Online Procurement Intermediaries with Differentiated Suppliers*

January 2004

Esther Gal-Or
Katz Graduate School of Business
University of Pittsburgh
Pittsburgh PA 15260
ESTHER@katz.pitt.edu

Mordechai Gal-Or
A. J. Polumbo School of Business
Duquesne University
Pittsburgh PA 15282
galor@duq.edu

Anthony Dukes
School of Economics & Management
University of Aarhus
Åarhus Denmark
adukes@econ.au.dk

Abstract

Industrial buyers who seek to procure inputs have the option of contracting the process out to procurement intermediaries. Many of these intermediaries now operate using Internet-based software to enhance the efficiency of their services. We develop a theoretical model of a buyer who wishes to procure an input from one of many differentiated suppliers. The buyer chooses between conducting the procurement herself and hiring a procurement intermediary. We use the model to investigate how and when such procurement intermediaries can be profitable, and to generate insight for the design of the online procurement process with regard to bidder recruitment and information revelation. The model suggests that the profitability of the intermediary relies crucially, on its ability to administer and evaluate quotes from potential suppliers more efficiently than the buyer can herself.

Key words: procurement intermediaries, auctions online, information revelation, supply chain, optimal search

**We wish to acknowledge the helpful comments of Anindya Ghose*

1. Introduction

Internet technologies often promise industrial buyers and their suppliers substantial transactional efficiencies in their sourcing activities. Many of the top Fortune 50 firms employ online auctions to source their inputs. The leading provider of online procurement auctions is FreeMarkets. According to its website, since its founding, FreeMarkets has helped customers around the world to source more than $40 billion in goods and services in more than 200 different supply categories. FreeMarkets rose to fame on the dot-com bandwagon, alongside companies such as Commerce One, PuchasePro.com, and Ariba. After the hype subsided, many Internet B-to-B intermediaries were forced to fold as they recognized that they provided little real value to industrial buyers. On the other hand, some have become profitable and, as the FreeMarkets case illustrates, Internet B-to-B intermediaries can provide a valuable service to industrial buyers. In the present paper, we develop a theoretical model to assess the potential for value creation by companies who serve as centralized procurement intermediaries and strategies they can use to guarantee profitability. We point out, in particular, that such intermediaries may be informationally disadvantaged in comparison to the buyer in assessing the extent of fit of different suppliers with the buyer's requirements. Their potential for value creation relies crucially, therefore, on their ability to administer and evaluate quotes from potential suppliers more efficiently than the buyer can herself. Such enhanced efficiency guarantees that the intermediary can secure a larger pool of suppliers as potential candidates to be considered by the buyer.

Our focus in this research is to understand Internet-based procurement services (also referred to as B-to-B intermediaries) as an alternative to traditional supply chain processes. Generally, such Internet services exist profitably if they offer transactional efficiencies over other procurement methods. However, since there are many sources of transaction costs, it is important to learn where specific efficiencies emerge when going online. As such, we fully investigate the economic incentives of an industrial buyer's supply chain activities independent of any Internet procurement service. We then evaluate conditions under which the existence of such an online procurement intermediary provides a benefit to the industrial buyer over its next best procurement alternative.

In the process of identifying potential sources of profitability of online procurement intermediaries, we also gain managerial insights, which might help in the design of online auctions. For instance, our analysis suggests that such online intermediaries should recruit more bidders than an industrial buyer would on her own. In addition, we illustrate how online procurement auctions offer an industrial buyer lower bids if bidders are fully informed of their degree of fit with the buyer's specific needs.

To illustrate the setting of this paper, suppose an automobile manufacturer seeks door handles for a particular model of car. The automaker is able to specify certain attributes of the door handles, such as dimensions, material, and color, and there are many qualified auto parts suppliers who can feasibly meet these specifications. But suppose, in addition, that the automaker has preferences over certain quality attributes, which suppliers fit to varying degrees. Such supplier-specific attributes might include, for example, workmanship, durability, and style. In order to fully evaluate the benefit from contracting with a potential supplier, the automaker must individually contact the supplier, obtain a quote, and determine the supplier's *fit* with respect to these attributes. This, however, is costly, especially if the set of sellers is large[1] because she must search among qualified suppliers and invest in some inspection process. Because suppliers are differentiated in this way, industrial buyers often select the supplier on other criteria in addition to quoted price. For example, it is not uncommon in the automotive industry that a buyer, after viewing all bids from participating parts suppliers, awards the contract based on a variety of factors in addition to price.[2] Our modeling framework permits buyers to choose a supplier on the criterion of total value net of price.

To evaluate the potential for value creation by the intermediary, we first consider the optimal procurement method that the automaker should utilize if searching on her own. She can either approach suppliers one by one and evaluate each fit and price sequentially or, alternatively, she can approach a number of suppliers and request simultaneous quotes (RFQ). Given that contacting and evaluating a given supplier comes at a cost, this issue between search methods is non-trivial. Furthermore, the method of search employed by the automaker affects the way in which each supplier forms his quote strategy. The automaker must also decide whether to reveal information to each potential supplier about his degree of fit with the buyer's

[1] There are reportedly over 30,000 suppliers of parts in the automotive industry (El Sawy, 2001).
[2] According to its website, COVISINT, the online procurement service for the automotive industry, enables automakers to award a contract to a supplier based on buyer-subjective attributes in addition to price.

requirements. Given that some of those requirements can be subjective, the extent of fit of a given supplier is private information that can only be observed by the automaker herself.

For sequential search, we illustrate that it is in the automaker's best interest to always conceal from each supplier his degree of fit. If she reveals this information, each supplier knows the buyer's true valuation of the contract, thus allowing him to extract the entire surplus of the automaker. In contrast, under RFQ, we demonstrate that the automaker should reveal to each supplier his degree of fit. When suppliers are uninformed, they bid independently of the extent of fit between their products and the buyer's requirements. In particular, low fit suppliers submit similar bids as those submitted by high fit suppliers. However, if each supplier knows his own fit, low fitness suppliers reduce their bids in order to remain attractive to the buyer, thus forcing high fitness suppliers to compete more aggressively. Such intensified competition benefits the automaker.

When procuring the input on her own, either the sequential search method with information concealment or the RFQ method with information revelation can be optimal, contingent upon the cost the automaker incurs when inspecting and screening potential suppliers. When evaluating the option of contracting out and paying for procurement services, the automaker expects her payoff to be at least as high as that she can obtain when searching on her own. The procurement intermediary has the potential to enhance the automaker's payoff only if its cost of identifying suppliers, evaluating their qualifications, and processing their quotes in lower than that of the automaker herself. One such possible source for enhanced efficiency may be the ownership of proprietary software, which permits the intermediary to more efficiently contact suppliers and administer the RFQ in the form of an online auction. The existence of the Internet makes such an auction easily feasible even if suppliers are in remote parts of the world.

Since the automaker has an informational advantage over the intermediary in assessing supplier-specific attributes, she can more successfully inform suppliers of their extent of fit with her requirements. Our analysis predicts, therefore, that the buyer may be able to implement more competitive bidding among a given number of suppliers than the intermediary can. Hence, in order to remain a viable option for the automaker, the intermediary should compensate for its informational disadvantage by recruiting many more suppliers to participate in the auction than the number chosen by the automaker, when searching on her own. This task can be accomplished only if the intermediary is far more efficient than the automaker in administering the RFQ process. As well, the intermediary can mitigate its informational disadvantage by offering additional services to the buyer. FreeMarkets, for instance, offers a very broad set of services and activities to its customers that include analysis of spend data, development of supply strategies, and sharing of best practice procurement methods, to name a few. The close interaction with the customers that such services facilitate allows FreeMarkets to gain better understanding of their needs. To guarantee that this improved familiarity with the buyer's specifications is also shared with suppliers, FreeMarkets offers them extensive RFQ support before they submit their bids.[3]

Others have recognized that there exist strategic considerations in a buyer's choice of procurement process. At a fundamental level, the early works in search have established that sequential search is preferable over simultaneous search when the distribution of prices is exogenous (DeGroot (1970)). In our setting, price setting by the sellers is endogenous and depends on the buyer's procurement method. In particular, we demonstrate that by soliciting simultaneous bids from suppliers the buyer may induce more aggressive pricing than when searching sequentially. Moreover, by utilizing a mechanism to pre-qualify suppliers the buyer can further intensify the extent of competition among them. Snir and Hitt (2000) have also pointed out the importance of such a pre-qualifying mechanism in the procurement of IT services. As in our model, in the market for software development the buyer evaluates bids from vendors based upon price as well as her subjective evaluation of the vendors' quality.

There has also been recent interest in analytical formulations of the B-to-B marketplace. Tomak & Xia (2002) and Yoo et al (2003a, 2003b) are studies that develop models with a large number of buyers and sellers that interact in the marketplace. Our setting is different in the sense that the online B-to-B intermediary arranges auctions tailored each to the needs of an individual buyer.

More specifically, Tomack and Xia (2002) are interested in analyzing the evolution of B-to-B exchanges overtime while we focus on the role information plays in determining the sellers' bidding behavior in a static model. Yoo et al model (electronic) B-to-B marketplaces to investigate the impact of marketplace ownership on the participation decision (Yoo et al 2003b) and on pricing (Yoo et al 2003a). In the latter paper, they identify that marketplaces owned by one side of the market ('biased') might create benefits over independent marketplaces ('neutral')

[3] See *FreeMarkets OnLine*, 1998, Harvard Business School Publishing, 9-598-109. It is noteworthy that FreeMarkets does not charge suppliers for this RFQ support. Its only source of revenue accrues from buyers.

because biased marketplaces better exploit network effects generated by additional participation. By their definition, the intermediaries we consider here are neutral. However, our analysis points out that, while the intermediary is independent, its profitability is directly tied to the surplus it generates for its client, the buyer.

