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Electronic B2B Marketplaces with Different Ownership Structures

Byungjoon Yoo
Korea University Business School, 1, 5-ga, Anam-Dong, Sungbuk-Gu, Seoul 136-701, Korea, byoo@alumni.cmu.edu

Vidyanand Choudhary
Merage School of Business, University of California, Irvine, Irvine, California 92697, veecee@uci.edu

Tridas Mukhopadhyay
Tepper School of Business, Carnegie Mellon University, Pittsburgh, Pennsylvania 15213, tridas@andrew.cmu.edu

This paper analyzes electronic marketplaces with different ownership structures: biased marketplaces and neutral marketplaces. Biased marketplaces can be either buyer-owned or supplier-owned, whereas neutral marketplaces are owned by independent third parties. We develop a single-period model, with fulfilled expectations equilibrium. The buyers experience positive network effects that are a function of the number of suppliers and the suppliers receive similar positive network effects depending on the number of buyers. We develop a general model with atomistic buyers and suppliers. We find that biased marketplaces set prices to induce greater participation (demand) from both buyers and suppliers compared to a neutral marketplace. This counterintuitive result can be understood in the context of the positive cross-network effects experienced by buyers and suppliers and the added benefit to the owner of a biased marketplace from participating in the marketplace. Biased marketplaces also provide greater social welfare compared to neutral marketplaces.

Key words: business-to-business; ownership; network effect; intermediary; marketplace
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1. Introduction

Electronic marketplaces promise seamless connectivity across enterprises, aggregation of buyers and suppliers, increased supply chain visibility, and dramatic reductions in transactions costs. Despite the end of the hype surrounding online marketplaces, the hard work of developing the innovations, standards, and technologies to unleash the power of electronic trading continues apace. Standards bodies including OASIS, UN/CEFACT, and RosettaNet have developed standards for business-to-business (B2B) integration including ebXML and RosettaNet that enable trading partners to integrate their processes and allow disparate systems to communicate with each other. The volume of business is, by far, the highest for B2B marketplaces followed by B2C and C2C. The value of B2B electronic transactions was 12 times the volume of B2C transactions, reaching $2.37 trillion in 2004 (eMartketer 2003). Electronic marketplaces continue to evolve at a rapid pace with increasing consolidation and the emergence of private exchanges.

The development of electronic marketplaces has provided researchers with many opportunities for research and led to the emergence of new areas of study such as "two-sided markets," supply chain integration, and management of information flow across organizational boundaries. Yet there remain many unanswered questions. This paper focuses on the implications of the ownership structure of electronic marketplaces on the participants such as buyers and sellers who use the marketplace. We define three potential ownership structures: (1) buyer-owned marketplaces where some buyers jointly own the marketplace, (2) supplier-owned marketplaces, and (3) neutral marketplaces that are owned by independent third parties (neither buyers nor suppliers). We also refer to buyer-and supplier-owned marketplaces as *biased marketplaces*.

Our goal is to study the impact of the three types of ownership structure on electronic marketplaces. While all three types are found in B2B marketplaces, only a subset of them are found in business-to-consumer (B2C) or consumer-to-consumer (C2C) marketplaces (buyer-owned marketplaces are not found in B2C markets and only neutral marketplaces exist in C2C markets). For example, large successful C2C markets (eBay, Yahoo auctions) are typically owned by independent firms. Many B2C marketplaces are also owned by independent third-party firms (Ubid.com, Bidz.com). However, there is an additional possibility in B2C markets—that the seller firms can jointly

own the electronic marketplace. In reality, due to the extreme diversity of products that consumers buy, the B2C space is dominated by online retailers that function as neutral intermediaries (WalMart.com, Amazon.com). Many manufacturers offer a direct online channel to consumers (Dell.com, sonystyle.com) and these may be considered a limiting case of a supplier-owned B2C marketplace. On the other hand, B2B marketplaces exhibit the full range of ownership structures with numerous neutral marketplaces (Freemarkets acquired by Ariba, Carrierpoint), buyer-owned marketplaces (Perfect Commerce, Worldwide Retail Exchange), and supplier-owned marketplaces (Exostar, Quadrem). Hence, we focus mostly on the implications of the ownership structure on B2B marketplaces but some of our results may also be applicable to other marketplaces.

The owners can exercise control over the marketplace by setting the policies and prices. The goal of the marketplace also changes as the ownership is held by a neutral intermediary or a group of buyers or sellers. Articles in the trade press have questioned the integrity of biased marketplaces (buyer or supplier owned) arguing that buyers (suppliers) may be at a disadvantage in a supplier-(buyer-) owned market. However, biased marketplaces may find it easier to gather critical mass and liquidity due to the owners' transactions. On the other hand, neutral marketplaces are often developed by existing intermediaries that want to take advantage of the new technology. Often these firms have deep expertise in information technology.

In this paper, we compare biased intermediaries to neutral intermediaries when the marketplace exhibits two-sided network effects. We present results from a general model of a marketplace and address several questions. Do prices charged by the marketplace from buyers and suppliers depend on the ownership structure? If yes, what kind of structure would buyers prefer and would it be different from the structure preferred by suppliers? Does the ownership structure impact the level of participation from buyers and suppliers? How is the surplus of buyers and suppliers affected by ownership and which structure is best from the viewpoint of maximizing social welfare? We find that prices, surplus, and participation levels do vary with ownership structure. Biased marketplaces provide greater surplus to buyers and suppliers compared to neutral marketplaces and biased marketplaces set prices to induce greater participation (demand) from both buyers and suppliers compared to a neutral marketplace.

This paper is organized as follows. Section 2 reviews prior literature related to electronic marketplaces. We develop our model in §3. We provide our results and a comparison of the three ownership structures in §4. The discussion and conclusions are presented in §5.

2. Literature Review

Bakos (1998) classifies the functions of marketplaces in to three categories: (1) matching, (2) aggregation functions, and (3) providing an institutional infrastructure such as legal and regulatory framework. Mahadevan (2003) provides a classification scheme for B2B marketplaces identifying 12 B2B market structures. Both researchers point out that the degree of buyer and supplier fragmentation affects the level of influence that buyers and suppliers can exert on a marketplace. Yoo et al. (2003) examine the impact of network effects, information service levels, and switching costs in the context of a neutral B2B exchange. Another classification scheme is provided by Kaplan and Sawhney (2000). They emphasize the aggregation role of marketplaces and, in particular, the cross-network effect where the addition of a buyer benefits only suppliers and the addition of a supplier benefits only the buyers. Brynjolfsson and Kemerer (1996) show that network externalities of spreadsheet software programs allow firms to charge a higher price for these programs. Wang and Seidmann (1995) show that the participation of more suppliers can generate positive externalities for the buyer and negative externalities for other suppliers in an electronic data interchange (EDI) network. In the context of EDI, Riggins et al. (1995) show how a buyer can attract suppliers to its EDI network in the presence of network effects and Barua and Lee (1997) show how to subsidize suppliers to attract them when an EDI system is introduced. Srinivasan et al. (1994) examine the impact of EDI on shipment performance and Mukhopadhyay et al. (1995) quantify the business value of EDI. Choudhury (1997) examines the appropriate form of EDI for various situations.

