
A Model of Neutral B2B Intermediaries

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ABSTRACT: Business-to-business (B2B) electronic commerce has become an important issue in the debate about electronic commerce. How should the intermediary charge suppliers and buyers to maximize profits from such a marketplace? We analyze a monopolistic B2B marketplace owned by an independent intermediary. The marketplace exhibits two-sided network effects where the value of the marketplace to buyers is dependent on the number of suppliers, and the value to suppliers is dependent on the number of buyers and suppliers. When these two-sided network effects exist, we find that the optimal price for buyers and the fraction of buyers in the electronic market are dependent on the switching cost and the strength of the network effect of both types: buyers and suppliers. The same is true for the optimal price for suppliers and the fraction of suppliers in the electronic market. In other words, the parameters that define the buyers also affect the optimal price for suppliers and the fraction of suppliers in the electronic market, and vice versa. Our results also point to

some counterintuitive optimal pricing strategies that depend on the nature of the industry served by the marketplace.

KEY WORDS AND PHRASES: business-to-business e-commerce, intermediation, network effect, pricing strategy.

Research Questions

THE RAPID GROWTH OF ELECTRONIC COMMERCE led to high expectations, many of which have not been realized. The struggle to survive of once-popular dotcoms in the business-to-consumer (B2C) markets is casting doubt on the potential of electronic commerce. However, many business-to-business (B2B) marketplaces have continued to thrive, and are conducting ever greater volumes of transactions. According to Forrester Research, the amount of B2B sales is several times that of B2C sales and will be even greater in the near future [7]. We focus on several unanswered questions in the context of designing B2B marketplaces on the Internet. How to attract buyers and suppliers to a B2B marketplace? How can intermediaries maximize revenue from suppliers and buyers in the marketplaces? Although practitioners have speculated about these questions, there is little academic research in this area.

Some B2B market intermediaries have successfully created marketplaces. One common characteristic among them is that, along with transaction services, they have provided information services such as industry-related news services for the industry (Citadon), consulting services (FreeMarkets), and other services. For example, industry-related news services can attract suppliers and buyers and help form a community to disseminate new information related to the industry. This, in turn, attracts more buyers and suppliers. Such information-related services are valuable to buyers and suppliers irrespective of the level of network effects. The intermediary may be able to transform this community into a customer base.

An important question facing intermediaries is how to price their services? What is the impact of network effects on the intermediaries strategy? In this research, we study the strategies of intermediaries including their pricing of services when the impact of network effects is significant. Usually network effects influence a consumer's valuation of a product depending on the number of consumers using a common product. The network effect in a marketplace is different in that the value of a marketplace to a buyer depends on the number of suppliers and vice versa. We discuss the nature of the network effects in marketplaces in detail in subsequent sections.

Theoretical Foundations

THERE ARE TWO MAIN BENEFITS OF electronic B2B marketplaces. The first is the speed and efficiency of transactions enabled by information technology (IT). Using advanced IT, suppliers and buyers can reduce transaction costs. The second benefit

accrues from the larger number of participants. By bringing together a large number of buyers and sellers, electronic marketplaces increase choices. Because of the ease of searching for suppliers in electronic marketplaces, buyers have a greater chance of finding cheaper prices or better transaction conditions. Also, suppliers can find buyers that better match their requirements when they want to sell their products.

When the value of a product depends on the number of users, we consider the product to exhibit network effects. The benefits from having a large number of participants are called *positive network effects*. As an example, a telephone is only valuable if there are other people with compatible telephones that a user wishes to call. In earlier research, Katz and Shapiro [8] discuss the strategies for products with positive network effects. They show how network effects can affect the decisions of companies, especially those relating to the compatibility of their products to industry standards. Brynjolfsson and Kemerer [2] empirically show that the network effects of spreadsheet software programs can increase the price of these programs. In this paper, the characteristics of network effects of the marketplace are quite different from the characteristics of network effects of products in previous studies. We call the network effects of products one-sided to differentiate it from the network effects of the marketplace. For each player, the value of the marketplace is dependent on the participation of the other party. As can be seen in Figure 1, the number of suppliers in the marketplace is important to the buyers and the number of buyers to suppliers.

The value of the marketplace to a buyer (supplier) increases when she can search for more suppliers (buyers). On the other hand, the value of the marketplace decreases for each supplier when there are more suppliers. We call this *negative network effects*. Wang and Seidmann [15] show that the participation of more suppliers can generate positive effects for the buyer and negative effects for other suppliers in an electronic data interchange (EDI) network. Following their model, we consider only the negative network effects for the supplier side. We assume that there are no supply-side constraints, and therefore, no negative network effects for the buyers.

Spulber [14] illustrates the economic importance of intermediaries and discusses several of the roles they play: setting prices and clearing markets, providing liquidity and immediacy, coordinating buyers and sellers, and guaranteeing quality and monitoring performance. Rubinstein and Wolinsky [13] model the matching process as a time-consuming series of pairwise meetings and introduce middlemen, who act as the buyers or suppliers, and therefore can accelerate the search process. Bhargava et al. [1] analyze the decision of an intermediary when there are aggregation benefits for buyers. But they only consider the aggregation benefit for buyers, not the aggregation benefit for suppliers or the negative network effects. Chircu and Kauffman [3] discuss the new role of intermediaries in electronic B2B markets compared to the role of intermediaries in traditional B2B markets. Dai and Kauffman [5] discuss the factors explaining the current trend of buyers moving from closed networks to open networks: from extranets to electronic B2B marketplaces.

Although there are benefits from joining electronic marketplaces, some switching costs also exist. When suppliers and buyers join these marketplaces, they have to incur some costs to adapt their current distribution channels. In previous EDI research,

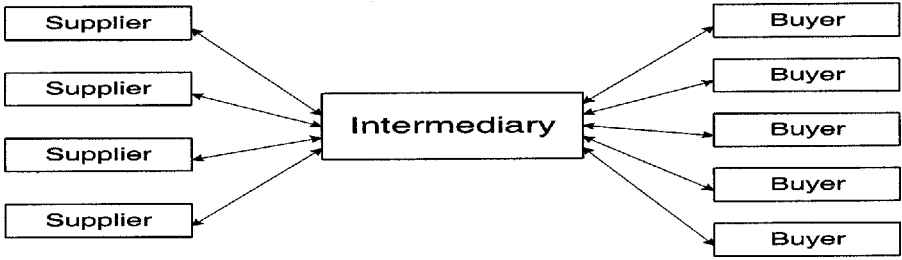


Figure 1. Two-Sided Network Effects of the Marketplace

many studies examined how to attract suppliers and buyers to EDI networks from traditional channels.

Riggins et al. [11] show how to attract suppliers to an EDI network run by a buyer in the presence of network effects. However, they consider the case of a single buyer and multiple suppliers. In this research, we show how the interactions between the levels of network effects of two parties—buyers and suppliers—affect the levels of participation in electronic markets. We also examine the pricing strategy of an intermediary when switching costs are considered.

