SINGLE VERSUS MULTIPLE SOURCE PURCHASING STRATEGY

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ABSTRACT

In this paper, we look at the choice between a single and a multiple source purchasing strategy. Using a game theoretic approach, we examine the impact of the economies of scale and specific knowledge on the choice of sourcing strategy, explicitly taking into account the small numbers interactions involving a buyer and two competing suppliers. We show that economies of scale and specific knowledge have opposing effects on sourcing strategies. While a single source strategy is favored when efficiency gains due to economies of scale are large, a multiple source strategy is the dominant strategy in the long run when specific knowledge acquired by a supplier becomes substantial. In following a multiple source strategy, it is also optimal for a buyer to split the supply contract symmetrically across the suppliers, in order to appropriate all efficiency gains that result from the acquisition of specific knowledge by its suppliers. However, splitting of the supply contract results in a reduction in gains due to the economies of scale.

INTRODUCTION

Buyers often face the question of whether to purchase its goods from one or multiple suppliers. The benefits and drawbacks of single and multiple source strategies, each by itself, are clear. If a buyer uses a single source, it will benefit from higher discounts and preferential treatment. However, the buyer faces the possibility that once it is 'locked' into a relationship with a single supplier, the incumbent supplier may demonstrate opportunistic behavior and take advantage of the situation by raising prices. On the other hand, should the buyer opt to source from multiple suppliers, the discounts it obtains from them may not be as favorable, although a multiple source strategy could insure against suppliers' opportunism.

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In practice, the current tendency is for a buyer to work with a supplier and try to exploit economies of scale through bulk purchasing. Although most suppliers and buyers try to create good relationships that will result in a win-win situation, it is not evident that a single source purchasing strategy is superior in practice (Leavy, 1994). The dilemma that buyers and suppliers face is that, building a strong single source partnership and investing in specific assets reduce operational costs. However, at the same time, switching costs are created, making both parties potentially vulnerable to each other's opportunistic behavior.

Through the years, there have been several papers that attempt to apply Transaction Cost Analysis (TCA) to address the issue of single versus multiple sourcing (e.g., Walker and Weber, 1984, Noordewier, *et al,* 1990). These papers argue for the wisdom of single sourcing due to its value creation potential. However, the arguments that are based on TCA tend to be subjective, as TCA itself lacks proper formalization. In addition, the main consideration of traditional TCA (Williamson, 1985) is in the issue of make or buy decisions – with perhaps only tangential consideration of the optimal number of suppliers, and implicitly assumes dyadic interactions in the analysis – which thus implicitly focuses only on a single source strategy. Hence, although attempts were made to extrapolate TCA arguments to small numbers interactions, whether such extensions are valid are less clear. To overcome these limitations, this paper therefore adopts a game theoretic approach to examine the merits of a single versus a multiple source strategy.

We present a game theoretic model that explicitly considers small numbers interactions involving a buyer and two competing suppliers, to examine the impact of such interactions on the choice of sourcing strategy. The objective of this paper is to provide a more definite and formal statement of the decision between single and multiple source strategies, and to identify conditions when each of these strategies might be superior. We incorporate the effects of economies of scale and specific knowledge in our model, to investigate how these factors impact the decision between a single and a multiple source strategy.

The organization of this paper is as follows. The next section reviews the literature related to the decision between a single and a multiple source strategy. Section 3 outlines the model and describes the concepts used to solve the game. We analyze the game in section 4, and discuss the results in section 5. We conclude with some limitations of the paper and provide directions for future research.

LITERATURE REVIEW

Several papers have adopted the TCA approach in their analyses of buyer-supplier relationships. For example, Dwyer and Oh (1988) applied TCA to explain three contractual channel systems in terms of decision-making structures and competitive positioning. Noordewier, *et al,* (1990), following the TCA approach, analyzed the performance outcomes of different governance forms of purchasing agreement. However, these papers do not address the issue of the optimal number of suppliers, in terms of single versus multiple sourcing. Recognizing the limitations of the TCA approach, Noordewier, *et al,* (1990) proposed an integration of TCA, which is efficiency-oriented, with a behavioral approach that emphasizes power and dependence, in future research. Heide and John (1988, 1992) have also stressed the importance of clearly understanding the underpinnings of TCA in analyzing channel relations. They prescribed safeguards for small firms in protecting their specific assets, and proposed the key role of supportive norms to assert control over assets. Recognizing the importance of specific assets in buyer-seller relationships as emphasized in TCA, we therefore incorporate the concept of specific knowledge, and explicitly examine the opportunistic behaviors of interacting parties, in our game theoretic analysis of sourcing strategies.

In the literature, there are several papers that debate the pros and cons of a single source versus a multiple source strategy (Leavy, 1994). The common argument for a single source strategy is based on the benefits that result from economies of scale and learning, which reduce costs, and hence increase total returns to buyers and suppliers in the long run. Parties in an exchange relationship are therefore advised to forgo individual short-term gains, and to take a long-term perspective in exchange relationships, in following a single source strategy. However, such arguments implicitly assume that an equitable sharing of the efficiency gains that result from the economies of scale and specific knowledge would be the natural outcome in long-term exchange relationships. Arguments for a single source strategy thus ignore opportunistic behaviors by contracting parties that could arise even in long-term relationships, and especially so when specific knowledge has been acquired asymmetrically by contracting parties.