An important aspect of our investigation concerns the buyer's decision (or the intermediary's decision on behalf of the buyer) whether to reveal supplier-specific information. Other studies have previously identified the importance of information revelation in the design of online procurement processes. Beil & Wein (2003) offer a dynamic auction mechanism designed to extract sellers' cost structures and improve the buyer's share of the transaction. In their paper, it is the buyer who suffers from incomplete information.[4] In our study, the supplier is asymmetrically informed about her own degree of fit with the buyer. Zhu (2002, 2003), more generally, considers the impact of information sharing on outcomes in electronic marketplaces and identifies that, while sharing information about prices and costs might yield short-term benefits to buyers, it might also produce adverse long-run effects by lowering the suppliers' participation incentives. In contrast to Zhu who assumes that information about the type of suppliers or buyers is automatically revealed once they decide to join the exchange, in our formulation the buyer (or the intermediary on the buyer's behalf) can strategically reveal information to the suppliers. We stress, in particular, the role of information in governing the extent of competition among the suppliers in reverse auctions.

A couple of relevant institutional studies are also worth mentioning. El Sawy (2001) and Dai and Kauffman (2002) develop, in particular, a conceptual classification of the different B-to-B exchange organizations. Using the terminology of Dai and Kauffman (2002), for instance, the procurement intermediary in our model can be classified as a "public exchange." In contrast, the administering of the RFQ by the buyer herself can be classified as a "private exchange."

There is also a related literature addressing the role e-commerce plays in retail markets. Most of this literature focuses on understanding Internet Shopping Agents (ISA) that allow consumers to costlessly search among many online retailers.[5] This literature has provided mixed

---

[4] Pinker et al (2003) point out *inter alia* that existing studies concerning informational asymmetries in procurement auctions, like those considered here, focus on supplier costs. (See, for example, Dasgupta & Spulber 1989/1990.) Our focus, on the other hand, is on supplier-specific *fit* attributes known *ex ante* only by the buyer.

[5] Anand & Aron (2003) identify and investigate another ecommerce retail institution known as 'Group Buying' in which consumers form *co-op* type organizations to gain buying power over suppliers. Their focus is on pricing strategies of the supplier in such a setting.

evidence on the extent of price competition fostered by online retailing. While Brynjolfsson and Smith (2000) and Morton, Zettelmeyer, and Silva-Risso (2001) find that online retail markets are more price competitive than conventional markets, Ellison and Ellison (2001) demonstrate that retailers can adopt obfuscation strategies to increase the search costs of consumers and alleviate, as a result, the extent of price competition on ISA's. Some studies have demonstrated the existence of price dispersion (Baye and Morgan (2001, 2002), and Brynjoylfsson and Smith (2000)), and others have addressed the role Internet technology plays in facilitating enhanced product differentiation or "versioning" (see Bakos (1997, 2001), Varian (2000), and Choudhary, Ghose, Mukhopdhyay, and Rajan (2003)).

Finally, the RFQ process we model is related to the general theory of auctions, which has been extensively explored in the economics literature (Maskin and Riley (1984), McAfee and McMillan (1987), and Milgrom and Weber (1982).) However, the application of this theory in the context of reverse auctions on the internet is limited.[6] The model we develop in this paper is aimed at filling this gap in the literature. As well, we wish to use the analysis to gain better understanding of the underlying "business model" of centralized procurement intermediaries on the Internet.

Our paper is organized as follows. In the next section we describe the main assumptions of the model. In section 3, we derive the optimal stopping rule for the buyer and the implied equilibrium prices chosen by the suppliers when the buyer searches sequentially among sellers. In section 4, we derive the equilibrium quote strategy of the suppliers when the buyer utilizes the RFQ method to procure the input. In section 5, we evaluate the possibility for value creation by a procurement intermediary, and in section 6 summarize the implications of our analysis for managers. In section 7 we offer concluding remarks. The appendices contain the proofs of most propositions and one possible extension of the basic model.

2. The Model

A single downstream firm seeks to procure an input required in its production. Suppliers vary according to the parameter $x \in [0,1]$, which measures the extent to which their products constitute a good fit with the buyer's requirements. There is a continuum of suppliers whose "extent of fit"

[6] See Pinker et al (2003) for a comprehensive managerial survey of the auction literature applied to online settings.

x is uniformly distributed on the unit interval. If the buyer purchases the input from a supplier of type x charging her the price p, her net utility is given as follows:

$$v(x, p) = mx - p\,. \quad (1)$$

Hence, the parameter m measures the emphasis the buyer places on obtaining the input from a supplier whose product specifications match the buyer's requirements.[7] For simplicity, we normalize the costs of production of suppliers to be equal to zero.

The buyer is considering two different methods for procuring the input. Under the first, she conducts an optimal search among potential suppliers. We assume that the cost of identifying a new supplier, negotiating a price with him, and evaluating the extent to which his product fits the buyer's specification is k. Using results obtained in the literature, we know that to guarantee optimality, the buyer should utilize an appropriately selected "stopping rule" while sampling sequentially among potential suppliers. (See DeGroot (1970), Lippman & McCall (1976), McCall (1970), Mirman & Porter (1974), and Rothchild (1974) as examples.) Alternatively, the buyer can solicit quotes from suppliers in the form of a *request for quotations* (RFQ). After suppliers submit quotes simultaneously, the buyer compares the quotes as well as the extent of fit of the different suppliers to choose the supplier who offers her the highest net payoff. The cost to the buyer of choosing a supplier via the RFQ method depends on her scrutiny in screening suppliers who are allowed to participate in the bidding as well as upon the extent of outreach of the RFQ, as measured by the number of suppliers n who are solicited to submit bids. We formulate the scrutiny of screening suppliers in the form of a minimum level of fitness $\hat{x}$, where only those suppliers whose fitness exceeds this threshold level are allowed to participate in the bidding.

Implementing the scrutiny level $\hat{x}$ may require that the buyer formulates the RFQ in a manner aimed at attracting only qualified suppliers of type $x \geq \hat{x}$. It also requires that the buyer establish a preliminary evaluation procedure to screen the eligible suppliers[8]. This evaluation process need not be so rigorous that it can establish the exact type x of each supplier. Rather, it only verifies whether the type falls in the required range $x \in [\hat{x}, 1]$. We designate by $TC_B(\hat{x}, n)$

[7] This utility specification is similar to that used in earlier models of quality competition. (See, for instance, Gabszewicz & Thisse (1979) or Gal-Or (1985).)
[8] Snir and Hitt (2000) have also discussed the advantages of utilizing a preliminary mechanism aimed at pre-qualifying suppliers in the IT professional service market.

the cost to the buyer of procuring the input using the RFQ method.[9] We assume that this cost function is convex and increasing in both of its arguments. A higher value of $\hat{x}$ implies that the buyer must allocate more resources to identify suppliers whose product specifications abide more closely with her requirements. Similarly, it is more costly for the buyer to search for a larger number of qualified suppliers. Note that when the buyer does not impose any restrictions on suppliers who can participate in the bidding, so that $\hat{x}=0$, her costs $TC(0,n)$ are simply nk, which corresponds to the cost of inspecting the exact specifications of the products of the n suppliers.

For each of the two methods to procure the input, the buyer can consider two different regimes. Under the first, Information Concealment Regime, the buyer guarantees that when suppliers set prices they cannot fully assess the extent of fit of their products with the buyer's specifications. Hence, with the sequential search method, the buyer ensures that in negotiating with each supplier, she does not reveal information about the supplier's type x. As a result, the supplier knows only that the extent of fit of his product is drawn from a uniform distribution on the unit interval, without being able to precisely assess the value of x.

With the RFQ method, the Information Concealment Regime dictates that the buyer intentionally withholds information about her exact specifications even if she can clearly articulate them in the RFQ. As a consequence, a supplier knows that his type, as well as those of his competitors in the bidding exceed the threshold $\hat{x}$ without being able to exactly infer where in this range his type falls.

Under the second regime, the Information Revelation Regime, each supplier is aware of his type x when setting the price of his product. When the buyer searches sequentially, this information is intentionally revealed by the buyer when negotiating with each supplier. When the buyer uses the RFQ method, she makes an effort to describe very precisely her requirements so that each supplier can perfectly infer his type. As a result, when each supplier submits his quote, he is familiar with his type but not with those of his competitors in the bidding.

[9] Note that the arguments of the cost function $TC_B(\cdot)$ are decision variables to be selected optimally by the buyer. The exogenous parameter m that reflects the importance the buyer places on fit, affects this optimal choice.

The different information that is available to suppliers under the two regimes has implications on their pricing behavior.[10] Under the first regime, when suppliers are uninformed about x, their prices cannot be contingent upon the value of x, thus $p \in \Re^+$. In contrast, under the second regime, when suppliers become familiar with x while negotiating with the buyer or interpreting the RFQ, their prices are chosen as functions of x, so that $p(x):[0,1] \to \Re^+$. Note also that the pricing behavior of the suppliers will depend upon the method utilized by the buyer to procure the input.[11]

We formulate the game as consisting of two stages. In the first, the buyer decides on the method to procure the input (sequential search versus RFQ) as well as on the extent of information to be revealed to suppliers (concealment versus revelation). If the buyer chooses the RFQ method, she also chooses at this stage the screening parameter $\hat{x}$ and the outreach parameter n. In the second stage, suppliers set prices and the buyer executes her choice. She either starts sampling sequentially among suppliers in a manner derived in the sequel, or solicits quotes from a group of n qualified suppliers. In the latter case, those suppliers submit their bids and the buyer chooses the one who offers her the highest net payoff.

3. Sequential Search

3.1 Information Concealment Regime

Based upon the results obtained in the literature on search, the optimal sequential search is characterized by a "stopping rule" that guides the buyer in determining whether to stop sampling suppliers. This stopping rule requires that at every stage of the search, the buyer evaluates whether the highest net payoff she can obtain from the suppliers sampled so far exceeds a certain threshold level that she derives optimally. If it does, the buyer stops sampling and purchases the input from this supplier. Consider first the case that all suppliers charge the same price p. Given this symmetry, the buyer formulates her search in terms of a critical acceptable level of fitness

---

[10] A more natural regime to consider is an intermediate case between the two extremes mentioned above. Specifically, it is reasonable to assume that each supplier can observe a noisy signal of *x* and condition his pricing on the value of this signal. Similar to the first regime mentioned above, in this intermediate case as well, the buyer is better informed than each supplier about the extent of fit of the supplier. See Appendix 2.