Bakos and Nault (1997) discuss the optimal structure of electronic networks using a cooperative game model. Lucking-Reiley and Spulber (2001) note the different ownership structure of marketplaces but comment that it is not clear whether any ownership structure will be more successful than others. They note that ownership tends to reside with the side that has the greatest concentration of market power and point out the regulatory issues raised by buyer- or supplier-owned marketplaces. Other research that has examined two-sided network effects includes Bhargava and Choudhary's (2004) examination of versioning strategy by intermediaries using value-added services and Rochet and Tirole's (2003) study of credit card payment networks. In the following section, we present our model of intermediation with three different ownership structures.

3. Model

Consider a monopolistic marketplace that facilitates transactions between buyers and suppliers within a particular industry. Buyers and suppliers benefit from matching and value-added services provided by the marketplace. Demand for the services provided by the marketplace is a function of the price charged by the marketplace as well as the size of its network, e.g., the number of buyers and suppliers. In particular, such markets exhibit cross-network effects so that buyers benefit from participating in a marketplace is greater when the marketplace offers links to many suppliers and vice-versa for suppliers. In a rational, fulfilled expectations model, the size of the network is ultimately determined by the price charged by the marketplace. In such a model, all players correctly anticipate other participants' responses and thus expect a certain network size which is ultimately realized in equilibrium. Hence, the demand for the marketplace's services from buyers may be expressed as $D_b(p_s, p_b)$ and from suppliers as $D_s(p_s, p_b)$, where the subscripts s and b denote suppliers and buyers, respectively, and p denotes the price charged by the marketplace. We assume that the demand functions are continuous and twice differentiable. An electronic marketplace is an example of a "two-sided network." It is clear that the benefit to a buyer (supplier) from participating in an electronic marketplace is affected by the price charged by the marketplace $p_b(p_s)$ so that demand reduces as price increases ($\partial D_b/\partial p_b < 0$, $\partial D_s/\partial p_s < 0$). Further, this leads to an indirect effect where increasing $p_b(p_s)$ reduces $D_s(D_b)$ because suppliers' (buyers') benefit is linked to the size of buyer (supplier) network which are adversely affected by increasing $p_b(p_s)$ due to the direct effect ($\partial D_b/\partial p_s < 0$, $\partial D_s/\partial p_b < 0$). We assume that the direct effect of changes in $p_b(p_s)$ on $D_b(D_s)$ is greater than the indirect effect of $p_s(p_b)$ on $D_b(D_s)$ ($\partial D_b/\partial p_b < \partial D_b/\partial p_s$, $\partial D_s/\partial p_s < \partial D_s/\partial p_b$). We also assume that the second derivatives are negative for concavity of the profit function ($\partial^2 D_b/\partial p_b^2 \le 0$, $\partial^2 D_s/\partial p_s^2 \le 0$, $\partial^2 D_b/\partial p_s^2 \le 0$, $\partial^2 D_s/\partial p_b^2 \le 0$).

The marketplace charges a fee from buyers and suppliers for its services. We assume that the marginal cost for services provided by an electronic marketplace is negligible, while the fixed cost of developing an electronic marketplace does not affect the pricing decision and is therefore ignored. Hence, the profit earned by a marketplace is simply the fee revenue generated from buyers and suppliers. The key difference between a neutral and a biased marketplace is that while owners of all marketplaces earn fee-based profits, the owners of biased marketplaces are also participants in the marketplace (either as buyers or suppliers). Therefore, they attempt to maximize not just the fee-based profit but the sum of fee-based profit and their benefit from participation.

The focus of this paper is on the implications of the three different ownership structures on the level of participation from buyers and suppliers and the social welfare generated. We model these three ownership structures below, starting with the neutral marketplace.

3.1. Neutral Marketplace

A marketplace that is not owned by buyers or suppliers but instead owned by a third party is referred to as a *neutral marketplace*. Based on prior discussion with respect to fixed and marginal costs, the profit function for a neutral marketplace is the fee-based revenue from buyers and suppliers and can be stated as

$$\pi_{NI}(p_s, p_b) = p_s D_s(p_s, p_b) + p_b D_b(p_b, p_s).$$

To solve for the optimal demand with general demand functions, we rewrite the profit function using the inverse demand function. This transformation is feasible when there exists a one-to-one mapping from (D_b, D_s) to (p_s, p_b). In Appendix A.1, we show that a one-to-one mapping exists when $(\partial D_s/\partial p_s)(\partial D_b/\partial p_b) > (\partial D_s/\partial p_b)(\partial D_b/\partial p_s)$. Our assumption that the magnitude of the direct effect is greater than that of the indirect effect implies that this condition is satisfied and therefore a one-to-one mapping exists. Following this transformation, the demand from buyers (suppliers) falls when the price for buyers (suppliers) is increased, hence, $\partial p_b/\partial D_b < 0$ ($\partial p_s/\partial D_s < 0$). Also, an increase in demand from buyers (suppliers) raises the willingness to pay of suppliers (buyers) due to the cross-network effect so that $\partial p_s/\partial D_b > 0$ ($\partial p_b/\partial D_s > 0$). We rewrite the profit function as

$$\pi_{NI}(D_s, D_b) = p_s(D_s, D_b)D_s + p_b(D_s, D_b)D_b. \quad (1)$$

The first-order conditions (FOC) obtained by taking the derivative of the profit function with respect to (D_s, D_b) are

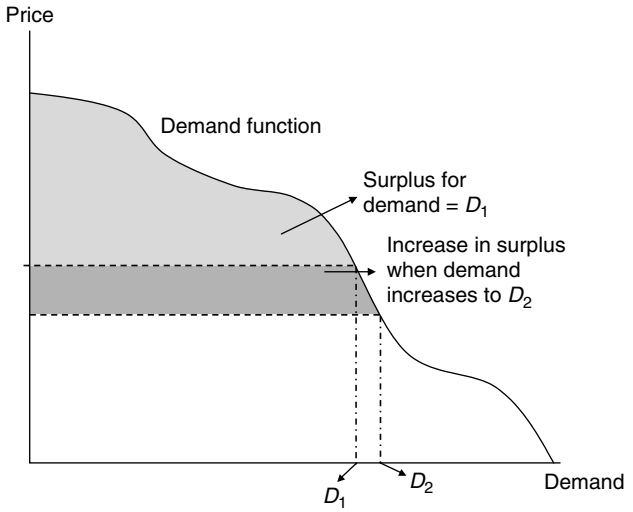
$$\frac{\partial \pi_{NI}}{\partial D_s} = p_s(D_s, D_b) + D_s\frac{\partial p_s}{\partial D_s} + D_b\frac{\partial p_b}{\partial D_s} = 0, \quad (2)$$

$$\frac{\partial \pi_{NI}}{\partial D_b} = p_b(p_s, p_b) + D_s\frac{\partial p_s}{\partial D_b} + D_b\frac{\partial p_b}{\partial D_b} = 0. \quad (3)$$

We assume that there exists a unique interior solution that maximizes the intermediary's profit. We show in Appendix A.2 that the slope of each of the FOCs is positive and provide a detailed discussion of conditions under which a unique interior optimal solution (D_b^*, D_s^*) exists.