A multiple source strategy has been advanced to provide backups in cases where the main supplier fails to deliver the products. However, the main argument that supports a multiple source strategy lies in the need to maintain control over suppliers' opportunism. To prevent opportunistic behaviour, Newman (1988) proposed the constant monitoring of a supplier's production cost. He assumed that this knowledge would ensure the sharing of production efficiency gains. However, this assumption may not always be true. In addition, monitoring is costly.

Given the limitations of monitoring as a means to control suppliers' opportunism, the introduction of competing suppliers into exchange relationships was thus suggested. With the presence of competing suppliers, those who act opportunistically would therefore face the threat of being replaced. However, the splitting of the supply contract among multiple suppliers leads to a reduction of the efficiency gains due to the economies of scale. Whether, and when, such a reduction in efficiency gains is justifiable in terms of the benefits that are derived from the control of suppliers' opportunism is also not clear. Given the pros and the cons of a single and a multiple source strategy, Leavy (1994) thus concluded that neither of these strategies was unequivocally the best. The presence of a strong price-quantity relationship, product specialization, frequency of purchase, and lack of qualified alternative supply sources affect operating cost as well as strategic options available (Segal, 1989).
It is for the purpose of understanding opportunistic behaviors by parties in interactions that the use of the game theoretic approach is most suitable (Moorthy, 1985). A formal examination of the effects of the economies of scale and specific knowledge on sourcing strategies would allow us to address the issues raised, and to identify and define more precisely the conditions that support a single source vis-à-vis a multiple source strategy.

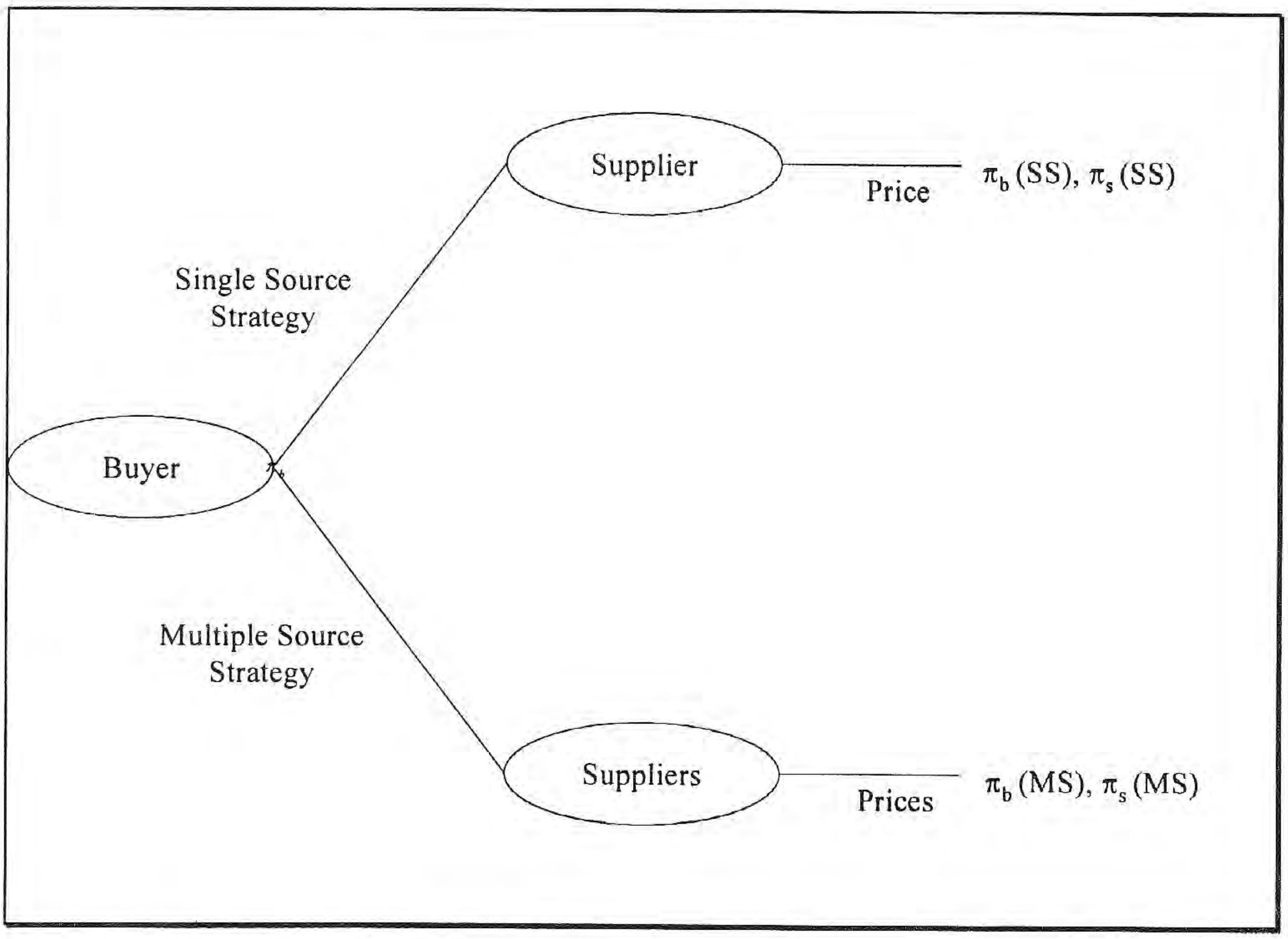
Some other research related to sourcing strategy include that of Trevelen's (1987), which examined sourcing strategy from a supplier's perspective. In his study, Treleven argued that suppliers could benefit from a single source arrangement, when the buyer-supplier relationship is one of genuine cooperation that includes the sharing of pertinent cost information. Recognizing the importance of buyer-supplier relationships, several papers investigated and attempted to identify the conditions that are necessary for successful buyer-supplier relationships. For example, Anderson and Narus (1990) proposed a model of supplier-buyer relationship, stressing the importance of satisfaction in maintaining a relationship. While Dabholka,r *et al,* (1994) argued that a proper balance of power is necessary to maintain a cooperative relationship. In contrast to these papers, we examine the buyer-supplier relationship from an economic perspective, to gain an understanding of the economic forces driving such relationships.

