Internet Exchange Formation and Competition When Potential Participants Can Coodinate

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Abstract

We analyze the formation and competition of market intermediaries when there are positive participation externalities between the two sides of the market; negative participation externalities within the same side; competition with traditional market; and implicit coordination among potential participants. The impact of implicit cooridination is studied in two ways. First, we develop both static models–which are appropriate when the number of potential participants is large–and dynamic models–which are appropriate when a limited number of participants observe each other's choices. Potential participants can better coordinate their decisions in the dynamic participation process. Second, we assume that participation decisions are coordinated by a "pessimistic belief" about formation or entry of a new intermediary. In order to overcome the pessimism, the owner of an intermediary has to offer a fee schedule that implements her preferred outcome as the unique (subgame-perfect) Nash equilibrium outcome. The theory explains when and in which direction "cross-subsidization" strategies appear and when the incumbent intermediary can deter entry profitably.

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1 Introduction

In the early summer of 2001, the Financial Times reported widespread suspicions about the suitability of business-to-business (B2B) exchanges for the airline industry. In the article, one consultant commented that suppliers "continue to be reluctant to sign up to portals and other e-mechanisms created by the prime contractors. The key reason for this is that the primary objective of e-procurement is perceived to be a reduction in the purchase price, therefore forcing pressures on [supplier] margins." (see Odell [22]). This outcome, should it obtain, may not be unique to the airline industry. By the beginning of 2001, about 1,600 B2B exchanges had been launched or announced. Yet by the summer of the same year, over 400 B2B exchanges already had shut down and countless more exchanges never materialized [18]. Of the surviving exchanges, only about 100 B2B exchanges handled any genuine transactions in the following few years according to market sources and some predict that perhaps as few as a handful of exchanges may survive in the long-run (see Cronin[10]).

Internet exchanges create a dilemma for suppliers. Although B2B exchanges can reduce transaction costs, suppliers may not capture any of these savings and, worse still, may face increased pricing pressure. Yet, suppliers that don't join may lose substantial business opportunities if many other suppliers join. Therefore, suppliers' refusal to participate in internet exchanges may hinge on their expectation of the participation decision of other suppliers. Such implicit coordination among suppliers implies that the study of coordination among potential participants is key to understanding whether Internet intermediaries form or not, or whether new intermediaries enter to compete against incumbents.

The study of coordination problems may arise in a broad class of what are referred to as two-sided markets. Examples of two-sided markets are numerous: newspapers and TV networks (readers or viewers and advertisers), matchmaking services (men and women), credit card networks (cardholders and merchants), text processing software (writers and readers), browsers (users and web servers), shopping malls (consumers and shops). [1] Common among internet intermediaries and these markets is not only the presence of two groups of customers for the services–buyers and sellers in case of market intermediaries–but also that higher participation of one group yields positive externalities for the other group. This externality raises the

[1] Rochet and Tirole [24] provide a longer list of two-sided markets.

so-called "chicken or egg" problem. In order to attract one group, an intermediary needs participation from a large number of the other group, who in turn are willing to participate only if they expect the former group to do so, too. How to resolve this conundrum is the central challenge for intermediaries, which affects not only how and whether it forms but also how it competes with future entrants.

Resolving this conundrum, we assert, depends critically on a number of market features that are not fully considered by the extant literature. Although past research on market intermediaries has produced many welfare analyses of intermediary design and illuminated the multiplicity of equilibria, models have neglected possible coordination issues among potential participants and the exchange owner's attempts to ensure its formation.

This paper investigates the fundamental economic logic behind the formation of and competition among internet intermediaries by considering the effect of these ignored but salient market features. First, we investigate negative externalities within the same group. If more men register with a matchmaking service, for instance, each man has a lower chance finding a desirable woman given a fixed number of women. If more people sell Britney Spears' CDs on eBay, each seller receives fewer bids given the fixed number of buyers. If more suppliers sign up for a B2B exchange, the chance of winning a bid declines for each supplier. When negative externalities within one group is greater than those in the other group, they affect the exchanges' optimal connection fee schedule, and thus, the way the efficiency gain from exchange formation is allocated among the parties. Such externalities also can effect the number of exchanges. For instance, when potential participants cannot coordinate their decisions, negative externalities could potentially cause two exchanges to coexist when markets are thick enough as shown in Ellison, Fudenberg and Mobius [14].[2]

In our work, unique implementation and dynamic participation process (in a dynamic game), which are explained later, help eliminate coordination failures. However, even with some coordination capability among potential participants, a pure strategy subgame-perfect Nash equilibrium for which the "first-mover" exchange successfuly forms and stays in the market may not exist in our dynamic competition game, when negative externalities within

[2] Auction sites in their model do not have gatekeepers who collect fees, and thus no pricing problem appears in their work.

one group are siginificant.

Second, the formation of a new intermediary may impose negative externalities on some nonparticipants, too. For instance, as more buyers engage in transactions in a B2B exchange, suppliers who do not join the B2B exchange have fewer business opportunities in the traditional market. Such negative externalities, which often characterize new intermediaries from other two-sided markets, create an opportunity for the intermediary owner to exploit more rent from participants than is generated by its formation. However, this same externality also generates incentives to potential participants to resist the formation of the exchange.[3]

Third, as we have suggested earlier, potential participants may be able to coordinate their participation choices even when they cannot explicitly communicate with each other. It is well known that markets with externalities often exhibit multiple equilibria. Potential participants can have various self-fulfilling expectations about whether others join or which intermediary they choose. Extant research on markets with externalities simply assume that the principal (e.g., owner of the intermediary, provider of the service, etc.) can achieve her preferred equilibrium or study the set of equilibria without asking how the principal can achieve the most preferred one (for example, see Segal [25], Baye and Morgan [3]) or discuss what scheme will induce the preferred equilibrium (Caillaud and Jullien [6] discuss transaction fees and Dybvig and Spatt [11] propose government intervention).[4] We investigate the effect of coordination among potential participants by assuming that potential participants always try to coordinate on the worst outcome for the exchange owner (*i.e.,* no participation), which is equivalent to requiring unique (subgame-perfect) Nash implementation, and by introducing a dynamic participation game, which we elaborate below.

We develop both static models–which are appropriate when the number of potential participants is large–and dynamic models–which are appropriate when a limited number of partic-

[3] Negative externalities on nonparticipants create an incentive for price discrimination because the intermediary can appropriate more rents from late adopters who have fewer outside opportunities than early adopters. See Owan and Nickerson [23] for the analysis.

[4] The only exception is Ambrus and Argenziano [2], who introduce the notion of coalitional rationalizability to rule out unreasonable expectations. The main idea is that players can coordinate on restricting their play to subset of the original strategy set if it is in the interest of every participants to do so. Such restriction typically eliminates the null equilibrium in which nobody joins in the market with positive externalities but still does not determine the equilibrium uniquely.

ipants observe each other's choices–to incorporate the market features described above. Each static and dynamic model we develop considers two cases: monopoly and competition. In the spirit of Segal [26], we look at the intermediary owner as the designer of a participation game and require her to implement full participation–the intermediary owner's preferred outcome–in the unique Nash equilibrium (or as the unique subgame-perfect Nash equilibrium outcome). In other words, we assume that participation decisions are coordinated by a "pessimistic belief" about formation or entry of a new intermediary. With this restriction on belief, formation attempts always fail if there are multiple equilibria, including one in which no firm participates. Hence, the owner of an intermediary has to offer a fee schedule that implements her preferred outcome as the unique (subgame-perfect) Nash equilibrium outcome to overcome the pessimism.

Our primary result in the static model is that unique implementation implies "cross-subsidization," which is required to "divide and conquer" potential participants in response to a possible coordination failure.[5] The exchange can overcome pessimistic expectations only by offering a subsidy to one side of the market. In the case of exchange competition, we show that any attempt by an entrant to capture participants from the incumbent ends up with "multihoming" by one group of firms (*i.e.,* the group connects to both exchanges). One subtle but important attribute of exchanges is whether the connection to the exchange implies the ability of multihoming participants to aggregate information from multiple exchanges for each transaction. If this is the case, two exchanges face perfect price competition among the non-multihomong participants (e.g., suppliers) when multihoming participants (e.g., buyers) can always find the best matching automatically. Then, the incumbent, even if it successfully forecloses entry, receives zero profit. In contrast, the incumbent can deter entry profitably when multihoming participants have to "pre-select" the exchange where transactions take place.