Model

WE ANALYZE THE PRICING DECISIONS of an independent intermediary who owns an electronic marketplace in an industry. We model two types of players in the marketplace: suppliers and buyers. Suppliers are firms that want to sell their products to buyers in the industry that the marketplace serves. Buyers are companies that want to buy resources from the marketplace. We denote suppliers and buyers as s and b , respectively. We assume that firms joining the electronic marketplace are either buyers or suppliers. Thus, for example, if a firm has ten transactions, four as a supplier and six as a buyer, it can be said that there is one buyer with four transactions and one supplier with six transactions assuming buying and selling decisions are independent. In our model, we assume that the intermediary owns the marketplace, and is independent of any supplier or buyer. The intermediary's objective is to maximize its profit from the marketplace. As a real-world example, consider Citadon, which is an independent intermediary providing a marketplace for suppliers and buyers in the construction industry.

The marketplace offers some information services for suppliers and buyers such as technical support and industry-related news services. These services create values for suppliers and buyers, v_s and v_b , which are independent of the number of suppliers or buyers. Also, the marketplace provides aggregation benefits, $e_s(n_b)$ and $e_b(n_s)$, which are dependent on the number of suppliers and buyers, n_s and n_b , using the marketplace. For example, when there are more suppliers, buyers are likely to find lower

product prices and better suppliers. The suppliers also benefit from more buyers. There are also negative network effects for suppliers. These are represented by $e_n(n_s)$, and are proportional to the number of suppliers, n_s . As shown in the EDI case by Wang and Seidman [15], the participation of more suppliers can generate negative effects for suppliers in the B2B marketplace since the increased competition among suppliers reduces the profit of each supplier.

To simplify, we assume that the aggregation benefit to suppliers is proportional to the number of buyers and, likewise, the aggregation benefit to buyers is proportional to the number of suppliers. Thus, in Equation (1), r_s , r_b , and r_n are exogenously determined positive constants that represent the intensity of the network effects $e_s(\cdot)$, $e_b(\cdot)$, and $e_n(\cdot)$, respectively.

$$e_s(n_b) = r_s \cdot n_b, e_b(n_s) = r_b \cdot n_s, e_n(n_s) = r_n \cdot n_s. \quad (1)$$

In a marketplace where the transactions are executed by reverse auction, the intensity of network effects for buyers is likely to be greater ($r_b > r_s$) because the mechanism of reverse auction precipitates price competition among suppliers. The main benefits of the reverse-auction mechanism are for buyers in finding better offers from suppliers. Even though there are some benefits for suppliers when they can meet more buyers in the marketplace, it is likely that these benefits for suppliers are smaller than the benefits from the reverse-auction mechanism for buyers. Thus, the participation of an additional supplier is more valuable to buyers than the participation of an additional buyer to suppliers in the marketplace. On the contrary, in a marketplace where the transactions are executed by forward-auction, the intensity of network effect for suppliers is likely to be greater ($r_s > r_b$). Also, in a marketplace where products are undifferentiated and buyers are more price sensitive, the competition among suppliers is more intense and the intensity of negative effect (r_n) will be greater. We normalize n_s and n_b so that n_s is the fraction of suppliers in the marketplace relative to the total number of suppliers in the industry, and similarly for n_b .

We assume that suppliers and buyers are currently using traditional distribution channels, but are considering switching to the electronic marketplace. In the electronic marketplace, as seen in Figure 1, the intermediary provides a marketplace where suppliers meet buyers and vice versa. Suppliers and buyers who are in the traditional marketplace are heterogeneous in terms of the switching costs of adapting their processes from the traditional to the electronic marketplace. We assume that the suppliers and buyers (x_s, x_b) are uniformly distributed in $(0, 1)$, where 0 represents no switching costs and 1 represents high switching costs. For example, buyers and suppliers who have already adopted IT for their processes will find it easier to switch to the electronic marketplace, whereas other buyers and suppliers with a lesser degree of IT adoption may encounter greater difficulty of switching. The difficulty of switching also depends on the general nature of the industry served by the marketplace. For example, if an industry has not developed standardized ways of product specification, it would be more difficult for buyers and suppliers in that industry to transfer to electronic marketplaces. We model the switching costs as $s_s \cdot x_s$ and $s_b \cdot x_b$ ($s_s, s_b > 0$),

where s_s, s_b represent the general industry-level difficulty of switching for suppliers and buyers and x_s, x_b represent the heterogeneity among individual suppliers and buyers in terms of their ability to adapt to the electronic marketplace. These switching costs include both the costs of purchasing and installing equipment to connect the business to the electronic marketplace and the costs involved in adapting the traditional business processes for the electronic marketplace.

Buyers and suppliers pay fees, p_s and p_b , to the intermediary for using its marketplace. These fees are the total amounts paid by each supplier and buyer. The increase in profits to suppliers (u_s) and buyers (u_b) is assumed to be caused by many factors including reduction in search costs and transaction costs, better match between buyer and supplier, and so on. The change in the profits of suppliers and buyers from joining the marketplace are:

$$u_s = v_s + r_s n_b - r_n n_s - s_s x_s - p_s \quad (2)$$

$$u_b = v_b + r_b n_s - s_b x_b - p_b. \quad (3)$$

Suppliers and buyers will participate in the marketplace if and only if the change in profit is positive as in Equation (4). Let x'_s and x'_b be the supplier and buyer, respectively, that are indifferent between switching and not switching to the electronic marketplace. Thus, we obtain the indifference equations stated in Equations (5) and (6).

$$u_s \geq 0, u_b \geq 0 \quad (4)$$

$$u_s = v_s + r_s n_b - r_n n_s - s_s x'_s - p_s = 0 \quad (5)$$

$$u_b = v_b + r_b n_s - s_b x'_b - p_b = 0. \quad (6)$$

As shown in Figure 2, all buyers (suppliers) of type x_b (x_s) less than x'_b (x'_s) will switch to the electronic marketplace. Therefore, the fractions of participants in electronic markets (n_b, n_s) of the electronic marketplace are given by:

$$n_s = x'_s, n_b = x'_b. \quad (7)$$

The intermediary intends to maximize its profit by charging fees to suppliers and buyers for using its marketplace. We summarize the assumptions in our model in Appendix A. Then the intermediary's decision problem is:

P1: Find p_s, p_b in order to maximize the total profit of the intermediary (Equation (8)) subject to the constraints on the fractions of participants in electronic markets (Equations (9) and (10)).

$$\max_{p_s, p_b} \pi = p_s \cdot n_s + p_b \cdot n_b \quad (8)$$

$$\text{s.t. } 0 \leq n_s \leq 1 \quad (9)$$

$$0 \leq n_b \leq 1. \quad (10)$$

What will be the optimal price levels and the optimal levels of participants in electronic markets? We examine these questions in the following subsections.