[11] In the optimal search literature, the standard assumption is that the distribution of prices is exogenous, and determined independently of the search method of the consumer. In contrast, the searching agent in our model is a monopsonist, whose procurement method significantly affects the suppliers' pricing strategies and, as a result, the distribution of prices from which the buyer samples.

x^*. At a given stage in the sampling, let supplier i be of the highest fitness level from all of those sampled so far. In order for this supplier to be chosen (i.e. $x_i \geq x^*$) the following inequality should hold.

$$mx_i - p \geq (1-x_i)(mE[x \mid x \geq x_i] - p) + x_i(mx_i - p) - k \,.$$

The LHS of the above inequality designates the net payoff of the buyer when purchasing from i given that this supplier is of type x_i. The RHS measures the expected payoff of the buyer when continuing to search for another supplier. This supplier may end up being of a higher type than x_i (with probability $1-x_i$). In this case, the buyer purchases from him since this newly sampled supplier is now considered the best and his fitness parameter lies in the acceptable region. Alternatively, the newly sampled supplier may be of a lower type than x_i (with probability x_i), in which case supplier i continues to be the best among those sampled. The buyer returns then to supplier i since his fitness value exceeds the minimal acceptable level x^*. Irrespective of the outcome of the continued search, the buyer must incur the extra search cost k. The minimal acceptable level x^* is derived by substituting $x_i = x^*$ and solving the above expression as an equality.[12]

Next, suppose that supplier i deviates slightly from the symmetric equilibrium[13] by charging the price p_i, and let $\hat{p}$ be the common price charged by all suppliers other than i. This deviation causes the buyer to re-calculate the minimal acceptable fitness level when evaluating supplier i. Designate this level by x_i^*. Supplier i will be chosen (i.e. $x_i \geq x_i^*$) if the following inequality holds:

$$mx_i - p_i \geq (1-\tilde{x}_i)(mE[x \mid x \geq \tilde{x}_i] - \hat{p}) + \tilde{x}_i(mx_i - p_i) - k \,, \qquad (2)$$

where $\tilde{x}_i \equiv x_i + \dfrac{\hat{p} - p_i}{m}$.

---

[12] It can be directly shown that $x^* = 1 - \sqrt{2k/m}$.

[13] We focus on the derivation of symmetric *interior* equilibria. For the derivation of such equilibria, it is sufficient that we consider only small deviations from the common equilibrium price. As a result, even when the buyer can costlessly observe the prices of suppliers and, possibly, exclude from inspection some suppliers due to their high prices she does not find it optimal to drop supplier *i*. Since this supplier deviates only slightly from the common price charged by all his competitors the buyer still finds it optimal to incur the cost *k* necessary in order to inspect his qualifications.

The interpretation of the RHS of (2) is very similar to that discussed earlier. If the buyer samples one additional supplier, he may offer her a higher net payoff than i if his type exceeds $\tilde{x}_i$ (with probability $1-\tilde{x}_i$). In that case, the buyer purchases the input from him. Otherwise, she returns to supplier i who is considered acceptable (given that $x_i \geq x_i^*$). Inequality (2) can be rewritten as follows

$$m\tilde{x}_i \geq mE[x \mid x \geq \tilde{x}_i] - \frac{k}{1-\tilde{x}_i}. \qquad (3)$$

To find the minimal acceptable level, solve (3) as an equality to obtain: $\tilde{x}_i = 1-\sqrt{2k/m}$. From the definition of $\tilde{x}_i$ it follows that

$$x_i^* = 1-\sqrt{\frac{2k}{m}} - \frac{\hat{p}-p_i}{m}. \qquad (4)$$

Note that supplier i can affect the "stopping rule" used by the buyer when evaluating him. Specifically, by charging a lower price than all of his competitors the supplier increases the probability that he will be selected by the buyer. The probability of him being selected is equal to $1-x_i^*$, which increases when p_i decreases. Conditional on being the most favored supplier so far, the expected revenues of i are given by $(1-x_i^*)p_i$ and the supplier chooses his price to maximize these expected revenues. The result of this maximization yields the following proposition.

Proposition 1 At the symmetric price equilibrium when sellers are uninformed about their types, the buyer searches sequentially[14] among suppliers if $k \leq m/8$. She continues to sample until she identifies a supplier whose fit exceeds x^*, where

$$x^* = 1-\sqrt{\frac{2k}{m}}. \qquad (5)$$

If $k > m/8$, the buyer does not conduct any search and withdraws from the market.

[14] The literature on optimal sequential search has established that for an exogenous distribution of prices, a consumer is better off sampling sequentially among suppliers rather than inspecting simultaneously a specified number $n > 1$ of suppliers. (See, for instance, DeGroot (1970), Chapter 13.)

(i) The common price charged by the suppliers at such an equilibrium is:

$$p = \sqrt{2km} \tag{6}$$

(ii) The expected profit of each supplier is:

$$E\pi = 2k \tag{7}$$

and the expected payoff of the buyer is:

$$Ev = m - 2\sqrt{2km}\,. \tag{8}$$

According to Proposition 1, the buyer actively searches among suppliers only if the cost of search k is sufficiently small. If $k > m/8$, the buyer cannot benefit from participating in the market, since the input prices she anticipates combined with her high costs of search render production unprofitable. Notice that in the region where search does take place, the threshold fit level exceeds ½, implying that only if the supplier's type is higher than the mean of the population the buyer will consider purchasing the input from him. Moreover, the threshold level increases when search costs are smaller and /or the buyer places greater emphasis on obtaining a good fit between the input type and the specification of her product (i.e. smaller k and bigger m values). A bigger threshold implies that the buyer is more selective, thus inducing fiercer price competition among the suppliers. Notice that the common price set by the suppliers at the symmetric equilibrium is always lower than the price a monopolist supplier would choose (i.e. from (6) $p \le m/2$ when $k \le m/8$).[15]

3.2 Information Revelation Regime

When the buyer chooses to inform the supplier about his type while negotiating with him, the supplier can choose his price to be contingent upon his extent of fit x. Let $\hat{p}(\cdot)$ designate the schedule chosen by all other suppliers except i. Continued search by the buyer may benefit her if she can identify an alternative supplier who offers her a higher net payoff. Assuming that this net payoff is a nondecreasing function of x (i.e., $\hat{v}(x) \equiv mx - \hat{p}(x)$ is nondecreasing), we can

[15] A monopolistic supplier who chooses the price p obtains a market share equal to $1 - p/m$. To maximize its profits, it chooses p to maximize $p(1 - p/m)$, yielding $p = m/2$ as the optimal price.

derive a condition similar to (2) guaranteeing that the buyer is better off buying from supplier *i* rather than continuing to search.[16] This condition is expressed as follows:

$$mx_i - p_i(x_i) \geq (1-\tilde{x}_i)\left[\frac{m(1+\tilde{x}_i)}{2} - \frac{1}{(1-\tilde{x}_i)}\int_{\tilde{x}_i}^{1}\hat{p}(t)dt\right] + \tilde{x}_i\left[mx_i - p_i(x_i)\right] - k \quad , \qquad (9)$$

where $\tilde{x}_i = \hat{v}^{-1}[mx_i - p(x_i)]$.

The interpretation of inequality (9) is very similar to that of (2) with the only difference being that the price chosen by the supplier is a function rather than a scalar. Inequality (9) implies that in order to maximize his revenues, supplier i should choose his price schedule just high enough to satisfy (9) as an equality. Doing so guarantees that the supplier charges the highest possible price while still inducing the buyer to purchase the input from him. Setting (9) as an equality while evaluating it at the symmetric equilibrium, so that $p_i(x) = \hat{p}(x) = p(x)$, $v_i(x) = \hat{v}(x) = v(x)$, and $\tilde{x}_i = x_i$, yields the following characterization of the common price chosen by the suppliers:

$$\frac{m(1-x)}{2} + p(x) - \frac{1}{(1-x)}\int_{x}^{1} p(t)dt - \frac{k}{(1-x)} = 0 \, . \qquad (10)$$

Equation (10) is a differential equation that can be solved for $p(\cdot)$. In Proposition 2, we characterize this solution assuming that the net payoff of the buyer is a monotone function of x; specifically, that the derivative of the function $v(x) = mx - p(x)$ never changes its sign.

Proposition 2 When each supplier can observe his own fit parameter when setting his price the buyer chooses to withdraw from the market since each supplier prices to extract the entire surplus of the buyer. Specifically, conditional on being inspected by the buyer, the supplier practices first degree price discrimination by choosing the price schedule $p(x) = mx$. As a result, the buyer cannot attain a positive net payoff from search.

According to Proposition 2, the buyer should never inform the supplier about his extent of fit if she chooses to procure the input through search. Equipped with this information, the

[16] The function $\hat{v}(x) \equiv mx - \hat{p}(x)$ need not be nondecreasing for all values of *x*. Even though *mx* is increasing with *x*, if $\hat{p}(x)$ is increasing at a rate faster than m the net payoff function may decrease.

supplier can emulate a perfectly discriminating monopolist. Given the sequential nature of the search, the buyer deals with each supplier one at a time. In this monopoly-monopsony relationship, transferring information from the buyer to the supplier improves the leverage of the latter, thus allowing him to set prices in a manner that extracts the buyer's surplus. A comparison of Propositions 1 and 2 yields the following result.

Corollary 1 If the buyer chooses to procure the input through search she should conceal information from suppliers so that they cannot infer their extent of fit with the buyer's requirements.

4. RFQ

4.1 Information Concealment Regime

As discussed earlier, the RFQ method is characterized by two parameters: the number of participating suppliers, n, and the scrutiny parameter, $\hat{x}$ that determines the definition of what constitutes a qualified supplier. The cost of the RFQ method increases in both of those parameters. Under the information concealment regime, the buyer withholds information from suppliers about her exact requirements, thus preventing them from assessing precisely the extent to which their products meet those requirements. Suppliers know, however, the scrutiny parameter selected by the buyer either since the RFQ reveals some information about this choice or because they can rationally predict what level of scrutiny is optimal for the buyer (suppliers can solve the maximization problem of the buyer to figure out the value of $\hat{x}$). Hence, when submitting quotes, suppliers know that only those fitness types greater than $\hat{x}$ participate in the bidding. They do not know, however, their exact type x. In the absence of such information, each supplier chooses his price as a scalar, independent of x (i.e. $p \in \Re^+$).