Our dynamic game models coordination capability among potential participants by allowing them to condition their decisions on decision made by others. For example, potential participants can adopt a "trigger strategy" (*e.g.,* do not join if no others join but join if

[5] If price discrimination within the same group is allowed, the level of "cross-subsidization" should be much smaller than is required here because the intermediary owner can subsidize only early adopters. As a result, price discrimination gives more surplus to the owner. See Owan and Nickerson [23] for more detailed analysis.

some join.). The trigger strategy effectively rules out the formation of an intermediary that makes one or both groups of participants worse off. No prior paper analyzes participation in two-sided markets in a dynamic setting. This modeling limitation automatically restricts the ability of potential participants to coordinate decisions because they are forced to make decisions without knowing the others' choices.

Coordination through a dynamic participation process has substantial impacts on both monopoly and competition cases. First, it increases monopoly profit by eliminating coordination failures; the monopolist does not need to offer cross-subsidization when negative externalities within the same group are limited. Second, although coordination through a dynamic participation process does not remove the risk of early adopters choosing a wrong exchange (and coordination failures still remain in choosing an exchange), the incumbent exchange could still foreclose entry profitably because it can set both buyer and supplier connection fees positive but low enough so that the entrant can not profitably subsidize participants.

Our dynamic model findings for the competition case are in contrast with Caillaud and Jullien [6][8], who conclude that a monopolist can foreclose entry only when they can use exclusivity contracts. The difference is due to our consideration of positive costs of connection which allow the incumbent exchange to offer positive fees.

The paper proceeds by first introducing the model of internet intermediaries in Section 2. We present a number of assumptions on externalities that best represent B2B exchanges. In Section 3, we discuss our static game and show how "coordination-failure-free" connection fee schedule is different from that in simple Nash implementation when potential participants cannot coordinate at all. Then, we discuss the optimal fee schedule and the possibility of profitable entry deterrence when the exchange is facing the threat of entry. In section 4, we demonstrate how an increasing level of coordination among potential participants (i.e., from a static model to a dynamic model) affects the optimal fee schedule and how competition affects the result. Section 5 discusses the possible extension to explore the role of additional instruments such as exclusivity contracts and the ownership structure in deterring entry. We conclude in section 6.

2 Model

We develop below a model of market intermediary that represents auction-based B2B exchanges. So, let us call the intermediary an *exchange* and assume that there are N_B homogeneous buyers and N_S homogeneous suppliers in the market. If interested in developing implications for regular internet auction sites such as eBay, simply replace buyers with sellers and suppliers with buyers because bidders are suppliers in reverse auctions used in most B2B exchanges. Assume there is a monopolist exchange or two competing exchanges with the same technology. For the moment, we consider the monopoly case. Let t_B and t_S be the connection fee charged by the monopolist exchange on buyers and suppliers, thus fees are uniform among those in the same group. We assume symmetric revenue functions in the sense that participants' revenues depend only on the numbers of buyers and suppliers in the exchange and all buyers (or suppliers) who make the same decision receive the same revenue: $u_B(x_i, X, Y)$ and $u_S(y_j, X, Y)$ where $x_i, y_j \in \{0, 1\}$ are the participation decisions made by buyer i and supplier j and X and Y are the number of buyers and suppliers who participate in the exchange. $x_i = y_j = 1$ indicates "join" and $x_i = y_j = 0$ "not join". Hence, the payoff for each participating buyer is $u_B(1, X, Y) - t_B$ while each participating supplier gets $u_S(1, X, Y) - t_S$. Revenues for nonparticipants are $u_B(0, X, Y)$ and $u_S(0, X, Y)$. We assume that the exchange incurs marginal costs c_B and c_S for connection of each buyer and supplier, respectively, thus its profit is $X(t_B - c_B) + Y(t_S - c_S)$. We assume c_B and c_S are sufficiently small so that none of the optimal fee schedules derived in the analysis of monopoly leads to negative profit. The marginal costs may include the one-time cost of necessary changes in the exchange database, installation of computer hardware and software for the supplier, and training personnel for the new technology.

We do not assume any micro-mechanism that gives us a specific form of $u_B(x_i, X, Y)$ and $u_S(y_j, X, Y)$ in generating our results but the reader can always consider a broad class of revenue functions (for example, see an auction model used in Ellison, Fudenberg and Mobius [14]) to obtain implications for specific contexts.

The following assumptions capture the properties of auction-based B2B exchanges.

(A1) $u_B(1, X, Y) \geq u_B(0, X-1, Y)$ and $u_S(1, X, Y) \geq u_S(0, X, Y-1)$ for all X and Y. $u_B(1, X, Y) > u_B(0, X-1, Y)$ and $u_S(1, X, Y) > u_S(0, X, Y-1)$ if and only if $Y \geq 1$ and

$X \geq 1$, respectively. $u_B(1, X, 0) = u_B(0, X, 0) = u_B(0, 0, Y) = u_B(0, 0, 0)$ and $u_S(1, 0, Y) = u_S(0, 0, Y) = u_S(0, X, 0) = u_S(0, 0, 0)$.

(A2) $u_B(1, X, Y)$ is non-increasing in X and non-decreasing in Y. $u_S(1, X, Y)$ is non-increasing in Y and non-decreasing in X.

(A3) $u_B(0, X, Y)$ and $u_S(0, X, Y)$ are non-increasing in X and Y.

(A4) $u_B(1, X, Y) - u_B(0, X-1, Y)$ is non-increasing in X and $u_S(1, X, Y) - u_S(0, X, Y-1)$ is non-increasing in Y.

(A5) The aggregate surplus for the exchange and its participants, $X(u_B(1, X, Y) - u_B(0, 0, 0) - c_B) + Y(u_S(1, X, Y) - u_S(0, 0, 0) - c_S)$, is the largest when $X = N_B$ and $Y = N_S$.

Because the buyers in the exchange can always conduct traditional procurement auctions and the suppliers in the exchange always have access to them, connection to the exchange should not reduce their revenue as is indicated by (A1). (A1) suggests that the exchange creates some value whenever it has at least one buyer and one supplier. (A2) posits positive externalities in participation between buyers and suppliers and negative externalities within the same groups. Why are there negative externalities? Buyers may be competing for better suppliers who have capacity constraints and cannot serve many buyers. As more buyers participate in the exchange, each has less a chance of buying from such lowest-cost suppliers. Likewise, as more suppliers participate in the exchange, auction mechanism or competition reduces the profit margin for the suppliers. (A3) indicates negative externalities on non-participants, namely, as more transactions shift to the exchange, those outside of the exchange participate in fewer trades.[6] (A4) states that buyers (suppliers) are less eager to join the exchange as more buyers (suppliers) participate in the exchange. Because of the negative externalities on non-participants, (A4) is not a direct corollary of (A2). (A4) is what Segal [26] called *decreasing externalities* within groups: buyers (suppliers) have *less* incentive to join the exchange as more buyers (suppliers) participate. Note that (A2) and (A3) jointly imply *increasing externalities* between groups: buyers (suppliers) have *more* incentive to join the

[6] There may be situations where $u^B(0, X, Y)$ is increasing in X or $u^S(0, X, Y)$ is increasing in Y because there will be less competition among buyers and suppliers in traditional markets as more of them move to the new intermediary. (A3) is sufficient but not necesary to derive the results for which we use (A3). Alternatively, we can assume that $u_B(0, X, N_S) \leq u_B(0, 0, 0)$, $u_S(0, N_B, Y) \leq u_S(0, 0, 0)$ and $X(u_B(0, 0, 0) - u_B(0, X-1, Y)) + Y(u_S(0, 0, 0) - u_S(0, X, Y-1))$ is non-decreasing in X and Y.

exchange as more suppliers (buyers) participate. (A5) implies increasing returns to scale in internet intermediaries, which appears to be a reasonable assumption for most of them. Note that (A5) does not necessarily imply that the full participation is socially efficient because the efficient outcome maximizes the social surplus $X(u_B(1,X,Y)-c_B)+(N_B-X)u_B(0,X,Y)+Y(u_S(1,X,Y)-c_S)+(N_S-Y)u_S(0,X,Y)$.