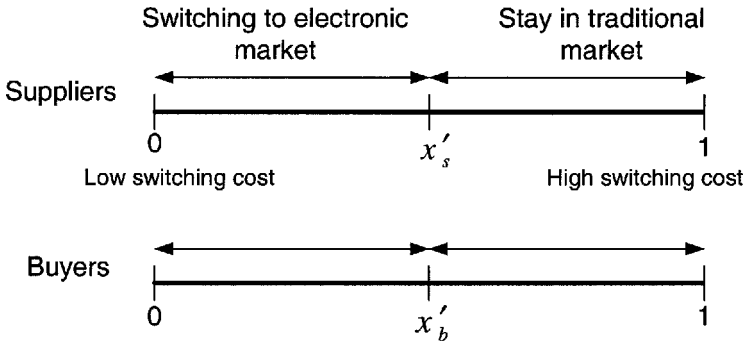


Figure 2. Fractions of Participants in Electronic Markets and Switching Costs

Interior Solution

The interior solution is obtained when the fractions of participants in electronic markets (n_s and n_b), which maximize the profit of the intermediary, Equation (8), are not bounded by the constraints of the fractions of participants in electronic markets in Equations (9) and (10).

$$0 < n_s^* < 1 \quad (11)$$

$$0 < n_b^* < 1. \quad (12)$$

Proposition 1. (Interior solution) The optimal price levels (p_s^* , p_b^*) and the optimal levels of participants in electronic markets (n_s^* , n_b^*), which maximize the profit of the intermediary, are

$$p_s^* = \frac{(r_s - r_b)(s_s + r_n)v_b + (2s_b(s_s + r_n) - r_b(r_s + r_b))v_s}{4s_b(s_s + r_n) - (r_s + r_b)^2},$$

$$p_b^* = \frac{(r_b - r_s)s_b v_s + (2s_b(s_s + r_n) - r_s(r_s + r_b))v_b}{4s_b(s_s + r_n) - (r_s + r_b)^2},$$

$$n_s^* = \frac{(r_b + r_s)v_b + 2s_b v_s}{4s_b(s_s + r_n) - (r_s + r_b)^2},$$

and

$$n_b^* = \frac{(r_b + r_s)v_s + 2(s_s + r_n)v_b}{4s_b(s_s + r_n) - (r_s + r_b)^2}.$$

Proof. Solving the profit functions of buyers and suppliers at the indifferent points in Equations (13) and (14), we get the price levels (p_s, p_b) in terms of the levels of the fractions of participants in electronic markets (n_s, n_b), as in Equations (15) and (16).

$$u_s = v_s + r_s n_b - r_n n_s - s_s n_s - p_s = 0 \quad (13)$$

$$u_b = v_b + r_b n_s - s_b n_b - p_b = 0 \quad (14)$$

$$-p_s = v_s + r_s n_b - r_n n_s - s_s n_s \quad (15)$$

$$-p_b = v_b + r_b n_s - s_b n_b. \quad (16)$$

We substitute these results into the profit function of the intermediary in Equation (8). We get the first-order conditions of the profit function for each type of participants in the electronic market (n_s, n_b).

$$\frac{d\pi}{dn_s} = 0 \quad (17)$$

$$\frac{d\pi}{dn_b} = 0 \quad (18)$$

Using Equations (11) and (12), assuming the constraints on the fractions of participants in electronic markets are not binding, the optimal prices to maximize the profit of the intermediary are:

$$p_s^* = \frac{(r_s - r_b)(s_s + r_n)v_b + (2s_b(s_s + r_n) - r_b(r_s + r_b))v_s}{4s_b(s_s + r_n) - (r_s + r_b)^2}$$

$$p_b^* = \frac{(r_b - r_s)s_b v_s + (2s_b(s_s + r_n) - r_s(r_s + r_b))v_b}{4s_b(s_s + r_n) - (r_s + r_b)^2}. \quad (19)$$

The optimal levels of the fractions of participants in electronic markets with the optimal prices substituted are stated in Equation (20). The supplier and buyer types are divided into two groups of buyers and suppliers, those who join the new electronic marketplace and those who remain in the traditional marketplace as shown in Figure 2.

$$n_s^* = \frac{(r_b + r_s)v_b + 2s_b v_s}{4s_b(s_s + r_n) - (r_s + r_b)^2}$$

$$n_b^* = \frac{(r_b + r_s)v_s + 2(s_s + r_n)v_b}{4s_b(s_s + r_n) - (r_s + r_b)^2}. \quad (20)$$

As stated previously, Equations (11) and (12) must be satisfied in order to get an interior solution. These conditions are satisfied when the following three conditions hold:

$$4s_b(s_s + r_n) - (r_s + r_b)^2 > 0 \quad (21)$$

$$4s_b(s_s + r_n) - (r_s + r_b)^2 > (r_b + r_s)v_b + 2s_bv_s \quad (22)$$

$$4s_b(s_s + r_n) - (r_s + r_b)^2 > (r_b + r_s)v_s + 2(r_n + s_s)v_b. \quad (23)$$

We assume that Equation (21) is satisfied for the rest of this paper and it is sufficient to guarantee that second-order conditions are also satisfied (see proof in Appendix B). When Equations (22) and (23) are violated, we get boundary solutions as detailed in the next section. (Q.E.D.)

From the optimal solutions of price levels and fractions of participants in electronic markets of suppliers' and buyers' (p_s^* , p_b^* , n_s^* , n_b^*) in Equations (19) and (20), we can see that both the optimal levels of participants in electronic markets (n_s^* , n_b^*) are influenced by the parameters that define the two types (r_s , r_n , v_s , s_s , r_b , v_b , s_b). As an example, if there is a reduction in switching costs for suppliers (s_s), thus causing an increase in the fraction of suppliers in electronic markets (n_s), the optimal fraction of buyers in electronic markets also increases because of the indirect effect from the increased number of suppliers through network $e_b(n_s)$. This can be seen in Figure 3.

For example, in the construction industry, if Internet technologies become widespread among suppliers, it will be relatively easy for suppliers to participate in electronic marketplaces and more suppliers will join the electronic marketplaces. This in turn will attract more buyers due to the larger aggregation benefits resulting from an increase in the number of suppliers even though there is no change in industry parameters (r_b , s_b , v_b) for buyers. In this model, we want to consider and analyze these mutual effects between suppliers and buyers that have not been accounted for in prior literature.

All the effects of the changes of the parameters on the optimal levels of participants in electronic markets (n_s^* , n_b^*) are straightforward, as expected. The fraction of participants in the electronic market of one type is always affected by changes in the conditions of the other type through indirect effects. For example, the optimal level of the fraction of suppliers in the electronic market increases with an increase in the strength of the network effects for either type ($(\partial n_s^*/\partial r_s) > 0$, $(\partial n_s^*/\partial r_b) > 0$). The negative network effects reduce the participation of both the suppliers and buyers ($(\partial n_s^*/\partial r_n) < 0$, $(\partial n_b^*/\partial r_n) < 0$). When more information services are provided for either type, the fraction of suppliers in the electronic market increases ($(\partial n_s^*/\partial v_s) > 0$, $(\partial n_s^*/\partial v_b) > 0$). Also, as expected, the optimal levels of participants in electronic markets are lower when there is greater difficulty in switching for either type at the industry level ($(\partial n_s^*/\partial s_s) < 0$, $(\partial n_s^*/\partial s_b) < 0$).