We focus, once again, on the derivation of symmetric equilibria where all suppliers submit identical bids. To derive the equilibrium, designate by p_i the bid submitted by a representative supplier and by $\hat{p}$ the common bid submitted by all other suppliers except *i*. Supplier *i* is the winner of the bidding if his type x_i combined with his bid p_i guarantees the highest net payoff to the buyer. Specifically, if:

$$mx_i - p_i \geq mx_j - \hat{p} \text{ for } j \neq i .$$

Restricting attention to the case that the buyer selects to solicit bids from at least two suppliers,[17] so that $n \geq 2$, the probability of the above event is

$$\Pr\left(x_j \leq x_i + \frac{\hat{p} - p_i}{m} \middle| x_j \geq \hat{x} \text{ all } j \neq i \right) = \frac{\left(x_i + \frac{\hat{p} - p_i}{m} - \hat{x} \right)^{n-1}}{(1-\hat{x})^{n-1}} .$$

Supplier *i* chooses his bid without knowing exactly his type x_i. Hence, the bid chosen by *i* maximizes his expected payoff expressed as follows:

$$E\pi_i = p_i \int_{\hat{x}}^{1} \frac{\left(x_i + \frac{\hat{p} - p_i}{m} - \hat{x} \right)^{n-1}}{(1-\hat{x})^{n}} dx_i . \tag{11}$$

Optimizing the above payoff function with respect to p_i, yields the results reported in Proposition 3.

Proposition 3 If the buyer solicits bids from n suppliers, utilizes the scrutiny parameter $\hat{x}$, and conceals information from suppliers about their types, the common bid submitted by the suppliers at the symmetric equilibrium is

$$p \equiv p_i = \hat{p} = \frac{m(1-\hat{x})}{n} . \tag{12}$$

The expected payoff of each supplier at this equilibrium is:

$$E\pi = \frac{m(1-\hat{x})}{n^2} , \tag{13}$$

and the expected payoff of the buyer is

$$Ev = m\hat{x} + \frac{m(1-\hat{x})(n^2 - n - 1)}{n(n+1)} - TC_B(\hat{x}, n) , \tag{14}$$

According to Proposition 3, suppliers compete more aggressively the bigger is the number of participating suppliers and the more selective the intermediary is in approving suppliers to participate in the bidding. In order to win the bid, each supplier has to submit a lower

[17] The case in which $n = 1$ can be easily analyzed as well. However, since there is no meaningful bidding behavior when only one bidder submits a quote, we omit this case to simplify the discussion.

quote if he knows that there is a bigger number of competing suppliers whose product specifications are better aligned with the buyer's requirements. Hence, bigger values of $\hat{x}$ and *n* result in lower expected profits of the suppliers. The buyer, in contrast, may benefit from choosing bigger values of $\hat{x}$ and *n* . First, she is more likely to procure an input that is closely aligned with her needs, and second, such a choice induces more aggressive pricing by the suppliers.

4.2 Information Revelation Regime

When the buyer shares with the suppliers information about her exact requirements, each supplier can infer his type and choose his bid contingent upon *x*. Let $p_i(\cdot)$ designate the price schedule selected by a representative supplier *i*, and let $\hat{p}(\cdot)$ designate the price schedule selected at the equilibrium by all suppliers other than *i*. As well, designate by $\hat{v}(x)$ the net payoff function of the buyer when obtaining the input from a supplier different than *i* whose fit parameter is *x*. Hence,

$$\hat{v}(x) = mx - \hat{p}(x) .$$

The buyer will purchase the input from i if the following inequality holds:

$$mx_i - p_i(x_i) \geq \max\{\hat{v}(x_j),\ j \neq i\} .$$

Assuming that the net payoff function $\hat{v}(\cdot)$ is nondecreasing, the probability that the buyer prefers i to all other suppliers is given as $\left\{\left[\hat{v}^{-1}(mx_i - p_i(x_i)) - \hat{x}\right]/(1-\hat{x})\right\}^{n-1}$. Hence, the expected payoff of supplier i can be expressed as follows:

$$E\pi_i(x_i) = \frac{p_i(x_i)\left[\hat{v}^{-1}(mx_i - p_i(x_i)) - \hat{x}\right]^{n-1}}{(1-\hat{x})^{n-1}}, \tag{15}$$

and the supplier chooses his price schedule to maximize the above payoff function. The result of this maximization is reported in Proposition 4.

Proposition 4 When the buyer guarantees that each supplier can infer his own type the price schedule selected by each supplier at the symmetric equilibrium is given by:

$$p(x) \equiv p_i(x) = \hat{p}(x) = \frac{m(x-\hat{x})}{n} . \tag{16}$$

The expected payoff of each supplier at such an equilibrium is:

$$E\pi = \frac{m(1-\hat{x})}{n(n+1)}, \tag{17}$$

and the expected payoff of the buyer is given as:

$$Ev = m\hat{x} + \frac{m(1-\hat{x})(n-1)}{(n+1)} - TC_B(\hat{x}, n). \tag{18}$$

Similar to the results reported in Proposition 3, the above proposition states that the RFQ method with information revelation yields more aggressive pricing by suppliers when the scrutiny parameter and the number of suppliers that participate in the bidding increase. As a result, the expected profits of suppliers decline when $\hat{x}$ or n are bigger. A comparison of (18) with (14) implies that the expected payoff of the buyer rises with information revelation. Specifically, from (12) and (16) it follows that informed suppliers compete more aggressively than uniformed suppliers when the buyer uses the RFQ method. As a result, the Information Revelation Regime yields lower expected profits to suppliers and a higher expected payoff to the buyer than the Information Concealment Regime.[18]

When the bid submitted by each supplier is chosen contingent upon the value of *x*, the price schedule is strictly increasing. Hence, any supplier who realizes that the specifications of his product are very different from those required by the buyer lowers his bid in order to remain attractive to the buyer. Such an anticipated adjustment on the part of his competitors implies that it is more difficult for each supplier to win the bidding than in an environment where prices of competitors remain constant. Suppliers are forced, therefore, to reduce the overall level of their prices, thus making the Information Revelation Regime a more competitive environment for suppliers. The comparison of the two regimes in the RFQ method is very different from that in the buyer search model, considered in the previous section.

[18] Even though we only consider the possibility that the buyer fully informs all the suppliers under the RFQ method our model can be extended to allow for partial sharing of information. Partial sharing can be implemented, for instance, if the buyer decides probabilistically on whether to share with the suppliers the buyer's requirements. One such probabilistic choice model that does not affect our derivations is when the intermediary chooses with a certain probability α to inform all the suppliers and with probability $(1-\alpha)$ to inform none. As a result, with probability α suppliers follow the pricing rule (16) and with the remaining probability $(1-\alpha)$ they follow the pricing rule (12). Price competition intensifies and the buyer's payoff increases as α increases, implying that the buyer will find it optimal to choose $\alpha = 1$. In future research, we plan to consider alternative models of partial sharing of information. For instance, the buyer may choose to inform only a subset of suppliers, or she may decide on whether to inform one supplier independent of her choice with respect to competing suppliers.

When the buyer searches sequentially among suppliers she is disadvantaged if suppliers can observe their types. In fact, suppliers can exercise first degree price discrimination, in this case, and extract the entire surplus of the buyer. In contrast, if the buyer uses the RFQ method, informing each supplier about his type induces him to actually compete more aggressively, thus benefiting the buyer. We summarize the above comparison in Proposition 5.

Proposition 5 If the buyer searches sequentially among suppliers she is better off if suppliers are unaware of her exact requirements. In contrast, if the buyer uses the RFQ method to procure the input and $n \geq 2$, the buyer benefits by informing each participating supplier of her exact requirements.

In view of the results reported in Proposition 5, we can now compare the expected payoff of the buyer when using the two different methods to procure the input. If the buyer searches sequentially, her expected payoff is given by (8) in Proposition 1 since she does not reveal information to suppliers in this case. If the buyer uses the RFQ method, her expected payoff is given by (18) in Proposition 4 since she does find it optimal to share information with suppliers in this case. We start by conducting the comparison when $\hat{x} = 0$, namely when the buyer does not screen suppliers who are allowed to participate in the bidding. In the absence of screening, the cost of the RFQ method is simply kn, which corresponds to the cost of sampling simultaneously n different suppliers. In the literature on optimal search, it has been established that sequential search using the "stopping rule" approach is superior to the sampling and simultaneous inspection of n observations from the population. However, this result was derived under the assumption that the distribution of prices in the population is exogenously determined, independent of the search rule selected by the decision maker. In our environment, the buyer is a monopsonist whose search method affects the extent of price competition among suppliers. It is unclear, therefore, which procurement method is preferable to the buyer. We report the results of the comparison when $\hat{x} = 0$ in Proposition 6, and restrict this comparison to the case that $k \leq m/8$ to guarantee that sequential search is a viable option to the buyer.

Proposition 6 Suppose $k \le m/8$ and define

$$k_L \equiv \frac{2m[n+2-2\sqrt{n+1}]}{n^2(n+1)} \qquad \text{and} \qquad k_H \equiv \frac{2m[n+2+2\sqrt{n+1}]}{n^2(n+1)}.$$

(i) When $n \le 5$, the buyer prefers sequential search over RFQ without any initial screening of suppliers (i.e. $\hat{x} = 0$) provided that $k \le k_L$. Otherwise, if $k_L < k \le m/8$ the RFQ method generates higher profits to the buyer.

(ii) When $n \ge 6$, the buyer prefers the sequential search method if either $k \le k_L$ or $k_H < k \le m/8$. Otherwise, if $k_L < k < k_H$ the RFQ method is the preferable choice of the buyer.

The parameter k that measures the cost of sampling and inspecting a single supplier determines the relative profitability of the two procurement methods. Higher costs result in less intensified price competition among suppliers under sequential search, implying that the RFQ method may be more advantageous to the buyer in this case. However, higher values of k imply also that the overall costs of search are higher under RFQ than under sequential search. The expected number of observations sampled under sequential search equals $1/(1-x^*)$, which is smaller than n if k is sufficiently large.

The results reported in Proposition 6 characterize regions of the parameter k over which one of the above mentioned counteracting effects dominates. When n is relatively small (less than or equal to 5) the sequential search method dominates for small values of k. In essence, small values of k guarantee sufficiently aggressive competition among suppliers under sequential search. When n is relatively large (6 or larger), sequential search dominates either for very low or for very high values of k. RFQ dominates for intermediate values of k.