One problem we encounter in solving the games described later is the multiplicity of equilibria. And, it is often the case that the B2B exchange owners' preferred equilibrium is different from the one preferred by some group of firms. When potential participants have some capability to coordinate their decisions, the B2B exchange's preferred equilibrium may not obtain. To avoid this problem, we require in the spirit of Segal [26] that the B2B exchange owner design its offers so as to implement its preferred outcome as the unique (subgame-perfect) Nash equilibrium outcome. In the static simultaneous-move game, we require the outcome to be implemented in the unique Nash equilibrium and, in the dynamic participation game, we require that the unique outcome results in every subgame-perfect Nash equilibrium. In section 3 and 4, we discuss the basic results in both monopoly and competition case.

3 Static Participation Game

3.1 Monopoly

In the static game, timing of the decisions is as follows: In the first stage, the B2B exchange makes offers to all buyers and suppliers in the market. We do not allow price discrimination, which is analyzed in Owan and Nickerson [23]. In the second stage, buyers and suppliers simultaneously decide whether to participate in the exchange or not. We rule out mixed strategies from the discussion because unique implementation eventually eliminates all mixed strategy equilibria. We assume that each potential participant, before making decisions, can observe offers made to the other group.

First, we consider simple Nash implementation. Since the strategy space for firms is {join, not join}, incentive compatibility constraints are identical to participation constraints. The constraints are

$$\begin{aligned} u_B(1,X,Y)-t_B &\geq u_B(0,X-1,Y) \\ u_B(1,X+1,Y)-t_B &\leq u_B(0,X,Y) \end{aligned} \tag{1}$$

and

$$\begin{aligned} u_S(1,X,Y)-t_S &\geq u_S(0,X,Y-1) \\ u_S(1,X,Y+1)-t_S &\leq u_S(0,X,Y). \end{aligned} \tag{2}$$

Suppose the B2B exchange believes it can coordinate firms on its preferred equilibrium when there are multiple equilibria. Then, the exchange solves the following problem:

$$\max_{0\leq X\leq N_S, 0\leq Y\leq N_S, t_B, t_S} \Pi^{ex} = X(t_B - c_B) + Y(t_S - c_S) \tag{3}$$
s.t. (1) and (2).

Note that, because of the within-group negative externalities (A2), the first inequalities of (1) and (2) will bind. Otherwise, the exchange owner can always increase her profit by raising the connection fee. Hence, the exchange owner solves

$$\max_{0\leq X\leq N_B, 0\leq Y\leq N_S} \Pi^{ex} = X(u_B(1,X,Y)-u_B(0,X-1,Y)-c_B)+Y(u_S(1,X,Y)-u_S(0,X,Y-1)-c_S). \tag{4}$$

Our first proposition shows that $X^* = N_B$ and $Y^* = N_S$ and the exchange extracts all or more than the surplus created by its formation. The critical problem neglected so far is how the exchange owner can ensure that her preferred equilibrium is selected. The proposition confirms the well-known problem of multiple equilibria in the market with positive externalities.

Proposition 1 *In the static game with a monopoly, if unique implementation is not required,* $X^* = N_B$ *and* $Y^* = N_S$ *and the optimal connection fees are* $t_B^* = u_B(1, N_B, N_S) - u_B(0, N_B - 1, N_S) > 0$ *and* $t_S^* = u_S(1, N_B, N_S) - u_S(0, N_B, N_S - 1) > 0$. *Let* S *be the surplus created by the formation of the exchange. Then, the profit of the exchange* $\Pi^{ex} \geq S$. *The strict inequality holds when there are strict negative inequalities on non-participants. However, there is always another equilibrium in which no buyer and supplier participates.*

Proof. To show the first half, see

$$\begin{aligned}\Pi^{ex} &= X(u_B(1,X,Y)-u_B(0,0,0)-c_B)+Y(u_S(1,X,Y)-u_S(0,0,0)-c_S)\\ &\quad +X(u_B(0,0,0)-u_B(0,X-1,Y))+Y(u_S(0,0,0)-u_S(0,X,Y-1))\end{aligned}$$

where the first two terms are maximized when $X^*=N_B$ and $Y^*=N_S$ from (A5). Since $u_B(0,X-1,Y)$ and $u_S(0,X,Y-1)$ are non-increasing in X and Y from (A3), the last two terms are maximized when $X^*=N_B$ and $Y^*=N_S$, too. Since the first inequalities of (1) and (2) are binding, $t_B^*=u_B(1,N_B,N_S)-u_B(0,N_B-1,N_S)>0$ and $t_S^*=u_S(1,N_B,N_S)-u_S(0,N_B,N_S-1)$. Then,

$$\begin{aligned}\max\Pi^{ex} &= N_B(u_B(1,N_B,N_S)-u_B(0,N_B-1,N_S)-c_B)\\ &\quad +N_S(u_S(1,N_B,N_S)-u_S(0,N_B,N_S-1)-c_S)\\ &\geq N_B(u_B(1,N_B,N_S)-u_B(0,0,0)-c_B)+N_S(u_S(1,N_B,N_S)-u_S(0,0,0)-c_S)\\ &= S.\end{aligned}$$

To show the second half, from (A1),

$$\begin{aligned}u_B(1,1,0)-t_B^* &= -t_B^*<0\\ u_S(1,0,1)-t_S^* &= -t_S^*<0,\end{aligned}\tag{5}$$

which imply that $(X,Y)=(0,0)$ is a Nash equilibrium. This concludes the proof. ∎

When there are more than two equilibria, they can be fully ranked by the following order: $(X^1,Y^1)>(X^2,Y^2)$ iff $X^1\geq X^2$ and $Y^1\geq Y^2$ where one of the inequalities is strict inequality. This property comes from the positive externalities between groups. We call the equilibria with maximum participation *maximum equilibrium* and the one with no participants *null equilibrium*. The maximum equilibrium certainly maximizes the profit of the exchange owner so it is her most preferred equilibrium. Which one is more likely to prevail? Note that $u_B(1,N_B,N_S)-t_B^*=u_B(0,N_B-1,N_S)\leq u_B(0,0,0)$ and $u_S(1,N_B,N_S)-t_S^*=u_S(0,N_B,N_S-1)\leq u_S(0,0,0)$ from (A3). When either buyers and suppliers are strictly worse off by the formation of the exchange, simple cheap talk will be enough to block the maximum equilibrium. More formally, the notion of coalition-proof Nash equilibrium proposed by Bernheim, Peleg and Whinston [4] rules out the maximum equilibrium when there are negative externalities on non-participants.[7]

Even if both buyers and suppliers are better off by the formation of the exchange, coordination failures may appear if there is some uncertainty about the rationality of potential participants or the payoffs from outcomes.[8] Our requirement of unique implementation is justified when all potential participants have the following "pessimistic belief" about the formation of a new exchange:

(PB1) Potential participants assign zero probability to "join" for the decision made by another firm whenever "not join" is rationalizable.

We impose this restriction on the belief system for the rest of the paper. When the suppliers' decisions are coordinated by the belief (PB1), the exchange owner needs to offer lower connection fees than are specified in Proposition 1 to ensure full participation. Since the null equilibrium exists as long as both t_B and t_S are non-negative (5), unique implementation requires cross-subsidization, namely, either $t_B < 0$ or $t_S < 0$. Suppose $t_S < 0$. Then, "join" is a strictly dominant strategy for all suppliers because $u_S(1, X, Y) - t_S > u_S(0, X, Y - 1)$ for any X and Y. Given the full supplier participation, exactly X buyers will participate if $u_B(1, X, N_S) - u_B(0, X-1, N_S) > t_B > u_B(1, X+1, N_S) - u_B(0, X, N_S)$. Hence, we also call this pricing strategy the "divide and conquer" strategy.

One technical issue is the "open set" problem encountered in the study of unique implementation.[9] Since the set of fee offers $\{(t_B, t_S)\}$ that implements the maximum participation uniquely is not closed, the exchange owner has no profit-maximizing outcome. By taking the closure of the set, or in other words, considering the set of nearly uniquely implementable outcomes, we can identify the "nearly optimal" connection fees. Here, the "nearly optimal" connection fees are $t_B = u_B(1, X^*, N_S) - u_B(0, X^* - 1, N_S)$ and $t_S = 0$ for X^* that maximizes $X(u_B(1, X, N_S) - u_B(0, X-1, N_S) - c_B) - N_S c_S$.