Next, we examine a supplier-owned marketplace and show how it is different from a neutral marketplace.

Figure 1 Increase in Demand from Buyers (Suppliers) Increases the Surplus to Buyers (Suppliers)



3.2. Supplier-Owned Marketplace

We model a supplier-owned marketplace where the marketplace is owned by some suppliers. The owner-suppliers earn the profits from the ownership of the marketplace and they obtain some benefit from participating in the marketplace. This additional benefit is simply the surplus obtained by the owner-suppliers from participating in the marketplace. The surplus obtained by suppliers is proportional to the realized demand from suppliers (D_s) (see Figure 1 for a visual depiction of changes in surplus with demand).

Hence, the objective function of a supplier-owned marketplace differs from that of a neutral marketplace—it contains an additional term (B_s). B_s is the participation benefit (net of price) that accrues to owners due to their participation in the marketplace:

$$\pi_{SI}(D_s, D_b) = D_s p_s(D_s, D_b) + D_b p_b(D_b, D_s) + B_s(D_s). \quad (4)$$

The benefit to the suppliers (B_s) is positive and increases with the demand from suppliers (D_s), ($B_s > 0$, $\partial B_s/\partial D_s > 0$).

Computing the FOCs of the objective function yields two equations that can be rewritten using Equations (2) and (3) as

$$\frac{\partial \pi_{SI}}{\partial D_s} = \frac{\partial \pi_{NI}}{\partial D_s} + \frac{\partial B_s}{\partial D_s} = 0, \quad (5)$$

$$\frac{\partial \pi_{SI}}{\partial D_b} = \frac{\partial \pi_{NI}}{\partial D_b} = 0. \quad (6)$$

We can see that an additional term is included in the first FOC of the supplier-owned marketplace (Equation (5)) compared to the FOC of the neutral marketplace (Equation (2)).

As in the case of the neutral marketplace, we assume that a unique interior optimal solution (D_b^*, D_s^*) exists, and in Appendix A.2, we show sufficient conditions for the unique optimal solution to exist.

3.3. Buyer-Owned Marketplace

A buyer-owned marketplace is similar to a supplier-owned marketplace. Buyers' objective is to maximize the sum of the profits earned from ownership of the marketplace and the owner-buyers' surplus (B_b) from participating in the marketplace. Thus, we have the following objective function:

$$\pi_{BI}(D_s, D_b) = D_s p_s(D_s, D_b) + D_b p_b(D_b, D_s) + B_b(D_b). \quad (7)$$

The surplus to owner-buyers from participation is positive and increasing in the demand from buyers ($B_b > 0$, $\partial B_b/\partial D_b > 0$).

Computing the FOCs of the objective function Equation (7), and rewriting using the FOCs from Equations (2) and (3), we obtain the following:

$$\frac{\partial \pi_{BI}}{\partial D_s} = \frac{\partial \pi_{NI}}{\partial D_s} = 0, \quad (8)$$

$$\frac{\partial \pi_{BI}}{\partial D_b} = \frac{\partial \pi_{NI}}{\partial D_b} + \frac{\partial B_b}{\partial D_b} = 0. \quad (9)$$

As in the case of the neutral marketplace, we assume that a unique interior optimal solution (D_b^*, D_s^*) exists, and in Appendix A.2, we show sufficient conditions for the existence of a unique (D_b^*, D_s^*).

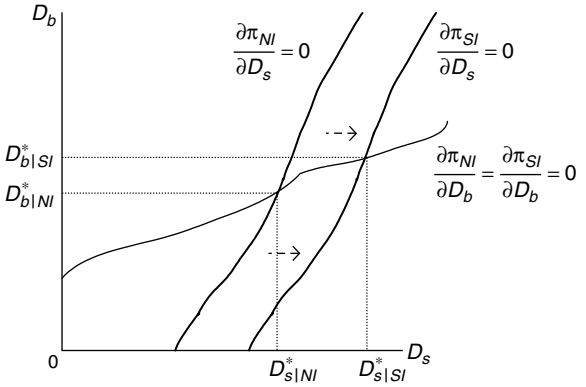
4. Comparison of Different Ownership Structures

4.1. Level of Participation

Proposition 1. *In equilibrium, the total demand from buyers (suppliers) for the services of a biased intermediary are greater than the total buyer (supplier) demand for a neutral intermediary* ($D^*_{s|SI} > D^*_{s|NI}$, $D^*_{b|SI} > D^*_{b|NI}$, $D^*_{s|BI} > D^*_{s|NI}$, $D^*_{b|BI} > D^*_{b|NI}$).

The detailed proof is provided in Appendix A.3. We provide the intuition for the result here. In the case of biased marketplaces (buyer-owned or supplier-owned), an increase in prices charged from the owners' side has a negative impact on demand and therefore on the owners' benefit (B_s, B_b) from using a biased marketplace, whereas the neutral intermediary does not earn any such benefit because it is neither a buyer nor a seller (by definition). Thus, B_s, B_b provide an additional incentive to the owners of biased marketplaces to increase the demand for their services leading to higher demand from both buyers as well as suppliers. This is illustrated in Figure 2,

Figure 2 Supplier-Owned Marketplace Results in More Participation of Suppliers and Buyers in the Electronic Marketplace than Neutral Marketplace by Lower Prices



Note. SI: Supplier-owned marketplace. *NI*: Neutral marketplace.

where the FOC $\partial \pi_{SI}/\partial D_s = 0$ contains an additional term $\partial B_s/\partial D_s$ (Equation (5)). Therefore, $\partial \pi_{SI}/\partial D_s = 0$ lies to the right of $\partial \pi_{NI}/\partial D_s = 0$. Thus, the equilibrium demand in a supplier-owned marketplace is greater ($D^*_{s|SI} > D^*_{s|NI}$, $D^*_{b|SI} > D^*_{b|NI}$). For buyer-owned marketplaces, the other FOC moves upward and we get a similar result. Our results hold as long as there exist some owners who participate in the marketplace (at every level of demand) and this is reflected in the objective function.

It is interesting to note that a biased marketplace will not necessarily charge lower prices compared to a neutral marketplace. One of the prices (p_s, p_b) charged by a biased marketplace can be greater than that charged by a neutral marketplace. However, the reduction in the other price is enough to ensure greater demand from both buyers and suppliers.

