Pricing Strategies of Electronic B2B Marketplaces with Two-Sided Network Externalities

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Abstract

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 externalities where the value of the marketplace to buyers is dependent on the number of suppliers, and value to suppliers is dependent on the number of buyers and suppliers. When these two-sided network externalities exist, we find that the optimal price for buyers and the fraction of buyers in 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 electronic markets. In other words, the parameters that define the buyers also affect the optimal price for suppliers and the fraction of suppliers in electronic markets. In other words, the parameters that define the buyers also affect the optimal price for suppliers and the fraction of suppliers in electronic markets. Our results also point to some counterintuitive optimal pricing strategies that depend on the nature of the industry served by the marketplace.

1. Research questions

The rapid growth of electronic commerce led to high expectations, some of which were too unrealistic to hold true. The struggles of famous dot-coms such as Amazon.com and Buy.com in business-to-consumer markets have cast doubt on the future of electronic commerce. While much attention was focused on business-to-consumer firms at the outset, far greater volumes of transactions were conducted in business-to-business markets. According to Forrester Research, the amount of business-to-business (B2B) sales is several times that of business-to-consumer (B2C) sales and will be even greater in the near future. However, in the context of designing B2B marketplaces on the Internet, there are several unanswered questions. How to attract buyers and suppliers to B2B marketplaces? How can intermediaries extract revenue from suppliers and buyers in the marketplaces? Many practitioners have speculated about these questions, but there is little academic research in this area.

Some B2B market intermediaries have successfully created marketplaces. One common factor 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 externalities. Then, the marketplace can make efforts to transform the community into a customer base.

An important question facing intermediaries is how to price their services? How will network externalities affect the strategy of the intermediary? In this research, we study the strategies of intermediaries including their pricing of services when the impact of network effects is significant. Usually network externalities affect a consumer's valuation of a product depending on the number of compatible products being used by other consumers. 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 effect in marketplaces in detail in subsequent sections.

This article is organized as follows: Section 2 briefly reviews previous studies related to B2B marketplaces. Section 3 discusses the basic marketplace model. Section 4 discusses the impact of market conditions on the optimal prices and level of participation in electronic markets. Finally, Section 5 presents our conclusions.

2. Theoretical foundations

There are two main benefits of electronic B2B marketplaces. The first one is the speed and efficiency of transactions enabled by information technology. Using advanced information technology, 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 externalities. The benefits from having a large number of participants are called ‘positive network externalities’. 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] discussed the strategies for products with positive network effects. They showed how network externalities can affect the decisions of companies, especially those relating to the compatibility of their products to industry standards. Brynjolfsson and Kemerer [2] empirically showed that the network externalities of spreadsheet software programs can increase the price of these programs. In this paper, the characteristics of network externalities of the marketplace are quite different from the characteristics of network externalities of products in previous studies. We call the network externalities of products one-sided to differentiate it from the network externalities of the marketplace. For each player, the value of the marketplace is dependent on the participation of the other party. As we can see in Fig.1, for buyers in the marketplace, the number of suppliers is the main concern and for suppliers, the number of buyers is the main focus.

Figure 1: Two-sided network externalities of the marketplace

The value of the marketplace to each player is increased when he or she can search for more buyers or suppliers because, with more buyers or suppliers, there is a greater probability of finding a better match or better offers. On the other hand, the value of the marketplace decreases for each when there are more competitors on her side. We call this ‘negative network externalities’ and it is determined by the participation of the players’ own side. Wang and Seidmann [12] showed 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 this model, we only consider negative network externalities for the supplier side. We assume that there are no supply side constraints, and therefore, no negative network externalities for the buyer’s side. Spulber [3] 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 [3] model the matching process as a time-consuming series of pairwise meetings and introduce middlemen who act as buyers or suppliers themselves and therefore can accelerate the other agents’ search processes. Bhargava et al. [3] analyzed the decision of an intermediary when there are aggregation benefits for buyers. But they only considered the aggregation benefit for buyers, not the aggregation benefit for suppliers, nor the negative network externalities.

