information transparency. The competition mode in the downstream industry determines which side will be hurt.*

Table 1. The Differential Effects of Information Transparency

Downstream Competition	Retailers	Manufacturers	Overall Effects
Cournot	+	-	+
Bertrand	-	+	+

Table 1 summarizes the effects of information transparency. Although greater information transparency benefits the total supply chain (Proposition 1), the informational benefit to one side always comes at a price to the other side. Such conflict of interest would have serious consequences. Those who are hurt would not participate in the e-market, which in turn will make the e-market not sustainable. This illustrates a fundamental challenge facing supply chain management. It also provides a possible theoretical explanation of the difficulty of B2B e-markets in industries (CIO 2002).

Since the total effect of information transparency is always positive, it follows that, regardless the competition mode in the downstream industry, the B2B e-market operator may always use the discriminatory pricing scheme proposed in Corollary 1 to reconcile the conflict of interest between the two sides.

5. Extensions

We will extend the base model in several dimensions in this section. We will see that the simple base model is in fact able to demonstrate the major result, while the extended model confirms its robustness.

5.1 Asymmetric Case

The base model above assumes that each of the two retailers has two pre-qualified manufacturers. Now, we relax this assumption by allowing R_i to have k_i pre-qualified manufacturers, and without losing generality, let $k_2 \geq k_1 \geq 2$. We still assume two retailers for now. Following a similar process as above, we get:

$$q_{ri}^T = \frac{1}{3}(d - 2c_{ri} + c_{rj}), \text{ and } q_{ri}^O = \frac{1}{6}[2d + E(c_{ri}) - 3c_{ri}].$$

Denote by m_i^{l1} the lowest marginal cost of R_i 's manufacturers, and m_i^{l2} the second lowest (note that $c_{ri} = m_i^{l2}$). Then the total expected profit of R_i 's manufacturers is $E[q_{ri}^b(m_i^{l2} - m_i^{l1})]$ ($b = T$ or O). The following results are established (proof in the Appendix):

Lemma 1: $E(m_i^{l1}) = 1/(k_i + 1)$, $E(m_i^{l2}) = 2/(k_i + 1)$, $\text{var}(m_i^{l2}) = 2(k_i - 1)/[(k_i + 1)^2(k_i + 2)]$,

$$\text{cov}(m_i^{l1}, m_i^{l2}) = (k_i - 1)/[(k_i + 2)(k_i + 1)^2].$$

Using these results and the expression of q_{ri}^T and q_{ri}^O , we derive the expected retailer profit and manufacturer profits as in the Appendix. It follows that:

$$E(\pi_{ri}^T) - E(\pi_{ri}^O) \equiv \Delta\pi_{ri} > 0, \quad E(\pi_m^T) - E(\pi_m^O) \equiv \Delta\pi_{mi} < 0, \quad \text{and } E(\Pi^T) - E(\Pi^O) \equiv \Delta\Pi > 0.$$

This means that information transparency benefits the total B2B e-market. But it hurts manufacturers while benefits retailers. The B2B e-market operator may use a discriminatory pricing scheme to internalize the conflict of interest. Hence, the result established earlier with the simple base model carries over to a setting when more manufacturers are involved. The highest possible price charged to retailer i is $\Delta\pi_{ri}$ while the lowest compensation to the winning manufacturer is $-\Delta\pi_{mi}$. Since $k_2 \geq k_1 \geq 2$ and $(k-1)/[(k+1)^2(k+2)]$ is a decreasing function in $k \geq 2, k \in N$, it is straightforward to show that $\Delta\pi_{r1} \geq \Delta\pi_{r2}$, $|\Delta\pi_{m1}| \geq |\Delta\pi_{m2}|$, and thus we have:

Proposition 4: *In a transparent e-market, the market operator may charge a lower price to a retailer who has more manufacturers than its competitor. That retailer's winning manufacturer should get less compensation than the other retailer's winning manufacturer.*

It is important to understand how the discriminatory pricing scheme would work. When both retailers have different numbers of pre-qualified manufacturers, they should be charged differently. Proposition 4 provides a guideline of

discriminatory pricing to the e-market operators. Given $k_2 \geq k_1 \geq 2$, it can be shown that $\text{var}(c_{r2}) \leq \text{var}(c_{r1})$, indicating that it is easier for R_1 to “guess” R_2 ’s cost than it is for R_2 to “guess” R_1 ’s cost in an opaque market. So it might seem intuitive that information transparency should bring about lower benefits to R_1 than to R_2 . But counter-intuitively, the above proposition suggests that information transparency benefits R_1 more than R_2 . The key reason is that the major benefit of information transparency to R_1 is not uncertainty reduction, but how competition is affected by information transparency. As discussed earlier, information transparency tends to help Cournot retailers coordinate their quantity strategies rather than intensify the overall competition. Since $k_2 \geq k_1 \geq 2$, R_2 is more likely to obtain a lower procurement price than R_1 , and is thus more competitive than R_1 . Intuitively, information transparency reduces R_1 ’s cost uncertainty in R_2 ’s eyes, and makes R_2 less aggressive than otherwise in an opaque market. And this is the key source of informational benefits to R_1 . Given the fact that R_2 is stronger than R_1 in terms of cost advantage, a reduction of aggressiveness of R_2 is certainly more valuable to R_1 than a reduction of aggressiveness of R_1 to R_2 , all else being equal.