[7] A coalition-proof Nash equilibrium is a Nash equilibrium and requires that no coalition is able to make a mutually advantageous deviation from the equilibium strategy profile in a self-enforcing way (*i.e.,* the deviation is a Nash equilibrium in the fictitious game imposed on the coalition by fixing the strategies for the complement of the coalition, and no subcoalition in the coalition can make profitable deviaitons from the deviation).

[8] The stag-hunt game, which is a good illustration of the issue, is discussed in Harsanyi and Selton [19].

[9] See the similar discussion in [26].

Since the free connection for suppliers prevents the exchange owner from appropriating any positive externalities of buyer participation on suppliers, it is possible that $X^* < N_B$, namely, full participation may not be optimal for the exchange owner even if it is efficient.

The most important managerial question is which side of the market should be subsidized? It is determined by the maximum economic rent that the exchange owner can extract from each side in the maximum equilibrium. The supplier side should be subsidized if and only if

$$\begin{aligned} & \max_X X(u_B(1, X, N_S) - u_B(0, X-1, N_S) - c_B) - N_S c_S \\ > \; & \max_Y Y(u_S(1, N_B, Y) - u_S(0, N_B, Y-1) - c_S) - N_B c_B. \end{aligned}$$

We summarize the result in the next proposition.

Proposition 2 *An outcome with the maximum participation, namely $X^* = N_B$ or $Y^* = N_S$, can be implemented as the unique Nash equilibrium if and only if $t_S < 0$ or $t_B < 0$. In the former case, $t_B < u_B(1, X^*, N_S) - u_B(0, X^* - 1, N_S)$ for X^* that solves $\max_X X(u_B(1, X, N_S) - u_B(0, X-1, N_S) - c_B)$ while in the latter case, $t_S < u_S(1, N_B, Y^*) - u_S(0, N_B, Y^* - 1)$ where Y^* solves $\max_Y Y(u_S(1, N_B, Y) - u_S(0, N_B, Y-1) - c_S)$. $t_S < 0$ $(t_B < 0)$ is optimal when $\max_X X(u_B(1, X, N_S) - u_B(0, X-1, N_S) - c_B) - N_S c_S > (<) \max_Y Y(u_S(1, N_B, Y) - u_S(0, N_B, Y-1) - c_S) - N_B c_B$.*

It is worth repeating the main findings in Proposition 2: (1) although cross-subsidization prevents coordination failure, it may also lead to an inefficient number of participants; and (2) the side of the market with greater within-group negative externalities should be subsidized. Furthermore, note that firms in at least one side of the market are worse off by joining the exchange. For example, suppose $t_B \fallingdotseq u_B(1, X^*, N_S) - u_B(0, X^* - 1, N_S)$ and $t_S \fallingdotseq 0$. Then, from (A3)

$$u_B(1, X^*, N_S) - t_B \fallingdotseq u_B(0, X^* - 1, N_S) \leq u_B(0, 0, 0),$$

where the strict inequality holds when there are strict negative externalities on nonparticipants. Suppliers who are subsidized could also be worse off if the within-group negative externalities for suppliers are significant and $u_S(1, X^*, N_S) - t_S \fallingdotseq u_S(1, X^*, N_S) < u_S(0, 0, 0)$. Therefore, the unique implementation may not necessarily solve potential conflicts of interests among potential participants and the exchange owner.

3.1.1 Competition

In this section, we study Stackleberg price competition between two exchanges, labelled $k = I$ (leader or incumbent) and E (follower or entrant), which have the same technology described in the previous sections. The timing of the game is as follows: in the first stage, exchange I announces its fixed connection fee schedule $t^I = (t^I_B, t^I_S)$; in the second stage, exchange E announces its fee schedule $t^E = (t^E_B, t^E_S)$; and in the final stage, all buyers and suppliers decide simultaneously whether and in which exchange to participate if any. The fee schedules are publicly observable.

We allow both buyers and suppliers to be connected to both exchanges because internet intermediation services usually are not exclusive. Following terminology found in the literature, we say that participants "multihome." Exclusivity contracts that do not allow multihoming are shown to help the incumbent firm to earn positive profits in Calliaud and Jullien [6][8]. Later, we briefly discuss why exclusivity contracts may not be needed and when they help the incumbent. Suppose X_k and Y_k are the numbers of buyers and suppliers in exchange k where $k = I$ or E.

When some of both buyers and suppliers multihome, buyers decide on which exchange actual transactions take place.[10] This asymmetry affects differently the revenues of multihoming buyers and suppliers. Furthermore, in many two-sided markets, access to the network does not immediately generate the surplus. In order to gain access to the information and the process to achieve the efficient matching, either side has to take some, often costly, actions. For example, buyers in a B2B exchange may have to send request for procurement (RFP), transfer files with detailed specification information, examine bids and negotiate with auction winner. Sellers in auction sites have to post the detailed information about the good they sell and choose the reservation price. Writers with text processing software have to choose a software to write texts and convert the original file to the processed file. Credit card holders have to do shopping to enjoy the benefit of a credit card. In most of these instances, the intermediaries are perfect substitutes and participants (users) have to "pre-select" an intermediary where actual transactions take place. In contrast, users of on-line match making service

[10] Similar asymmtry also is assumed in Rochet and Tirole (2002) whose model represents the credit card market: a cardholder selects the card when the merchant accepts multiple cards.

and advertisers in newspaper and TV networks may post their ads simultaneously on multiple intermediaries and benefit from both. Assuming that buyers have only one procurement need, we consider the following two cases:

(Pre-Selection): when a buyer multihomes, it has to "pre-select" an exchange where its supplier is chosen and the transaction takes place. In case of B2B exchanges, this means that a buyer can conduct only one procurement auction in either exchange.

(Post-Selection): when a buyer multihomes, it can "post-select" an exchange where its transaction takes place after aggregating information from both exchanges. In the case of B2B exchanges, this means that a buyer can run two procurement auctions at the same time on both exchanges and aggregate bids without any additional costs.

When buyers multihome but "pre-select" exchange, what affects the buyer/supplier revenues is not the number of buyers in the exchange but the number of buyers who actually trade in the exchange. When buyers "post-select" an exchange, suppliers compete not only with the other suppliers in the same exchange but also with those in the other exchange. In the extreme case when all buyers multihome and post-select, the revenues for buyers and suppliers are as if all were connected to one exchange. (*i.e.* $u_B(1, N_B, N_S)$ and $u_S(1, N_B, N_S)$). Suppliers multihoming, whether buyers can post-select or not, does not matter because the buyers have access to all suppliers in either exchange. Once again, the revenue functions in such cases are identical to those in the monopolist exchange with full participation.

In order to extend (A5), the assumption on the increasing returns to scale, to the competition case, we impose an additional assumption. Suppose two exchanges coexist and attract all potential participants but none of the buyers and suppliers engage in multihoming. Let (X_I, Y_I) and (X_E, Y_E) be the number of buyers and suppliers in exchange I and exchange E, respectively. Let $\widetilde{u}_B(X_k, Y_k)$ and $\widetilde{u}_S(X_k, Y_k)$ be the revenues of buyers and suppliers in exchange k. Note that $\widetilde{u}_B(X_k, Y_k) \neq u_B(1, X_k, Y_k)$ and $\widetilde{u}_S(X_k, Y_k) \neq u_S(1, X_k, Y_k)$ where u_B and u_S are the revenue functions for participants in a monopolist exchange because participants in the exchange can also profit from trading with non-participants in the monopoly case. We assume that the merge of the two exchanges always increase social surplus.

(A6) $N_B u_B(1, N_B, N_S) + N_S u_S(1, N_B, N_S) > X_I \widetilde{u}_B(X_I, Y_I) + Y_I \widetilde{u}_S(X_I, Y_I) + X_E \widetilde{u}_B(X_E, Y_E) +$

$Y_E\widetilde{u}_S(X_E, Y_E)$ where $X_I + X_E = N_B$ and $Y_I + Y_E = N_S$.

