Electronic Markets, Search Costs and Firm Boundaries

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Abstract. We study how firm boundaries are affected by the reduction in search costs when business-to-business electronic markets are adopted. Our paper analyzes a multi-tier industry in which upstream parts suppliers incur procurement search costs, and downstream manufacturers incur incentive contracting costs with these parts suppliers. We develop a model that integrates search theory into the hidden-action principal-agent model and characterize the optimal contract, showing that the delegation of search results in an outcome analogous to an effective increase in the search cost of the intermediary, reflected in the magnitude of the cutoff price in the second-best stopping rule. This contract is used to specify the manufacturer's make versus buy decision, and to analyze how the technological changes associated with electronic markets affect vertical organizational scope. Our main results show that when search is information-intensive, electronic markets will result in constant decreases in search costs that reduce the vertical scope of organizations. In contrast, when search is communication-intensive, electronic markets will result in proportionate reductions in search costs that lead to an increase in vertical integration; the latter outcome also occurs if search costs converge. We also discuss the implications of our results for the general problem of designing contracts that optimally delegate costly search to an intermediary.

JEL Codes: L22; D83, L14

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1. Introduction

Electronic business-to-business markets such as Covisint reduce procurement search costs, a specific kind of transaction cost. One would therefore expect their adoption to lead to an increase in market-based transactions, and a corresponding reduction in the vertical scope of organizations. Additionally, since procurement search is more important in those parts of the supply chain which involve commodity-like inputs, one would not expect changes in search costs induced by electronic markets to directly affect downstream firms buying complex parts, since these firms tend to prefer long-term procurement contracts with a few well-known suppliers[2].

However, there are likely to be at least three *indirect* effects of a reduction in search costs on organizational scope. Firstly, if search costs fall for both manufacturers and intermediate parts suppliers, then manufacturers may choose to take advantage of the lower transaction costs, bypass the intermediary parts suppliers and manufacture the intermediate parts in-house. This would lead to an increase in the vertical scope of organization, especially when upstream manufacturing technology is not proprietary. Secondly, the reduction in search costs affects price dispersion in the commodity parts market. The extent of this change in prices depends on whether search is undertaken by the intermediary or the manufacturer, and the relative magnitude of their corresponding search costs. Finally, there will be a reduction in the agency costs of contracting between the manufacturer and the intermediate parts supplier, caused by the reduction in the parts suppliers' search costs and the reduction in input price dispersion, which in turn would make a reduction in the vertical scope of organization more desirable. Consequently, the net change in organizational scope is unclear, and depends on both the direct (cost) effect of varying search costs, and the relative magnitude of these three effects.

We analyze these effects in a multi-tier model of an industry, where upstream parts suppliers face procurement search costs, and downstream manufacturers face agency costs from bilateral contracts with their parts suppliers. The hidden action of the parts supplier is the effort expended in commodity procurement search. The search costs of the party procuring the downstream inputs determines the price levels and dispersion for these inputs. The downstream manufacturer makes a choice between outsourcing (buying the intermediate part from the parts supplier) or insourcing (making the intermediate part). We derive the optimal bilateral outsourcing contract in this context

[2] For instance, a manufacturer like General Motors buys most of its car seats, a complex intermediate part, from an intermediary parts supplier like Delphi, who in turn buys their inputs from a variety of commodity suppliers. A reduction in search costs is likely to affect the interaction between Delphi and its suppliers far more than it *directly* affects the interaction between GM and Delphi.

under fairly general assumptions, and then investigate the effects of different types of reductions in search costs on the vertical scope of organizations.

Our results show that the changes in organizational scope depend on the nature of the industrial buying situation, and the corresponding type of technology that supports the search process. If business-to-business search in an industry is information-intensive, involving collecting and processing product information from non-personal or published sources, our model predicts that technologies like online product catalogs, Internet-based supplier portals, and product/price comparison engines that induce *constant* decreases in search costs will result in a *decrease* in vertical integration. In contrast, when procurement search tends to involve extensive bilateral communication (as suggested by the industrial buying literature), then marketplace communication platforms like EDI, XML and related collaborative systems that reduce the unit cost of each communication step will decrease search costs *proportionately* across firms in the industry. and our model predicts that this will result in an *increase* in vertical integration. Additionally, if shared procurement technologies and processes cause search costs for electronic market participants to converge to a common lower value, our model predicts that this change will also result in an *increase* in vertical integration. Overall, the testable predictions of our model suggest that industry-wide electronic business-to-business markets are likely to increase the vertical scope of organizations in the long term.

Our approach is novel to the literature on firm boundaries in its focus on *pre-contractual* transaction costs (in our context, the costs of searching for appropriate trading partners) and their effects on the scope of firms. In contrast, most recent theories of firm boundaries (Klein, Crawford and Alchian, 1978, Grossman and Hart, 1986) focus instead on post-contractual opportunistic behavior. Related models that suggest vertical integration as a way of overcoming the disadvantages associated with asymmetric information include Arrow (1975), Perry (1989) and Lewis and Sappington (1991) [a more balanced and detailed analysis of where our results place in the literature is in progress, and we apologize for its absence].

We do not propose a new model of search, drawing instead from the analytical framework of Stahl (1989, 1996), since his specification most closely resembles the business scenario we analyze (in contrast with other models of search by Stigler, 1961, Diamond, 1971, Salop and Stiglitz, 1977, Shilony, 1977 and Varian, 1980). Buyers search sequentially for a homogeneous product with constant marginal costs from a group of n identical suppliers. We exogenously specify that the suppliers provide the buyers with perfect recall, rather than treating it as one of their choice variables, as in Daughety and Reinganum (1991, 1992), though an extension with incorporates the endogenous effects of electronic markets on a strategic choice of recall is in progress. A proportion of consumers (called shoppers) have zero search costs, while the others have a constant positive search cost. In equilibrium, all sellers choose the same mixed strategy, randomizing between an identical interval of prices, which leads to a well-defined price distribution in the market. We embed this model of search in a principal-agent model, when an intermediary agent searches on behalf of a principal buyer, and the agent's search effort is unobservable by the principal. The context of a principal delegating costly search to a specialized agent has applications beyond our paper, and since there are endogenous effects that the contract will have on the price dispersion faced by the agent, our model is a new contribution to this literature.

2. Model

There is a single downstream manufacturer (henceforth called the *buyer*), who assembles and sells a finished product (the *product*) at an exogenously specified price π. In order to manufacture the product, the buyer needs a specialized part (henceforth called the *part*). In order to manufacture the part,a commodity input [3] (henceforth called the *commodity*) is needed. The commodity is supplied by a set of m competing *tier-2 suppliers*. Each tier-2 supplier chooses a (potentially different) commodity price. Due to the potential price dispersion, the buyer is forced to engage in costly search, sampling each potential tier-2 supplier's price until she discovers an acceptable price for the commodity. We assume that a fraction μ of potential customers for the commodity (which include the buyer) have a positive search cost c_P, and that a fraction $1-\mu$ of potential customers, whom we term traders, have a search cost of zero. Examples of the latter category of customers include commodity traders. The presence of these traders ensures a smooth distribution of commodity prices in equilibrium, and they play no further substantive role in the model. Given c_P, the tier-2 suppliers' mixed-strategy Nash equilibrium pricing strategy[4] is denoted $f^*(p)$.

To distinguish between the making of the product, the buying/making of the part and the buying of the commodity, we refer to the buyer's make-buy choice as being between *insourcing* and *outsourcing*. The buyer insources if she makes the part herself. The buyer outsources if she contracts with a third party, who buys the commodity, makes the part, and sells it to the buyer,

[3] So long as the parts and commodities are independent, the model can generalize to multiple parts, each requiring multiple commodity inputs.

[4] Since the tier-2 sellers are identical, we focus on symmetric mixed-strategy Nash equilibrium pricing strategies, consistent with Stahl, 1989.

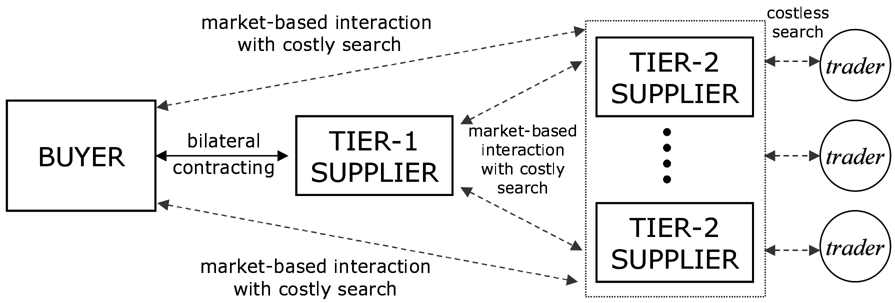


Figure 2.1: Vertical structure of industry in the model

who then makes the product.

The costs of insourcing the part can now be summarized. Firstly, to evaluate each potential tier-2 supplier, the buyer incurs a search cost of c_P. Secondly, she incurs the direct cost of buying the commodity, which depends on the commodity price p. Next, there is the cost of transforming the commodity into the part. Finally, there is the manufacturing cost of making the product form the part. In order to focus on search costs, we have normalized the costs of manufacturing the part and the product to zero[5].