As shown above, information transparency makes manufacturers worse off because a high-cost retailer in a transparent e-market is less likely to “incorrectly” order large quantity than in an opaque market. Note that R_1 is more likely to be a higher-cost retailer comparing to R_2 . It suggests that the negative effect of information transparency would have a stronger impact on R_1 ’s winning manufacturer than on R_2 ’s winning manufacturer. That is why R_1 ’s winning manufacturer should get more compensation.

5.2 Many-to-Many B2B E-Market

So far we have considered two retailers only in the downstream industry. Now, we extend the analysis to a more general setting with n retailers, each of them having k pre-qualified manufacturers ($n, k \geq 2, n, k \in N$). Retailer i ’s problem in a transparent B2B e-market is:

$$\max_{q_{ri}} \pi_{ri}(q_{ri}) = \left(d - q_{ri} - \sum_{j \neq i} q_{rj} - c_{ri} \right) q_{ri}, \quad (i, j = 1 \dots n).$$

Solving this problem, and noting that retailer i knows c_{rj} (and thus q_{rj}), we get

$$q_{ri}^T = \frac{1}{n+1} \left(d - nc_{ri} + \sum_{j \neq i} c_{rj} \right). \tag{14}$$

In parallel, retailer i ’s problem in an opaque market is:

$$\max_{q_{ri}} E[\pi_{ri}(q_{ri})] = \left[d - q_{ri} - E\left(\sum_{j \neq i} q_{rj} \right) - c_{ri} \right] q_{ri} \quad (i, j = 1 \dots n).$$

Solving this problem, and noting that $E(q_{ri}) = E(q_{rj})$ ($i \neq j$) at the symmetric equilibrium, we have

$$q_{ri}^O = \frac{(d - c_i)}{2} - \frac{(n-1)(d - Ec)}{2(n+1)} \tag{15}$$

where $Ec = E(c_{ri})$ ($i = 1 \dots n$). Using (14), (15), and the results in Lemma 1, we have

$$E(\pi_{ri}^T) - E(\pi_{ri}^O) \equiv \Delta\pi_r > 0, \quad E(\pi_m^T) - E(\pi_m^O) \equiv \Delta\pi_m < 0, \quad E(\Pi^T) - E(\Pi^O) \equiv \Delta\Pi > 0.$$

This result is the same as that in Table 1. This shows that our major result is quite robust to model specifications. Further, it can be shown that $\Delta\pi_r$, $|\Delta\pi_m|$, and $\Delta\Pi$ are increasing functions of n and decreasing functions of k . Noting that n and k measure the *intensity of competition* in downstream and upstream respectively, we have:

Proposition 5: *The value of information transparency to the total B2B e-market ($\Delta\Pi$), to a retailer ($\Delta\pi_r$), and the minimum compensation given to the winning manufacturer ($|\Delta\pi_m|$) increase with respect to the intensity of the downstream competition (n), but decrease with respect to the intensity of the upstream competition (k).*

If the downstream industry has a greater number of retailers (n is large), it is more difficult for them to coordinate their quantity strategies (without the e-market). Given that the major benefit of information transparency is to help retailers coordinate their quantities, it follows that information transparency should be more valuable to retailers when n is larger. This also implies the following *prediction*:

Corollary 3: *A transparent B2B e-market would work better in a market with a fragmented downstream industry where information-based coordination is more valuable.*

Now, consider the manufacturers. As we have seen, if one side of the e-market obtains more efficiency, it comes with the expense of the other side. So it is not surprising to find that the winning manufacturer suffers a greater loss from information transparency when n is larger. Then the compensation to the manufacturer should go up in order to make the e-market sustainable. In contrast, when k is larger, the uncertainty of c_{ri} is smaller because $\text{var}(c_{ri})$ is a decreasing function of k . Consequently, the informational benefits to eliminate or lower uncertainty turn to be smaller.