As in the monopoly case, multiple equilibria can arise. Negative externalities within the same group create situations where two otherwise identical intermediaries can coexist (see Ellison, Fudenberg and Mobius [14]) when potential participants cannot coordinate their decisions. This duopoly outcome may not be preferable for participants because of the increasing returns to scale and possible rent extraction by the exchange owners through imperfect competition. Once again, we assume that potential participants have a strong focal point and can coordinate on that. Namely, potential participants have the following "pessimistic belief" against the formation of any exchange and, if there is entry, against exchange E. This assumption requires incumbent and entrant exchanges to implement their preferred outcomes in the unique Nash equilibrium:

(PB2) Potential participants assign zero probability to "join only E," "join only I," and "multihome" for the decision made by another firm whenever "not join" is rationalizable. When "not join" is not rationalizable, they assign zero probability to "join only E" and "multihome" for the decision made by another firm whenever "join only I" is rationalizable.

This assumption requires that both exchange I and exchange E adopt a cross-subsidization strategy and, for a fixed t^I, exchange E attempts to form in the unique Nash equilibrium. Once the optimal fee schedule (t^E) for exchange E is identified, we look for t^I that makes it impossible for exchange E to make profit. The latter part of this assumption is equivalent to the "bad-expectation" market allocation that Caillaud and Jullien [8] used to support their "dominant-firm equilibria."

Because the market belief is pessimistic about the entry of exchange E, $t_B^E > 0$ and $t_S^E > 0$ never leads to a successful entry because both buyers and suppliers expect no benefit from joining exchange E. The optimal strategy for exchange E is "divide and conquer." The exchange has to subsidize one side of the market so that choosing exchange E is the best response even if all other firms choose exchange I. Because the market belief is also pessimistic about the formation of any exchange, exchange I needs to offer $t_B^I < 0$ or $t_S^I < 0$ to eliminate the null equilibrium. Therefore, there are four cases in which exchange I and exchange E may coexist.

a) $t_B^I < 0$, $t_S^I > 0$, $t_B^E < 0$ and $t_S^E > 0$.

b) $t_B^I < 0$, $t_S^I > 0$, $t_B^E > 0$ and $t_S^E < 0$.

c) $t_B^I > 0$, $t_S^I < 0$, $t_B^E < 0$ and $t_S^E > 0$.

d) $t_B^I > 0$, $t_S^I < 0$, $t_B^E > 0$ and $t_S^E < 0$.

In case a), buyers will multihome. When buyers can post-select, suppliers gain nothing by multihoming and are indifferent between exchange I and exchange E under any market belief. Therefore, $t_S^E < t_S^I$ will be enough to attract all suppliers from exchange I. Exchange I can never deter entry profitably in this case. When buyers can only pre-select, $t_S^E < t_S^I$ is typically not enough to attract any suppliers because buyers will conduct procurement auctions only in exchange I if exchange E fails to attract sufficient number of suppliers. Possible coordination failures require exchange E to offer substantially lower fees than exchange I.

In case b), exchange E succeeds in attracting all suppliers; but, all of them, under (PB2) and (A6), will multihome fearing that exchange E will fail to attract buyers. Then, buyers will not join exchange E regardless of whether post-selection is allowed or not unless $t_B^E < 0$. Hence, exchange E can never make profit.

In case c), exchange E succeeds in attracting all buyers; but, all of them, under (PB2) and (A6), will multihome fearing that exchange E will fail to attract suppliers. Then, suppliers will not join exchange E regardless of whether post-selection is allowed or not unless $t_S^E < 0$. Exchange E will fail to form.

In case d), suppliers will multihome. Then, buyers are indifferent between exchange I and exchange E under any market beliefs regardless of whether post-selection is allowed or not. Therefore, $t_B^E < t_B^I$ will be enough to attract all buyers from exchange I. Exchange I can never deter entry profitably in this case.

To sum up the results, successful entry by an entrant that faces a pessimistic expectation in the market requires it to subsidize the same side as the incumbent. When the incumbent subsidizes suppliers, the incumbent can never deter entry profitably while, when the incumbent subsidizes buyers, it can do so only in the pre-selection case.

Proposition 3 *When buyers can post-select an exchange, exchange I can deter entry only* *with zero profit. When buyers can only pre-select exchange, exchange I can deter entry with monopoly profit by charging $t_B^I \fallingdotseq 0$ and $t_S^I \fallingdotseq u_S(1, N_B, N_S) - u_S(0, N_B, N_S - 1)$.*

Proof. The sketch of proof is already presented above. We will only examine case a) with pre-selection.

Now, suppose $t_B^I < 0$ and $t_B^E < 0$, and all buyers multihome. (PB2) and (A6) require that suppliers should expect buyers to trade in exchange I. Given this pessimistic expectation against exchange E, a supplier will participate if

$$\max\{u_S(0, N_B, N_S - 1) - t_S^E, u_S(1, N_B, N_S) - t_S^I - t_S^E\} > u_S(1, N_B, N_S) - t_S^I. \qquad (6)$$

Since $t_S^I < u_S(1, N_B, N_S) - u_S(0, N_B, N_S - 1)$ from Proposition 2 and the inequality is equivalent to $t_S^E < 0$. Hence, exchange E can never capture market share profitably in case a). Exchange I should charge the monopoly price, which is $t_B^I \fallingdotseq 0$ and $t_S^I \fallingdotseq u_S(1, N_B, N_S) - u_S(0, N_B, N_S - 1)$ from Proposition 2. ■

Proposition 3 suggests that in an exchange where buyers have to commit to trade in one exchange, either due to costs or procedures set by the exchange, the incumbent can deter entry while earning monopoly profit. In contrast, in an exchange where buyers are free to change the quantity they procure or do not have to commit to trade (e.g. priceline.com), price competition among intermediaries may eliminate any surplus they can appropriate.

So far, we have assumed that firms cannot make decisions after observing the others'. In the next section, we demonstrate that allowing them to do so substantially improves their coordination capability.

3.2 Dynamic Participation Game (ND)

We analyze with this dynamic game the impact of coordination by potential participants to obtain their preferred equilibrium in both monopoly and competition cases.

3.2.1 Monopoly

Consider the following multi-period game in which nonparticipants are repeatedly asked to join:

(1) after firms are offered connection fees, they are asked in the first period to make a decision simultaneously whether to participate or not;

(2) in the second period and thereafter, only firms who have not joined are asked to reconsider their decisions simultaneously, after observing who joined in the previous period;

(3) firms cannot change their decisions once they decide to join the exchange and the exchange owner can commit to its first offers;

(4) the game ends when no additional firms join in a period.

The structure of the game allows potential participants to condition their decisions on those made by others and adopt a "trigger strategy" with which they punish, by joining, those firms who deviate from the mutually beneficial agreement.

As we argued in the previous section, in the one-shot game, it is quite possible that one or both sides of the potential participants are worse off with the exchange under the nearly optimal fee schedule. Therefore, the buyers or suppliers might want to block the formation of the exchange. If potential participants can postpone their decisions to see the others' move, they can condition their decisions on those of the others. For example, they might adopt the following trigger strategy: *I will join if others do but will not join otherwise.* Then, the optimal fee offers that induce the maximum equilibrium in the one-shot game will not guarantee the desired equilibrium for the exchange in the game in which potential participants may make decisions sequentially. We assume (PB1) again and focus on the outcome that can be achieved as the unique subgame-perfect Nash equilibrium outcome. We cannot implement such outcome in the unique subgame-perfect Nash equilibrium because there are many subgame-perfect equilibria that generate the same participation outcome. For example, consider the full participation equilibrium in which every firm joins in the first period and the one in which all firms participate sequentially, one by one. Since there is no cost of delay in decision-making, these two equilibria are equivalent.

The next proposition shows that, in the dynamic participation game, the unique implementation in the above sense requires that the connection fees be set low enough so that all the firms are offered at least the same payoff as they enjoy without the exchange.

Proposition 4 *Having all buyers and suppliers in the exchange is optimal. All firms partic-*

ipate as the unique subgame-perfect Nash equilibrium outcome if and only if

$$t_B < u_B(1, N_B, N_S) - u_B(0,0,0) \text{ and } t_S < u_S(1, N_B, N_S) - u_S(0,0,0).$$

Proof. We prove the proposition in three steps.