The buyer may also outsource the part from a specialist intermediary (henceforth called the *tier-1 supplier*) who, by virtue of specialization, has a lower search cost c_A. The buyer can observe the commodity price p obtained by the tier-1 supplier, but cannot observe the number of candidate tier-2 suppliers that the tier-1 supplier samples before buying the commodity. Since the part is specialized, and the tier-1 supplier bears idiosyncratic risk in supplying the part, we assume that the tier-1 supplier is risk-averse, with preferences represented by the utility function $u(x)$ which is twice-differentiable, strictly increasing and strictly concave. All parties (that is, the buyer, the tier-1 suppliers, and the tier-2 suppliers) know $u(x)$, c_P, and c_A.

In order to induce the tier-1 supplier to search optimally, the buyer offers the tier-1 supplier a contract $[p + w(p)]$, which reimburses the tier-1 supplier for the price p of the commodity, and additionally specifies a performance-based wage $w(p)$. The buyer's optimal contract must be designed to ensure participation from the tier-1 supplier (individual rationality), and to induce the tier-1 supplier to search optimally (incentive-compatibility).

The cost drivers of outsourcing the part can now be summarized. Firstly, the buyer benefits

[5]This is equivalent to assuming that all parties have access to the same manufacturing technology for the part. The main results of the paper are not directionally affected by assuming positive (and different) part manufacturing costs, so long as the presence of the electronic market does not affect these costs. Since the buyer always incurs the product manufacturing cost, there is no loss of generality in normalizing this to zero.

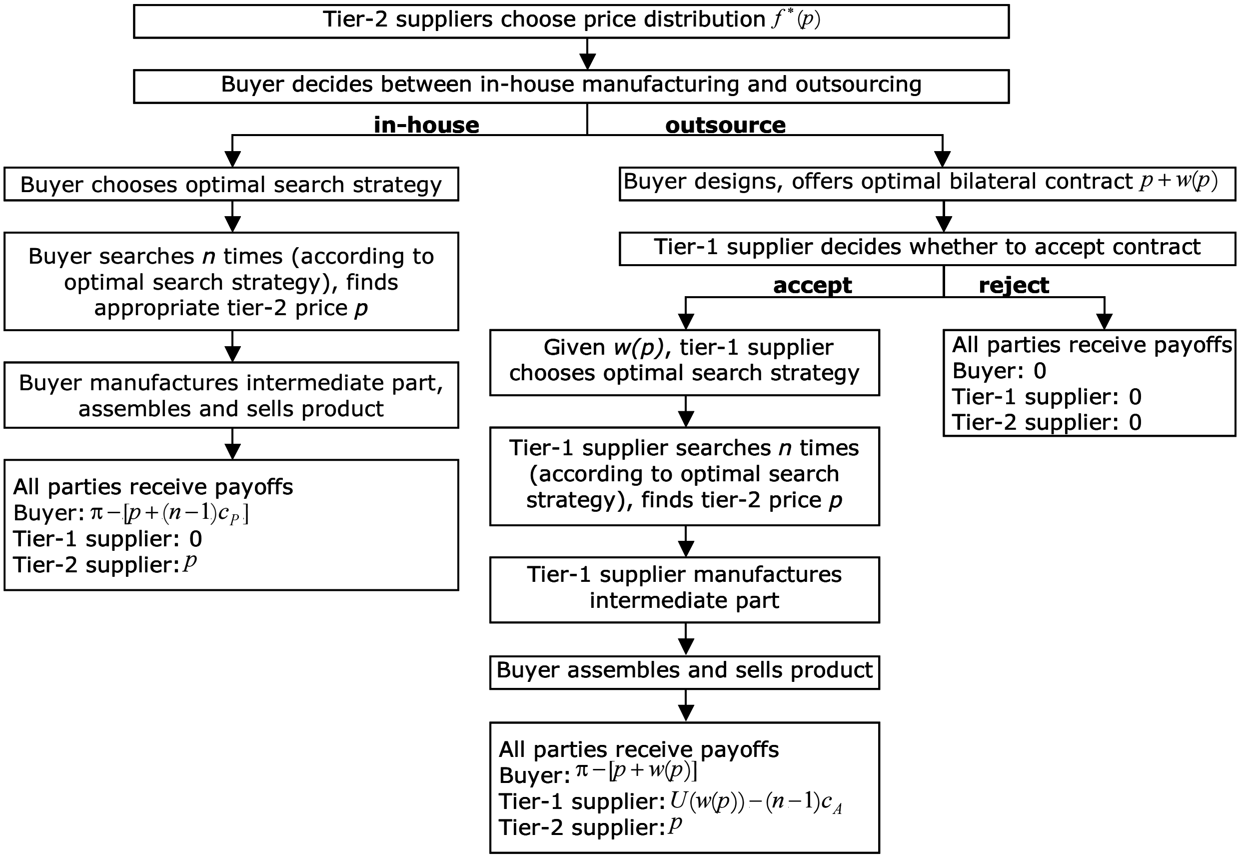


Figure 2.2: Sequence of events in the model

from the tier-1 supplier's lower search cost, but incurs an agency cost in hiring the tier-1 supplier. Secondly, the tier-1 supplier passes on the price of the commodity to the buyer, which depends on the search intensity of the tier-1 supplier. Finally, there are the manufacturing costs which we have normalized to zero.

The ex-post payoffs are as follows. If the tier-1 supplier (the agent) searches and obtains a commodity price p she receives a payment of $[p + w^*(p)]$, of which she pays p to the tier-2 supplier for the commodity, and derives utility of $u(w^*(p)) - (n-1)c_A$, where n is the number of searches undertaken. Consistent with the literature on search, we assume the first search to be costless. The corresponding payoff to the buyer (the principal), who is risk-neutral, is $\pi - [p + w^*(p)]$. If, on the other hand, the buyer chooses to manufacture the part in-house, her payoff from obtaining a commodity price p is $\pi - [p + (n-1)c_P]$, where n is now the number of searches undertaken by the buyer.

The sequence of events is summarized in Figure 2.2. To decide whether to insource or outsource, the buyer compares the ex ante costs of each alternative, and outsources if their expected costs are lower from this option. Any technological change that increases (decreases) the frequency of this outcome therefore reduces (increases) the buyer's organizational scope. For simplicity, we have chosen $m = 2$ for the subsequent analysis. The results generalize directionally to the case of m tier-2 suppliers, though the analysis is substantially more complex.

3. Search costs, contracting, and make versus buy

The first part of this section derives the tier-2 suppliers' equilibrium pricing strategies, and the buyer's payoff from insourcing. The next part derives the optimal outsourcing contract, demonstrating that it has a simple two-part form, and characterizes the buyer's payoff from outsourcing. The third part establishes that for a fixed buyer search cost, the buyer's make-buy choice is monotonic in the tier-1 supplier's search cost. The final part examines how organizational scope changes when search costs vary, by comparing the relative changes in the buyer's payoffs from insourcing and outsourcing, for different kinds of changes in search costs.

3.1. Insourcing

We first consider the case of insourcing, where the buyer procures the commodity directly from a tier-2 supplier, makes the intermediate part, and then makes the final product. Suppose each tier-2 supplier chooses a symmetric mixed-strategy pricing strategy $f(p)$ with support $p \in [r_0, \overline{p}]$, and corresponding distribution function $F(p)$. The following lemma, based on Stahl (1989), establishes that the optimal search strategy for the buyer is to search until a price below a cutoff price r_P is found, or all tier-2 suppliers have been exhaustively sampled.

Lemma 1. *The buyer's optimal search strategy for the tier-2 commodity is to search until a price less than or equal to a cutoff price r_P has been obtained, or all tier-2 suppliers have been sampled, where r_P is specified by:*

$$c_P = \int_{r_0}^{r_P} F^*(p)dp \qquad (3.1)$$

Given Lemma 1, the equilibrium pricing strategy of the tier-2 suppliers should place zero probability on any value of $p > r_P$, since no buyer (or trader) will purchase from a supplier whose price is higher than r_P, and placing a probability $\int_{r_P}^{\overline{p}} f(p)dp$ on the price r_P is a profitable deviation from any strategy for which $f(p) > 0$ for $p > r_P$. In other words, in the tier-2 suppliers' equilibrium strategy, $\overline{p} = r_P$.

The next lemma characterizes the symmetric mixed-strategy Nash equilibrium pricing strategy of the tier-2 suppliers.

Lemma 2. *The unique symmetric mixed-strategy Nash equilibrium pricing strategy $f^*(p)$ for all tier-2 is specified by the following equations:*

$$f^*(p) = \left(\frac{1-\mu}{2\mu}\right)\frac{r_P}{p^2} \text{ for } p \in [r_0, r_P] \quad (3.2)$$

$$r_0 = \left[\frac{1-\mu}{1+\mu}\right] r_P \quad (3.3)$$

$$c_P = \int_{r_0}^{r_P} F^*(p)dp \quad (3.4)$$

where $F^*(p)$ is the distribution function corresponding to the density $f^*(p)$

Given this pricing strategy, the ex-ante expected payoff to the buyer from insourcing is simply

$$\Pi^I = \pi - \int_{r_0}^{r_P} pf^*(p)dp = \pi - (r_P - c_P), \quad (3.5)$$

since the first tier-2 supplier sampled by the buyer is bound to have a price below the cutoff price r_P, the first search is costless for the buyer, and by using (3.1).