Proposition 1 is a key finding in this paper. The increase in demand from buyers and suppliers can be from two sources: An increase in the number of buyers and suppliers participating in a biased marketplace and an increase in the level of participation of each buyer and supplier. When buyers and suppliers are continuously heterogenous in the threshold benefit above which they choose to participate with the intermediary, then such an increase in demand would be driven in part by an increase in the number of buyers and suppliers participating in a biased marketplace compared to a neutral marketplace. This seems counterintuitive because the trade press has argued that fewer suppliers would participate in a buyer-owned marketplace (such as Covisint) (Kisiel 2004). It has also been argued that while buyers tend to have greater bargaining power and are less threatened by a supplier-owned marketplace, they may still be cautious about participating in a supplier-owned marketplace such as Exostar (Mecham 2002). To the contrary, our finding is that an owner who uses the marketplace has a greater incentive to expand the accessibility of the marketplace. This occurs because the owner as user receives additional network benefits from an expanding user base.

It is difficult to compare the demand for a buyer-owned marketplace with that of a supplier-owned marketplace. Which marketplace attracts greater demand depends on the relative magnitude of the added benefit from participation (B_s, B_b) and the slope of the two FOCs. When the slope of each of the FOCs is close to unity ($\partial \pi_{NI}/\partial D_s \approx 1 \approx \partial \pi_{NI}/\partial D_b$), a buyer-owned marketplace is likely to obtain greater demand from both buyers and suppliers (compared to a supplier-owned marketplace) because the benefit from participation for suppliers (B_s) is likely to be less than that for buyers (B_b). The benefit to suppliers can be smaller when there is greater competition among suppliers due to lack of supply-side constraints and limited demand from buyers. When the slopes of the FOCs are steep ($\sim\infty$), the demand increases become asymmetric with a relatively larger increase in demand for the owner's side (D_s in the case of supplier-owned marketplaces and D_b in the case of buyer-owned marketplaces).

While there are many factors that determine the success or failure of a marketplace, our research indicates that biased marketplaces will have an advantage over neutral marketplaces when they are compared along the ownership dimension.

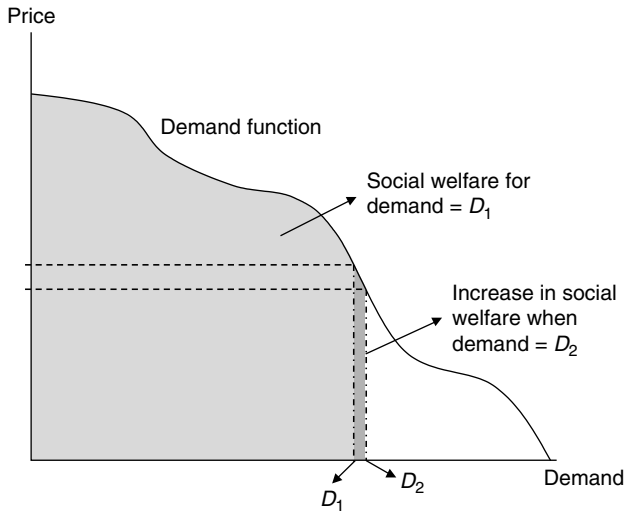
4.2. Surplus Level

We now compare the social welfare generated by a neutral marketplace and that generated by biased marketplaces.

Proposition 2. *The social welfare generated by biased marketplaces is greater than that generated by a neutral marketplace.*

The social welfare (sum of surplus of all players) can be expressed as the sum of the surplus obtained by all buyers, suppliers, and the intermediary. The proof of this proposition is straightforward. Note that the price charged contributes to the surplus of the owner while it is deducted from the benefit to the users. Hence, when we add the surplus of all players to compute social welfare, the price charged cancels as it is added and subtracted for each participating buyer and supplier. Whenever demand is downward sloping (as in our model), greater demand from each of the players (buyers and suppliers) implies greater social welfare. This can be easily visualized by plotting a downward-sloping demand function as shown in Figure 3. It is evident that an increase in demand leads to increased social welfare. Given the concerns expressed in various trade-press articles

Figure 3 Increase in Demand of the Marketplace's Services Leads to Greater Social Welfare



about biased marketplaces, it is interesting to find that they always offer greater social welfare compared to neutral marketplaces.

5. Discussion and Conclusion

We have examined the role of ownership structure of electronic marketplaces on various participants in the marketplace including buyers, suppliers, and the owner of the marketplace. We assume that the marketplace provides positive network effects that increase the benefits of buyers when a larger number of suppliers participate in the marketplace and vice versa. We find that when the owner of the marketplace also benefits from participating in its marketplace, this additional benefit influences the owner to set prices in a way that increases the overall level of participation of buyers and suppliers. Biased marketplaces provide greater benefits to participants as compared to a neutral marketplace. While biased marketplaces provide a greater share of the added benefits to the owners' side, all participants obtain a larger surplus from a biased marketplace relative to a neutral marketplace. This counterintuitive result can be understood in the context of the positive cross-network effects experienced by buyers which is dependent on the number of suppliers and vice versa. This creates an incentive to balance the number of buyers and suppliers. In addition, the biased marketplace owners' objective of optimizing their participation benefits leads to an incentive to increase the number of buyers and suppliers. Key results were derived using an analytical model with general demand functions demonstrating the robustness of this "ownership" effect.

There are many factors that influence the adoption and eventual success of B2B marketplaces. This paper is limited to the examination of the impact of ownership structure on the marketplace. Even so, our results emphasize the importance of the ownership structure and are supported by accumulating evidence from maturing B2B markets. For example, consider the case of eBay, where many small businesses buy and sell. Proposition 1 indicates that in equilibrium, the pricing of a neutral marketplace is likely to cause fewer buyers and sellers to use the marketplace than would have been the case with a biased marketplace. This proposition is hard to test empirically, however, it is interesting to note that eBay instituted a significant price increase in January 2005 that caused a major outcry from the Professional eBay Sellers Alliance (PESA),[1] a trade association of more than 600 of eBay's highest volume sellers. There is anecdotal evidence that many buyers and sellers have either reduced their participation level or withdrawn from eBay (Mangalindan 2005).

The best evidence in support of the weakness of neutral intermediaries comes from their vulnerabilities as seen in the past few years. Many neutral B2B exchanges have struggled to survive such as VerticalNet, SciQuest, ChemDex (now NexPrise), and MarketMile (now Ketera Technologies) and often have transformed themselves into solution providers selling information technology, software, and infrastructure solutions to enable companies to establish private exchanges. Audretsch and Mahmood (1995) study the likelihood of survival of new firms across a number of factors including the ownership structure. They find that there is a higher probability of survival for firms that are subsidiary or new branches of existing firms. Our results suggest that the same may be true in the case of electronic marketplaces. Day et al. (2003) find that the survival rate for independent B2B exchanges between Spring 2000 and July 2002 was 43%, while that for incumbent-based exchanges was 51%. One strategy for neutral markets to achieve the benefits of a biased marketplace is illustrated by the case of Neoforma, which gave Novation (the largest hospital group purchasing organization in the United States) a 46% ownership stake and developed a custom marketplace for Novation (Day et al. 2003). Similarly, MetalSite, which was a neutral intermediary, gave ownership stakes to steel manufacturers such as Bethlehem Steel in return for guaranteed transaction volumes. ChemConnect, which started as a neutral marketplace, is now partially owned by 46 chemical companies. Thus, a number of neutral marketplaces

[1] In January 2005, eBay increased fees for a range of services: 40% increase in Gallery fees, up to 400% increase in fees to use Buy-It-Now, and a 52% increase in commissions charged on eBay store sales. The PESA issued a press release (*PRNewswire*, Jan. 26, 2005) expressing dismay at the fee increases.

perceive an advantage from having ownership from buyers and suppliers who use the marketplace.