5.3 Sealed Auction

In this subsection, the B2B e-market structure is the same as the base model (see Figure 1). The difference is that the upstream manufacturers compete for the downstream retailer order via a sealed auction (or first-bid auction) rather than an open auction (or second-bid auction). Although this case is not a common practice, we examine it because information transparency will have a *direct* effect on manufacturers, whereas manufacturers are *indirectly* affected by information transparency.²

We want to examine whether the major results still hold in this special cases. The problem of a manufacturer turns out to be an optimal bidding strategy with endogenous quantity. Hansen (1988) has analyzed a simple model with one-level market and linear demand function. It is generally infeasible to get an analytical solution for the manufacturer's bidding strategy even under a simple setting (Hansen 1998). Following the method used in Hansen (1988), we have obtained the following results. In a transparent B2B e-market, the manufacturer's optimal bidding strategy $b^T(m_i)$ satisfies

$$\frac{d[b^T(m_i)]}{dm_i} = \frac{[d + E(c_r^T) - 2b^T(m_i)][b^T(m_i) - m_i]}{(1 - m_i)[2m_i + d + E(c_r^T) - 4b^T(m_i)]},$$

where $E(c_r^T) = \int_0^1 2(1 - m)b^T(m)dm$. In an opaque B2B e-market, the manufacturer's optimal bidding strategy $b^O(m_i)$ turns to satisfy

$$\frac{d[b^O(m_i)]}{dm_i} = \frac{[2d + E(c_r^O) - 3b^O(m_i)][b^O(m_i) - m_i]}{(1 - m_i)[3m_i + 2d + E(c_r^O) - 6b^O(m_i)]},$$

² In the base model, the optimal bidding strategy of a manufacturer remains the same in a transparency B2B e-market and an opaque B2B e-market. So manufacturers are indirectly affected by information transparency via the quantities chosen by retailers. But if manufacturers compete for downstream orders via a sealed auction, then their bidding strategies are different in opaque and transparent B2B e-market. Information transparency will have a *direct* effect on manufacturers.

where $E(c_r^o) = \int_0^1 2(1-m)b^o(m)dm$. It is infeasible to obtain the analytical results for $b^T(m_i)$ and $b^o(m_i)$.

We have conducted numerical experiments and found that our results in Table 1 still hold. The Mathematica program of numerical experiments is available upon request from authors.

6. Closing Remarks

This paper considers information transparency in a two-level business-to-business electronic market with competition existing in both upstream and downstream. We find that information transparency enabled by the e-market benefits the total B2B e-market no matter the downstream competition mode is Cournot competition or Bertrand competition. Prior supply chain management literature has shown that information sharing about demand benefits the total supply chain. In this paper, we consider a two-level B2B e-market model that different from prior supply chain literature. First, 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 multiple players). Second, information transparency in this paper refers to transparency about competitor's cost rather than the demand. Thus this paper takes one step further toward understanding the important but subtle effects of information sharing on supply chains.

Although information transparency benefits the total B2B e-market, the effect on each one side is always in conflict with the other side. Surprisingly, we find that it is always the case that one side (either manufacturers or retailers) will be hurt; conflict of interest persists. Those who are hurt by information transparency would have little incentive to participate in the e-market. This illustrates a fundamental challenge facing B2B e-market management. It also provides a possible theoretical explanation of the reluctance of many suppliers and manufacturers to join B2B e-markets in several industries (CIO 2002). Our theoretical prediction seems to be supported by a recent empirical study conducted by Soh et. al. (2006) that shows that buyers and sellers have conflicting interests regarding price transparency.

To encourage participation in information sharing when informational rents are not evenly distributed, several studies in the literature proposed contract schemes. Alternatively, we propose a market-based approach, that is, the e-market operator may use a discriminatory pricing scheme to internalize the conflict of interest between retailers and manufacturers so as to ensure participation incentives from both sides.

Our theoretical results might have some managerial implications. The conflict of interest is found to be a serious issue with regard to incentives of information sharing in B2B e-market. One possible way out of this dilemma is that a pricing scheme should be carefully designed to make both sides better off with information transparency. Otherwise either manufacturers or retailers would not participate in the e-market. Any theoretical value of information transparency will not materialize. The discriminatory pricing scheme proposed by this paper may help align incentives and achieve coordination. Such an approach might work better than the contract scheme proposed in earlier literature for two reasons. First, the B2B e-market is an intermediary that is not motivated to manipulate the information to be revealed, and thus is more likely to be trusted by both sellers and buyers, while contractors who pre-commit information sharing still have incentives to cheat by providing incorrect information to others. Second, our approach is a less costly method to achieve coordination among *many* players while developing a contact for so many players might turn out to be infeasible.

Finally, this paper offers important managerial insights about the value of information transparency. We have shown informational effects under various settings. These results are useful guidelines to design and manage electronic markets.