3.2. Outsourcing

We next consider the case of outsourcing. The buyer's problem is to design the profit-maximizing contract $p + w(p)$, while inducing incentive-compatible search on the part of the tier-1 supplier, and ensuring the tier-1 supplier's participation. We continue to maintain that c_P, the search cost of the buyer, determines the equilibrium tier-2 commodity prices, and hence the pricing strategy for these suppliers continues to be as specified by Lemma 2.

Once the contract $p + w(p)$ is specified, the tier-1 supplier will sample tier-2 suppliers until the expected gains from an additional search is less than the expected increase in expected utility. Therefore, given any contract in which $w(p)$ is non-increasing in p, there will be a cutoff price at which the tier-1 supplier stops searching. We formulate the buyer's problem for each such arbitrary cutoff price r_A that the buyer may wish to induce the tier-1 supplier to stop searching at. Denote this contract for an arbitrary r_A as $p+w(p, r_A)$. Given any such r_A, the buyer must design $w(p, r_A)$ so that r_A is indeed the cutoff price at which the tier-1 supplier stops searching, which leads to the following incentive-compatibility constraint:

$$[IC]: \int_{r_0}^{r_A} [u(w(p,r_A)) - u(w(r_A,r_A))] f^*(p)dp \geq c_A. \tag{3.6}$$

The contract must also ensure the tier-1 supplier's participation. The formulation of this participation constraint, and of the buyer's objective function are constructed by assigning the appropriate probability to each possible outcome for a cutoff price of r_A – the details of this are available in Appendix B. Summing up, the buyer's contract design problem reduces to:

$$\max_{w(.,r_A)} \ \pi - \left([2 - F(r_A)] \int_{r_0}^{r_A} f^*(p)[p + w(p,r_A)]dp + \int_{r_A}^{r_P} 2f^*(p)[1 - F^*(p)][p + w(p,r_A)]dp \right)$$

subject to :

$$[IC] \ : \ \int_{r_0}^{r_A} [u(w(p,r_A)) - u(w(r_A,r_A))] f^*(p)dp \geq c_A \tag{3.7}$$

$$[IR] \ : \ [2 - F(r_A)] \int_{r_0}^{r_A} f^*(p)u(w(p,r_A))dp + \int_{r_A}^{r_P} 2f^*(p)[1 - F^*(p)]u(w(p,r_A))dp - c_A[1 - F^*(r_A)] \geq \underline{U} \tag{3.8}$$

Solving the buyer's problem leads to the following proposition:

Proposition 1. *The optimal bilateral contract $p + w^*(p,r_A)$ that induces a cutoff price of r_A has the following simple structure:*

$$\begin{aligned} w^*(p,r_A) &= u^{-1}(\underline{U} + c_A \frac{1 - F^*(r_A)}{F^*(r_A)}) \text{ for } p \leq r_A \\ w^*(p,r_A) &= u^{-1}(\underline{U} - c_A) \text{ for } p > r_A \end{aligned} \tag{3.9}$$

Therefore, the buyer pays the tier-1 supplier the commodity price and (a) a constant higher wage $w^H(r_A) = u^{-1}(\underline{U} + c_A \frac{1-F^*(r_A)}{F^*(r_A)})$ if the tier-1 supplier obtains a commodity price $p \leq r_A$ and (b) a constant lower wage $w^L(r_A) = u^{-1}(\underline{U} - c_A)$ if the tier-1 supplier obtains a commodity price $p > r_A$.

The structure of the contract derived in Proposition 1 is illustrated in Figure 3.1. Despite the fact that the outcome set (price of the commodity obtained) is continuous, the nature of the agent's task (search) naturally lends itself to a partition of this space into favorable and unfavorable outcomes. This is because even when the payoffs are continuous and directly to the party

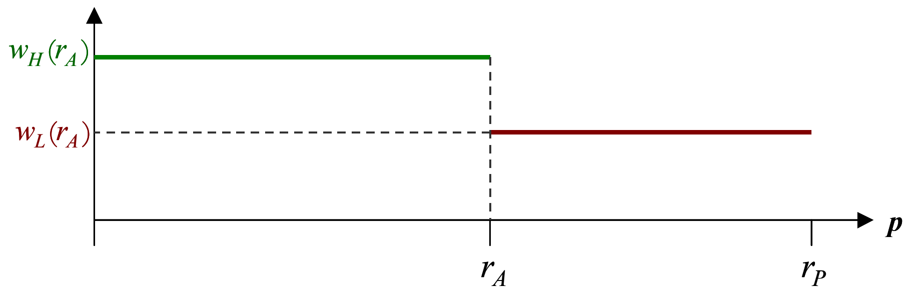


Figure 3.1: Performance-based portion of bilateral contract between buyer and tier-1 supplier.

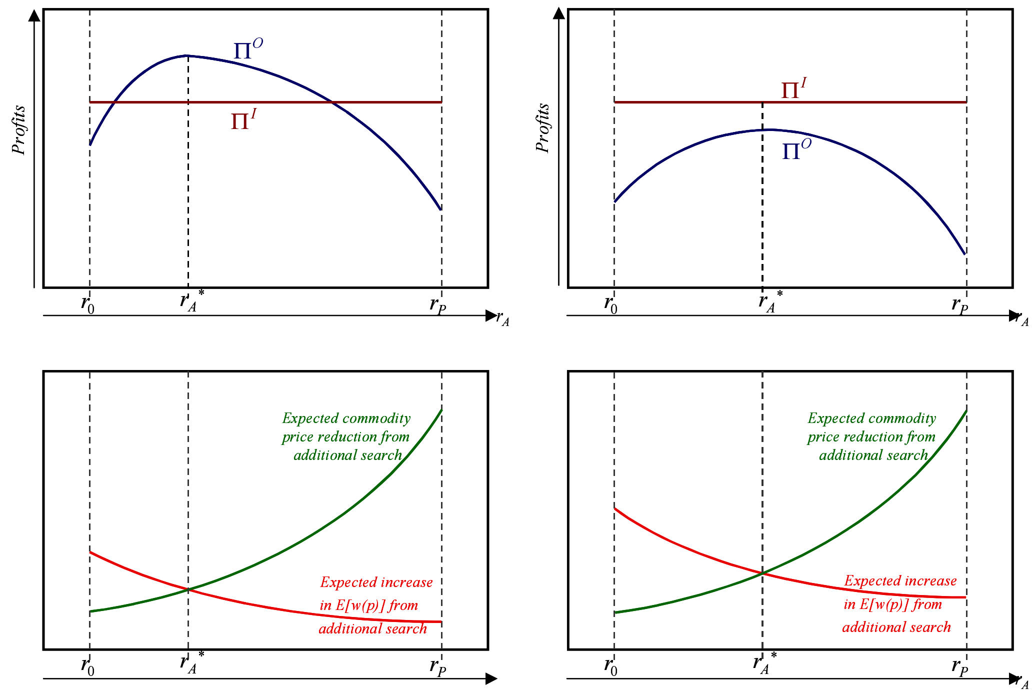
searching (as is the case in the first-best), the decision rule for whether to search again is based on a deterministic cutoff price. Proposition 1 shows that this induces the principal (the buyer) to structure a contract that explicitly makes the payoff from the task of the agent (the tier-1 supplier) discrete. Additionally, the tier-1 supplier can take one of two (or in general, one of m) discrete actions (search once, twice), rather than having a continuous action space (as is the case in moral hazard models in which the agent chooses effort). This provides some intuition for why the optimal contract is discontinuous and flat, rather than varying smoothly with observed outcome p.

The buyer maximizes profits by choosing the value of r_A that maximizes profits, given that their optimal contract for a fixed r_A is as specified by Proposition 1. Rearranging the buyer's objective function, this optimal cutoff price r_A^* solves:

$$\begin{aligned} r_A^* &= \arg\min_{r_A \in [r_0, r_P]} [2 - F^*(r_A)]F^*(r_A)w^H(r_A) + [1 - F^*(r_A)]^2 w^L(r_A) \\ &\quad + [2 - F^*(r_A)] \int_{r_0}^{r_A} pf^*(p)dp + 2\int_{r_A}^{r_P} pf^*(p)[1 - F^*(p)]dp \end{aligned} \tag{3.10}$$

and the buyer's payoff from outsourcing is therefore

$$\begin{aligned} \Pi^O &= \pi - [[2 - F^*(r_A^*)]F^*(r_A^*)w^H(r_A^*) + [1 - F^*(r_A^*)]^2 w^L(r_A^*) \\ &\quad + [2 - F^*(r_A^*)] \int_{r_0}^{r_A^*} pf^*(p)dp + 2\int_{r_A^*}^{r_P} pf^*(p)[1 - F^*(p)]dp]. \end{aligned} \tag{3.11}$$



(a) When outsourcing is preferable **(b) When insourcing is preferable**

Figure 3.2: Illustrates the profits from outsourcing and insourcing respectively, and how they vary with the buyer's choice of r_A (the cutoff price which the tier-1 supplier is induced to stop searching at by the bilateral contract), for two candidate sets of parameter values. The figure below the profit curve illustrates that at the optimal value $r_A = r_A^*$, the expected value of an additional search by the agent exactly balances the expected cost to the buyer (principal) of inducing this search. However, since r_A^* is strictly higher than the agent's first-best search strategy, the contract results in an effective increase in the magnitude of agent's search cost. In (a), which illustrates a lower value of c_A, outsourcing is more profitable. In (b), which illustrates a higher value of c_A, even the best choice of r_A yields lower profits than those from insourcing, and so the buyer chooses to manufacture the intermediate part in-house.