Many successful B2B markets are buyer-owned including Perfect Commerce, the largest electronic utility trading exchange with ownership stakes from 19 of the largest North American utilities. WorldWide Retail Exchange, founded by 17 retailers, is one of the largest marketplaces in the retail industry. Similarly, large suppliers have also developed supplier-owned marketplaces. In the aerospace industry, Exostar is a supplier-owned marketplace founded by BAE Systems, Boeing, Lockheed-Martin, and Raytheon.

Recently, there has been a shift toward private exchanges, which are limiting cases of biased marketplaces where a single large owner excludes others of its own type (either buyers or suppliers) from participating in the marketplace. Our model can be extended to analyze optimal strategies for such large buyers or suppliers. It is easy to show that a large buyer may choose to exclude competing buyers under certain conditions. This can be motivated by many factors—if a large buyer views the electronic marketplace as a source of competitive advantage, it would be reluctant to share the same with competitors. B2B marketplaces are also mechanisms for information sharing, the desirability of which depends on many factors that are themselves the focus of research (see Gal-Or 1986, Zhu 2004). Thus, eliminating competing buyers from the marketplace would serve to limit information sharing among buyers. Additionally, private marketplaces foster tighter business process linkages between a buyer and its suppliers. An increasing number of large buyers are choosing to develop private exchanges (Cooke 2003, Ng 2002). For example, Hewlett Packard has developed GetSupply, a private exchange for procuring parts using long-term flexible contracts. Dell and Wal-Mart are well known for their tight electronic linkages with suppliers. Similarly, some large suppliers are also operating private exchanges. GE PolymerLand is a B2B exchange for resin and plastics that is wholly owned by a single supplier—General Electric (GE). Hence, GE has the option to limit participation from competing suppliers (Pryweller 2002).

While private exchanges are popular with large buyers, they are too expensive for smaller firms. In this respect, the development of new standards for B2B integration such as ebXML and RosettaNet is likely to enhance the attractiveness of public B2B marketplaces.

Taken together, this anecdotal evidence suggests that the ownership structure of a biased marketplace does provide some advantage although this is only one factor among many that influence the survival of a B2B marketplace. This paper examines equilibrium outcomes and does not analyze the transition from existing physical markets to online marketplaces. Dynamic factors such as first mover advantage, user expectations, strategic pricing, and barriers to entry may be examined in a multiperiod model to explain the transition process.

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Appendix

A.1. Conditions for the Existence of a One-to-One Mapping

Lemma 1. *Suppose that I and J are open intervals in $\mathbb{R}$, the continuously differentiable functions u, v: $I \times J \to \mathbb{R}$ have nonnegative first-order partial derivatives, and $u_x v_y > u_y v_x$ everywhere on $I \times J$. Then, the map ψ: $I \times J \to \mathbb{R}^2$: $(x, y) \mapsto (u(x, y), v(x, y))$ is* 1-1.

Proof. By translation, it suffices to establish the following: Suppose that $(0, 0) \in I \times J$, $u(0, 0) = v(0, 0) = 0$, and $v(x, y) = 0$ for some $(x, y) \neq (0, 0)$. Then, $u(x, y) \neq 0$.

$v_y > 0$ on $I \times J$, hence $y \mapsto v(x, y)$ is increasing for any x. Thus, for any $x \in I$, there exists at most one $y \in J$ for which $v(x, y) = 0$. Moreover, $x \mapsto v(x, y)$ is nonincreasing, hence $xy \leq 0$ when $v(x, y) = 0$. Finally, observe that there exists $a < 0 < b$ s.t. the equation $v(x, y) = 0$ has a solution $y \in J$ iff $x \in (a, b)$.

By the Implicit Function Theorem, there exists a nonincreasing function h: $(a, b) \to J$ s.t. $v(x, h(x)) = 0$. Moreover, $h'(x) = -v_x(x, h(x))/v_y(x, h(x))$. If $x > 0$, then

$$\begin{aligned} u(x, h(x)) &= \int_0^x \frac{du(t, h(t))}{dt}\, dt \\ &= \int_0^x (u_x(t, h(t)) + u_y(t, h(t))h'(t))\, dt \\ &= \int_0^x \frac{u_x v_y - u_y v_x}{v_y}(t, h(t))\, dt > 0. \end{aligned}$$

Similarly, $u(x, h(x)) < 0$ if $x < 0$.

To apply this lemma to our problem, let $x = p_s$, $y = p_b$, $u = -D_s$, $v = -D_b$. The condition $u_x v_y > u_y v_x$ then becomes $(\partial D_s/\partial p_s)(\partial D_b/\partial p_b) > (\partial D_s/\partial p_b)(\partial D_b/\partial p_s)$.

A.2. Conditions for the Existence of a Unique Equilibrium

In this appendix, we show sufficient conditions for the existence of a unique interior optimal solution (D_s^*, D_b^*) in the case of each of the three marketplaces: neutral, supplier-owned, and buyer-owned. Note that to prove the propositions in this paper, we assume only the existence of a unique interior optimal solution. The conditions stated in this section are sufficient but not necessary, hence our results will hold even when these sufficient conditions are violated provided a unique interior solution still exists.

A.2.1. Neutral Marketplace. From FOC Equation (2), we have

$$\frac{\partial \pi_{NI}}{\partial D_s} = p_s(D_s, D_b) + D_s\frac{\partial p_s}{\partial D_s} + D_b\frac{\partial p_b}{\partial D_s} = 0$$

$$\Rightarrow D_b = -\frac{p_s(D_s, D_b) + D_s(\partial p_s/\partial D_s)}{\partial p_b/\partial D_s}$$

$$\Rightarrow \frac{\partial D_b}{\partial D_s} = \frac{\partial}{\partial D_s}\left[-\frac{p_s(D_s, D_b) + D_s(\partial p_s/\partial D_s)}{\partial p_b/\partial D_s}\right]$$

$$\Rightarrow \frac{\partial D_b}{\partial D_s} = \left[\frac{\partial^2 p_b}{\partial D_s^2}\left(D_s\frac{\partial p_s}{\partial D_s} + p_s\right) - \left(\frac{\partial^2 p_s}{\partial D_s^2}D_s + 2\frac{\partial p_s}{\partial D_s}\right)\frac{\partial p_b}{\partial D_s}\right]\cdot\left(\frac{\partial p_b}{\partial D_s}\right)^{-2}.$$

We now establish that $\partial D_b/\partial D_s > 0$. Note that based on the FOC (Equation (2)), we know that $D_s(\partial p_s/\partial D_s) + p_s = -D_b(\partial p_b/\partial D_s) < 0$. By assumption, we have that $\partial^2 p_b/\partial D_s^2 < 0$, $\partial^2 p_s/\partial D_s^2 < 0$, $\partial p_s/\partial D_s < 0$, $\partial p_b/\partial D_s > 0$, hence the numerator is positive. The denominator is also positive (being a full square), hence the slope of this FOC is positive. Also, from Equation (2), it can be easily verified that there does not exist $D_b > 0$ that solves the FOC when $D_s = 0$ (because both the two remaining terms are always positive). Hence, there exists $D_s > 0$ that solve the FOC when $D_b = 0$ (because of the two remaining terms, one is positive and the other is negative).