This paper leaves several issues open for further research. First, this study has not taken consumer welfare into account. How would the social welfare (the total welfare of supply chain plus consumers) be affected by information sharing? Second, our simple two-level B2B e-market model can be used to study not only information transparency but also other interesting issues such as the effects of inter-organizational IT system integration and business partner selections. Finally, empirical studies may help test the theoretical results in either a real-world or an experimental setting. These questions are left for further analysis. We hope that the initial results reported above will motivate more research in this area.

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Appendix

Asymmetric Case (Lemma 1)

Recall that m_i^{l1} is the lowest marginal cost among k_i manufacturers. Then,

$$G(x, k_i) = \Pr(m_i^{l1} \leq x) = 1 - \Pr(\text{all manufacturers' costs} > x) = 1 - (1-x)^{k_i},$$

and thus $E(m_i^{l1}) = 1/(k_i + 1)$. Consider m_i^{l2} , the second lowest marginal costs among k_i manufacturers,

$$\begin{aligned} \Pr(m_i^{l2} \leq x) &= 1 - \Pr(\text{all manufacturers' costs} > x) - \Pr(\text{only one manufacturer's cost} \leq x) \\ &= F(x, k_i) = 1 - (1-x)^{k_i} - k_i \cdot x(1-x)^{k_i-1}, \end{aligned}$$

and thus $E(m_i^{l2}) = 2/(k_i + 1)$, $\text{var}(m_i^{l2}) = 2(k_i - 1)/[(k_i + 1)^2(k_i + 2)]$.

The conditional CDF of m_i^{l1} , given m_i^{l2} , is

$$H(x|m_i^{l2}) = x/m_i^{l2} \quad (x \in [0, m_i^{l2}]).$$

Hence,

$$\begin{aligned} E(m_i^{l2} \cdot m_i^{l1}) &= \int_0^1 \int_0^{m_i^{l2}} m_i^{l2} \cdot m_i^{l1} dH(m_i^{l1}|m_i^{l2}) dF(m_i^{l2}, k_i), \\ \text{cov}(m_i^{l1}, m_i^{l2}) &= E(m_i^{l2} \cdot m_i^{l1}) - E(m_i^{l2}) \cdot E(m_i^{l1}) = \frac{k_i - 1}{(k_i + 2)(k_i + 1)^2}. \end{aligned}$$

Asymmetric Case (Proposition 4)

Using the results in Lemma 1 and the expression of q_{ri}^T and q_{ri}^O , we derive the expected retailer profit and manufacturer profits as follows:

$$\begin{aligned} E(\pi_{ri}^T) &= \frac{1}{9} \left[d - \frac{4}{(k_i + 1)} + \frac{2}{(k_j + 1)} \right]^2 + \frac{2(k_j - 1)}{9(k_j + 1)^2(k_j + 2)} + \frac{8(k_i - 1)}{9(k_i + 1)^2(2 + k_i)}, \\ E(\pi_m^T) &= E[q_{ri}^T \cdot (m_i^{l2} - m_i^{l1})] = \frac{1}{9} \left[d - \frac{4}{(k_i + 1)^2} + \frac{2}{(k_i + 1)(k_j + 1)} \right] - \frac{2(k_i - 1)}{3(k_i + 1)^2(k_i + 2)}, \\ E(\pi_{ri}^O) &= \frac{1}{9} \left[d - \frac{4}{(k_i + 1)} + \frac{2}{(k_j + 1)} \right]^2 + \frac{1(k_i - 1)}{2(k_i + 1)^2(2 + k_i)}, \\ E(\pi_m^O) &= E[q_{ri}^O \cdot (m_i^{l2} - m_i^{l1})] = \frac{1}{9} \left[d - \frac{4}{(k_i + 1)^2} + \frac{2}{(k_i + 1)(k_j + 1)} \right] - \frac{(k_i - 1)}{2(k_i + 1)^2(k_i + 2)}, \end{aligned}$$

It follows that:

$$E(\pi_{ri}^T) - E(\pi_{ri}^O) \equiv \Delta\pi_{ri} = \frac{1}{18} \left[\frac{7(k_i - 1)}{(k_i + 1)^2(k_i + 2)} + \frac{4(k_j - 1)}{(k_j + 1)^2(k_j + 2)} \right] > 0,$$

$$E(\pi_m^T) - E(\pi_m^O) \equiv \Delta\pi_{mi} = -\frac{(k_i - 1)}{6(k_i + 1)^2(k_i + 2)} < 0, \text{ and}$$

$$E(\Pi^T) - E(\Pi^O) \equiv \Delta\Pi = \frac{4}{9} \left[\frac{k_1 - 1}{(k_1 + 1)^2(k_1 + 2)} + \frac{k_2 - 1}{(k_2 + 1)^2(k_2 + 2)} \right] > 0.$$