While there are benefits from joining electronic marketplaces, some switching costs also exist. When suppliers and buyers join these marketplaces, they have to incur some expenses to adapt their current distribution channels. In previous Electronic Data Interchanges (EDI) research, many studies examined how to attract suppliers and buyers to EDI networks from traditional channels. Riggins et al. [9] showed how to attract suppliers to an EDI network run by a buyer in the presence of network effects. Even though, in past studies, researchers mentioned that network externalities in the marketplace depend on the level of participation of other parties, such as buyers to suppliers and suppliers to buyers, few researchers have examined cases where the level of participation of other parties affects the value of the marketplace. In this research, we show how the interaction between the levels of network externalities 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.

3. A basic 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 which 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, Inc. 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 not dependent on 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 \( n_b \). For example, when there are more suppliers, buyers are likely to find lower product prices and better matching suppliers. The same is true for suppliers. The negative network externalities for suppliers are represented by \( e_n(n_s) \) and these are proportional to the number of suppliers, \( n_s \). As shown in the EDI case by Wang and Seidman [12], the participation of more suppliers can generate negative externalities 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 benefits to suppliers are proportional to the number of buyers and, likewise, the aggregation benefits to buyers are proportional to the number of suppliers. Thus, in Eq. 1, \( r_s \), \( r_b \) and \( r_n \) are constants that represent the intensity of the network effects \( e_s \), \( e_b \) and \( e_n \) respectively. In a marketplace where the transactions are executed by reverse auction, the intensity of network externality for buyers is likely to be greater \( (r_b > r_s) \) because the mechanism of reverse auction precipitates the 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 is smaller than the benefits directly from the reverse auction mechanism for buyers. So, the participation of an additional supplier is more valuable to buyers than the participation of an additional buyer to suppliers in the marketplace. To the contrary, in a marketplace where the transactions are executed by forward auction, the intensity of network externality 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 externality \( (r_n) \) 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 \( n_b \).

\[
e_s(n_b) = r_s n_b, \quad e_b(n_s) = r_b n_s, \quad e_n(n_s) = r_n n_s \quad (1)
\]

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 Fig.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 transferring their transactions 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 information technology for their processes will find it easier to switch to the electronic marketplace while other buyers and suppliers with a lesser degree of information technology 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 \( s_s x_s \) and \( s_b x_b \) 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 marketplaces. These fees are the total amounts for each supplier and buyer to use the marketplace. The profit functions of suppliers and buyers from joining the marketplace are provided in Eq. 2 and Eq. 3.

\[
us = vs + r_s p_b - r_n n_s - s_s x_s - p_b \quad (2)
\]
\[
ub = vb + r_b n_s - s_b x_b - p_b \quad (3)
\]
Suppliers and buyers will participate in the marketplace if and only if the profit is positive as in Eq. 4. Let \( x_s^{\prime} \) and \( x_b^{\prime} \) be the supplier and buyer that is indifferent between switching and not switching to the electronic marketplace. Thus we obtain the indifference equations stated in Eq. 5 and Eq. 6.

\[
\begin{align*}
\text{Electronic Market} & \quad \text{Traditional Market} \\
\text{Suppliers} & \\
0 & \quad x_s^{\prime} & \quad 1 \\
\text{Easy to transfer} & \\
\text{Buyers} & \\
0 & \quad x_b^{\prime} & \quad 1 \\
\end{align*}
\]

Figure 2: Fractions of participants in electronic markets and switching costs

As shown in Fig. 2, all buyers (suppliers) of type \( x_b \) (\( x_s \)) less than \( x_b^{\prime} \) (\( x_s^{\prime} \)) will switch to the electronic marketplace. Therefore, the fractions of participants in electronic markets \( (n_s, n_b) \) of the electronic marketplace are given by:

\[
n_s = x_s^{\prime}, \quad n_b = x_b^{\prime} \quad (7)
\]

The intermediary intends to maximize its profit by charging fees to suppliers and buyers for using its marketplace. Then the intermediary’s decision problem

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

\[
\begin{align*}
\text{max} \pi & = p_s n_s + p_b n_b \quad (8) \\
\text{s.t.} \quad 0 & \leq n_s \leq 1 \quad (9) \\
0 & \leq n_b \leq 1 \quad (10)
\end{align*}
\]

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

### 3.1. Interior solution

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

\[
\begin{align*}
0 & < n_s^{\ast} < 1 \quad (11) \\
0 & < n_b^{\ast} < 1 \quad (12)
\end{align*}
\]