From FOC Equation (3), we have

$$\frac{\partial \pi_{NI}}{\partial D_b} = p_b(D_s, D_b) + D_s\frac{\partial p_s}{\partial D_b} + D_b\frac{\partial p_b}{\partial D_b} = 0$$

$$\Rightarrow D_s = -\frac{p_b + D_b(\partial p_b/\partial D_b)}{\partial p_s/\partial D_b}$$

$$\Rightarrow \frac{\partial D_s}{\partial D_b} = \frac{\partial}{\partial D_b}\left[-\frac{p_b + D_b(\partial p_b/\partial D_b)}{\partial p_s/\partial D_b}\right]$$

$$\Rightarrow \frac{\partial D_s}{\partial D_b} = \left[\frac{\partial^2 p_s}{\partial D_b^2}\left(p_b + D_b\frac{\partial p_b}{\partial D_b}\right) - \left(\frac{\partial^2 p_b}{\partial D_b^2}D_b + 2\frac{\partial p_b}{\partial D_b}\right)\frac{\partial p_s}{\partial D_b}\right]\cdot\left(\frac{\partial p_s}{\partial D_b}\right)^{-2}.$$

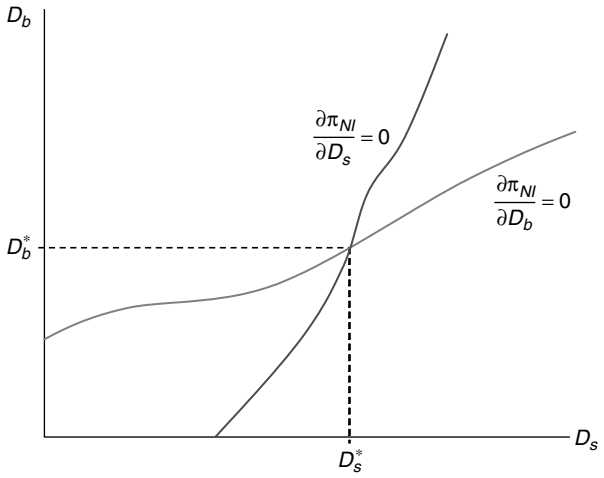
We now show that the slope $\partial D_s/\partial D_b > 0$. Note that based on the FOC (Equation (3)), we know that $p_b + D_b(\partial p_b/\partial D_b) = -D_s(\partial p_s/\partial D_b) < 0$. By assumption, we have that $\partial^2 p_s/\partial D_b^2 < 0$, $\partial^2 p_b/\partial D_b^2 < 0$, $\partial p_b/\partial D_b < 0$, $\partial p_s/\partial D_b > 0$, hence the numerator is positive. The denominator is also positive, therefore the slope of this FOC is positive.

Also, from Equation (3), it can be easily verified that there does not exist $D_s > 0$ that solves the FOC when $D_b = 0$ (because both the two remaining terms are always positive). There exists $D_b > 0$ that solve the FOC when $D_s = 0$ (because of the two remaining terms, one is positive and the other is negative).

Based on this characterization of the slope and intercept of each FOC, we obtain Figure A1. We assume that a unique interior solution exists. To identify conditions that can ensure a unique interior solution, note that this occurs when the two FOCs intersect exactly once in the feasible region. The following condition specifies that the slopes of the two FOCs must be such that they cross each other once:

$$a \cdot b > 1$$

Figure A1 **The Intersection of the First-Order Conditions Yields the Optimal Demand (D_s^*, D_b^*)**



$$\left[\frac{\partial^2 p_b}{\partial D_s^2}\left(D_s\frac{\partial p_s}{\partial D_s} + p_s\right) - \left(\frac{\partial^2 p_s}{\partial D_s^2}D_s + 2\frac{\partial p_s}{\partial D_s}\right)\frac{\partial p_b}{\partial D_s}\right]\cdot\left(\frac{\partial p_b}{\partial D_s}\right)^{-2} > a, \tag{10}$$

$$\left[\frac{\partial^2 p_s}{\partial D_b^2}\left(p_b + D_b\frac{\partial p_b}{\partial D_b}\right) - \left(\frac{\partial^2 p_b}{\partial D_b^2}D_b + 2\frac{\partial p_b}{\partial D_b}\right)\frac{\partial p_s}{\partial D_b}\right]\cdot\left(\frac{\partial p_s}{\partial D_b}\right)^{-2} > b, \tag{11}$$

where (a, b) are positive real constants. This is a sufficient condition for the existence of a unique interior solution.

The second-order conditions stated below are satisfied at this point when Equation (14) holds so that the unique interior solution to the FOCs represents the optimal interior solution (D_s^*, D_b^*).

The second-order conditions for the neutral marketplace are

$$\frac{\partial^2 \pi_{NI}}{\partial D_s^2} = 2\frac{\partial p_s}{\partial D_s} + D_s\frac{\partial^2 p_s}{\partial D_s^2} + D_b\frac{\partial^2 p_b}{\partial D_s^2} < 0, \tag{12}$$

$$\frac{\partial^2 \pi_{NI}}{\partial D_b^2} = 2\frac{\partial p_b}{\partial D_b} + D_s\frac{\partial^2 p_s}{\partial D_b^2} + D_b\frac{\partial^2 p_b}{\partial D_b^2} < 0, \tag{13}$$

$$\frac{\partial^2 \pi_{NI}}{\partial D_s^2}\cdot\frac{\partial^2 \pi_{NI}}{\partial D_b^2} > \left(\frac{\partial^2 \pi_{NI}}{\partial D_b \partial D_s}\right)^2, \tag{14}$$

$$\frac{\partial^2 \pi_{NI}}{\partial D_b \partial D_s} = \frac{\partial p_s}{\partial D_b} + D_s\frac{\partial^2 p_s}{\partial D_b \partial D_s} + \frac{\partial p_b}{\partial D_s} + D_b\frac{\partial^2 p_b}{\partial D_b \partial D_s}.$$

Each of the terms in Equations (12) and (13) can be verified to be negative based on assumptions stated in §3, hence these two second-order conditions are satisfied.