3.3. Relative search costs and organizational scope

Clearly, the buyer chooses to outsource (insource) if $\Pi^O > \Pi^I$ ($\Pi^O < \Pi^I$). Comparing (3.5) and (3.11) and rearranging, *outsourcing* is optimal if the following condition is satisfied:

$$[2-F^*(r_A^*)]F^*(r_A^*)w^H(r_A^*)+[1-F^*(r_A^*)]^2w^L(r_A^*) \leq \int_{r_A^*}^{r_P} pf^*(p)[2F^*(p)-1]dp-[1-F^*(r_A^*)]\int_{r_0}^{r_A^*} pf^*(p)dp. \tag{3.12}$$

The intuition behind this expression is straightforward. Given the optimal bilateral contract, the LHS of (3.12) is the expected payment to the tier-1 supplier; $[2 - F^*(r_A^*)]F^*(r_A^*)$ is the ex-ante probability of the favorable outcome, and $[1-F^*(r_A^*)]^2$ is the ex-ante probability of the unfavorable

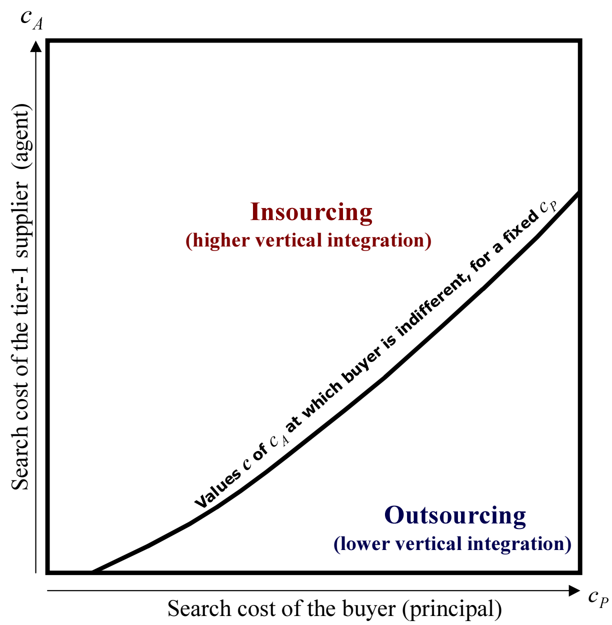


Figure 3.3: Illustrates the result of of Proposition 2, by depicting the regions in which the buyer chooses to outsource, and those regions in which the buyer chooses to insource.

outcome. The RHS of (3.12) is the expected reduction in commodity prices as a consequence of the tier-1 supplier's superior search. Clearly, when the latter is greater than the former, the buyer prefers to outsource. Correspondingly, when the LHS of (3.12) is greater than the RHS of (3.12), the buyer prefers to insource.

The next proposition shows that this decision is monotonic in the tier-1 supplier's search cost c_A in the following sense – there is generally a continuous lower range of value of c_A over which the buyer outsources, and a continuous higher range of values of c_A over which the buyer insources.

Proposition 2. *For any buyer search cost $c_P > 0$:*

(a) If $c_A = c_P$, then the firm always prefers insourcing to outsourcing

(b) The buyer's profits from outsourcing decrease monotonically with c_A.

Therefore, if there exists a threshold value $c \in (0, c_P)$ at which the buyer is indifferent between outsourcing and insourcing, the buyer outsources when $c_A < c$, and the buyer insources when $c_A > c$.

Figure 3.3 illustrates the result from Proposition 2. At each high enough value of c_P, there is a corresponding value c of c_A at which the buyer is indifferent between outsourcing and insourcing. At each fixed value of c_P, the buyer outsources for $c_A < c$, and insources for $c_A > c$. The graph

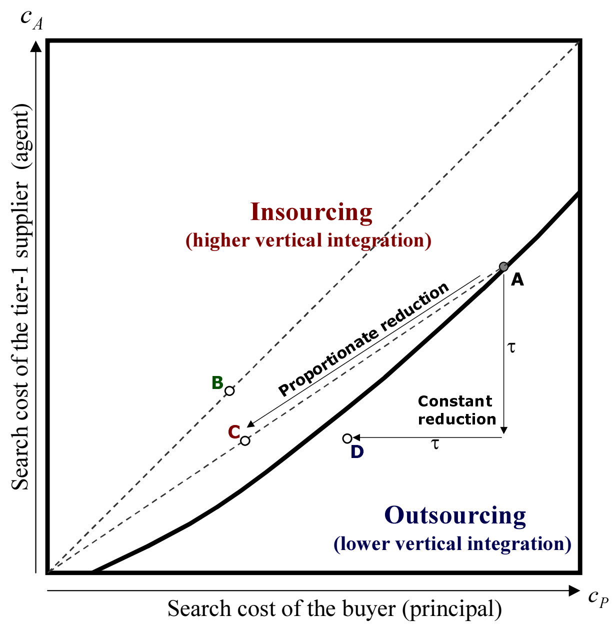


Figure 3.4: Illustrates the results of Propositions 3, 4 and 5. Starting at any indifferent point A, when the electronic market causes search costs to converge to a common value B, the buyer prefers to insource. Any proportionate reduction in costs (along the dotted line joining A to the origin) results in an indifferent buyer choosing to insource, confirming Proposition 4. In contrast, a constant bilateral reduction in search costs, to point D results in an indifferent buyer opting to outsource, as shown by Proposition 5.

of c as a function of c_P is increasing and convex, and its slope is bounded above by 1. It also lies entirely below the 45^o line, as demonstrated by part (a) of the proposition.

Given c_P, the existence of the threshold value c depends on whether the buyer ever chooses to outsource. If outsourcing is preferable when the tier-1 supplier has zero search costs (that is, for $c_A = 0$), then an immediate corollary of (a) and (b) in Proposition 2 is that there is a positive threshold value $c \in (0, c_P)$. On the other hand, if the tier-1 supplier's reservation utility is high enough, or the buyer's search cost low enough, to make insourcing optimal even when $c_A = 0$, the buyer will choose to manufacture the intermediate part in-house for all $c_A > 0$.

3.4. Changes in organizational scope as search costs vary

When an electronic market is adopted in an industry, the changes in search costs are likely to be different for different firms in the industry. In this section, we explore how organizational scope varies as there are differential changes in search costs across the buyer and the tier-1 supplier.

In order to characterize directional changes in organizational scope in a general way, and only in contexts of interest, we do the following. We assume that under the status-quo (prior to the adoption of the electronic market), the buyer is indifferent between outsourcing and insourcing. This is equivalent to assuming that c_A is at the threshold level c corresponding to c_P, as described in Proposition 2. We then vary the search costs c_A and c_P in a systematic way, and establish whether the changes in search costs cause the buyer to insource or outsource. If the buyer *insources* as a consequence of the changes in the search costs, we conclude that search costs changes of that kind are likely to *increase* organizational scope. Correspondingly, if the buyer *outsources* as a consequence of the changes in the search costs, we conclude that search costs changes of that kind are likely to *decrease* organizational scope.

The first result, which follows directly from Proposition 2(a), establishes that if the electronic market causes search costs converge to a common value, this leads to a decrease in organizational scope.

Proposition 3. *An electronic market that causes the search costs of both the buyer and the tier-1 supplier to converge to a common value results in* ***higher*** *organizational scope.*

Next, we examine the effects of a *proportionate* reduction in both c_P and c_A:

Proposition 4. *An electronic market that causes the search costs of both the buyer and tier-1 supplier to reduce by the same constant proportion $k < 1$ – that is, from their original values c_P, c_A to new values kc_P, kc_A – results in* ***higher*** *organizational scope.*

Intuitively, the result in Proposition 4 is driven by the invariance of the tier-1 supplier's outside alternatives, and the corresponding increased importance of the tier-1 supplier's reservation utility when search costs decrease across the industry.

Finally, we establish the effects of a *constant* reduction in both c_P and c_A:

Proposition 5. *An electronic market that causes the search costs of both the buyer and tier-1 supplier to reduce by the same constant amount τ – that is, from their original values c_P, c_A to new values $(c_P - \tau), (c_A - \tau)$ – results in* ***lower*** *organizational scope*

Some intuition for this proposition can be obtained by considering an extreme case, when $\tau = c_A$. This represents a reduction in search costs that takes the tier-1 supplier's search costs to zero. Since $c_P > c_A$, the buyer still has a positive search cost after the reduction, and consequently, finds it profitable to outsource.

Nature of product	Raw materials, **processed materials**, **generic parts**, specialized parts, capital equipment, MRO (maintenance, repair and operations), business services.
Procurement situation	**New task**, **modified rebuy**, straight rebuy.
Steps in the process	Recognition of need, specification determination and description, **search for qualified suppliers**, **RFP**, **proposal analysis and evaluation**, **supplier selection**, order routine specification, performance feedback and evaluation

Figure 4.1: Classifies B2B procurement based on the nature of the product and buying situation; also summarizes the steps in the B2B buying process.