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

\[
\begin{align*}
p_s^{\ast} & = \frac{(r_s - r_b)(s_s + r_a)v_b + (2s_s(s_s + r_a) - r_b(r_s + r_a))v_s}{4s_s(s_s + r_a)(r_s + r_a)^3} \\
p_b^{\ast} & = \frac{(r_b - r_s)s_bv_s + (2s_s(s_s + r_a) - r_b(r_s + r_a))v_s}{4s_b(s_s + r_a)(r_s + r_a)^3} \\
n_s^{\ast} & = \frac{(r_s + r_a)v_s + 2s_s v_s}{4s_s(s_s + r_a)(r_s + r_a)^3} \\
n_b^{\ast} & = \frac{(r_b + r_s)v_b + 2(s_s + r_a)v_b}{4s_b(s_s + r_a)(r_s + r_a)^3}
\end{align*}
\]

**Proof.** From solving the profit functions of buyer and supplier at the indifferent points in Eq. 13 and Eq. 14, we can get the price levels \( (p_s, p_b) \) in terms of the levels of the fractions of participants in electronic markets \( (n_s, n_b) \) in Eq. 15 and Eq. 16.

\[
\begin{align*}
us & = v_s + r_s p_b - r_b n_s - s_s n_s - p_b = 0 \quad (13) \\
ub & = v_b + r_b n_s - s_b n_b - p_b = 0 \quad (14)
\end{align*}
\]

\[
\begin{align*}
\rightarrow p_s & = v_s + r_s p_b - r_b n_s - s_s n_s \quad (15) \\
\rightarrow p_b & = v_b + r_b n_s - s_b n_b \quad (16)
\end{align*}
\]

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

\[
\begin{align*}
\frac{d\pi}{dn_s} & = 0 \quad (17) \\
\frac{d\pi}{dn_b} & = 0
\end{align*}
\]

Using Eq. 11 and Eq. 12, assuming the constraints on the fractions of participants in electronic markets are not binding, the optimal levels of the fractions of participants in electronic markets are as follows.

\[
\begin{align*}
n_s^{\ast} & = \frac{r_s(v_s - p_b) + s_s(v_s - p_b) - r_b(v_b - p_b)}{s_s s_b - r_b r_a + r_a r_b} \\
n_b^{\ast} & = \frac{r_b(v_b - p_s) + s_b(v_b - p_s)}{s_s s_b - r_b r_a + r_a r_b}
\end{align*}
\]

Then the optimal price to maximize the profit of the intermediary is as follows.

\[
p_s^{\ast} = \frac{(r_s - r_b)(s_s + r_a)v_b + (2s_s(s_s + r_a) - r_b(r_s + r_a))v_s}{4s_s(s_s + r_a)(r_s + r_a)^3} \quad (19)
\]
The optimal levels of the fractions of participants in electronic markets with the optimal prices substituted are stated in Eq. 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 Fig.2.

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

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

For the interior solution to hold, the relationships among parameters as in Eq. 21, Eq. 22 and Eq. 23 should satisfy conditions Eq. 11 and Eq. 12.

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

$$4s_b(s_b + r) - (r_s + r_b)^2 > (r_b + r_s)v_b + 2s_b v_b$$ (22)

$$4s_b(s_b + r) - (r_s + r_b)^2 > (r_b + r_s)v_b + 2s_b v_b$$ (23)

From the optimal solutions of price levels and fractions of participants in electronic markets of suppliers and buyers’ types ($p^*_s, p^*_b, n_s^*, n_b^*$) in Eq. 19 and Eq. 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 ($r_s, r_b, v_s, s_s, r_n, v_b, s_b$). As an example, if there is a reduction in switching costs for suppliers ($s_b$), thus causing an increase in their 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 effect ($e_b(n_s)$). This can be seen in Fig.3.

**Fig 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 ($s_b$) from .17 to 1.5. ($s_b = 1$, $v_s = v_b = 2$, $r_s = 4$, $r_b = 2$, $r_n = .05$) Here, both the optimal levels of the fractions of participants in electronic markets are reduced when there is higher difficulty of switching.