Boundary Solution

Now we present boundary solutions that occur when the fractions of participants in electronic markets (n_s , n_b) are either zero or one. In other words, these results apply to the cases when the constraints on the fractions of participants in electronic markets in

Fractions of
Participants

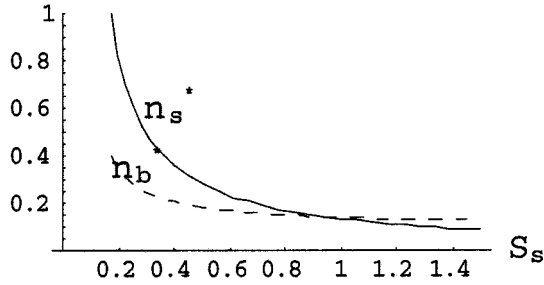


Figure 3. Fractions of Participants in Electronic Markets with Different Levels of Difficulty of Switching. The changes in the optimal fractions of participants in electronic markets with different levels of difficulty of switching for suppliers (s_s) from 0.17 to 1.5 ($s_b = 1$, $v_s = v_b = 0.2$, $r_b = 0.4$, $r_s = 0.2$, $r_n = 0.05$). Here, both the optimal levels of the fractions of participants in electronic markets are reduced when there is a higher difficulty of switching.

Equations (9) and (10) are binding. There are eight possible cases where either constraint is tight: 1. ($n_s = 0$, $n_b = 0$); 2. ($n_s = 0$, $n_b = 1$); 3. ($n_s = 0$, $0 < n_b < 1$); 4. ($n_s = 1$, $0 < n_b < 1$); 5. ($n_s = 1$, $n_b = 0$); 6. ($n_s = 1$, $n_b = 1$); 7. ($0 < n_s < 1$, $n_b = 0$); 8. ($0 < n_s < 1$, $n_b = 1$).

Proposition 2. Whenever the value of information services (v_s , v_b) is positive, the fractions of participants in electronic markets (n_s , n_b) are positive and strictly greater than zero.

This is a very intuitive result. Whenever it is possible for the intermediary to provide benefits at no marginal cost, it is optimal for the intermediary to set prices so that some buyers and suppliers can use its services. Thus, five of the eight cases are not feasible: 1. ($n_s = 0$, $n_b = 0$); 2. ($n_s = 0$, $n_b = 1$); 3. ($n_s = 0$, $0 < n_b < 1$); 4. ($n_s = 1$, $n_b = 0$); 5. ($0 < n_s < 1$, $n_b = 0$). The detailed proof is in Appendix C.

There are three remaining cases with boundary solutions where either n_s or n_b is equal to one.

Case 1. Both markets are fully covered ($n_s^* = 1$, $n_b^* = 1$).

This is the case where both constraints, Equations (9) and (10), are binding ($n_s = 1$, $n_b = 1$). Then, from the indifference points in Equations (13) and (14), we get the optimal price levels.

$$p_s^* = v_s + r_s - r_n - s_s$$

$$p_b^* = v_b + r_b - s_b.$$

Case 2. Buyers' market is fully covered ($n_b^* = 1$, $0 < n_s^* < 1$).

In this case, the constraint on the fraction of buyers, Equation (10), is binding. Then we get price levels in terms of the fractions of participants in electronic market levels (n_s , n_b).

$$p_s = v_s + r_s \cdot 1 - r_n n_s - s_s n_s$$

$$p_b = v_b + r_b n_s - s_b.$$

With these prices (p_s, p_b) plugged into the profit function of the intermediary, we can get the optimal level of the fraction of suppliers in the electronic market (n_s^*) from the first-order condition ($(d\pi/dn_s) = 0$). Then the optimal price level for suppliers and buyers and the optimal level of the fraction of suppliers in the electronic market are:

$$p_s^* = \frac{r_s + v_s - r_b - r_n}{2},$$

$$p_b^* = \frac{r_b^2 - r_b r_n + r_b r_s - 2s_s s_b + 2s_s v_b + r_b v_s}{2s_s}$$

$$n_s^* + \frac{r_b + r_s + v_s - r_n}{2s_s} < 1$$

$$n_b^* = 1.$$

Case 3. Suppliers' market is fully covered ($n_s^* = 1, 0 < n_b^* < 1$).

Following the steps in Case 2 ($n_b^* = 1, 0 < n_s^* < 1$), the optimal price levels and the optimal level of the fraction of buyers in the electronic market are:

$$p_s^* = \frac{r_s (r_b + r_s + v_b) - 2s_b (r_n + s_s - v_s)}{2s_b}$$

$$p_b^* = \frac{r_b - r_s + v_b}{2}$$

$$n_s^* = 1$$

$$n_b^* = \frac{r_b + r_s + v_b}{2s_b} < 1.$$

We can see the optimal levels of participants in electronic markets and the optimal price levels for buyers and suppliers in Figures 4 and 5. In both figures, the optimal price levels and the optimal levels of participants in electronic markets are kinked at two r_b levels. The first kink is the point where the market for buyers is fully covered, and Case 2 ($n_b^* = 1, 0 < n_s^* < 1$) applies between the first and second kinks. The second kink is the point where the market for suppliers is fully covered, and Case 1 ($n_s^* = 1, n_b^* = 1$) applies. As shown in Figure 5, the price can also turn negative. In the real

Fractions of Participants

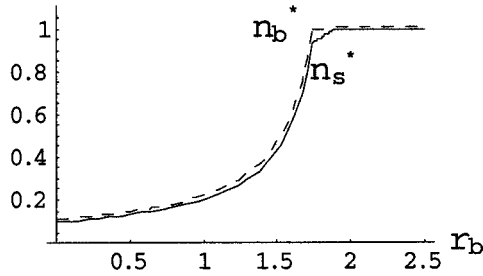


Figure 4. Fractions of Participants in Electronic Markets at the Boundary Case. The changes of optimal levels of participants in electronic markets with different levels of the strength of network effects for buyers (r_b) from 0 to 2.5 ($s_s = s_b = 1$, $v_s = v_b = 0.2$, $r_s = 0.2$, $r_n = 0.15$). Here, the market of buyers is fully covered (Case 2) at the first kinks of n_s^* and n_b^* . Then the market of suppliers is fully covered (Case 1: both fully covered) at the second kink of n_s^* .