If the buyer chooses the RFQ method she selects the parameters $\hat{x}$ and n to maximize her expected payoff in (18). Ignoring the integer constraint on n yields the following two first order conditions to determine the optimal values of $\hat{x}$ and n:

$$\frac{\partial Ev}{\partial \hat{x}} = \frac{2m}{(n+1)} - \frac{\partial TC_B}{\partial \hat{x}} = 0,$$
$$\frac{\partial Ev}{\partial n} = \frac{2m(1-\hat{x})}{(n+1)^2} - \frac{\partial TC_B}{\partial n} = 0 \qquad (19)$$

If the cost function $TC_B(\hat{x}, n)$ is separable in its two arguments (for instance, $TC_B(\hat{x}, n) = kn + \alpha\hat{x}^2/2$), then the above two first order conditions imply that the parameters $\hat{x}$ and n are substitutes. Specifically, if the buyer chooses to recruit additional suppliers to participate in the bidding she finds it optimal to reduce the extent of scrutiny is screening them and vice-versa.

If the solution to (19) is an interior equilibrium, so that $\hat{x} > 0$, the comparison between the two procurement methods is more complicated, since larger values of $\hat{x}$ increase both the costs and the expected benefit of the RFQ method. It is unclear, therefore, whether the regions of relative dominance reported in Proposition 6 remain qualitatively similar. Different values of the parameter k are likely to still introduce counteracting effects in determining which method dominates.

The above derivations imply that the buyer has to consider both procurement methods in deciding which one to employ. She chooses the one that guarantees her the higher net expected payoff. Designate by Ev^*_{RFQ} the expected net payoff of the buyer when using the RFQ method, which incorporates the optimal choice of the parameters $\hat{x}$ and n that solve (19) as well as full disclosure of information to each supplier about his type. Similarly, let Ev^*_{SS} designate the buyer's expected net payoff by using optimal sequential search, which involves concealment of information from suppliers. As a result, the overall expected net payoff of the buyer can be expressed as

$$Ev^* = \max\{Ev^*_{\text{RFQ}}, Ev^*_{\text{SS}}\}. \qquad (20)$$

5. Online Procurement Intermediary

As an alternative to procuring the input herself, the buyer can hire the services of an intermediary who uses, for example, proprietary Internet-based software to execute reverse-auctions on behalf of the buyer. By using the Internet, the intermediary provides efficiency gains by reducing the cost of administering the RFQ process. One source of efficiency gains is for the improved ability of communicating with suppliers regarding essential transaction details. (See Lucking-Riley & Spulber (2001) for other sources of efficiency gains.)

Similar to the RFQ method considered in the previous section, the quality of the service provided by the intermediary can also be characterized in terms of two parameters: a threshold level of fit $\hat{x}$ used by the intermediary to screen eligible suppliers and the number of suppliers n who are identified as being appropriate to participate in the auction. We designate the costs of the intermediary as $TC_I(\hat{x}, n)$, and assume this cost function to be convex and increasing in its two arguments.

The derivations conducted in the previous sections can help us assess the extent to which the intermediary can offer value to the buyer. As in the RFQ method, the values of the parameters $\hat{x}$ and n determine the extent of competition among suppliers in the auction. Moreover, bigger values guarantee that the buyer is more likely to find a good fit with her requirements. In fact, we can use (14) and (18) to express the expected payoffs that the intermediary can generate for the buyer gross of her payment to the intermediary:

$$EGV = \begin{cases} m\hat{x} + \dfrac{m(1-\hat{x})(n^2 - n - 1)}{n(n+1)} & \text{under the Information Concealment Regime} \\ m\hat{x} + \dfrac{m(1-\hat{x})(n-1)}{(n+1)} & \text{under the Information Revelation Regime} \end{cases}$$

The ability of the intermediary to offer a valuable service to the buyer depends upon the costs it has to incur in order to generate the above gross payoff. Hence, in understanding the relationship between the buyer and the intermediary it is essential to conduct a comparison between the cost functions $TC_I(\cdot)$ and $TC_B(\cdot)$. Given that the attribute x might not be easily specified, it is likely that the buyer would have an advantage over the intermediary in screening suppliers according to the minimum threshold $\hat{x}$. Since the buyer is more familiar with her own preferences, she can implement any desired scrutiny level at a lower cost than the intermediary can. It is reasonable to assume, therefore, that the marginal cost of increased scrutiny is lower for the buyer than for the intermediary. Specifically,

$$\frac{\partial TC_B(\hat{x}, n)}{\partial \hat{x}} < \frac{\partial TC_I(\hat{x}, n)}{\partial \hat{x}}.$$

Similarly, the intermediary may be at a disadvantage, in comparison to the buyer, in implementing the Information Revelation Regime. Given that it is difficult for the buyer to articulate her preferences with respect to the attribute x, the intermediary may have difficulties in revealing to suppliers their exact fit with the buyers' requirements.[19] As a result, the intermediary may not be able to generate for the buyer the higher expected payoff feasible when suppliers bid in the auction equipped with full information about their own types.

In contrast to its information disadvantage, the intermediary may have a significant cost advantage in recruiting suppliers to participate in the auction. The software developed by e-sourcing intermediaries takes advantage of the global reach of the Internet to identify many more potential suppliers than the buyer could solicit on her own. As a result, it is likely that the marginal cost of recruiting additional suppliers to participate in the auction is higher for the buyer than for the intermediary. Hence, we assume that

$$\frac{\partial TC_B(\hat{x},n)}{\partial n} > \frac{\partial TC_I(\hat{x},n)}{\partial n}.$$

Given the bilateral nature of the relationship between buyer and intermediary, we assume that the parties agree on the terms of the transaction between them, via negotiations.[20] In the negotiations, they choose a mutually acceptable rule to share the added value generated by the intermediary (if positive). This added value depends upon the ability of the intermediary to implement the Information Revelation Regime. Specifically, the added value is given by $EGV - Ev^*$, which corresponds to the difference between the expected value the intermediary can generate for the buyer by administering the on-line auction and the payoff the buyer can generate on her own. Assuming that the parties agree to split the contribution of the intermediary at a rate β to the intermediary and $1-\beta$ to the buyer, the intermediary chooses $\hat{x}$ and n to maximize the following objective:

$$R(\hat{x},n) = \begin{cases} \beta\left[m\hat{x} + \dfrac{m(1-\hat{x})(n^2-n-1)}{n(n+1)} - Ev^*\right] - TC_I(\hat{x},n) & \text{under Information Concealment} \\ \beta\left[m\hat{x} + \dfrac{m(1-\hat{x})(n-1)}{n+1} - Ev^*\right] - TC_I(\hat{x},n) & \text{under Information Revelation.} \end{cases} \quad (21)$$

If the buyer assists the intermediary in informing the suppliers about their types, so that the Information Revelation Regime is feasible, then the objective in (21) indicates that the

[19] FreeMarkets tries to create a very close relationship with its customers, in the form of a broad set of additional services, in order to better understand their needs.
[20] See Yoo et al (2003a) for discussion of specific pricing strategies. Our negotiations set-up abstracts away from this issue in order to focus on informational design and other profitability factors.

intermediary chooses a lower scrutiny level in screening suppliers than the buyer does when she chooses the RFQ method.[21] Since the intermediary obtains a fraction β of the benefit from increased scrutiny whereas the buyer internalizes the full benefit, and since the marginal cost of increased scrutiny is higher for the intermediary than it is for the buyer, the intermediary chooses a lower value of $\hat{x}$. As far as the incentives to recruit suppliers, three different effects should be recognized. First, on the negative side, the intermediary can capture only a fraction β of the benefit from increasing n, whereas the buyer internalizes the full benefit, implying the existence of reduced incentives to recruit suppliers. However, on the positive side, since the level of scrutiny and the number of participants in the auction are substitutes in generating value for the buyer, the lower scrutiny level selected by the intermediary implies that it has stronger incentives to increase the number of participants. Moreover, its lower marginal cost of recruiting suppliers provides the intermediary with an additional reason to include a bigger number of suppliers in the auction than the buyer does when she uses the RFQ method to procure the input.

To resolve the ambiguity in comparing the incentives of the intermediary and the buyer, consider the following specification of the cost function:

$TC_i(\hat{x}, n) = k_i n + (\alpha_i / 2)\hat{x}^2$, where $i = B, I$,

$k_B > k_I$ and $\alpha_B < \alpha_I$.

Assuming that the intermediary can implement the Information Revelation Regime, the above specification yields the following solutions for $\hat{x}$ and n:

$$\begin{aligned} \hat{x}_I &= \frac{2m\beta}{\alpha_I(n_I+1)} \quad \text{and} \quad n_I + 1 = \sqrt{\frac{2m\beta(1-\hat{x}_I)}{k_I}} \\ \hat{x}_B &= \frac{2m}{\alpha_B(n_B+1)} \quad \text{and} \quad n_B + 1 = \sqrt{\frac{2m(1-\hat{x}_B)}{k_B}}. \end{aligned} \tag{22}$$

It is easy to show that the above solution implies that $\hat{x}_I < \hat{x}_B$ and $n_I > n_B$. Hence, the intermediary substitutes for a lower level of scrutiny with a larger number of participants in the auction.

[21] Note that the buyer has strong incentives to assist the intermediary in informing the suppliers since doing so increases the added value generated by the intermediary and, as a result, the expected payoff of the buyer. (She obtains a fraction $1-\beta$ of the increased added value.)

The intermediary will survive in the market only if the overall payoff it can generate exceeds the payoff the buyer can generate on her own. Combining the expected payoff of the intermediary and buyer yields the following overall payoff generated by the intermediary:

$$W_I \equiv \frac{2m^2\beta(2-\beta)}{\alpha_I(n_I+1)^2} + \frac{m(n_I-1)}{n_I+1} - k_I n_I, \tag{23}$$

where n_I solves (22). If the buyer uses the RFQ method to procure the input on her own the overall payoff she generates amounts to

$$W_B \equiv \frac{2m^2}{\alpha_B(n_B+1)^2} + \frac{m(n_B-1)}{n_B+1} - k_B n_B, \tag{24}$$

where n_B solves (22). The intermediary survives in the market only if $W_I > W_B$, which essentially implies that the intermediary can sufficiently increase the number of participants in the auction to compensate for the reduced scrutiny it exercises in screening suppliers.