In the construction industry, if Internet technologies become wide-spread among suppliers, it will be relatively easier 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 the industry parameters for buyers, the fraction of buyers in the electronic market is increased. In this model, we want to consider and analyze these mutual effects between suppliers and buyers which 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 externalities for the either type ($\frac{\partial n_s^*}{\partial r_s} > 0, \frac{\partial n_s^*}{\partial r_b} > 0$). The negative network externalities have a negative impact on both the suppliers and buyers ($\frac{\partial n_b^*}{\partial r_s} < 0, \frac{\partial n_b^*}{\partial r_b} < 0$). When more information services are provided for either type, the fraction of suppliers in the electronic market increases ($\frac{\partial n_s^*}{\partial v_s} > 0, \frac{\partial n_s^*}{\partial v_b} > 0$). 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 ($\frac{\partial n_s^*}{\partial s_s} < 0, \frac{\partial n_b^*}{\partial s_b} < 0$).

### 3.2. Boundary solution

Now we present boundary solutions which occurs 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 Eq. 9 and Eq. 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. ($n_b = 1, 0 < n_s < 1$), 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 always positive.

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. So 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 A.

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, Eq. 9 and Eq. 10, are binding \((n_s=1, n_b=1)\). Then from the indifference points in Eq. 13 and Eq. 14, we get the optimal price levels.

\[
p_s^* = v_s + r_s - r_u - s_s
\]
\[
p_b^* = v_b + r_b - s_b
\]

Case 2: Buyers’ market is fully covered \((n_b^*=1, 0 < n_s^* < 1)\).

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

\[
p_s = v_s + r_s - r_u - s_s n_s
\]
\[
p_b = v_b + r_b n_b - s_b
\]

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 \(\frac{d \pi}{dn_s} = 0\). Then the optimal price level for suppliers and buyers and the optimal level of the fraction of suppliers in the electronic market are as follows.

\[
p_s^* = \frac{r_s + v_s - r_b - r_u}{2}
\]
\[
p_b^* = \frac{r_b^2 - r_b r_u + r_b r_s - 2 s_b s_s + 2 s_s v_b + r_s v_s}{2 s_s}
\]
\[
n_s^* = \frac{r_s + v_s + v_b - r_u}{2 s_s}, n_b^* = 1
\]

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 as follows.

\[
p_s^* = \frac{r_s + v_s - r_b - r_u}{2 s_b}
\]
\[
p_b^* = \frac{r_b - r_s + v_b}{2}
\]

Case 3: Suppliers’ market is fully covered \((n_s^*=1, 0 < n_b^* < 1)\).

We can see the optimal levels of participants in electronic markets and the optimal price levels for buyers and suppliers in Fig. 4 and Fig. 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 of 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 of suppliers is fully covered, and Case 1 \((n_s^*=1, n_b^*=1)\) applies. As shown in Fig 5, the price can also turn negative. In the real world, this can be interpreted as some subsidy or free services to help suppliers or buyers to participate.
**Fig 5**: Price levels at the interior and boundary cases: The changes of optimal price level with different levels of the strength of network externalities for buyers \((r'_s)\) from 0 to 2.5. \((s_b = s_s = 1, v_b = v_s = 2, r' = 2, r_n = .15)\)

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.

We summarize the boundary solutions of the fractions of participants in electronic markets and price levels as follows.

<table>
<thead>
<tr>
<th>Case (n_s = 1)</th>
<th>(n_b = 1)</th>
<th>(n_s = 1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value (n^*_b)</td>
<td>(0 &lt; n^*_b &lt; 1)</td>
<td>(0 &lt; n^*_b &lt; 1)</td>
</tr>
<tr>
<td>(p_s^*) (v_s + r_s - s_b - r_n) &amp; (\frac{r'_s + v'_s - r'_n}{2s_b}) &amp; (\frac{r'_s + v'_s + v'_n - r'_n}{2s_b})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(p_b^*) (v_b + r_b - s_b) &amp; (\frac{s'_b - s'_n + 2s'_b r'_s}{2r'_s}) &amp; (\frac{s'_b}{2s_b})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(n_s)</td>
<td>(1) &amp; (1)</td>
<td></td>
</tr>
<tr>
<td>(n_b)</td>
<td>(1) &amp; (\frac{n'_s + v'_s + v'_n}{2s_b})</td>
<td></td>
</tr>
</tbody>
</table>

**Table 1**: Boundary solutions of the levels of the fractions of participants in electronic markets and price levels

4. Impact of market conditions on optimal strategies

When there is an interior solution with Eq. 11 and Eq. 12, we can see the relationship between the parameters and optimal price levels.