Price

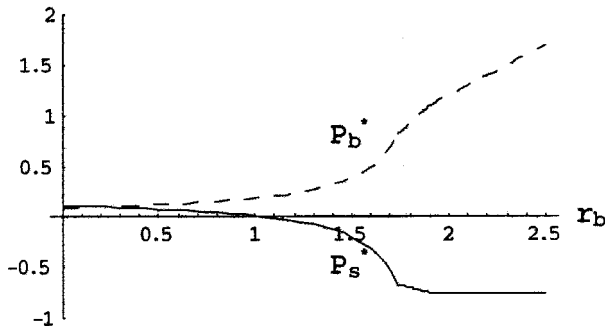


Figure 5. Price Levels at the Interior and Boundary Cases. The changes of optimal price level with different levels of the strength of network effects for buyers (r_b) from 0 to 2.5 ($s_s = s_b = 1$, $v_s = v_b = 0.2$, $r_s = 0.2$, $r_n = 0.15$). Here, the slopes of optimal price levels are kinked at the point where either market is fully covered (Case 2 or 3). Then optimal price levels for boundary solutions apply. The negative price for suppliers can be interpreted as a subsidy.

world, this can be interpreted as a subsidy or free services provided to increase the number of suppliers and buyers participating in the marketplace.

We summarize the boundary solutions of the fractions of participants in electronic markets and price levels in Table 1.

Impact of Market Conditions on Optimal Strategies

WHEN THERE IS AN INTERIOR SOLUTION with Equations (11) and (12), we can see the relationship between the parameters and optimal price levels.

Table 1. Boundary Solutions of the Levels of the Fractions of Participants in Electronic Markets and Price Levels

Case \ Value	$n_s = 1$ $n_b = 1$	$n_b = 1$ $0 < n_s^* < 1$	$n_s = 1$ $0 < n_b^* < 1$
p_s^*	$v_s + r_s$ $-s_s - r_n$	$\frac{r_s + v_s - r_b - r_n}{2}$	$\frac{r_s(r_b + r_s + v_b)}{2s_b}$ $\frac{-2s_b(r_n + s_s - v_s)}{2s_b}$
p_b^*	$v_b + r_b$ $-s_b$	$\frac{r_b^2 - r_b r_n + r_b r_s}{2s_s}$ $+\frac{r_b v_s - 2s_b s_s}{2s_s}$ $+\frac{2s_s v_b}{2s_s}$	$\frac{r_b - r_s + v_b}{2}$
n_s	1	$\frac{r_b + r_s + v_s - r_n}{2s_s}$	1
n_b	1	1	$\frac{r_b + r_s + v_b}{2s_b}$

Impact of Network Effects on Price Levels

Optimal price levels are different when the strengths of network effects are different. Intuitively, when the strength of the positive network effects is greater, the value of the marketplace and the prices are expected to be higher. But, in some cases, the optimal price levels are lower with greater strength of network effects. The following propositions state the impact of positive and negative network effects of both supplier and buyer types on optimal price levels.

Proposition 3. When the difficulty of switching and the value of services are the same to buyers and suppliers ($s_b = s_s, v_b = v_s$) and the difficulties of switching are greater than the strengths of network effects ($s_s, s_b > r_s, r_b$), the price charged to suppliers p_s^* is higher, whereas the price charged to buyers p_b^* is lower with increase in the strength of the network effects for suppliers r_s . Similarly, the price charged to buyers p_b^* is higher, whereas the price charged to suppliers p_s^* is lower with increase in the strength of the network effects for buyers r_b .

Proof. Since there are many mixed effects due to several parameters, the direction of change of optimal price to the change in the relative strengths of network effects (r_s, r_b) is ambiguous. However, when the difficulty of switching and the

value of information services are the same to buyers and suppliers, and the difficulties of switching are greater than the strengths of network effects, the changes in p_s^* , p_b^* become clear. The first derivatives of network effect parameters (r_s , r_b) on optimal prices of suppliers and buyers, p_s^* and p_b^* in Equation (19) are provided in Equation (24). Because all terms of $\partial p_s^*/\partial r_s$ are positive and all terms of $\partial p_s^*/\partial r_b$ are negative, $\partial p_s^*/\partial r_s$ is positive and $\partial p_s^*/\partial r_b$ is negative.

$$\begin{aligned} \frac{\partial p_s^*}{\partial r_s} &= \frac{(8s_s s_b - 3r_b^2 - 2r_s r_b)r_n v_b + (4s_b s_s + r_s^2 - 3r_b^2 - 2r_b r_s)s_s s_b}{\left\{4s_b (s_s + r_n) - (r_s + r_b)^2\right\}^2} \\ &+ \frac{(4r_s s_s s_b - r_b^3 - 2r_s r_b^2 - r_b r_s^2)v_s + r_n r_s^2 v_b + 4r_n^2 s_b v_b + 4r_n r_s s_b v_s}{\left\{4s_b (s_s + r_n) - (r_s + r_b)^2\right\}^2} > 0, \quad \frac{\partial p_b^*}{\partial r_b} > 0 \end{aligned} \quad (24)$$

$$\begin{aligned} \frac{\partial p_s^*}{\partial r_b} &= \frac{-(8s_s s_b - 3r_b^2 - 2r_s r_b)r_n v_b - (4s_b s_s + r_s^2 - 3r_b^2 - 2r_b r_s)s_s s_b}{\left\{4s_b (s_s + r_n) - (r_s + r_b)^2\right\}^2} \\ &+ \frac{-(4r_s s_s s_b - r_b^3 - 2r_s r_b^2 - r_b r_s^2)v_s - r_n r_s^2 v_b - 4r_n^2 s_b v_b - 4r_n r_s s_b v_s}{\left\{4s_b (s_s + r_n) - (r_s + r_b)^2\right\}^2} < 0, \quad \frac{\partial p_b^*}{\partial r_s} < 0. \end{aligned}$$

(Q.E.D.)

$\partial p_b^*/\partial r_b$ is similar to $\partial p_s^*/\partial r_s$, whereas $\partial p_b^*/\partial r_s$ is similar to $\partial p_s^*/\partial r_b$; therefore, we have only provided details for $\partial p_s^*/\partial r_s$ and $\partial p_s^*/\partial r_b$. When the strength of the network effects for a type is greater, the value of the marketplace to that type is greater. Furthermore, the price charged to that type would be higher ($(\partial p_b^*/\partial r_b) > 0$, $(\partial p_s^*/\partial r_b) > 0$). We may expect that the price for the other type will also be higher because of the indirect effect due to two-sided network effects. But, counterintuitively, the optimal price for a type is lower when the strength of network effects for the other type is greater ($(\partial p_s^*/\partial r_b) < 0$, $(\partial p_b^*/\partial r_s) < 0$). The reason for this is explained below.

The increase in r_b has two opposing effects on p_s^* : (1) The increase in r_b causes an increase in n_b since the buyers have an increased valuation for the marketplace due to higher r_b . This effect increases the suppliers' valuation of the marketplace, which drives the intermediary to increase its profits from suppliers by increasing p_s . (2) An increase in r_b increases the importance of n_s since $r_b \cdot n_s$ is part of the profit function of buyers. This encourages the intermediary to reduce p_s to attract more suppliers. The strength of r_b relative to r_s determines which of these two effects is greater.