The results of Propositions 3 through 5 are illustrated in Figure 3.4. Consider a buyer at the indifferent point A prior to the adoption of the electronic market. When the search costs of both the buyer and tier-1 supplier converge, to any point B on the 45^o line, the buyer then chooses to insource. When they reduce proportionately (along the line joining A to the origin) to point C, the buyer chooses to insource. In contrast, when they each reduce by a constant factor τ to the point D, the buyer chooses to outsource.

4. The effect of electronic market technologies on firm boundaries

Section 3.4 characterizes directional changes in firm boundaries for different kinds of changes in search costs. In this section, we associate the nature of B2B search and the related marketplace technologies with specific kinds of changes in search costs, and infer the corresponding changes in organizational scope that they are likely to induce.

Unlike consumer search, B2B search is quite involved, and requires substantial organizational resources. Figure 4.1 summarizes a classification of the nature of B2B buying, based on Kotler (2002) and Robinson, Faris and Wind (1967). The types of products/situations that are generally considered search-intensive are highlighted, as are the steps in the process that are most likely to contribute to search costs. During this search process, buyers often must evaluate multiple vendor and product characteristics, requiring *information acquisition* from multiple sources[6], as well as *communication* between and collaborative decision making by a number of different participants in the buying organization[7].

[6] Dempsey (1978) identifies and classifies these attributes into five factors: basic economic criteria (price, quality, delivery), attendant services (repair, packaging), geographic affinity (location), assurance mechanisms (production facilities, delivery capability, control systems), and vendor stability (labor relations, management and organization).

[7] Webster and Wind (1972) classify participants in the industrial procurement process into the roles of users, buyers, deciders, gatekeepers and influencers. Users affect the buying decision positively by specifying product

4.1. Information-intensive search

In general, information sources are classified as either personal or non-personal, and as commercial or non-commercial[8]. We term the search *information-intensive* if it involves the acquisition and processing of a substantial amount of non-personal information. Many marketplace technologies substantially lower the cost of acquiring and evaluating this kind of information. Examples include online product catalogs, Internet-based supplier portals, and product/price comparison engines.

When marketplace participants gain access to these information systems, their search costs are therefore likely to reduce by a constant amount[9]. However, it is highly unlikely that search costs will reduce to zero, since there are still costly evaluation steps involved for each candidate supplier This kind of change in search costs is illustrated in Figure 4.2, and as demonstrated by Proposition 5, our model predicts that it tends to lead to a *reduction* in organizational scope.

4.2. Communication-intensive search

It may appear that acquisition of published information is the crucial cost driver of search. However, our analysis of the industrial procurement process suggests that inter-entity (person, department, firm) *communication* is always a critical cost driver. Acquiring information often involves communication – with personal commercial sources like salespeople and trade shows personnel, and with personal non-commercial sources like outside consultants and colleagues. Additionally, several departments[10] within the buyer firm are involved in the evaluation of each supplier proposal, with significant iterative communication during the process. Participants in the buying firm don't necessarily consult the same non-personal information sources, and are therefore likely to have different opinions that are reconciled by iterative communication before making the buying decision. This is

requirements, or negatively by refusing to work with certain materials. Buyers have the formal authority to arrange for the procurement, and tend to be purchasing managers. Deciders tend to be senior managers who approve the buying decision. Gatekeepers control the flow of information to other participants in the buying decision. Influencers could be distinct from any of the above, and exert direct or indirect influence on the buying decision.

[8] This is based on Moriarty and Spekman (1984). Personal information sources are capable of providing specialized information directly addressing a specific buyer's concerns, whereas impersonal information sources provide general information that all potential buyers are likely to find useful. Commercial information sources are those that the seller provides, and so are likely to be biased. Examples of personal commercial sources are salespeople and trade shows; of personal non-commercial sources are internal departments, outside consultants and colleagues; of impersonal commercial sources are trade-publication ads, sales literature and catalogs; of impersonal non-commercial sources are trade press articles and rating services. In Moriarty and Spekman listing of perceived importance of fourteen information sources, six of the top seven are personal sources.

[9] This kind of constant reduction in search costs is especially likely in straight-rebuy situations, since it requires the evaluation of relatively few vendor and product attributes, using impersonal sources of information, and involves fewer decision makers.

[10] For instance, Jackson, Keith and Burdick (1984) show that personnel from purchasing, manufacturing, engineering, top management and other departments influence the process to varying degrees.

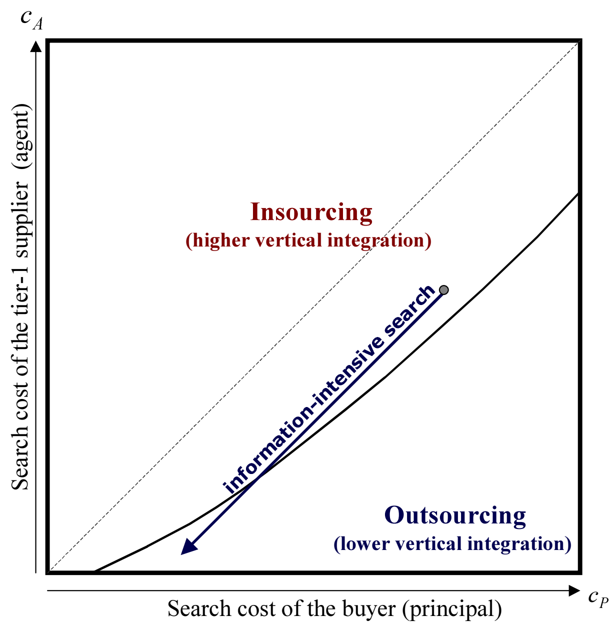


Figure 4.2: Illustrates how electronic marketplaces change organizational scope when search is information-intensive.

especially true in new task and modified re-buy situations, which require the evaluation of multiple vendor and product attributes.

Electronic markets reduces this cost of iterative communication. For example, Covisint's Connect platform moves beyond EDI to provide it's marketplace participants with sophisticated any-to-any translation capability that can handle both EDI and XML technologies in one environment; their Communicate platform also serves as the framework for OEM-to-supplier and supplier-to-supplier communications. These information systems make each iteration of communication less expensive, faster, less error-prone, and richer. This decreases the number of iterations required, as well as the cost of each iteration, and therefore results in a *proportionate* decrease in search costs across firms. This kind of change in search costs is illustrated in Figure 4.3, and as demonstrated by Proposition 4, our model predicts that it will tend to lead to an *increase* in organizational scope.

5. Discussion and conclusions

The existence of specialized search intermediaries in many industries suggests that the magnitude of search costs can vary substantially between different parties. This becomes pertinent in predicting the extent to which a firm is vertically integrated in many industrial buying contexts, since the costs of procurement search can be substantial, and there are gains from specialization. When electronic

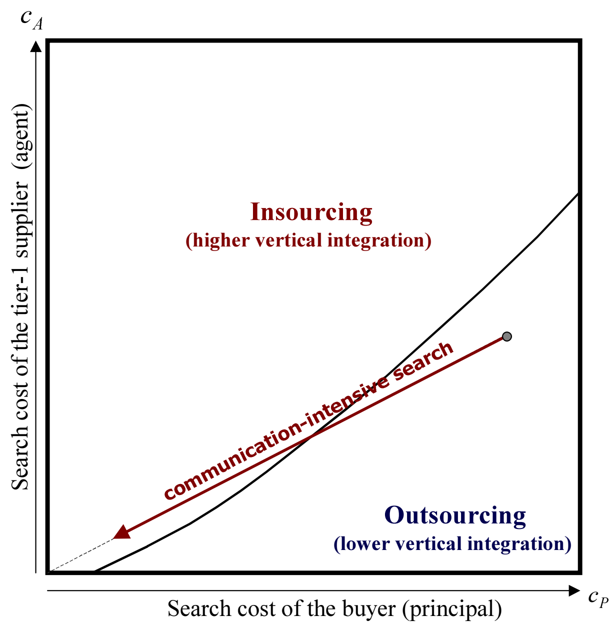


Figure 4.3: Illustrates how electronic marketplaces change organizational scope when search is *communication-intensive*.

markets which dramatically alter the magnitude of these costs are adopted by an increasing number of industry participants, it raises the question of how these changes in search costs affect the vertical scope of organizations. Since the magnitude of the search costs affects other aspects of the make-buy decision, such as contracting costs and input prices, the answer to this question is not immediately clear.