**Impact of network externalities on price levels**

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

**Proposition 3** When the strength of the network externalities for suppliers \(r_s\) is greater, the price charged to suppliers \(p_s^*\) is higher while the price charged to buyers \(p_b^*\) is lower when the difficulty of switching and the value of services are the same to buyers and suppliers \((s_b = s_s, v_b = v_s)\). Likewise, the same result applies for buyers.

**Proof**. Because there are many mixed effects of several parameters, the direction of the change of optimal price to the change in the relative strengths of network externalities \((r_s, r_b)\) is ambiguous. However, when the difficulty of switching and the value of information services are the same to buyers and suppliers, the changes in \(p_s^*\), \(p_b^*\) are unambiguous. The conditions are stated in Eq. 24.

\[
v_b = v_s = v, s_b = s_s = s, s > r_s, r_b \quad (24)
\]

The first derivatives of network parameters \((r_s, r_b)\) on optimal prices of suppliers and buyers, \(p_s^*\) and \(p_b^*\) in Eq. 22 are:

\[
\frac{\partial p_s^*}{\partial r_s} = \frac{(8s_b s_s - 3r_s^2 - 2r_b r_s) v_s + (4s_s r_s + r_s^3 - 3v_s^2 - 2v_s r_s) s_b s_s}{(4s_b (s_s + r_s) - (r_s + r_b) s)^{2}} > 0
\]

\[
\frac{\partial p_b^*}{\partial r_s} > 0
\]

\[
\frac{\partial p_s^*}{\partial r_b} = \frac{8s_s s_b - 3r_s^2 - 2r_b r_s) v_s + (4s_s r_s + r_s^3 - 3v_s^2 - 2v_s r_s) s_b s_s}{(4s_s (s_s + r_b) - (r_s + r_b) s)^{2}} > 0
\]

\[
\frac{\partial p_b^*}{\partial r_b} > 0
\]

(Q.E.D.)

When the effect of network externalities for a type is greater, the value of the marketplace to that type is
greater. Furthermore, the price charged to that type will be increased \( \frac{\partial p_s}{\partial r_s} > 0 \), \( \frac{\partial p_s}{\partial r_b} < 0 \). Then we may expect that the price for the other type also will be higher because of the indirect effect due to two-sided network externalities. But, counterintuitively, the optimal price for a type is lower when the strength of network externalities for the other type is greater \( \frac{\partial p_b}{\partial r_b} < 0 \), \( \frac{\partial p_b}{\partial r_s} < 0 \). The reason for this result is as follows.

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 \( r_b n_s \) is part of the profit function of buyers. This result 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 \( r_b > r_s \), 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 Eq. 24 hold.

In real life, the price for suppliers to use electronic B2B marketplaces will be lower in the reverse-auction or buyer-favored marketplaces compared to that at the forward-auction or supplier-favored marketplaces. The reason why buyers favor reverse auction and suppliers favors the forward auction is that reverse auction mechanism intensifies the price competition among suppliers and forward auction mechanism enables greater competition among buyers. For example, Citadon, Inc. runs a buyer-favored B2B marketplace \( (r_b > r_s) \) in the construction industry using reverse-auctions. The price to buyers for using this marketplace is likely to be higher than that charged by other marketplaces that are not buyer favored \( (r_s > r_b) \). Similarly, the suppliers in such a marketplace are likely to pay a lower price compared to marketplaces that are supplier favored. In comparison, e-STEEL which is a forward-auction based neutral B2B marketplace in the steel industry, only charges transaction fees proportional to the transaction amounts to suppliers while buyers pay nothing.

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

**Proposition 4** This proposition is about the impact of changes in the strength of the negative externalities of suppliers’ side \( (r_s) \) on the optimal price levels of the marketplace.

1. **(1)** When the strength of network externalities for buyers is greater than that for suppliers \( (r_b > r_s) \), then the price for suppliers (buyers) is higher (lower) if the strength of the negative externalities due to competition among suppliers \( (r_b) \) increases.

2. **(2)** When the strength of network externalities for buyers is smaller than that for suppliers \( (r_b < r_s) \), then the price for suppliers (buyers) is lower (higher) if the strength of the negative externalities among suppliers \( (r_b) \) increases.