Specifically, when r_b is greater than r_s the second effect dominates and the intermediary reduces p_s when there is an increase in r_b . We derive these results assuming that the conditions in Equation (24) hold.

We derive some counterintuitive results about the optimal price levels with different levels of negative network effects.

Proposition 4. This proposition is about the impact of changes in the strength of the negative effects among suppliers' (r_n) on the optimal price levels in the marketplace.

(1) When the strength of network effects for buyers is greater than that for suppliers ($r_b > r_s$), then the price for suppliers (buyers) is higher (lower) with an increase in the strength of the negative network effects.

(2) When the strength of network effects for buyers is smaller than that for suppliers ($r_b < r_s$) then the price for suppliers (buyers) is lower (higher) with an increase in the strength of the negative network effects.

From the first derivatives of the optimal prices (p_s^* , p_b^*) with respect to the parameter of negative network effects (r_n), as in Equation (19), we can see these somewhat counterintuitive results. We may expect that because of the greater negative network effects among suppliers and the resulting negative effect on the valuations of suppliers and buyers, the prices for suppliers and buyers will always be lower. However, when $r_b > r_s$ (the participation of suppliers is more valuable to buyers than that of buyers to suppliers), the price for suppliers is higher and the price for buyers is lower when r_n increases. The reason is as follows.

There are two opposing effects stated in 1 and 2 following. Consider the intermediary's optimal prices when the negative network effect is small, as in the left region of Figure 6, and when suppliers' participation is more valuable ($r_b > r_s$).

1. As discussed previously, when $r_b > r_s$, the intermediary lowers p_s to encourage the participation of suppliers and raises p_b .

However, when the strength of the negative network effect increases, there is a reduction in the value of network effects because the increased negative network effects offset the value of the positive network externalities on both suppliers and buyers. Thus, the incentive for the intermediary to subsidize suppliers by reducing the price charged to suppliers is reduced. This causes the intermediary to decrease the subsidy in the form of the reduced price to suppliers, leading to an increase in p_s and a reduction in p_b .

2. The increase in r_n causes a reduction in suppliers' valuation of the marketplace, which encourages the intermediary to reduce the price charged to suppliers (p_s).

When $r_b > r_s$, the first effect dominates and the firm increases p_s .

In the example of Citadon, which is a reverse-auction based, buyer-favored marketplace ($r_b > r_s$), if there are greater negative effects to suppliers from having more of their competitors (increase in r_n), the intermediary should charge more for suppliers. This result seems counterintuitive because the value of the marketplace is reduced to suppliers with this negative effect. The reason for this is explained below. Due to the

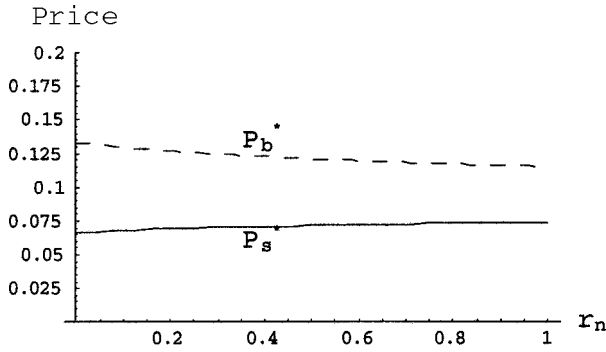


Figure 6. Price Levels with Different Levels of Negative Network Effects. The changes of optimal prices with different levels of negative network effects (r_n) from 0 to 1 ($s_s = s_b = 1$, $v_s = v_b = 0.2$, $r_b = 0.6$, $r_s = 0.2$). Here, the difference between prices is reduced when the strength of negative network effects increases.

greater negative effect, the impact of positive network effects is lower. So, for the intermediary, the incentive to lower the price for suppliers to attract them is reduced. When the marketplace is a reverse-auction based, buyer-favored marketplace ($r_b > r_s$), the optimal price for suppliers is higher because the “price-reducing” effect from the reduced value of the marketplace to suppliers is smaller than the “price-increasing” effect from the reduced incentive for the intermediary to reduce the price for suppliers.

Impact of Information Service Levels on Price Levels

Optimal price levels are different with changes in the level of information services (v_b, v_s). Intuitively, when the value of information service levels is higher, the value of the marketplace and the price are expected to be higher. But, in some cases, the price levels are lower with higher information service levels. The impact of information service levels of both supplier and buyer types on optimal price levels is stated in the following proposition:

Proposition 5. The impact of information service levels on the optimal price levels in the marketplace:

(1) When the value of the information services for suppliers, v_s (buyers, v_b), is greater, the price charged to the suppliers, p_s^* (the buyers, p_b^*), is higher.

(2a) When the value of the information services for buyers, v_b (suppliers, v_s), is greater, the price charged to suppliers, p_s^* (the buyers, p_b^*), is lower if the strength of network effects for buyers (suppliers) is greater than that for suppliers (buyers), $r_b > r_s$ ($r_s > r_b$).

(2b) When the value of the information services for buyers, v_b (suppliers, v_s), is greater, the price charged to suppliers, p_s^* (the buyers, p_b^*), is higher if the strength

of network effects for the buyers (suppliers) is smaller than that for suppliers (buyers), $r_b < r_s$ ($r_s < r_b$).

From the first derivatives of the optimal prices (p_s^* , p_b^*) with respect to the service levels (v_s , v_b) as in Equation (22), this proposition can be easily proven. When the value of the information services for buyers is greater, the value of the marketplace to buyers is greater. Also, the price charged to buyers will be higher ($(\partial p_b^*/\partial v_b) > 0$). Then we may expect that the price for suppliers also will be higher because the greater value of the marketplace to buyers increases the value to suppliers through the indirect effect. But, counterintuitively, the optimal price for suppliers is lower when the value of the information services for buyers is increased when $r_b > r_s$. The reason for this result is as follows.

The increase in v_b has two opposing effects on p_s^* : (1) The increase in v_b causes an increase in n_b since the buyers have an increased valuation for the marketplace due to higher v_b . This increases the suppliers' valuation of the marketplace, which drives the intermediary to increase its profits from suppliers by increasing p_s . (2) An increase in v_b forces the intermediary to reduce p_s in order to increase n_s to maximize its profit.

Specifically, when r_b is greater than r_s , the second effect dominates and the intermediary reduces p_s . Similarly, this result can be applied to the case when the value of the information services for suppliers is greater.

For example, when more information services are provided for suppliers, more suppliers join the marketplace and the intermediary can charge a higher price to suppliers. But the intermediary should carefully consider the pricing decision for buyers. In the reverse-auction based, buyer-favored market ($r_b > r_s$), the participation of suppliers is more important than the participation of buyers. When more information services are provided to buyers, the value of the electronic marketplace is greater for suppliers because of the indirect effect from having more buyers in the marketplace. But by reducing the price for suppliers and attracting more suppliers to the marketplace, the profit for the intermediary can be increased.