Our paper informs this question by integrating search theory, which predicts the effects of the changes in search costs caused by the marketplace systems on input price distributions, and the hidden action principal-agent model, which forms the basis for analyzing the costs of bilateral contracting between a parts supplier and a finished-goods manufacturer. Our main findings are that changes in organizational scope depend critically on the nature of search and the corresponding capabilities of the technology associated with the electronic market. If search is information-intensive, then our model predicts that electronic markets will result in a decrease in the vertical scope of firms. In contrast, if search is communication-intenstive, our model predicts that electronic markets will increase the vertical scope of downstream organizations. Often, electronic marketplaces combine technologies that reduce the cost of acquiring published information with those that facilitate faster and less costly communication. These have opposing effects on the desirability of vertical integration, and the resulting changes in organizational scope depends on the relative information-intensity and communication-intensity of search. Overall, however, the latter type of system tends to dominate technology choice in electronic markets. Also, a precursor to the adoption of an electronic market may be the implementation of a common technology platform that spans many business processes, and the associated reengineering of these processes (Sanders, 2001). If a tier-1 supplier's search cost advantage is embedded in a superior procurement process, this kind of reengineering could potentially result in the convergence of the buyer and tier-1 supplier's search costs, and lead to an increase in the scope of the buyer firm. In light of this, our model suggests that industry-wide electronic business-to-business markets are likely to increase the vertical scope of organizations in the long term. Establishing this direction of change empirically, which would also involve a structured analysis and collection of data relating to the effects of marketplace technologies on procurement costs, is an important future research direction, and our model provides the necessary theoretical basis and testable predictions.

In this paper, we have exogenously specified that the suppliers provide the buyers with perfect recall. However, the extent of recall is an important strategic variables, as shown in Daughety and Reinganum (1991, 1992). An extension we are currently working on treats the extent of recall as a strategic choice by tier-2 suppliers. Our preliminary results suggest that strategic and endogenous recall may reduce the marginal effect that changes in search costs have on the price distribution of the input commodities, since lower search costs are likely to accompanied by an increase in the likelihood of a pricing equilibrium similar to 'take it or leave it', which would raise equilibrium prices. There is also an effect that the choice of recall has on the optimal outsourcing contract. Since the delegation of search results in an outcome analogous to an increase in the search cost of the intermediary (reflected in the magnitude of the cutoff price in the second-best stopping rule), the principal can indirectly make a strategic choice of the effective search costs of the intermediary, and thereby influence the type of equilibrium that results in the commodity market. Formalizing this completely remains work in progress.

There are many other interesting contexts that feature both costly search and contracting under asymmetric information, and especially the delegation of costly search to an intermediary (an example that is especially relevant in the New York area being real-estate search). Our model provides a first explanation for why these contracts are often 'all or nothing'. This is part of a larger class of problems that investigate how differing search costs, and correspondingly, different search behavior across agents can affect the decision-making process of each of these agents (Reinganum, 1982), and we hope to extend the model developed in our paper to inform this question further. Additionally, our framework could be extended in a number of interesting ways. In some industries, downstream buyers may not be aware of their intermediate tier-1 supplier's search cost. A procurement contract between the buyer and tier-1 supplier would then be characterized by adverse selection as well as moral hazard (a somewhat related problem is addressed by Dai and Lewis, 2003). Another extension to the current model would be to endogenize the value of the tier-1 supplier's outside alternative, making it depend on the relative concentration of buyers and tier-1 suppliers in the market. We are currently working on these extensions, and hope to complete them in the near future.

References

1. Arrow, K. (1975) Vertical integration and communication, *Bell Journal of Economics* 6, 173-183.

2. Bakos, Y. (1997) Reducing buyer search costs: implications for electronic marketplaces, *Management Science* 43

3. Baron, D. and D. Besanko (1987) Monitoring, moral hazard, asymmetric information, and risk sharing in procurement contracting, *Rand Journal of Economics*18, 509-532.

4. Coase, R. (1937) The nature of the firm, *Economica* 4, 386-405

5. Crocker, K. (1983) Vertical integration and the strategic use of private information, *Bell Journal of Economics* 14, 236-248.

6. Dempsey, W. (1978). Vendor selection and the buying process, *Industrial Marketing Management* 7, 257-267.

7. Diamond, P. (1971) A Model of Price Adjustment, *Journal of Economic Theory* 3, 158-168.

8. Dai, C. and Lewis, T. (2003) Delegating Procurement to Experts. Available at *http://faculty.fuqua.duke.edu/bio/lewis/expertsauca.pdf*

9. Daughety, A. and Reinganum, J. (1991) Endogenous availability in search equilibrium, *RAND Journal of Economics* 22, 287-306.

10. Daughety, A. and Reinganum, J. (1992) Search equilibrium with endogenous recall, *RAND Journal of Economics* 23, 184-202.

11. Goldberg, V. (1976) Regulation and administered contracts, *Bell Journal of Economics*, 7:426-448.

12. Grossman, S., and Hart, O.(1986) The costs and benefits of ownership: a theory of vertical and lateral integration, *The Journal of Political Economy* 94, 691-719.

13. Gurbaxani, V. and S. Whang, (1991) The impact of information systems on organizations and markets, *Communications of the ACM*, 34 (1), 59-73.

14. Hoffman, W., Keedy, J., and Roberts, K. (2002) The unexpected return of B2B, *The McKinsey Quarterly* 3.

15. Jackson, D., Keith, J. and Burdick, R. (1984) Purchasing agents' perceptions of industrial buying center influence: a situational approach, *Journal of Marketing* 48, 75-83.

16. Klein, B., Crawford, R. and Alchian, A. (1978) Vertical integration, appropriable rents, and the competitive contracting process, *Journal of Law and Economics* 21, 297-326.

17. Kotler, P. (2002) *Marketing Management.* Prentice Hall.

18. Laffont, J. and Martimort, D (2002) *The Theory of Incentives: The Principal-Agent Model.* Princeton University Press.

19. Lewis, T. and Sappington, D. (1991) Technological change and the boundaries of the firm, *American Economic Review* 81, 887-900.

20. Moriarty, R. and Spekman, R. (1984) An empirical investigation of the information sources used during the industrial buying process. *Journal of Marketing Research.* 21, 137-147.

21. Perry, M. (1989) Vertical integration: determinants and effects, in Schmalensee and Willig, *Handbook of Industrial Organization* 1. Amsterdam: North-Holland.

22. Reinganum, J. (1982) Strategic search theory, *International Economic Review* 23, 1-17.

23. Robinson, P., Faris, C., and Wind, Y. (1967) *Industrial buying and creative marketing.* Allyn and Bacon.

24. Salop, S. and Stiglitz, J. (1977) Bargains and ripoffs: a model of monopolistically competitive price dispersion, *Review of Economic Studies* 44, 493-510.

25. Sanders, M. (2001). What does eMarketplace buying cost? *Forrester Research.*

26. Shilony, Y. (1977) Mixed pricing in oligopoly, *Journal of Economic Theory* 14, 373-388.

27. Stahl, D. (1989) Oligopolistic pricing with sequential consumer search, *American Economic Review* 79, 700-712.

28. Stahl, D. (1996) Oligopolistic pricing with sequential consumer search and heterogeneous search costs, *International Journal of Industrial Organization*14, 243–268.

29. Stigler, G.. (1961). The economics of information, *Journal of Political Economy* 69, 213-225.

30. Varian, H. (1980) A model of sales, *The American Economic Review* 70, 651-659.

31. Webster, F. and Wind, Y. (1972) *Organizational Buying Behavior.* Prentice-Hall.

A. Proofs

Proof. of Lemma 1: (Based on Stahl, 1989) Suppose each tier-2 supplier plays the same mixed strategy $f(p)$. Given an observed price z, a buyer with search cost c_P will search again only if the benefit from additional search $\Delta(z)$ is greater than c_P. The benefit from additional search given z is:

$$\Delta(z) = z - \left[\int_{r_0}^{z} pf(p)dp + \int_{z}^{\overline{p}} zf(p)dp \right], \tag{A.1}$$

which can be rewritten as

$$\Delta(z) = z - \left[\int_{r_0}^{z} p\frac{dF(p)}{dp}dp + z(1 - F(z)) \right] = \int_{r_0}^{z} F(p)dp. \tag{A.2}$$

The buyer optimal cutoff price r_P equates the benefit from additional search to the search cost c_P, and therefore solves

$$\Delta(r_P) = c_P. \tag{A.3}$$

Since$F(p) > 0$ for $p > r_0$, $\Delta(z)$ is strictly increasing in z, and therefore (A.3) has a unique solution, and the result follows. ■

Proof. of Lemma 2: (Based on Stahl, 1989) Consider a candidate tier-2 supplier who faces the mixed strategy $f(p)$ from its opponent. The profits from a choice of price p to this supplier can be reduced to

$$\pi(p) = \left(\mu \left[1 - F(p) \right] + \frac{1-\mu}{2} \right) p. \tag{A.4}$$

Substituting $p = r_P$ into (A.4) yields

$$\pi(r_P) = \frac{1-\mu}{2} r_P. \tag{A.5}$$

The tier-2 supplier must make the same expected profit from each price in the support of their mixed strategy $p \in [r_0, r_P]$. Substituting (A.5) into (A.4) yields

$$\left(\mu \left[1 - F^*(p) \right] + \frac{1-\mu}{2} \right) p = \frac{1-\mu}{2} r_P, \tag{A.6}$$

which yields

$$F^*(p) = 1 - \left(\frac{1-\mu}{2\mu} \right) \left(\frac{r_P}{p} - 1 \right), \tag{A.7}$$

and therefore,

$$f^*(p) = \frac{dF^*(p)}{dp} = \left(\frac{1-\mu}{2\mu} \right) \frac{r_P}{p^2}. \tag{A.8}$$