From the first derivatives of the parameter of negative network externalities \( (r_b) \) on the optimal prices \( (p_s^*, p_b^*) \) as in Eq. 19, we can see these somewhat counterintuitive results. We may expect that, because of the greater negative network externalities 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 \( r_b \) increases. The reason is as follows.

There are two opposing effects stated in (1) and (2) below. Consider the intermediary’s optimal prices when the negative network effect is small as in the left region of Fig. 6 and when suppliers’ participation is more valuable \( (r_b > r_s) \) Case.

1. **(1)** As discussed previously, when \( r_b > r_s \), the intermediary lowers \( p_s \) to encourage the participation of suppliers and raises \( p_b \) relatively.

![Fig 6: Price levels with different levels of negative network externalities](image)

The changes of optimal prices with different level of negative network externalities \( (r_s) \) from 0 to 1. \( (s_s = s_b = 1, v_s = v_b = 2, r_b = 0.2, r_s = 0.8) \) Here, the difference between prices is reduced when the strength of negative network externalities increases.
However, when the strength of the negative network effect increases, there is a reduction of the value of network externalities because the increased negative network externalities offset the value of the positive network externalities on both the side of suppliers and buyers. So, 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 is as follows. Due to the greater negative effect, the effect of positive network externalities is lower. So, for the intermediary, the incentive to lower the price for suppliers to attract them is reduced when the positive effect of network externalities is reduced. When the marketplace is 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 of the marketplace is:

(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 externalities 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 externalities 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 service levels (\( v_S \), \( v_B \)) on the optimal prices (\( p_S^* \), \( p_B^* \)) as in Eq. 22, this proposition can be easily proven. When the value of the information services for a type is greater, the value of the marketplace to that type is greater. Also, the price charged to that type will be increased (\( \frac{\partial p^*_B}{\partial v_B} > 0 \), \( \frac{\partial p^*_S}{\partial v_S} > 0 \)). Then we may expect that the price for the other type also will be higher because the greater value of one type increases the value of the other type by indirect effect. But, counterintuitively, the optimal price for a type is lower when the value of the information services of the other type is greater if the strength of network externalities of the type is greater than that for the other type. The reason for this result is as follows.

The increase in \( v_B \) has two opposing effects on \( p_B^* \): (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 \( p_S \) to increase \( n_S \) to maximize its profit by manipulating the size of \( n_S \) and \( n_B \).

Specifically, when \( r_B \) is greater than \( r_S \), the second effect dominates and the intermediary reduces \( p_S \).

For example, when more information services are provided for suppliers, more suppliers join the marketplace and the intermediary can charge higher price to suppliers. But the intermediary should carefully consider the pricing decision for the price charged to 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 for buyers are provided, 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 are different with the different levels of difficulty of switching \(s_s, s_b\). Intuitively, when switching to electronic marketplace is more difficult, the value of the marketplace and the price of it are expected to be lower. But, in some cases, the price levels are higher with higher difficulty of switching. The following is the proposition about the impact of switching difficulty of both suppliers and buyers’ sides 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 externalities 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, \(s_s\) and \(s_b\), increases.

2. When the strength of network externalities 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, \(s_s\) and \(s_b\), increases.

From the first derivatives of the switching cost parameters \(s_s, s_b\) on the optimal prices \(p^*_s, p^*_b\) as in Eq. 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. The reason is as follows.

![Fig 7: Price levels with different levels of the difficulty of switching](image)

The changes of optimal prices with different levels of the difficulty of switching for suppliers \(s_s\) from .17 to 1.5 \((s_s = 1, v_s = v_b = 2, r_s = .4, r_b = .2, r_s = .05)\). Here, the difference between prices is reduced when there is higher difficulty in switching.