If the intermediary is unable to implement the Information Revelation Regime, it is more difficult for it to remain attractive to the buyer since the overall value it can generate declines when suppliers remain uninformed about their types. To guarantee its survival, in this case, its marginal cost of identifying additional suppliers, as measured by k_I, should be especially small (in comparison to k_B) to guarantee that it finds it optimal to include many more suppliers than the buyer does on her own.

6. Managerial Implications

It is useful to summarize the implications of the previous analysis for IT firms who are involved in online procurement processes or develop IT products for the online auctions. These points might also be of interest to any industrial buyer who considers using an online intermediary for her procurement process.

Internet services involved in e-commerce, such as online procurement service firms, are profitable, in general, if they reduce transaction costs relative to traditional dealing. However, transaction costs savings come in many forms (see Pinker et al, 2003) and it is important for Internet firms to know their advantage in this area. Our analysis suggests that an online procurement service can be profitable through its lower cost in administering large numbers of bidders relative to the buyer herself. Sources of such cost advantages come in several forms. For instance, Moai Technologies provides auction systems, known as CompleteSource, that allow buyers to negotiate bid terms online, which improves the buyers ability to deal with a larger number of suppliers who might be, otherwise, not considered. And, as discussed previously, FreeMarkets develops proprietary software that facilitates efficient real-time bidding with a large number of suppliers.

An important design parameter for the procurement process is the scrutiny level, or the lower bound for suppliers' degree of fit with the buyer (the $\hat{x}$ parameter in our analysis). Since this is dependent on the buyer's specific needs, the buyer is more likely to have better ability than the intermediary to screen potential suppliers. Despite this disadvantage, the analysis of the previous section suggests that the intermediary can remain a beneficial alternative to the buyer by exploiting its real advantage in the administration of a large number of buyers. The analysis suggests, furthermore, that any improvement in the intermediary's ability to screen potential suppliers will further enhance its potential to offer the buyer savings in its procurement process. Online services such as FreeMarkets, for example, tries to create a very close relationship with its customers, in the form of a broad set of additional services, in order to better understand their needs.[22]

Finally, our analysis has an important implication regarding the informational design of the online auction. The intermediary can induce more competitive bidding by informing suppliers of their degree of fit with the buyer (the value of x_i for supplier i). A supplier who knows that his fit level is relatively low strategically lowers his bid to remain attractive to the buyer. Furthermore, a supplier who knows his fit is relatively high must lower his bid to compete with these low-fit/low-bidding suppliers.

Several successful online procurement service firms exercise some form of information revelation in their RFQ process. For example, the firm Frictionless Commerce relies heavily on informing bidders of the *score* or ranking of bidders in terms of meeting the demands of the buyer (Beil & Wein, 2003).[23] The principle for information revelation in auctions holds as well for the buyer conducting her own RFQ. But if the intermediary recruits more bidders at a lower scrutiny level, information revelation becomes more important for the intermediary to remain a beneficial alternative for the buyer.

[22] See *FreeMarkets OnLine*, 1998, Harvard Business School Publishing, 9-598-109.
[23] There are other examples. Sorcity.com encourages two-way communication between the buyer and the qualified suppliers. And, as noted previously, FreeMarkets offers potential suppliers free RFQ support to help them know their match with the buyer's specific requirements.

7. Concluding Remarks

We have developed a theoretical model to explain the source of profitability and the related behavior of an intermediary who organizes Internet-based auction to source the inputs required by its clients. We identify as a source of profitability for the intermediary its ability to administer efficiently reverse-auctions on behalf of its clients using, for instance, Internet-based e-sourcing software. We also use this model to offer strategies that might improve the profitability of the intermediary with regard to bidder recruitment and information revelation to the participating suppliers. We show that the intermediary is more likely to be profitable when it can recruit a larger number of bidders, relative to the buyer's own optimal number, and when it can reveal to each bidder his degree of fit before the auction takes place.

We also point out that the profitability of the intermediary depends on how successful the buyer can be when she procures the input herself, since this defines the buyer's outside option. In contrast to the intermediary, it might be optimal for the buyer to conceal information from suppliers when there is a small number of potential suppliers and search costs are relatively low. In this latter case, if the buyer searches on her own she does it sequentially, one supplier at a time.

Our model is based upon several simplifying assumptions. In future research, we wish to investigate whether the results are sensitive to those assumptions. It will be useful to investigate, for instance, whether the results change if the distribution of fitness types is not uniform or if suppliers differ also in terms of their costs of production. As well, we have restricted attention to only one type of auction in the analysis. In the future, we wish to consider alternative types such as second price, sealed bid and open auctions. We do not expect our main result concerning the role of information to be significantly altered. As in the first-price, sealed bid auction, we expect suppliers to bid more aggressively when they are fully aware of their fit parameters.

Another simplifying assumption, which is made in our formulation of buyer search, is that previously contacted suppliers cannot strategically change their price upon contact again from the buyer. Relaxing this assumption might presumably put downward pressure on prices. This might occur, for instance, when the buyer wishes to return to a previously contacted supplier and use other quotes to put pressure on him to lower his originally quoted price. On the other hand, if the supplier anticipates the possible return of the buyer, he might shade his originally quoted price upward. Which effect dominates leaves an open question for future research aimed at a better understanding of search behavior.

Finally, we have not considered here the effect of competitive threats to the intermediary's profitability. In a previous working paper version of this manuscript we consider two possible threats. In one instance, there might exist competing intermediaries who are either more cost efficient in their auction administration or offer a better share of the efficiency gains to their customers. Ellison et al (2003) and Santos & Scheinkman (2001) present recent research on competing auctions and exchanges, respectively. Their approach might provide additional answers to questions concerning competing intermediaries.

In a second instance, suppliers might strategically bypass the intermediary and approach the buyer directly through, for instance, advertising. Such behavior on the part of the supplier reduces the search costs of the buyer and consequently reduces the potential of the intermediary to add value to the procurement process. (A simple, but formal analysis of this scenario appears in the previous working paper and is available upon request.)

References

Anand, K. and Aron, R. (2003), "Group-Buying on the Web: A Comparison of Price Discovery Mechanisms," *Management Science,* Vol. 49(11): 1546-1562.

Bakos, Y. (1997), "Reducing Buyer Search Costs: Implications for Electronic Marketplaces," *Management Science*, Vol. 43(12): 1676-1692.

Bakos, Y. (2001), "The Emerging Landscape for Retail E-Commerce," *Journal of Economic Perspectives*, Vol. 15(1): 69-80.

Baye, M. and Morgan, J. (2001), "Information Gatekeepers on the Internet and the Competitiveness of Homogeneous Product Markets," *American Economic Review*, Vol. 91(3): 454-474.

Baye, M. and Morgan, J. (2002), "Information Gatekeepers and Price Discrimination on the Internet," *Economic Letters*, Vol. 76: 47-51.

Beil, D. and Wein, L. (2003), "An Inverse-Optimization-Based Auction Mechanism to Support a Multiattribute RFQ Process," *Management Science*, Vol. 49(11): 1529-1545.

Brynjolfsson, E. and Smith, M. (2000), "Frictionless Commerce? A Comparison of Internet and Conventional Retailers," *Management Science*, Vol. 46(4): 563-585.

Choudhary, V., Ghose, A., Mukhopadhyay, T., and Rajan, U. (2003), "Personalized Pricing and Quality Differentiation on the Internet," working paper, GSIA, Carnegie Mellon University.

Dai, Q. and Kauffman, R. (2002, forthcoming), "Business Models for Internet-based Procurement Systems and B2B Electronic Markets: An Exploratory Assessment," *International Journal of Electronic Commerce*.

Dasgupta, S. and Spulber, D. (1989/1990), "Managing Procurement Auctions," *Information Economics Policy* Vol. 4: 5-29.

DeGroot, M. (1970), *Optimal Statistical Decisions*, McGraw-Hill Book Company.

Ellison, G. and Ellison, S., (2001), "Search, Obfuscation, and Price Elasticities on the Internet," working paper, MIT and NBER.

Ellison, G., Fudenburg, D. and Mobius, M. (2002) "Competing Auctions," working paper, Harvard University.

El Sawy, O. (2001), "Identifying Structural Models of B2B Procurement Exchanges," Final Technical Report, Marshall School of Business, University of Southern California.

Gabszewicz, J. and Thisse, J. (1979), "Price Competition, Quality, and Income Disparities," *Journal of Economic Theory*, Vol. 20(3): 340-359.

Gal-Or, E. (1985) "Differentiated Industries without Entry Barriers," *Journal of Economic Theory*, Vol. 37(2): 310-339.

Lippman, S. and McCall, J. (1976), "The Economics of Job Search: A Survey," *Economic Inquiry,* Vol. 14:347-68.

Lucking-Riley, D. and Spulber, D. (2001), "Business-to-Business Electronic Commerce," *Journal of Economic Perspectives,* Vol. 15(1): 55-68.

McCall, J. (1970), "Economics of Information and Job Search," *Quarterly Journal of Economics,* Vol. 84(1): 113-26.

Mirman, L. and Porter, W. (1974) "A Microeconomic Model of the Labor Market Under Uncertainty," *Economic Inquiry,* Vol. 12: 135-45.

Morton, F., Zettelmeyer, F., and Silva-Risso, J. (2001), "Internet Car Retailing," *The Journal of Industrial Economics,* Vol. 49(4): 501-519.

Pinker, E., Seidmann, A. and Vakrat, Y. (2003), ”Managing Online Auctions: Current Business and Research Issues,” *Management Science*, Vol. 49(11): 1457-1484.

Rothchild, M. (1974), “Searching for the Lowest Price When the Distribution of Prices is Unknown,” *Journal of Political Economy*, Vol. 82(4): 689-711.

Santos, T. and Scheinkman, J. (2001), “Competing Exchanges,” *Quarterly Journal of Economics*, Vol. 116(3): 1027-1062.

Snir, E. and Hitt, L. (2001), "The Emerging Knowledge Economy: Exchange in Internet Spot Markets for IT Services," Wharton School Working Paper.