Using the fact that $F(r_0) = 0$ in (A.7) yields

$$r_0 = \left[\frac{1-\mu}{1+\mu} \right] r_P, \tag{A.9}$$

and completes the proof. ■

Proof. of Proposition 1: Given a fixed r_A, since π is fixed, the buyer's problem is equivalent to:

$$\min_{w(.,r_A)} \left([2 - F(r_A)] \int_{r_0}^{r_A} f^*(p)[p + w(p, r_A)]dp + \int_{r_A}^{r_P} 2f^*(p)[1 - F^*(p)][p + w(p, r_A)]dp \right) \tag{A.10}$$

subject to :

$$[IC] \quad : \quad \int_{r_0}^{r_A} [u(w(p)) - u(w(p, r_A))].f^*(p)dp \geq c_A \tag{A.11}$$

$$[IR] \quad : \quad [2 - F(r_A)] \int_{r_0}^{r_A} f^*(p)u(w(p, r_A))dp + \int_{r_A}^{r_P} 2f^*(p))[1 - F^*(p)]u(w(p, r_A))dp - c_A[1 - F^*(r_A)] \geq \underline{U} \tag{A.12}$$

The Lagrangian for this problem is:

$$\begin{aligned} L(\lambda_1, \lambda_2, w(., r_A)) \quad = \quad & \left([2 - F(r_A)] \int_{r_0}^{r_A} f^*(p)[p + w(p, r_A)]dp + \int_{r_A}^{r_P} 2f^*(p)[1 - F^*(p)][p + w(p, r_A)]dp \right) \\ & + \lambda_1 \left(\int_{r_0}^{r_A} [u(w(p)) - u(w(p, r_A))].f^*(p)dp - c_A \right) \\ & + \lambda_2 \{ [2 - F(r_A)] \int_{r_0}^{r_A} f^*(p)u(w(p, r_A))dp \\ & + \int_{r_A}^{r_P} 2f^*(p))[1 - F^*(p)]u(w(p, r_A))dp - c_A[1 - F^*(r_A)] - \underline{U} \} \end{aligned} \tag{A.13}$$

Optimizing pointwise for $w(., r_A)$ in the intervals $[r_0, r_A]$ and $[r_A, r_P]$ respectively yields first-order conditions that simplify to:

$$\frac{\partial L}{\partial w} = 0 : \frac{1}{u_1(w(p))} = \lambda_1 + \frac{\lambda_2}{2 - F(r_A)} \text{ for } p \in [r_0, r_A] \tag{A.14}$$

and

$$\frac{\partial L}{\partial w} = 0 : \frac{1}{u_1(w(p))} = \lambda_1 \text{for } p \in [r_A, r_P] \tag{A.15}$$

Therefore, $w(p)$ is a constant value $w^H(r_A)$ in $[r_0, r_A]$, and a different constant value $w^L(r_A)$ in $[r_A, r_P]$. Since $u_{11}(x) < 0$, it follows that $w^H(r_A) > w^L(r_A)$. Using the first-order conditions $\frac{\partial L}{\partial \lambda_1} = 0$ and $\frac{\partial L}{\partial \lambda_2} = 0$ (that is, using the fact that the conditions IC and IR will bind), and simplifying yields the functional forms for $w^H(r_A)$ and $w^L(r_A)$. ■

Proof. of Proposition 2: (a) Assume the converse – that is, when $c_A = c_P$, the cost of outsourcing is less than the cost of insourcing. Suppose now that the buyer insources and uses exactly the same search strategy as prescribed to the tier-1 supplier by the optimal bilateral contract (a cutoff of r_A^*). This would lead to exactly the same ex-ante expected search costs (since $c_A = c_P$), and the same ex-ante expected commodity price (since the search strategy is identical). This would also lead to costs that were weakly higher than the buyer's optimal insourcing search strategy. The fact that the cost of outsourcing is less than the costs of this optimal insourcing strategy imply that ex-ante expected wages are negative, which contradicts the fact that $\underline{U} > 0$.

(b) The buyer chooses the stopping rule r_A that maximizes the objective function:

$$\Pi(r_A) = \pi - \{[2 - F^*(r_A)]F^*(r_A)w^H(r_A) + [1 - F^*(r_A)]^2 w^L(r_A) + [2 - F^*(r_A)] \int_{r_0}^{r_A} pf^*(p)dp + 2\int_{r_A}^{r_P} pf^*(p)[1 - F^*(p)]dp\}. \quad \text{(A.16)}$$

Simplifying $\frac{d\Pi(r_A)}{dr_A} = 0$ yields the following first-order necessary condition for this problem:

$$2f^*(r_A^*)[1-F^*(r_A^*)][w^H(r_A^*)-w^L(r_A^*)]+f^*(r_A^*)\left(r_A^*F(r_A^*) - \int_{r_0}^{r_A^*} pf^*(p)dp\right) = -F^*(r_A^*)[2-F^*(r_A^*)]w_1^H(r_A^*). \quad \text{(A.17)}$$

Now, from Proposition 1, we know that:

$$u(w^H(r_A^*)) = \underline{U} + c_A \frac{1 - F^*(r_A^*)}{F^*(r_A^*)}. \quad \text{(A.18)}$$

Differentiating both sides of (**??**) with respect to r_A and rearranging yields:

$$w_1^H(r_A^*) = -\frac{c_A f^*(r_A^*)}{[u_1(w^H(r_A^*))][F^*(r_A^*)]^2}. \quad \text{(A.19)}$$

Also, integration by parts yields the identity:

$$r_A^*F(r_A^*) - \int_{r_0}^{r_A^*} pf^*(p)dp = \int_{r_0}^{r_A^*} F^*(p)dp. \quad \text{(A.20)}$$

Furthermore, the optimal choice cutoff r_A^* should be such that having found a price r_A^*, the expected reduction in commodity price from a second search by the agent must exactly balance the increase in wages that this search entails, or

$$\int_{r_0}^{r_A^*} F^*(p)dp = \left(\int_{r_0}^{r_A^*} w^H(r_A^*)f^*(p)dp + \int_{r_A^*}^{r_P} w^L(r_A^*)f^*(p)dp\right) - w^L(r_A^*), \quad \text{(A.21)}$$

which implies that:

$$[w^H(r_A^*) - w^L(r_A^*)] = \frac{1}{[F(r_A^*)]} \int_{r_0}^{r_A^*} F^*(p)dp. \tag{A.22}$$

Substituting the expressions for $w_1^H(r_A^*)$ from (A.18), $r_A^* F(r_A^*) - \int_{r_0}^{r_A^*} pf^*(p)dp$ from (A.20) and $[w^H(r_A^*) - w^L(r_A^*)]$ from (A.22) into (A.17) and rearranging terms yields the simplified first-order condition:

$$\frac{[2 - F^*(r_A^*)]}{[F(r_A^*)]} \int_{r_0}^{r_A^*} F^*(p)dp = \frac{[2 - F^*(r_A^*)]}{[F(r_A^*)]} \frac{c_A}{u_1(w^H(r_A^*))}, \tag{A.23}$$

which in turn implies that

$$c_A = u_1(w^H(r_A^*)) \int_{r_0}^{r_A^*} F^*(p)dp. \tag{A.24}$$

Differentiating both sides of (A.24) with respect to c_A and rearranging yields:

$$\frac{dr_A^*}{dc_A} = \frac{1}{u_{11}(w^H(r_A^*))w_1^H((r_A^*) \int_{r_0}^{r_A^*} F^*(p)dp + u_1(w^H(r_A^*))F^*(r_A)}. \tag{A.25}$$

Since $u_1(x) > 0$, $u_{11}(x) < 0$, and $w_1^H(r_A) < 0$ from (A.19), the RHS of (A.25) is strictly positive, and therefore, $\frac{dr_A^*}{dc_A} > 0$.

Now, using (A.22) and (3.1), and regrouping terms in the integrals, (A.16) reduces to:

$$K(r_A^*) = r_P - \int_{r_A^*}^{r_P} \left(2F^*(p) - [F(p)]^2\right) dp + w^L(r_A^*), \tag{A.26}$$

and it is straightforward to verify that $K(r_A)$ is strictly increasing in r_A^*. Since $\frac{dr_A^*}{dc_A} > 0$, the result follows. ■

Proof. of Proposition 3: This follows directly from Proposition 2(a). ■

Proof. of Proposition 4: Denote the commodity price density and distribution under at the original levels of search costs c_P and c_A as $f(p)$, $F(p)$, and at the new levels of search costs kc_P and kc_A as $f^k(p)$, $F^k(p)$. Also, denote the lower support of the price distribution and the optimal search cutoffs under the original levels of search costs c_P and c_A as r_0, r_P and r_A, and the optimal search cutoffs under at the new levels of search costs kc_P and kc_A as r_0^k, r_P^k and r_A^k respectively. Finally, denote the buyer's original levels of costs from outsourcing and insourcing (at the original levels of search costs c_P and c_A) as C^O and C^I respectively, and the buyer's new levels of profits from outsourcing and insourcing (at the new levels of search costs kc_P and kc_A) as C^{kO} and C^{kI}

respectively. It follows from (3.1) that

$$\begin{aligned} C^I &= r_P - c_P && \text{(A.27)} \\ C^O &= [2 - F^*(r_A^*)]F^*(r_A)w^H(r_A) + [1 - F^*(r_A)]^2 w^L(r_A) && \text{(A.28)} \\ &\quad +[2 - F^*(r_A)] \int_{r_0}^{r_A} p f^*(p)dp + 2 \int_{r_A}^{r_P} p f^*(p)[1 - F^*(p)]dp\} \end{aligned}$$