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 Fig. 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 externalities because the increased difficulty of switching reduces the effect of network externalities by reducing the optimal numbers of suppliers and buyers who participate in the marketplace \((n'_s, n'_b)\). So, 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 the propositions discussed in section 4.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>(p^*_s)</th>
<th>(p^*_b)</th>
<th>Assumptions</th>
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<td>-</td>
<td>(s_s = s_b)</td>
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<tr>
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<td>-</td>
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</tr>
<tr>
<td>(s_b)</td>
<td>-</td>
<td>+</td>
<td>when (r_s &gt; r_b)</td>
</tr>
</tbody>
</table>

Table 2: Summary of propositions of section 4

Impact of parameters on price levels 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 \( (\omega_i \text{ or } \omega_j) \) is fully covered, the incentive to reduce price for the type with a higher value of participation (buyer if \( r_s > r_p \), supplier if \( r_b > r_s \)) to attract the type does not exist any more. For example, when buyers’ market is fully covered \( (n_b^1 = 1, n_s^1 < 1) \), the price for buyers \( (p_b) \) increases when the intensity of network externality on suppliers \( (r_s) \) increases in the case of boundary solution while the price for buyers decreases in the interior solution. Because already all buyers have participated in the marketplace \( (n_b^* = 1) \), there is no more need for the intermediary to reduce the price charged to buyers to attract them.

5. Conclusion

Our theoretical analyses have shown that the existence of network externalities and the mutual effect of the buyer’s market on the supplier’s market and vice versa affect the optimal pricing strategy and optimal levels of participants in electronic markets of B2B intermediaries. From 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 the two types: suppliers and buyers in the electronic marketplace are dependent on the parameters that define the two types. In other words, an impact on the conditions of one type also affects the fractions of participants in electronic markets and price levels of the other type because of the existence of two-sided network effects. Also, when the relative strength of network externalities of a certain type is greater, that type pays a higher price to the B2B intermediary. Thus the type, either buyer or supplier, to whom the network externalities or aggregation benefit is more important compared to the other type, would pay more to the B2B marketplace and exploit the competition among the other type. When the information service for a type is more valuable, the price charged to that type is higher. But the impact of the different levels of information service on the price charged to the other type depends on the relative strength of the network effect. For example, in reverse-auction based, buyer-favored marketplace, we can expect that the price charged to suppliers will be higher when more information services are provided for buyers leading to greater participation of the buyers. But, counterintuitively, since the value of participation of suppliers to the electronic marketplace is more valuable than the participation of buyers in a buyer favored marketplace, therefore the intermediary should lower the price charged from suppliers to attract more suppliers. Our results including this example suggest that intermediaries should have a broader vision in designing their marketplaces to increase their profits in electronic marketplaces.

In this research, 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. We also hope to analyze a duopoly model which incorporates competition between intermediaries in electronic markets in our future research. Due to some 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 think the propositions developed in this model are applicable to such real-world situations. Also, we hope to analyze different ownership structures of B2B marketplaces which involve suppliers and buyers who own the marketplace. From these extensions, we expect 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.

6. References

A Proof for infeasibility of zero fractions of participants in electronic markets (n_s, n_b=0)

**Proof.** As we know, 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.

\[ u_{s|n_s=n_s} = v_s + c_s(n_b) - c_b(n_s) - s_s n_s - p_s = 0 \]
\[ \rightarrow p_s = v_s + r_s n_b - r_b n_s - s_s n_s^* \]
\[ u_{b|n_b=n_b} = v_b + c_b(n_s) - s_b n_b - p_b = 0 \]
\[ \rightarrow p_b = v_b + r_b n_s^* - s_b n_b^* \]

The profit function of the intermediary can be shown as follows.

\[ \pi = p_s n_s + p_b n_b = (v_s + r_s n_b^* - r_b n_s^* - s_s n_s^*) \cdot n_s^* \]
\[ + (v_b + r_b n_s^* - s_b n_b^*) \cdot n_b^* \]

Then if we differentiate the profit function by the fraction of participants in electronic markets of 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 Eq. 25 and Eq. 26. So we can see that, as far as the information service levels (v_s, v_b) are positive, the optimal levels of the participants in electronic markets should be always positive.

\[ \frac{d\pi}{dn_s} = (v_s + r_s n_s^*) - 2 s_s n_s^* + r_b n_s^* = 0 \] (26)
\[ \rightarrow n_s^* = \frac{r_s n_s^* + v_s + r_b n_s^*}{2 (s_s + r_s)} \quad \text{(Substituted into } \pi \text{ equation)} \]
\[ \rightarrow \frac{d\pi}{dn_s} = \frac{r_s n_s^* + v_s + r_b n_s^*}{2 s_s} = 0 \]
\[ \rightarrow n_s^* = \frac{(r_s + r_b)}{2 (s_s + r_s)} v_s + v_b > 0 \]

(Q.E.D.)