A.2.2. Supplier-Owned Marketplace. We repeat the steps to obtain sufficient conditions for a unique optimal solution for the case of a supplier-owned marketplace. The FOCs are

$$\frac{\partial \pi_{SI}}{\partial D_s} = p_s(D_s, D_b) + D_s\frac{\partial p_s}{\partial D_s} + D_b\frac{\partial p_b}{\partial D_s} + \frac{\partial B_s}{\partial D_s} = 0 \tag{15}$$

$$\Rightarrow D_b = -\frac{p_s(D_s, D_b) + D_s(\partial p_s/\partial D_s) + \partial B_s/\partial D_s}{\partial p_b/\partial D_s} \tag{16}$$

$$\Rightarrow \frac{\partial D_b}{\partial D_s} = \frac{\partial}{\partial D_s}\left[-\left(p_s(D_s, D_b) + D_s\frac{\partial p_s}{\partial D_s} + \frac{\partial B_s}{\partial D_s}\right)\right]\cdot\left(\frac{\partial p_b}{\partial D_s}\right)^{-1} \tag{17}$$

$$\Rightarrow \frac{\partial D_b}{\partial D_s} = \left[\frac{\partial^2 p_b}{\partial D_s^2}\left(D_s\frac{\partial p_s}{\partial D_s} + p_s + \frac{\partial B_s}{\partial D_s}\right) - \left(\frac{\partial^2 p_s}{\partial D_s^2}D_s + 2\frac{\partial p_s}{\partial D_s} + \frac{\partial^2 B_s}{\partial D_s^2}\right)\frac{\partial p_b}{\partial D_s}\right]\cdot\left(\frac{\partial p_b}{\partial D_s}\right)^{-2} \tag{18}$$

$$\Rightarrow \frac{\partial D_b}{\partial D_s} = \left[\frac{\partial^2 p_b}{\partial D_s^2}\left(-D_b\frac{\partial p_b}{\partial D_s}\right) - \left(\frac{\partial^2 p_s}{\partial D_s^2}D_s + 2\frac{\partial p_s}{\partial D_s} + \frac{\partial^2 B_s}{\partial D_s^2}\right)\frac{\partial p_b}{\partial D_s}\right]\cdot\left(\frac{\partial p_b}{\partial D_s}\right)^{-2}. \tag{19}$$

The second FOC is identical to the case of the neutral marketplace ($\partial\pi_{SI}/\partial D_b = \partial\pi_{NI}/\partial D_b$) and hence the slope is unchanged:

$$\frac{\partial D_s}{\partial D_b} = \left[\frac{\partial^2 p_s}{\partial D_b^2}\left(p_b + D_b\frac{\partial p_b}{\partial D_b}\right) - \left(\frac{\partial^2 p_b}{\partial D_b^2}D_b + 2\frac{\partial p_b}{\partial D_b}\right)\frac{\partial p_s}{\partial D_b}\right]\cdot\left(\frac{\partial p_s}{\partial D_b}\right)^{-2}.$$

The intercept for the FOCs can be shown to be positive using the procedure used for the neutral marketplace.

The following are sufficient conditions that ensure that a unique interior solution exists:

$$a\cdot b > 1,$$

$$\left[\frac{\partial^2 p_b}{\partial D_s^2}\left(-D_b\frac{\partial p_b}{\partial D_s}\right) - \left(\frac{\partial^2 p_s}{\partial D_s^2}D_s + 2\frac{\partial p_s}{\partial D_s} + \frac{\partial^2 B_s}{\partial D_s^2}\right)\frac{\partial p_b}{\partial D_s}\right]\cdot\left(\frac{\partial p_b}{\partial D_s}\right)^{-2} > a, \tag{20}$$

$$\left[\frac{\partial^2 p_s}{\partial D_b^2}\left(p_b + D_b\frac{\partial p_b}{\partial D_b}\right) - \left(\frac{\partial^2 p_b}{\partial D_b^2}D_b + 2\frac{\partial p_b}{\partial D_b}\right)\frac{\partial p_s}{\partial D_b}\right]\cdot\left(\frac{\partial p_s}{\partial D_b}\right)^{-2} > b. \tag{21}$$

When the following second-order conditions are satisfied, the unique solution to the FOCs is a maxima. When these conditions are not satisfied, no interior maxima exists.

$$\frac{\partial^2\pi_{SI}}{\partial D_s^2} = 2\frac{\partial p_s}{\partial D_s} + D_s\frac{\partial^2 p_s}{\partial D_s^2} + D_b\frac{\partial^2 p_b}{\partial D_s^2} + \frac{\partial^2 B_s}{\partial D_s^2} < 0, \tag{22}$$

$$\frac{\partial^2\pi_{SI}}{\partial D_b^2} = 2\frac{\partial p_b}{\partial D_b} + D_s\frac{\partial^2 p_s}{\partial D_b^2} + D_b\frac{\partial^2 p_b}{\partial D_b^2} < 0, \tag{23}$$

$$\frac{\partial^2\pi_{SI}}{\partial D_s^2}\cdot\frac{\partial^2\pi_{SI}}{\partial D_b^2} > \left(\frac{\partial^2\pi_{SI}}{\partial D_b\partial D_s}\right)^2, \tag{24}$$

$$\frac{\partial^2\pi_{SI}}{\partial D_b\partial D_s} = \frac{\partial p_s}{\partial D_b} + D_s\frac{\partial^2 p_s}{\partial D_b\partial D_s} + \frac{\partial p_b}{\partial D_s} + p_b\frac{\partial^2 p_b}{\partial D_b\partial D_s}.$$

A.2.3. Buyer-Owned Marketplace. We now obtain sufficient conditions for a unique optimal solution for the case of a supplier-owned marketplace. The first FOC is identical to the case of the neutral marketplace ($\partial\pi_{BI}/\partial D_s = \partial\pi_{NI}/\partial D_s$), and hence the slope is the same:

$$\Rightarrow \frac{\partial D_b}{\partial D_s} = \left[\frac{\partial^2 p_b}{\partial D_s^2}\left(D_s\frac{\partial p_s}{\partial D_s} + p_s\right) - \left(\frac{\partial^2 p_s}{\partial D_s^2}D_s + 2\frac{\partial p_s}{\partial D_s}\right)\frac{\partial p_b}{\partial D_s}\right]\cdot\left(\frac{\partial p_b}{\partial D_s}\right)^{-2}. \tag{25}$$