Step 1: *If exactly $X(>0)$ buyers and $Y(>0)$ suppliers participate in the exchange as the unique subgame perfect Nash equilibrium outcome, $t_B < u_B(1,X,Y) - u_B(0,0,0)$ and $t_S < u_S(1,X,Y) - u_S(0,0,0)$.*

Suppose $X(>0)$ buyers and $Y(>0)$ suppliers participate in any subgame-perfect Nash equilibrium but $t_B \geq u_B(1,X,Y) - u_B(0,0,0)$ and $t_S \geq 0$. We show that there exists another subgame-pefect Nash equilibrium in which no firms join, which lead to a contradiction. Consider the following strategy profile: (for buyers) *join* up to X buyers if any buyers join but *do not join* otherwise; and (for suppliers) *join* up to Y suppliers if any buyers join but *do not join* otherwise. The strategy profile constitutes a subgame-perfect Nash equilibrium because: (1) the assumption that $X(>0)$ buyers and $Y(>0)$ suppliers participate in any subgame-perfect Nash equilibrium implies that, once X buyers and Y suppliers participate, no other firms have incentives to join; and (2) $u_B(1,X,Y) - t_B \leq u_B(0,0,0) = u_B(0,0,Y')$ and $u_S(1,0,Y') - t_S \leq u_S(0,0,0)$ for any Y' imply that no firm should participate unless there has been buyer participation.

When $t_B \geq u_B(1,X,Y) - u_B(0,0,0)$ and $t_S < 0$, $Y = N_S$. The following equilibrium strategy profile induces a subgame-pefect Nash equilibrium in which only suppliers join: *join* up to X buyers if any buyers do so but *do not join* otherwise (for buyers); and *always join* (for suppliers). The buyer's strategy is the best response because $u_B(1,X,N_S) - t_B \leq u_B(0,0,N_S) = u_B(0,0,0)$ and the above reasoning (1), while the supplier's strategy is also optimal because $u_S(1,0,N_S) - t_S > u_S(0,0,N_S - 1)$. The proof is similar for the case $t_S \geq u_S(1,X,Y) - u_S(0,0,0)$.

Step 2: *$N_B(u_B(1,N_B,N_S) - u_B(0,0,0) - c_B) + N_S(u_S(1,N_B,N_S) - u_S(0,0,0) - c_S)$ gives an upper bound for the profit of the exchange that can be achieved as the unique subgame-perfect Nash equilibrium outcome.*

Suppose X buyers and Y suppliers participate in the exchange in the unique subgame perfect Nash equilibrium. From Step 1, the profit of the exchange has the following upper limit:

$$\begin{aligned}
& X(t_B - c_B) + Y(t_S - c_S) \\
< \ & X(u_B(1, X, Y) - u_B(0,0,0) \ - c_B) + Y(u_S(1, X, Y) - u_S(0,0,0) - c_S) \\
\leq \ & N_B(u_B(1, N_B, N_S) - u_B(0,0,0) - c_B) + \ N_S(u_S(1, N_B, N_S) - u_S(0,0,0) - c_S)
\end{aligned}$$

where the last inequality is derived from (A5).

Step 3: *N_B buyers and N_S suppliers participate in the exchange as the unique subgame perfect Nash equilibrium outcome when $t_B < u_B(1, N_B, N_S) - u_B(0,0,0)$* and *$t_S < u_S(1, N_B, N_S) - u_S(0,0,0)$.*

Consider the strategy profile "always participate in the first round" for both buyers and suppliers. This strategy profile constitutes a subgame-perfect Nash equilibrium because $u_B(1, N_B, N_S) - t_B > u_B(0,0,0) \geq u_B(0, N_B - 1, N_S)$ and $u_S(1, N_B, N_S) - t_S > u_S(0,0,0) \geq u_S(0, N_B, N_S - 1)$. Now, we need to show that the full participation is the *unique* subgame-perfect Nash equilibrium outcome. We consider the subgame where X buyers and Y suppliers have already participated in the exchange. When $X = N_B$ and $Y \geq 1$, "join" is the dominant strategy for suppliers because $u_S(1, N_B, Y') - t_S \geq u_S(1, N_B, N_S) - t_S > u_S(0,0,0) \geq u_S(0, N_B, Y'')$ for any $Y', Y'' \geq 1$. When $X = N_B$ and $Y = 0$, a supplier should join because by joining she induces the full participation and secures the payoff $u_S(1, N_B, N_S) - t_S > u_S(0, N_B, 0)$. By induction, the full participation is the unique equilibrium outcome in any subgame where N_B buyers have already participated in the exchange. Next, assume $X = N_B - 1$. If the only buyer outside the exchange decides to join, her payoff is $u_B(1, N_B, N_S) - t_B$ because her participation induces $(N_S - Y)$ suppliers outside the exchange to participate as proved above. If she stays out and never decides to join, she gets $u_B(0, N_B - 1, Y')$ where $Y' \geq Y$ is the best response from the suppliers to the last buyer's decision not to join the exchange. Then, this last buyer should participate because $u_B(1, N_B, N_S) - t_B > u_B(0,0,0) \geq u_B(0, N_B - 1, Y')$. By induction, the full participation is the unique subgame-perfect Nash equilibrium outcome.

From Step 2 and Step 3, we find that the upper bound $N_B(u_B(1, N_B, N_S) - u_B(0,0,0) - c_B) + \ N_S(u_S(1, N_B, N_S) - u_S(0,0,0) - c_S)$ in Step 2 is actually the supremum of the profit that the exchange owner can achieve as the unique subgame-perfect Nash equilibrium outcome.

Also, Step 1 and Step 3 suggest that the inequalities are the necessary and sufficient condition. The exchange owner should set t_B and t_S as close to $u_B(1, N_B, N_S) - u_B(0,0,0)$ and $t_S < u_S(1, N_B, N_S) - u_S(0,0,0)$, respectively, as possible and induce all buyers and suppliers to join the exchange in the equilibrium. ■

Since the payoffs for all firms change little by the B2B exchange formation, the exchange owner almost fully appropriates the social surplus generated by the formation. Note that, when $u_B(1, N_B, N_S) - u_B(0,0,0) > c_B$ and $u_S(1, N_B, N_S) - u_S(0,0,0) < c_S$ hold, which is quite plausible in an auction-based B2B exchange, cross-subsidization will be observed.

3.2.2 Competition

We consider the following game procedure:

(1) after firms are offered connection fees, they are asked in the first period to make a decision simultaneously whether to participate or not and in which exchange to participate. Firms can participate in both exchanges;

(2) in the second period and thereafter, firms who have not joined both exchanges are asked to reconsider their decisions simultaneously, after observing who joined in the previous period;

(3) firms cannot cancel their participation and the exchange owner can commit to its first offers;

(4) the game ends when no additional firms join either exchange in a period.

Once again, without any restrictions on the belief system, there exist many equilibria. Our approach is to consider similar coordination assumed in the static model and evaluate how the dynamic structure affects the outcome. Hence, we assume (PB2) and require unique implementation. The pessimistic market belief about the entry of exchange E rules out inefficient equilibria in which both exchanges attract buyers and suppliers. On the other hand, it creates lock-in and makes it more difficult to switch to exchange E when doing so is beneficial to all firms. We show that, in contrast with the static game, the exchange owner may be able to deter entry profitably regardless of whether buyers pre-select or post-select an exchange.

Then, exchange E can attract all buyers and suppliers as the unique subgame-perfect Nash equilibrium outcome if and only $t_B^I > t_B^E$ and $t_S^I > t_S^E$ as shown in the proof of Proposition 5.

Then, exchange I can deter entry only if it sets $t_I = (t_B^I, t_S^I)$ at the level where exchange I earns zero profit.

Now, suppose $u_S(1, N_B, N_S) \leq u_S(0,0,0)$. From Proposition 4, in order to attract suppliers, the exchange has to offer a strictly negative connection fee $t_S^I < u_S(1, N_B, N_S) - u_S(0,0,0) \leq 0$. Now, the entrant does not need to set $t_S^E < t_S^I$ because all suppliers will multihome if $t_S^E < 0$. This result means exchange I can never deter entry even with zero profit when $u_S(1, N_B, N_S) < u_S(0,0,0)$, which requires $t_S^I \ll 0$. Exchange E which can attract suppliers with $t_S^E > t_S^I$ can price buyer connection fees more aggressively than exchange I. Therefore, when there are sufficient negative externalities among suppliers and potential participants can coordinate decision-making, we should expect either multiple internet intermediaries or the exchange needs other instruments to maintain monopoly. We will come back to this point later.