Using (A.7) from the proof of Lemma 2:

$$F(p) = 1 - \left(\frac{1-\mu}{2\mu}\right)\left(\frac{r_P}{p} - 1\right), \tag{A.29}$$

which implies that

$$c_P = \int_{r_0}^{r_P} \left[1 - \left(\frac{1-\mu}{2\mu}\right)\left(\frac{r_P}{p} - 1\right)\right] dp. \tag{A.30}$$

Integrating and using (3.3), this simplifies to

$$c_P = r_P \left[1 - \left(\frac{1-\mu}{2\mu}\right) \log\left(\frac{1-\mu}{1+\mu}\right)\right] \tag{A.31}$$

Since $c_P^k = kc_P$, (A.31) implies that $r_P^k = kr_P$. As a consequence, (3.3) implies that $r_0^k = kr_0$, and as a consequence, $r_A^k = kr_A$. Therefore, from (A.27),

$$C^{kI} = kC^I. \tag{A.32}$$

Moreover, we now have:

$$F^k(p) = 1 - \left(\frac{1-\mu}{2\mu}\right)\left(\frac{kr_P}{p} - 1\right), \tag{A.33}$$

which implies that

$$F^k(p) = F(\frac{p}{k}). \tag{A.34}$$

Similarly, we have:

$$f(p) = \left(\frac{1-\mu}{2\mu}\right)\frac{r_P}{p^2}, \tag{A.35}$$

and

$$f^k(p) = \left(\frac{1-\mu}{2\mu}\right)\frac{kr_P}{p^2}, \tag{A.36}$$

which implies that

$$f^k(p) = \frac{1}{k} f(\frac{p}{k}). \tag{A.37}$$

At the old levels of search costs, the buyer is indifferent, and therefore $C^O = C^I$, which in turn implies, using (A.32), that $C^{kI} = kC^O$, or

$$C^{kI} = k\left[[2 - F(r_A)] \int_{r_0}^{r_A} f(p)[p + w(p, r_A)]dp + \int_{r_A}^{r_P} 2f(p)[1 - F(p)][p + w(p, r_A)]dp\right]. \tag{A.38}$$

Using the identity $\int_a^b g(x)dx = \frac{1}{k}\int_{ka}^{kb} g(\frac{x}{k})dx$,(A.38) can be rewritten as:

$$C^{kI} = [2 - F(r_A)] \int_{kr_0}^{kr_A} f(\frac{p}{k})[\frac{p}{k} + w(\frac{p}{k}, r_A)]dp + \int_{kr_A}^{kr_P} 2f(\frac{p}{k})[1 - F(\frac{p}{k})][\frac{p}{k} + w(\frac{p}{k}, r_A)]dp, \quad \text{(A.39)}$$

and the expression for costs of outsourcing yields:

$$C^{kO} = [2 - F^k(kr_A)] \int_{kr_0}^{kr_A} f^k(p)[p + w(p, kr_A)]dp + \int_{kr_A}^{kr_P} 2f^k(p)[1 - F^k(p)][p + w(p, kr_A)]dp. \quad \text{(A.40)}$$

Using (A.34) and (A.37), all the terms *not* containing $w(., r_A)$ are equal on the RHS of (A.39) and (A.40). To compare the terms containing $w(., r_A)$, observe that the individual rationality constraint $[IR]$ before search costs decrease can be written as:

$$[2 - F(r_A)] \int_{kr_0}^{kr_A} f(\frac{p}{k})u[w(\frac{p}{k}, r_A)]dp + \int_{kr_A}^{kr_P} 2f(\frac{p}{k})[1 - F(\frac{p}{k})]u[w(\frac{p}{k}, r_A)]dp = k\underline{U} + kc_A[1 - F(r_A)], \quad \text{(A.41)}$$

and $[IR]$ after search costs decrease can be written as:

$$[2 - F(r_A)] \int_{kr_0}^{kr_A} f(\frac{p}{k})u[w(p, kr_A)]dp + \int_{kr_A}^{kr_P} 2f(\frac{p}{k})[1 - F(\frac{p}{k})]u[w(p, kr_A)]dp = \underline{U} + kc_A[1 - F(r_A)]. \quad \text{(A.42)}$$

Since $\underline{U} > 0$, the RHS of (A.41) is lesser than the RHS of (A.42). Comparing the $w(., r_A)$ terms on the RHS of (A.39) and the RHS of (A.40) with the LHS of (A.41) and the LHS of (A.42), and using the fact that $u(.)$ is increasing yields $C^{kI} < C^{kO}$, and the result follows. ■

Proof. of Proposition 5: The locus of all points (c_P, c_A) such that the buyer is indifferent between insourcing and outsourcing is increasing in c_P, and its slope is always less than 1. For any c_P and c_A on this locus, it follows that $(c_P - \tau, c_A - \tau)$ lies below this locus, for all $\tau > 0$ The result follows. ■

B. Formulating the buyer's contracting problem

Let the first price observed by the tier-1 supplier be p_1. If she decides to search again the second price observed is p_2. The final price chosen is $\min[p_1, p_2]$. When the tier-1 supplier searches once, she could encounter either of the two tier-2 suppliers with equal likelihood. In either case, the tier-2 supplier could have a price $p_1 < r_A$ with probability $F(r_A)$, in which case the tier-1 supplier stops searching. Or the tier-2 supplier could have a price $p_1 > r_A$ with a probability $[1 - F(r_A)]$, in which case the tier-1 supplier must sample the second tier-2 supplier, and incur a search cost c_A. Now the second tier-2 supplier could offer a price $p_2 < r_A$, in which case the tier-1 supplier chooses her offer. Or the second tier-2 supplier could offer a price $p_2 > r_A$, in which case the tier-1 supplier

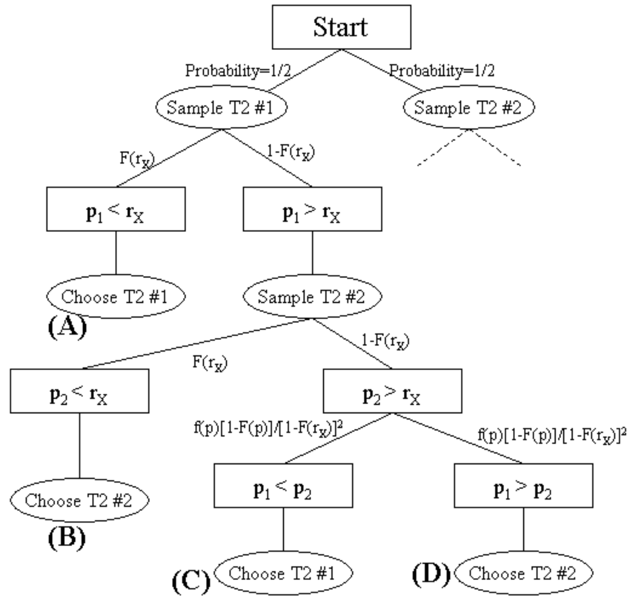


Figure B.1: Partial tree of outcomes when the tier-1 supplier searches.

selects $\min[p_1, p_2]$. These possible outcomes are summarized in Figure B.1.

Under outcome (A) the ex-ante expected payment from the tier-1 supplier to the tier-2 supplier is $\int_{r_0}^{r_A} pf^*(p)dp$. Therefore the expected payment from the buyer to the tier-1 supplier is $\frac{1}{2}\int_{r_0}^{r_A} f^*(p)[p+w(p)]dp$. Similarly, the buyer's expected payment to the tier-1 supplier under outcome (B) is $\frac{1}{2}[1-F^*(r_A;c_P)]\int_{r_0}^{r_A} f^*(p)[p+w(p)]dp$ and under outcome (C) or (D) is $\frac{1}{2}\int_{r_A}^{r_P} f^*(p)[1-F^*(r_A)][p+w(p)]dp$. The expected costs of outcomes (C) and (D) are identical. There are corresponding outcomes (E) through (H) on the other side of the tree (indicated by dotted lines). Summing over each of these eight outcomes yields the expected cost

$$[2-F^*(r_A)]\int_{r_0}^{r_A} f^*(p)[p+w(p)]dp + 2\int_{r_A}^{r_P} f^*(p)[1-F^*(p)][p+w(p)]dp,$$

which when subtracted from the price π yields the buyer's objective function. Correspondingly, under each outcome of figure B.1, the tier-1 supplier receives a wage $w(p)$ which yields utility $u(w(p))$. Calculating expected value over each outcome, and taking into account that a search cost of zero is incurred in outcome (A) because the first search is costless, and a search cost c_A in outcomes (B), (C) and (D), yields the tier-1 supplier's expected payoff:

$$[2-F(r_A)]\int_{r_0}^{r_A} f^*(p)u(w(p))dp + \int_{r_A}^{r_P} 2f^*(p))[1-F^*(p)]u(w(p))dp - c_A[1-F^*(r_A)],$$

which must be greater than or equal to the tier-1 supplier's reservation utility $\underline{U}$.