The second FOC is

$$\frac{\partial\pi_{BI}}{\partial D_b} = p_b(D_s, D_b) + D_s\frac{\partial p_s}{\partial D_b} + D_b\frac{\partial p_b}{\partial D_b} + \frac{\partial B_b}{\partial D_b} = 0$$

$$\Rightarrow D_s = -\frac{p_b + D_b(\partial p_b/\partial D_b) + \partial B_b/\partial D_b}{\partial p_s/\partial D_b}$$

$$\Rightarrow \frac{\partial D_s}{\partial D_b} = \frac{\partial}{\partial D_b}\left[-\frac{p_b + D_b(\partial p_b/\partial D_b) + \partial B_b/\partial D_b}{\partial p_s/\partial D_b}\right]$$

$$\Rightarrow \frac{\partial D_s}{\partial D_b} = \left[\frac{\partial^2 p_s}{\partial D_b^2}\left(p_b + D_b\frac{\partial p_b}{\partial D_b} + \frac{\partial B_b}{\partial D_b}\right) - \left(\frac{\partial^2 p_b}{\partial D_b^2}D_b + 2\frac{\partial p_b}{\partial D_b} + \frac{\partial^2 B_b}{\partial D_b^2}\right)\frac{\partial p_s}{\partial D_b}\right]\cdot\left(\frac{\partial p_s}{\partial D_b}\right)^{-2}$$

$$\Rightarrow \frac{\partial D_s}{\partial D_b} = \left[\frac{\partial^2 p_s}{\partial D_b^2}\left(-D_s\frac{\partial p_s}{\partial D_b}\right) - \left(\frac{\partial^2 p_b}{\partial D_b^2}D_b + 2\frac{\partial p_b}{\partial D_b} + \frac{\partial^2 B_b}{\partial D_b^2}\right)\frac{\partial p_s}{\partial D_b}\right]\cdot\left(\frac{\partial p_s}{\partial D_b}\right)^{-2}.$$

The intercept for the FOCs can be shown to be positive using the procedure used for the neutral marketplace.

The following are sufficient conditions that ensure that a unique interior solution exists:

$$a\cdot b > 1,$$

$$\left[\frac{\partial^2 p_b}{\partial D_s^2}\left(D_s\frac{\partial p_s}{\partial D_s} + p_s\right) - \left(\frac{\partial^2 p_s}{\partial D_s^2}D_s + 2\frac{\partial p_s}{\partial D_s}\right)\frac{\partial p_b}{\partial D_s}\right]\cdot\left(\frac{\partial p_b}{\partial D_s}\right)^{2} > a, \tag{26}$$

$$\left[\frac{\partial^2 p_s}{\partial D_b^2}\left(-D_s\frac{\partial p_s}{\partial D_b}\right) - \left(\frac{\partial^2 p_b}{\partial D_b^2}D_b + 2\frac{\partial p_b}{\partial D_b} + \frac{\partial^2 B_b}{\partial D_b^2}\right)\frac{\partial p_s}{\partial D_b}\right]\cdot\left(\frac{\partial p_s}{\partial D_b}\right)^{2} > b. \tag{27}$$

When the following second-order conditions are satisfied, the unique solution to the FOCs is a maxima. When these conditions are not satisfied, no interior maxima exists.

The three second-order conditions for the buyer-owned marketplace are

$$\frac{\partial^2\pi_{BI}}{\partial D_s^2} = 2\frac{\partial p_s}{\partial D_s} + D_s\frac{\partial^2 p_s}{\partial D_s^2} + D_b\frac{\partial^2 p_b}{\partial D_s^2} < 0, \tag{28}$$

$$\frac{\partial^2\pi_{BI}}{\partial D_b^2} = 2\frac{\partial p_b}{\partial D_b} + D_s\frac{\partial^2 p_s}{\partial D_b^2} + D_b\frac{\partial^2 p_b}{\partial D_b^2} + \frac{\partial^2 B_b}{\partial D_b^2} < 0, \tag{29}$$

$$\frac{\partial^2\pi_{BI}}{\partial p_s^2}\cdot\frac{\partial^2\pi_{BI}}{\partial p_b^2} > \left(\frac{\partial^2\pi_{BI}}{\partial p_b\partial p_s}\right)^2, \tag{30}$$

$$\frac{\partial^2\pi_{BI}}{\partial D_b\partial D_s} = \frac{\partial p_s}{\partial D_b} + D_s\frac{\partial^2 p_s}{\partial D_b\partial D_s} + \frac{\partial p_b}{\partial D_s} + p_b\frac{\partial^2 p_b}{\partial D_b\partial D_s}.$$

A.3. Proof of Proposition 1

In the prior section of this appendix, we established that the slope of the FOCs of the neutral marketplace are sloping upward as shown in Figure A1. We will first show that the equilibrium demand $(D_b^*, D_s^*)_{SI}$ is always greater than $(D_b^*, D_s^*)_{NI}$. The proof for the buyer-owned marketplace follows symmetrically. Note that the FOCs of the supplier-owned marketplace are related to that of the neutral marketplace in this way:

$$\frac{\partial\pi_{SI}}{\partial D_s} = \frac{\partial\pi_{NI}}{\partial D_s} + \frac{\partial B_s}{\partial D_s} = 0, \tag{31}$$

$$\frac{\partial \pi_{SI}}{\partial D_b} = \frac{\partial \pi_{NI}}{\partial D_b} = 0. \tag{32}$$

Note that the second FOC is identical so that the curve is unchanged as shown in Figure 2 and Figure A1. We will now show that $\partial \pi_{SI}/\partial D_s = 0$ lies to the right of $\partial \pi_{NI}/\partial D_s = 0$ (the x-axis is D_s and the y-axis is D_b). It is evident from Figure 2 that this will result in an equilibrium demand for the supplier-owned marketplace $(D_b^*, D_s^*)_{SI}$ such that $D^*_{b|SI} > D^*_{b|NI}$ and $D^*_{s|SI} > D^*_{s|NI}$.

$$\frac{\partial \pi_{NI}}{\partial D_s} = p_s(D_s, D_b) + D_s \frac{\partial p_s}{\partial D_s} + D_b \frac{\partial p_b}{\partial D_s} = 0$$

$$\Rightarrow D_{s|NI} = \frac{p_s(D_s, D_b) + D_b(\partial p_b/\partial D_s)}{|\partial p_s/\partial D_s|}.$$

Note that $p_s > 0$, $\partial p_s/\partial D_s < 0$, $\partial p_b/\partial D_s > 0$, $\partial B_s/\partial D_s > 0$.

$$\frac{\partial \pi_{SI}}{\partial D_s} = p_s(D_s, D_b) + D_s \frac{\partial p_s}{\partial D_s} + D_b \frac{\partial p_b}{\partial D_s} + \frac{\partial B_s}{\partial D_s} = 0$$

$$\Rightarrow D_{s|SI} = \frac{p_s(D_s, D_b) + D_b(\partial p_b/\partial D_s) + \partial B_s/\partial D_s}{|\partial p_s/\partial D_s|}.$$

Hence, $D_{s|SI} = D_{s|NI} + (\partial B_s/\partial D_s)/|\partial p_s/\partial D_s|$. Therefore, $\partial \pi_{SI}/\partial D_s = 0$ lies to the right (the x-axis is D_s and the y-axis is D_b) of $\partial \pi_{NI}/\partial D_s = 0$.

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