Tomkat, K. and Xia, M. (2002), “Evolution of B2B Marketplaces,” *Electronic Markets*, Vol. 12(2): 89-94.

Varian, H. (2000), "Versioning Information Goods," in Brian Kahin and Hal Varian (Eds) *Internet Publishing and Beyond: The Economics of Digital Information and Intellectual Property*, MIT Press.

Yoo, B., Choudhary, V. and Mukhopadhyay, T. (2003a), “A Model of Neutral B2B Intermediaries,” *Journal of Management Information Systems*, Vol. 19(3): 43-68.

Yoo, B., Choudhary, V. and Mukhopadhyay, T. (2003b), "Neutral vs. Biased Marketplaces: A Comparison of Electronic B2B Marketplaces with Different Ownership Structures," unpublished manuscript.

Zhu, K. (2002), “Information Transparency in Electronic Marketplaces: Why Data Transparency May Hinder the Adoption of B2B Exchanges,” *Electronic Markets*, Vol. 12(2): 92-99.

Zhu, K. (2003), "Information Transparency of Business-to-Business Electronic Marketplaces: A Game-Theoretic Analysis," University of California Irvine Working Paper, forthcoming in *Management Science*.

Appendix 1

Proof of Proposition 1

(i), (ii) Using the expression for x_i^* from (4), we can obtain the objective function of supplier i as follows:

$$E\pi_i = (1 - x_i^*)\, p_i = \left[\sqrt{\frac{2k}{m}} + \frac{\hat{p} - p_i}{m}\right] p_i \,. \tag{A.1}$$

Optimizing with respect to p_i we get:

$$\frac{\partial E\pi_i}{\partial p_i} = \sqrt{\frac{2k}{m}} + \frac{\hat{p} - 2p_i}{m} = 0\,. \tag{A.2}$$

Substituting symmetry into (A.2), we obtain that $p_i = \hat{p} = p = \sqrt{2km}$ as stated in (6). Similarly, substituting symmetry into (4) yields the minimal acceptable level (5).

If the buyer sampled already one supplier her expected payoff from following the above mentioned stopping rule designated by Ew, can be expressed as follows:

$$Ew = \Pr(x \geq x^*)(mE[x | x \geq x^*] - p) + \Pr(x < x^*)(Ew - k)\,. \tag{A.3}$$

If the current supplier is of type greater than x^* the buyer purchases from her. Otherwise, she pays the extra search cost *k*, at which point she faces the same environment once again. Solving for Ew yields:

$$Ew = \frac{m(1 + x^*)}{2} - p - \frac{x^* k}{(1 + x^*)} = m - 2\sqrt{2km} + k\,.$$

The cost of sampling the first supplier is k, implying that the expected payoff of the buyer, designated by Ev, from following the sequential search method is given by (8). This expected payoff is non-negative if $k \leq m/8$. Hence, only in this case the buyer will conduct the search for the input in order to participate in production.

To find the expected profits of each supplier, substitute the solution for p into (A.1) to obtain (7). Q.E.D.

Proof of Proposition 2

First we show that if the buyer sampled already one supplier, say supplier i, $p_i(x) = \hat{p}(x) = mx$ is an equilibrium. If the buyer expects the price schedule of all suppliers other than i to be $\hat{p}(x) = mx$ she has no incentive to continue her search since she anticipates a negative payoff from such an activity. In response to the buyer's anticipated absence of search, supplier i raises his price to extract the entire surplus of the buyer, implying that $p_i(x) = \hat{p}(x) = mx$. Given such anticipated pricing by the suppliers the buyer withdraws from the market altogether.

Next we show that if the function $\hat{v}(x) \equiv mx - \hat{p}(x)$ is monotone, the above mentioned pricing by the suppliers is the unique equilibrium, assuming that the buyer has already sampled one supplier. We show this result under the assumption that $\hat{v}(x)$ is always non-decreasing. A similar proof applies when $\hat{v}(x)$ is assumed to be always non-increasing. The differential equation (10) characterizes the symmetric equilibrium, given that the buyer has already observed the fit parameter of one supplier. Define,

$$y(x) = \int_x^1 p(t)dt$$

implying that

$$y'(x) = -p(x).$$

Substituting into (10) yields:

$$y'(x) = \frac{m(1-x)}{2} - \frac{y(x)}{(1-x)} - \frac{k}{(1-x)}. \tag{A.4}$$

To solve (A.4) we first derive the solution to the homogenous differential equation:

$$y'(x) = \frac{-y(x)}{(1-x)}. \tag{A.5}$$

The function $z(x) = T(1-x)$, with T as the constant of integration, is the general solution to (A.5). Using the variation of coefficient method we conjecture that the solution to (A.4) is $y(x) = T(x)(1-x)$. Substituting this conjecture back into (A.4) yields a differential equation in $T(x)$ as follows:

$$T'(x) = \frac{m}{2} - \frac{k}{(1-x)^2}. \tag{A.6}$$

The general solution of (A.6) is

$$T(x) = \frac{mx}{2} - \frac{k}{(1-x)} + R,$$

where *R* is a constant of integration. Hence the general solution for $y(x)$ that solves (A.4) is:

$$y(x) = \frac{mx(1-x)}{2} - k + R(1-x).$$

From the definition of $y(x)$ if follows, therefore, that

$$p(x) = R - \frac{m}{2} + mx, \text{ and } v(x) = mx - p(x) = \frac{m}{2} - R.$$

Since the solution yields a flat net-payoff function that is independent of *x*, the buyer will not find it optimal to search, thus leading to the proposed equilibrium in which the supplier sampled extracts the complete surplus of the buyer. As a result, the buyer does not find it optimal to incur the cost k that is necessary in order to inspect the first supplier. Q.E.D.

Proof of Proposition 3

Optimizing (11) with respect to p_i yields the first order condition:

$$\frac{\partial E\pi_i}{\partial p_i} = \int_{\hat{x}}^{1} \frac{\left(x_i + \frac{\hat{p}-p_i}{m} - \hat{x}\right)^{n-1}}{(1-\hat{x})^n} dx_i - \frac{p_i}{m(1-\hat{x})^n}\int_{\hat{x}}^{1}(n-1)\left[x_i + \frac{\hat{p}-p_i}{m} - \hat{x}\right]^{n-2} dx_i = 0 \qquad \text{(A.7)}$$

Evaluating the above integrals and substituting symmetry into (A.7), yields the solution for the common price given in (12). Substituting this common price back into (11) yields the expected payoff of each supplier. The expected payoff of the buyer when $n \geq 2$ is derived as follows:

$$\begin{aligned} Ev &= mE\left[\max\{x_1,\ldots,x_n\} \middle| x_i \geq \hat{x} \quad i = 1,\ldots,n\right] - p - TC_B(\hat{x},n) \\ &= m\int_{\hat{x}}^{1} \frac{xn(x-\hat{x})^{n-1}}{(1-\hat{x})^n} dx - \frac{m}{n}(1-\hat{x}) - TC_B(\hat{x},n). \end{aligned}$$

Evaluating the above integral yields (14). Q.E.D.

Proof of Proposition 4

Optimizing (15) with respect to $p_i(x_i)$ yields the following first order condition when $n \geq 2$:

$$\frac{\partial E\pi_i(x_i)}{\partial p_i(x_i)} = \frac{\left[\hat{v}^{-1}(mx_i - p_i(x_i)) - \hat{x}\right]^{n-1}}{(1-\hat{x})^{n-1}} - \frac{p_i(x_i)(n-1)\left[\hat{v}^{-1}(mx_i - p_i(x_i)) - \hat{x}\right]^{n-2}}{(1-\hat{x})^{n-1}\hat{v}'\left(\hat{v}^{-1}(mx_i - p_i(x_i))\right)} = 0. \qquad \text{(A.8)}$$

At the symmetric equilibrium, $p(x) \equiv p_i(x) = \hat{p}(x)$ implying that $v(x) \equiv v_i(x) = \hat{v}(x) = mx - p(x)$, and $\hat{v}^{-1}(mx_i - p_i(x_i)) = v^{-1}(mx_i - p_i(x_i)) = x_i$. Substituting into (A.8) yields

$$\frac{\partial E\pi_i(x_i)}{\partial p_i(x_i)} = \frac{(x_i - \hat{x})^{n-1}}{(1-\hat{x})^{n-1}} - \frac{p(x_i)(n-1)(x_i - \hat{x})^{n-2}}{(1-\hat{x})^{n-1} v'(x_i)} = 0 .$$

Since $v'(x_i) = m - p'(x_i)$ we obtain the following first order differential equation in $p(\cdot)$.

$$(x-\hat{x})^{n-1} - \frac{p(x)(n-1)(x-\hat{x})^{n-2}}{m - p'(x)} = 0 .$$

Rearranging terms we obtain:

$$p'(x) = m - \frac{p(x)(n-1)}{(x-\hat{x})} . \qquad \text{(A.9)}$$

We first solve the homogenous equation

$$\frac{p'(x)}{p(x)} = -\frac{(n-1)}{(x-\hat{x})}$$

to obtain the general solution $p(x) = T(x-\hat{x})^{-(n-1)}$. Using the variation of coefficient method, we conjecture that the solution of (A.9) takes the form $p(x) = T(x)(x-\hat{x})^{-(n-1)}$. Substituting into (A.9) we obtain the following differential equation in $T(x)$:

$$T'(x) = m(x-\hat{x})^{n-1} .$$

The general solution for $T(x)$ is:

$$T(x) = \frac{m(x-\hat{x})^n}{n} + R ,$$

where R is a constant of integration. Hence, the general solution to (A.9) is

$$p(x) = \frac{m(x-\hat{x})}{n} + \frac{R}{(x-\hat{x})^{n-1}} .$$

Notice first that $R \geq 0$, otherwise the price would be negative for x values close to $\hat{x}$. As well, the net payoff of the buyer has to be nonnegative, implying that $R = 0$. Otherwise, $\lim_{x \to \hat{x}} v(x) \to -\infty$. Hence, the nonnegative price schedule that satisfies the first order condition (A.9) for all $x \geq \hat{x}$ is:

$$p(x) = \frac{m(x-\hat{x})}{n} , \qquad \text{(A.10)}$$

yielding the net payoff function of the buyer:

$$v(x) = mx - \frac{m(x-\hat{x})}{n} = \frac{m(n-1)x}{n} + \frac{m\hat{x}}{n} . \tag{A.11}$$

This payoff function is strictly increasing, thus confirming our initial assumption concerning the shape of the function $\hat{v}(\cdot)$. The expected payoff of each supplier is obtained by substituting $p(x)$ from (A.10) back into (15). The expected payoff of the buyer is obtained as follows:

$$Ev = E[\max\{v(x_1), v(x_2), \cdots, v(x_n)\} \mid x_i > \hat{x} \text{ all } i] - TC_B(\hat{x}, n)$$
$$= \int_{\hat{x}}^{1} \left[\frac{mx(n-1)}{n} + \frac{m\hat{x}}{n} \right] \frac{n(x-\hat{x})^{n-1}}{(1-\hat{x})^n} dx - TC_B(\hat{x}, n) = m\hat{x} + \frac{m(1-\hat{x})(n-1)}{(n+1)} - TC_B(\hat{x}, n).$$

Q.E.D.