Impact of Switching Costs on Price Levels

Optimal price levels vary with different levels of difficulty of switching (s_s , s_b). Intuitively, when switching to the electronic marketplace is more difficult, the value of the marketplace and the price for it are expected to be lower. But, in some cases, the price levels are higher with greater difficulty of switching. The following is a proposition about the impact of switching difficulty of both suppliers and buyers on optimal price levels.

Proposition 6. The impact of switching costs on the optimal price levels of the marketplace are:

(1) When the strength of network effects for buyers is greater than that for suppliers ($r_b > r_s$), the price for suppliers (buyers) is higher (lower) if the difficulty of switching for suppliers or buyers, s_s or s_b , increases.

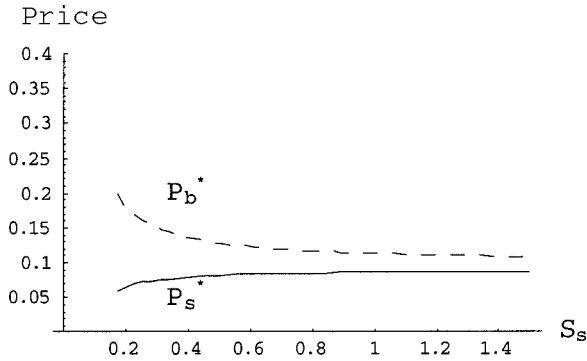


Figure 7. Price Levels with Different Levels of the Difficulty of Switching. The changes of optimal prices with different levels of the difficulty of switching for suppliers (s_s) from 0.17 to 1.5 ($s_b = 1$, $v_s = v_b = 0.2$, $r_b = 0.4$, $r_s = 0.2$, $r_n = 0.05$). Here, the difference between prices is reduced when there is higher difficulty in switching.

(2) When the strength of network effects for buyers is smaller than that for suppliers ($r_b < r_s$), the price for suppliers (buyers) is lower (higher) if the difficulty of switching for suppliers or buyers, s_s or s_b , increases.

From the first derivatives of the optimal prices (p_s^* , p_b^*) with respect to switching cost parameters (s_s , s_b) as in Equation (19), this proposition can be easily proven. We may expect that, because of the higher difficulty of switching, the electronic marketplace becomes less attractive and the price for suppliers and buyers would be lower if it is more difficult for suppliers to switch to the electronic marketplace. However, when $r_b > r_s$ (the participation of suppliers is more valuable to buyers than that of buyers to suppliers), the price for suppliers is higher and the price for buyers is lower when s_s or s_b increases. We explain this further in the following paragraph.

There are two opposing effects: (1) Consider the intermediary's optimal prices when the difficulty of switching to the electronic marketplace is small. As discussed previously and as shown in Figure 7, when $r_b > r_s$, the intermediary lowers p_s and raises p_b to attract more suppliers to the marketplace since the participation of suppliers is more valuable to buyers than that of buyers to suppliers. However, when the difficulty of switching increases, there is a reduction in the value of network effects because the increased difficulty of switching reduces the effect of positive network effects by reducing the optimal numbers of suppliers and buyers who participate in the marketplace (n_b^* , n_s^*). Thus, the incentive for the intermediary to subsidize suppliers whose value of joining the marketplace is higher, by reducing the price charged to suppliers, decreases. This causes the intermediary to decrease the subsidy in the form of the reduced price to suppliers, leading to an increase in p_s and a reduction in p_b . (2) The increase in s_s or s_b causes a reduction in suppliers' valuation of the marketplace, which encourages the intermediary to reduce the price charged to suppliers (p_s).

When $r_b > r_s$, the first effect dominates and the intermediary increases p_s .

We summarize, in Table 2, the propositions discussed in the fourth section.

Table 2. Summary of Propositions

Parameter (increase)	p_s^*	p_b^*	Assumptions
r_s	+	-	$S_s = S_b$
r_b	-	+	$V_s = V_b$
r_n	-	+	when $r_s > r_b$
	+	-	when $r_s < r_b$
V_s	+	+	when $r_s < r_b$
		-	when $r_s > r_b$
V_b	+	+	when $r_s < r_b$
	-		when $r_s > r_b$
S_s	+	-	when $r_s < r_b$
	-	+	when $r_s > r_b$
S_b	-	+	when $r_s > r_b$
	+	-	when $r_s < r_b$

Impact of Parameter Values on Prices in Boundary Cases

In boundary cases, some of the propositions on the impact of parameters in the case of interior solutions hold, but others do not hold. The main reason why these differences appear is as follows. Once either side of the marketplace (n_b^* or n_s^*) is fully covered, the incentive to reduce price for the type with a higher value of participation (buyer if $r_s > r_b$, supplier if $r_b > r_s$) to attract the type ceases to exist. For example, when buyers' market is fully covered ($n_b^* = 1$, $n_s^* < 1$), the price for buyers (p_b^*) increases when the intensity of network effect on suppliers (r_s) increases in the case of boundary solution, whereas the price for buyers' decreases in the interior solution. Because all buyers have participated in the marketplace ($n_b^* = 1$), there is no further need for the intermediary to reduce the price charged to buyers to attract them.

Managerial Implications

IN THIS PAPER, WE HAVE EXAMINED marketplaces where buyers benefit from network effects based on the number of suppliers and their benefit from network effects based on the level of participation of buyers. Further, we provide rationale for the existence of negative network effects due to competition among suppliers. The results in Proposition 3 provide some managerial insights as to the optimal pricing strategy in the presence of such network effects. We show that some of the optimal prices fall even though the value of the marketplace increases when the strength of the positive network effects increases. In Propositions 4 and 5, we show that the same is true for the negative network effects as well as the level of information services. These propositions also highlight the importance of the relative strength of the positive network effects for buyers and suppliers. Therefore, it is important for managers to recognize whether the strength of the positive network effects for buyers is greater than that for

suppliers, or vice versa. When the strength of the positive network effects for buyers is greater than that for suppliers, it is optimal to reduce the price charged from suppliers with increase in the level of information services to buyers otherwise, the intermediary should be increasing prices charged to suppliers. It is difficult to estimate these network effects. However, knowledge about the nature of the marketplace may provide clues as to which network effect is stronger. For example, a marketplace that features posted prices and limited variety of goods is likely to have lower network effects for buyers compared to a marketplace featuring reverse auctions and a wide variety of goods.

Therefore, the price charged to suppliers will be lower in reverse-auction or buyer-favored marketplaces compared to that in forward-auction or supplier-favored marketplaces. For example, FreeMarkets runs a buyer-favored B2B marketplace using reverse-auctions. Most of the market-making costs are charged to buyers [10]. Recently, FreeMarkets changed its pricing policy, and has stopped charging the participating suppliers. In comparison, New View (formerly e-STEEL), which is a forward-auction-based neutral B2B marketplace in the steel industry, charges transaction fees proportional to the transaction amounts (seven-eighths of 1 percent [6]) to suppliers, whereas it is free for buyers.