We summarize our results.

Proposition 5 *When buyers can post-select an exchange, exchange I can deter entry of exchange E profitably if and only* $u_B(1, N_B, N_S) > u_B(0,0,0)$ *and* $u_S(1, N_B, N_S) > u_S(0,0,0)$. *The (nearly) optimal fee schedule is* $t_S^{I*} = \min\{\frac{N_B}{N_S} c_B + c_S, u_S(1, N_B, N_S) - u_S(0,0,0)\}$ *and* $t_B^{I*} = \min\{\frac{N_S}{N_B} c_S + c_B, u_B(1, N_B, N_S) - u_B(0,0,0)\}$. *When* $u_B(1, N_B, N_S) < u_B(0,0,0)$ *or* $u_S(1, N_B, N_S) < u_S(0,0,0)$, *there is no subgame-perfect Nash equilibrium in which exchange I captures all firms with (PB2). When buyers can only pre-select exchange, exchange I can always deter entry profitably. The (nearly) optimal fee schedule is* $t_S^{I*} = u_S(1, N_B, N_S) - u_S(0,0,0)$ *and* $t_B^{I*} = \min\{\frac{N_S}{N_B} c_S + c_B, u_B(1, N_B, N_S) - u_B(0,0,0)\}$.

Proof. From Proposition 4, if exchange I can foreclose entry, its fee schedule has to satisfy $t_B^I < u_B(1, N_B, N_S) - u_B(0,0,0)$ and $t_S^I < u_S(1, N_B, N_S) - u_S(0,0,0)$ in order to implement the formation as the unique subgame-perfect Nash equilibrium outcome. We first show that, in order for exchange E to capture some firms, it has to adopt the "cross-subsidization" strategy, namely $t_B^E < 0$ or $t_S^E < 0$. Suppose instead $t_B^E \geq 0$ and $t_S^E \geq 0$. Then, no buyer will join exchange E because

$$\widetilde{u}_B(1,0) - t_B^E \leq 0 < u_B(1, N_B, N_S) - t_B^I$$

where the first term is the payoff to the buyer who joins exchange E when all other firms participate in exchange I. Remember that such a buyer should expect that all other firms join exchange I from (PB2). Similarly, no suppliers will join exchange E. Therefore, $t_B^E < 0$ or $t_S^E < 0$ is a necessary condition for exchange E to successfully form.

We now derive the optimal cross-subsidization fee schedule for exchange E and then see if exchange I can choose its fee schedule $t_I = (t_B^I, t_S^I)$ to preempt any profitable entry by exchange E. Suppose $t_B^E < 0$. Then, all buyers will participate in exchange E but multihome if they expect suppliers to join exchange I. When buyers pre-select an exchange, suppliers will not join exchange E unless $\widetilde{u}_S(0,1) - t_S^E > u_S(1, N_B, N_S) - t_S^I$, which implies $t_S^E \ll 0$. Since offering $t_B^E < 0$ and $t_S^E \ll 0$ gives negative profit to exchange E, it will not do so and suppliers will never join exchange E. Therefore, exchange I can charge the monopoly supplier connection fee, namely, slightly less than $t_S^{I*} = u_S(1, N_B, N_S) - u_S(0,0,0)$ from Proposition 4. When buyers post-select an exchange, suppliers will join exchange E if $t_S^E < t_S^I$, in which case buyers do not engage in multihoming. In this case, exchange I should set t_S^I so that any $t_S^E < t_S^I$ and $t_B^E < 0$ lead to negative profit for exchange E. Namely, choose t_S^I such that

$$N_B(t_B^E - c_B) + N_S(t_S^E - c_S) < -N_B c_B + N_S(t_S^I - c_S) \leq 0.$$

Hence, the optimal supplier connection fee for exchange I that will deter entry for $t_B^E < 0$ is

$$t_S^{I*} = \min\{\frac{N_B}{N_S} c_B + c_S, u_S(1, N_B, N_S) - u_S(0,0,0)\}.^{11} \tag{7}$$

Next, suppose $t_S^E < 0$. Then, all suppliers will participate in exchange E. All buyers will join exchange E and the suppliers will not multihome if $t_B^E < t_B^I$. Then, exchange I should set t_B^I so that any $t_B^E < t_B^I$ and $t_S^E < 0$ lead to negative profit for exchange E. Similarly to the case of $t_S^E < 0$, the optimal buyer connection fee for exchange I that will deter entry for $t_B^E < 0$ is

$$t_B^{I*} = \min\{\frac{N_S}{N_B} c_S + c_B, u_B(1, N_B, N_S) - u_B(0,0,0)\}. \tag{8}$$

Let us summarize the optimal fee schedule for exchange I. Because exchange E can choose either $t_B^E < 0$ or $t_S^E < 0$, exchange I should charge $t_S^{I*} \risingdotseq u_S(1, N_B, N_S) - u_S(0,0,0)$ and (8) when buyers can only pre-select an exchange, and charge (7) and (8) when buyers can post-select an exchange.

Exchange I can always deter entry profitably when buyers can only pre-select an exchange. When buyers can post-select an exchange, however, exchange I can do so only when $u_B(1, N_B, N_S) > u_B(0,0,0)$ and $u_S(1, N_B, N_S) > u_S(0,0,0)$. To make this point clear, suppose $u_S(1, N_B, N_S) \leq u_S(0,0,0)$ and $\frac{N_S}{N_B} c_S + c_B < u_B(1, N_B, N_S) - u_B(0,0,0)$. The second inequality is true whenever $u_S(1, N_B, N_S) \leq u_S(0,0,0)$ from (A5). Then,

$$N_B(t_B^{I*} - c_B) + N_S(t_S^{I*} - c_S) \leq N_B(\frac{N_S}{N_B} c_S + c_B - c_B) + N_S(0 - c_S) = 0$$

implying that exchange I can never make profits by deterring entry in a pure strategy Nash equilibrium.

When $u_B(1, N_B, N_S) < u_B(0,0,0)$ or $u_S(1, N_B, N_S) < u_S(0,0,0)$, exchange E actually has the late-mover advantage. Suppose $u_S(1, N_B, N_S) < u_S(0,0,0)$ for example. Consider two cases: (1) $0 > t_S^I \geq \frac{1}{2}(u_S(1, N_B, N_S) - u_S(0,0,0))$; and (2) $t_S^I < \frac{1}{2}(u_S(1, N_B, N_S) - u_S(0,0,0))$. Note that, in both cases, exchange E has to offer $t_S^E < \min\{u_S(1, N_B, N_S) - u_S(0,0,0) - t_S^I, 0\}$ to capture all suppliers as the unique subgame-perfect Nash equilibrium outcome. In case (1), $t_S^E < t_S^I < 0$ and suppliers engage in multihoming. In this case, exchange I can offer a better deal to buyers without losing money than exchange E, *i.e.* $t_B^E > t_B^I$ and, as a result, exchange E does not enter. Without the entry of exchange E and $t_S^I > u_S(1, N_B, N_S) - u_S(0,0,0)$, no firm will participate in exchange I under (PB2). In case (2), $t_S^I < t_S^E < 0$ and suppliers engage in multihoming. This time, exchange E without losing money can offer a better deal to buyers than exchange I. Hence, exchange E always attracts all buyers and exchange I should not enter. Hence, there is no subgame-perfect Nash equilibrium in which exchange I captures all firms with (PB2). ■