Proof of Proposition 6

When $\hat{x} = 0$, $TC_B(\hat{x}, n) = nk$, implying that sequential search dominates RFQ if

$$m - 2\sqrt{2km} > \frac{m(n-1)}{(n+1)} - nk .$$

The above inequality can be rewritten as

$$T(k) \equiv \frac{n^2}{4} k^2 - \frac{(n+2)}{(n+1)} mk + \frac{m^2}{(n+1)^2} > 0 . \tag{A.12}$$

Solving the above quadratic expression when equal to zero yields the roots k_L and k_H. When $n \le 5$, $k_H > m/8$ and when $n \ge 6$, $k_H \le m/8$, which yields the conclusion stated in the Proposition. (See Figure 1.) Q.E.D.

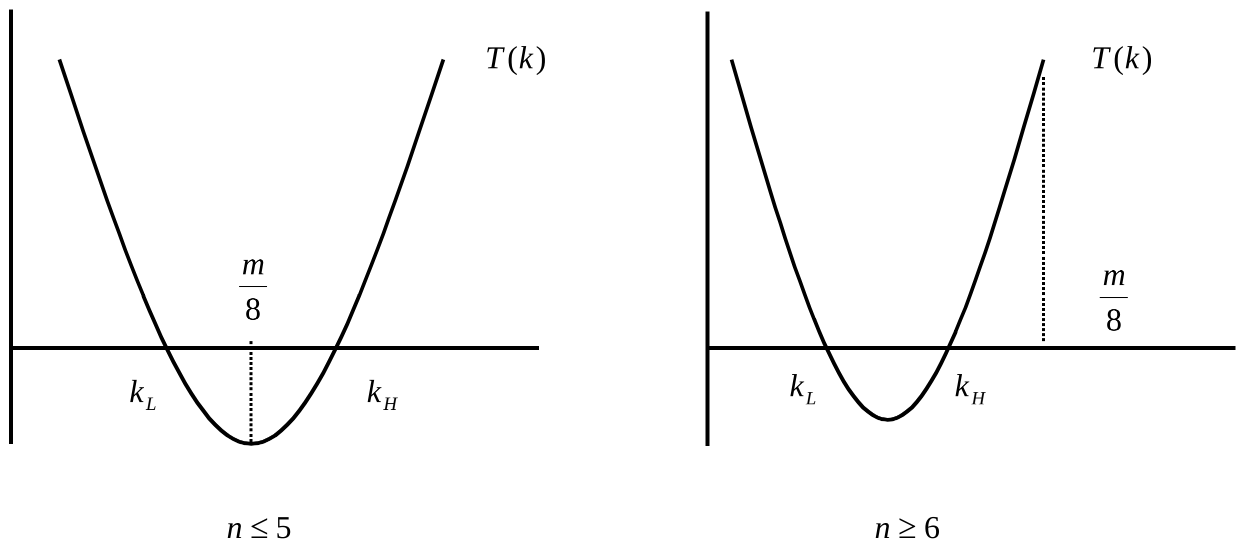

Figure 1 Relative Profitability of Sequential Search versus RFQ

Appendix 2

In this Appendix, we consider a model with partial information sharing between the buyer and the suppliers. Specifically, the buyer decides probabilistically on whether to inform the suppliers about her specifications. As well, the probability of informing one supplier is independent of the probability of informing others. Let α designate the probability that the buyer will inform a given supplier. We will demonstrate that at the symmetric equilibrium with $n \geq 2$, the price chosen by the suppliers is higher than that selected when $\alpha = 1$. Hence, partial sharing yields less intense price competition among suppliers than complete information sharing.

Let $p(x)$ designate the price schedule chosen by supplier i if the buyer informs him and let p designate the (constant) price he chooses if he is uninformed, then $p = E[\, p(x) \,|\, x \geq \hat{x}\,]$ Let $\hat{p}(x)$ and $\hat{p}$ designate the corresponding prices selected by all suppliers other than i at the symmetric equilibrium. Supplier i expects to win the auction when he is informed if the following system of $(n-1)$ inequalities holds:

$$mx_i - p(x_i) \geq mx_j - \alpha\hat{p}(x_j) - (1-\alpha)\hat{p}, \quad j \neq i. \tag{B.1}$$

The RHS of (B.1) reflects the fact that supplier i is uncertain of whether his competitors are informed. The probability of the event expressed by (B.1) is

$$\frac{\left(H^{-1}\left(mx_i - p(x_i) + (1-\alpha)\hat{p}\right) - \hat{x}\right)^{n-1}}{(1-\hat{x})^{n-1}},$$

where the function $H(\cdot)$ is defined as follows:

$$H(x) \equiv mx - \alpha\hat{p}(x).$$

Assuming that the function $H(\cdot)$ is strictly increasing, supplier i chooses his price $p(x_i)$ to maximize his expected payoff as follows:

$$\max_{p_i(x_i)} L(p(x_i)) = p(x_i)\frac{\left[H^{-1}(mx_i - p(x_i) + (1-\alpha)\hat{p}) - \hat{x}\right]^{n-1}}{(1-\hat{x})^{n-1}}. \qquad \text{(B.2)}$$

Optimizing (B.2) yields the following first order condition:

$$\frac{\partial L}{\partial p_i} = \frac{(Y(p_i) - \hat{x})^{n-1}}{(1-\hat{x})^{n-1}} - \frac{(n-1)p_i\left[Y(p_i) - \hat{x}\right]^{n-2}}{(1-\hat{x})^{n-1}H'(R(p_i))} = 0, \qquad \text{(B.3)}$$

where $p_i = p(x_i)$ and $Y(p_i) \equiv H^{-1}(mx_i - p_i + (1-\alpha)\hat{p})$.

The second order condition requires that $\partial^2 L / \partial p_i^2 < 0$, which holds provided that $H'' \leq 0$. At the symmetric equilibrium $p(x) = \hat{p}(x)$ and $p = \hat{p} = E(p(x) | x \geq \hat{x}) \equiv Ep$. Substituting symmetry into (B.3) yields:

$$\left.\frac{\partial L}{\partial p_i}\right|_{\text{symmetry}} = \frac{\left[H^{-1}(mx - p(x) + (1-\alpha)Ep) - \hat{x}\right]^{n-1}}{(1-\hat{x})^{n-1}} - \frac{(n-1)p(x)\left[H^{-1}(mx - p(x) + (1-\alpha)Ep) - \hat{x}\right]^{n-2}}{(1-\hat{x})^{n-1}H'\left(H^{-1}(mx - p(x) + (1-\alpha)Ep)\right)} = 0. \qquad \text{(B.4)}$$

Next, we assume that the price schedule that solves (B.4) is identical to that obtained in the main text when $\alpha = 1$. Specifically $p(x) = \frac{m(x-\hat{x})}{n}$ and $Ep \equiv E[p(x) | x \geq \hat{x}] = \frac{m(1-\hat{x})}{2n}$.

Assuming this solution yields that:

$$\begin{cases} H(x) = mx - \frac{\alpha m(x-\hat{x})}{n} = \frac{m}{n}\left[(n-\alpha)x + \alpha\hat{x}\right] \\ H'(x) = \frac{m(n-\alpha)}{n} \\ mx - p(x) + (1-\alpha)Ep = \frac{m(n-1)}{n}x + \frac{m}{2n}\left[(1-\alpha) + (1+\alpha)\hat{x}\right]. \end{cases} \qquad \text{(B.5)}$$

Note that the assumed solution satisfies the conditions that $H' > 0$ and $H'' \leq 0$. From (B.5) it follows that:

$$H^{-1}(y) = \frac{ny}{(n-\alpha)m} - \frac{\alpha\hat{x}}{n-\alpha},$$

and as a result,

$$\begin{aligned} H^{-1}(mx - p(x) + (1-\alpha)Ep) &= \frac{n}{(n-\alpha)m}\left[\frac{m(n-1)}{n}x + \frac{m}{2n}[(1-\alpha)+(1+\alpha)\hat{x}]\right] - \frac{\alpha\hat{x}}{n-\alpha} = \\ &= \frac{(n-1)x}{(n-\alpha)} + \frac{(1-\alpha)(1+\hat{x})}{2(n-\alpha)}. \end{aligned} \quad \text{(B.6)}$$

Substituting (B.5) and (B.6) back into the LHS of (B.4) yields:

$$\left.\frac{\partial L}{\partial p_i}\right|_{p=\frac{m(x-\hat{x})}{n}} = \frac{\left[\frac{(n-1)(x-\hat{x})}{n-\alpha} + \frac{(1-\alpha)(1-\hat{x})}{2(n-\alpha)}\right]^{n-2}}{(1-\hat{x})^{n-1}} \frac{(1-\hat{x})(1-\alpha)}{2(n-\alpha)} > 0 \text{ if } \alpha < 1.$$

Since the derivative is strictly positive when $\alpha < 1$ and since $\partial^2 L / \partial p_i^2 < 0$ it follows that the solution for $p(x)$ at the symmetric equilibrium is strictly bigger than the assumed solution. Hence, partial information sharing yields alleviated price competition in comparison to complete sharing when $\alpha = 1$. Since the buyer benefits from intensified price competition among suppliers, she will always find it optimal to fully inform them (i.e. $\alpha = 1$.)