For neutral intermediaries, it is important to target industries and products where switching costs are lower. Sectors where the IT infrastructure is well developed and there are large numbers of small firms are better suited for development of neutral marketplaces. Development of IT is likely to reduce the switching costs, whereas the fragmented industries are likely to provide stronger network effects. In the real world, these are important criteria for developers of independent marketplaces such as Ventro and VerticalNet in determining target industries [4, 9]. Further, intermediaries can use information services to attract buyers and suppliers to the marketplace initially, allowing the marketplace to benefit from network effects.

Conclusion

OUR THEORETICAL ANALYSES HAVE SHOWN that the existence of network effects and the mutual effect of the buyer's participation on the supplier's participation and vice versa impact the optimal pricing strategy and optimal levels of participants in electronic marketplaces. Based on our model, we derive the pricing strategy that an independent intermediary can use to maximize its profit. How much should the intermediary charge? Based on our assumptions, the fractions of participants in electronic markets as well as the prices charged from suppliers and buyers in the electronic marketplace are dependent on the parameters that define the two types.

In this paper, for simplicity, we assume that equal prices are charged from all suppliers and all buyers, whereas the cost of information services are all fixed costs that do not affect the pricing decisions of intermediaries as long as the total profit is positive. Also, we assume a monopolistic and independent intermediary with a single-period model. We intend to extend this analysis to a dynamic model with multiple

periods (for example [12]). We also hope to analyze a duopoly model, which incorporates competition between intermediaries in electronic markets, in our future research. Due to certain characteristics of the B2B marketplace such as network effects, it is possible that, in certain segments, only one marketplace will survive. In other segments, the emergence of a dominant marketplace is likely. In financial markets, for instance, a single exchange tends to receive most of the transactions and profits. In such cases, our monopoly model is a close approximation, and we believe that the propositions developed in this model are applicable to such situations. We also hope to analyze different ownership structures of B2B marketplaces that involve suppliers and buyers who own the marketplace. Based on these extensions, we intend to propose models of B2B marketplaces that are owned by suppliers or buyers and to compare the results on the price levels and fractions of participants in electronic markets to the results of the current model of an independent intermediary.

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Appendix A

Assumptions of Our Model

Contents	Parameters	Assumptions
All parameters	r_s, r_b, r_n, s_s, s_b	All parameters have positive values (≥ 0).
Prices	p_s, p_b	Total amounts paid by suppliers and buyers to use the market-place. (Same for each buyer and each supplier.)
Implementation costs		The total profit of the intermediary including fixed costs is assumed to be positive. We set fixed costs as zero for simplicity in our model.
Network effects	$e_s(n_b), e_b(n_s), e_n(n_s)$	The network effects are linearly related to the number of suppliers and buyers.
$4s_b(s_s + r_n) - (r_s + r_b)^2 > 0$ (Equation (21)) Marginal costs		Necessary for the second-order conditions to hold. All marginal costs including per-transaction costs assumed to be zero.
Heterogeneities in buyers and suppliers		Heterogeneity limited to switching costs.

Appendix B

Proof for Second-Order Conditions to Make Sure the Optimal Solutions Are Maximizing the Profit Function of Intermediary

Proof. There are three second-order conditions to be satisfied and we can see that all conditions are satisfied.

$$\frac{d^2\pi}{dn_s^2} = -2\left(1 + \frac{r_n}{s_s}\right)s_s < 0$$

$$\frac{d^2\pi}{dn_b^2} = -2s_b < 0$$

$$\frac{d^2\pi}{dn_s^2} \frac{d^2\pi}{dn_b^2} - \left(\frac{d^2\pi}{dn_s dn_b}\right)^2 = 4s_b(s_s + r_n) - (r_b + r_s)^2 > 0.$$

It can be seen that the first two conditions are always satisfied. The third condition is also satisfied when Equation (21) is satisfied. (Q.E.D.)

Appendix C

Proof for Infeasibility of Zero Fractions of Participants in Electronic Markets ($n_s, n_b = 0$)

Proof. For the supplier and buyer at the indifference point (n_s, n_b), the price is equal to the benefit from joining the intermediary's market. Thus, the price levels can be shown in terms of the optimal levels of participants in electronic markets.

$$\begin{aligned} u_{s|x_s = n_s} &= v_s + e_s(n_b) - e_n(n_s) - s_s x_s - p_s = 0 \\ -\mathcal{P}_s &= v_s + r_s n_b^* - r_n - s_s n_s^* \\ u_{b|x_b = n_b} &= v_b + e_b(n_s) - s_b x_b - p_b = 0 \\ -\mathcal{P}_b &= v_b + r_b n_s^* - s_s n_b^*. \end{aligned}$$

The profit function of the intermediary can be shown as

$$\begin{aligned} \pi &= p_s n_s + p_b n_b = \left(v_s + r_s n_b^* - r_n n_s^* - s_s n_s^* \right) \cdot n_s^* \\ &\quad + \left(v_b + r_b n_s^* - s_s n_b^* \right) \cdot n_b^*. \end{aligned}$$

Then, if we differentiate the profit function by the fraction of participants in electronic markets of the supplier (n_s^*) or buyer (n_b^*) and solve the first-order conditions, we can see that the optimal levels of participants (n_s^*, n_b^*) are always greater than zero in electronic markets in Equations (25) and (26). Therefore, when the information service levels (v_s, v_b) are positive, the optimal levels of the participants in electronic markets will always be positive.

$$\frac{d\pi}{dn_b^*} = r_s n_s^* + v_b + r_b n_s^* - 2s_s n_b^* = 0 \quad (25)$$

$$\rightarrow n_b^* = \frac{r_s n_s^* + v_b + r_b n_s^*}{2s_s} \quad (\text{Substituted into } \pi \text{ equation})$$

$$\rightarrow \frac{d\pi \left(n_b^* = \frac{r_s n_s^* + v_b + r_b n_s^*}{2s_s} \right)}{dn_s^*} = 0 \rightarrow n_s^* = \frac{(r_s + r_b)}{2s_b} v_b + v_s > 0$$

$$\frac{d\pi}{dn_s^*} = \left(v_s + r_s n_b^* \right) - 2r_n n_s^* - 2s_s n_s^* + r_b n_b^* = 0 \quad (26)$$

$$\rightarrow n_s^* = \frac{r_s n_b^* + v_s + r_b n_b^*}{2(s_s + r_n)} \text{ (Substituted into } \pi \text{ equation)}$$

$$\rightarrow \frac{d\pi \left(n_s^* = \frac{r_s n_b^* + v_s + r_b n_b^*}{2(s_s + r_n)} \right)}{dn_b^*} = 0 \rightarrow n_b^* = \frac{(r_s + r_b)}{2(r_n + s_s)} v_s + v_b > 0$$

(Q.E.D.)