There are several important remarks for Proposition 5. Although the dynamic participation process helps potential participants to coordinate to avoid the inefficient null equilibrium, it does not affect the nature of competition between exchanges unless firms can cancel their registration without incurring costs at any time. Although firms can condition their decisions on those of others (*e.g.,* we will join exchange E if most of others choose exchange E), early adopters still have to bear a significant risk of choosing a wrong exchange. We have ruled out possible coordination failures by imposing pessimism on the beliefs held by potential participants about the entry of exchange E, as we did in the static game. Therefore, the difference between Proposition 3 and Proposition 5 can be only traced back to the difference between Proposition 2 and Proposition 4: in the dynamic game, the incumbent exchange does not have to engage in cross-subsidization and thus can set both buyer and supplier connection fees positive. But, these fees must be low enough to make the expected profit of the entrant, which needs to adopt cross-subsidization, negative. In the static game, both incumbent and entrant subsidize the same group, say suppliers, and initiate perfect price competition on the other side of the market, buyers for example, leading to zero profit except for the pre-selection case. The result that the incumbent exchange could deter entry profitably even when multihoming is allowed contradicts the finding by Caillaud and Jullien [6] that it cannot. The difference is driven by our consideration of fixed costs of connection, c_B and c_S. If we set $c_B = c_S = 0$ in (7) and (8), we obtain $t_B^{I*} = t_S^{I*} = 0$ as long as $u_B(1, N_B, N_S) > u_B(0, 0, 0)$ and $u_S(1, N_B, N_S) > u_S(0, 0, 0)$ and thus exchange I earns zero profit. With positive connection costs, the incumbent can offer positive connection fees while keeping the maximum profit the entrant can earn to zero or less. With no connection costs, the incumbent has no way to charge positive fees without accommodating the entrant. Finally, the proposition demonstrates the difficulty of forming and maintaining a monopoly when negative externalities on the same side are significant, *i.e.* $u_B(1, N_B, N_S) < u_B(0, 0, 0)$ or $u_S(1, N_B, N_S) < u_S(0, 0, 0)$. In such cases, no pure strategy subgame-perfect Nash equilibrium exists in which exchange I enters. There are mixed-strategy Nash equilibria in which both exchange I and exchange E capture some buyers and suppliers but they are inefficient.

3.3 Extension

Our work thus far assumes that the exchange charges only fixed connection fees–no transaction fees that depend on the trade volume through the intermediary are incurred. The use of transaction fees would make a difference in general in the static monopoly model. Unique implementation requires cross-subsidization to avoid coordination failures; but, the exchange owner can balance the subsidy by charging transaction fees, if they are allowed. Therefore, having both transaction fees and fixed fees could potentially provide exchanges with enough instruments to ensure and fully appropriate surplus in a monopoly environment. Transaction fees, however, create an inefficiency by distorting buyers' reservation prices and suppliers' bidding decisions in auctions, which are the market-clearing mechanisms adopted in most B2B exchanges. Thus, auction-based exchanges that employ transaction fees have to make tradeoffs between the fixed fee and the variable fee because of this inefficiency. As long as sizable fixed fees are required, most of our qualitative results still hold. We avoid such complication by focusing on fixed connection fees. In contrast, our dynamic model successfully eliminates coordination failures and the exchange can capture the full surplus without relying on transaction fees in the monopoly case. Thus, transaction fees are not necessary to derive the optimal fee schedule. In the competition case, we assume that firms can multihome and competition pushes the transaction fees to zero whenever two exchanges compete, which rules out the possibility that transaction fees affect our results.

In our sections on competition, we rule out the possibility of exclusivity contracts. Such contracts won't be necessary when the incumbent exchange can deter entry with substantial profit, *e.g.,* when a limited number of participants observe each other's choices (our dynamic model) and/or when buyers need to pre-select an exchange. Even when exclusivity contracts are effective instruments for the incumbent exchange to lock in participants, forward-looking buyers and suppliers should be reluctant to accept such contracts especially when entry of another exchange is anticipated. This may explain why we rarely observe exclusivity contracts in internet intermediaries. Then, the exchange needs to seek other mechanisms to appropriate rents created by its formation.

Another possibility is the choice of a suitable ownership structure. There are three types of B2B exchanges: private (owned by a buyer), consortium (owned by a group of buyers or suppliers, but mostly buyers) or public (owned by a third party).[12] Private and consortium exchanges certainly have advantage over public exchanges in foreclosing entry because the "divide and conquer" strategy by the entrant never works against member-owned exchanges if a majority of buyers or suppliers are owners. To see this point, suppose the incumbent exchange is owned by all buyers in the industry. Offering a subsidy to suppliers in the exchange is a losing proposition for the entrant because suppliers will continue to multihome and the owner-buyers can continue to trade in their exchange. Attracting owner-buyers from the exchange requires the entrant to offer monopoly rents to the buyers, which also leaves no

[12] A recent development is that public exchanges now provide IT and hosting services for individual buyers to create an out-sourced version of a private exchange. Such outsourced private exchanges rely on the buyer using the communication standards set by the third-party, which appears to yield an economy of scale (e.g., Jones [12], Wilson [30]). Nonetheless, these public-hosted exchanges are private in the sense that information in the exchange is restricted to the buyer and participating suppliers.

profit to the entrant. Hence, member-owned exchanges can deter entry while appropriating monopoly rents. A member-owned exchange also solves coordination failures in its formation. Since the participation of one side of the market is ensured, the other side of the market has no other choice than to join. Member-owned exchanges have additional benefits. In Owan and Nickerson [23], we show that the exchange can exploit more rent by discriminating among potential participants. If the B2B exchange is managed by a third party, setting discriminatory fee schedule may be very costly because of asymmetric information. The public exchange would face a higher cost of assessing product values and supplier costs than individual buyers that have amassed knowledge from past dealings. In addition, since participating buyers have an incentive to distort their private information in order to increase the number of bidders at other parties' cost, choosing the optimal price should be difficult for such B2B exchanges. On the other hand, consortium exchanges and, even more so, private exchanges, should be able to implement price discrimination at a lower cost because information is less asymmetric and information distortion incentives are diminished for consortium and eliminated for private B2B exchanges.

4 Conclusion

We have shown that successful exchange formation often requires "cross-subsidization." Cross-subsidization in the static game is an attempt to "divide and conquer" potential participants in response to coordination failures when there are many potential participants and/or their participation decisions are not observable to the other firms. The "divide and conquer" strategy is not necessary, however, when a limited number of potential participants can observe their participation and thus can condition their decisions on the others' (dynamic game). This implicit coordination through a dynamic participation process increases the monopoly profit by eliminating coordination failures.

Cross-subsidization may also arise for another reason. When firms can coordinate their decisions, they will join an exchange only when they are better off by doing so. When there are significant negative participation externalities among those in the same group, it may be the case that one group of participants needs to be compensated for the expected loss from participation. For example, when suppliers are expected to face substantial competition and downward price pressure in the exchange and they can implicitly coordinate their decisions, the exchange needs to offer a subsidy to induce supplier participation.

The above difference between the static and dynamic games also affect competition results. When firms cannot coordinate, both incumbent and entrant exchanges adopt the "divide and conquer" cross-subsidization strategy, which leads to multihoming on one side and perfect price competition between the two exchanges for the other side when multihoming firms can post-select an exchange. The result is zero profit for the exchanges except when pre-selection is required, which favors the incumbent by inducing imperfect competition. When firms can coordinate participation decisions and the incumbent exchange does not adopt cross-subsidization (*i.e.* negative externalities within group are not significant), the incumbent can deter entry profitably by setting both buyer and supplier connection fees positive; but, their fees must be low enough so that the "divide and conquer" cross-subsidization pricing by the entrant only results in negative profit for the entrant. When there are significant negative externalities within group and thus cross-subsidization is necessary to compensate the loss, however, there is no pure-strategy subgame-perfect Nash equilibrium in which the incumbent exchange maintains its monopoly.

One question to be answered is which side of the market should be subsidized when cross-subsidization is necessary. If cross-subsidization is intended to cope with coordination failures, the side of the market that receives less surplus should be subsidized so that the exchange can extract most surplus from the other side of the market. This comparison may not be readily obvious in some cases. One case for which we have a more clear answer is when multihoming buyers need to pre-select an exchange. The exchange needs to subsidize buyer participation in order to maintain a profitable monopoly. In contrast, when cross-subsidization is intended to compensate the loss from participation, those on the side of the market who face significant negative externalities within group should be subsidized.

Findings in this paper explain the roles of cross-subsidization and the importance of a number of critical characteristics of internet intermediaries and market structures in determining the optimal fee schedule that ensures the full participation. Although we mainly illustrate B2B exchanges in our model, our theory is general because we do not specify functional forms of revenues. The model allows negative externalities within groups and negative externalities on non-participants as well as positive externalities between groups and thus covers any type of two-sided market that has these characteristics.

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