Model

Our model is a 2-stage sequential game (Figure 1), which is repeated over two periods. In stage one, the buyer has to decide between sourcing from a single supplier, or from two suppliers. This choice affects the prices that suppliers can charge. Hence, given the buyer's sourcing decision, the supplier(s) responds by determining the optimal price to charge in stage two of the game. This game structure is then repeated in another period, in order to capture the effects of specific knowledge over time. Figure 1 illustrates the

game tree for a single period in the extensive form, where π_b (SS) and π_b (MS) refer to the buyer's payoffs under a single source and a multiple source strategy, respectively. Similarly, π_s (SS) and π_s (MS) refer to the supplier's payoffs under a single source and a multiple source strategy, respectively. Applying the subgame perfection criteria, we can then derive the Nash equilibrium for the game (eg. Rasmusen, 1989), in terms of the buyer's optimal sourcing strategy and the suppliers' optimal prices.

Figure 1: Game theoretic model of sourcing strategy



As our goal is to analyze the sourcing strategy alternatives available to a buyer, we will narrow our focus to the interactions between the buyer and its suppliers to prevent confounding variables affecting the analysis. The sales and demand for the buyer's goods and services along with the industry conditions are thus taken to be constants. In addition, for simplicity, we assume a zero discount rate for the payoffs in period 2. The game can be generalized to multiple periods. This can be easily dealt with by

discounting the future payoffs for the analysis. As extending the game further than two periods and introducing a discount rate will complicate the analysis without providing substantial contribution, they are not considered here.

Let the price quoted for each unit of the supplies be represented by P, and let the unit cost of production be c. The profit per unit of the product supplied, earned by the suppliers, is P-c. A supplier's payoffs is thus $q(P-c)$, where q is the quantity produced by a supplier. Since q depends on the buyer's decision to use a single or a multiple source strategy, while c is endogenous on economies of scale, and specific knowledge, a supplier thus maximizes payoffs by choosing price P. With the exception that they may acquire specific knowledge asymmetrically, the two suppliers are assumed to be identical in terms of their production technology. Let the total quantity of supplies required by the buyer be Q per period, which is exogenous. Thus, a supplier awarded a contract will produce a quantity q per period, such that $0 < q \leq Q$, which depends on whether the buyer follows a single source or a multiple source strategy.

Payoffs over the 2 periods of our repeated game are represented by (π_b, π_s), where π_b refers to the payoffs to the buyer, which is the costs of supplies to the buyer. While, π_s refers to the profits for each supplier. The total costs to the buyer and the total profits to each supplier are given by $\pi_b = \sum_i P_i Q_i$, and $\pi_s = \sum_i (P_i - c_i) q_i$, respectively, where $i = 1, 2$, refers to periods 1 and 2. Hence, the buyer's objective functions can be defined as;

Max. π_b = Min.$_n$ $\sum_i P_i Q_i$, by choosing n to minimize cost of purchase, where, n $\in$ {single source strategy, multiple source strategy}. Whereas, a supplier's objective function is defined as:

Max. π_s = Max.$_P$ $\sum_i (P_i - c_i) q_i$, by choosing prices to maximize supply profits.

Incorporating Economies of Scale Effect

The effect of the economies of scale is defined as the decline in average cost (per unit of product) with an increase in production volume per unit of time. With no capacity constraints to production, the cost of production per unit of product therefore reduces with an increase in quantity, due to the impact of economies of scale. For example, by following a single source strategy, unit transportation cost may be reduced as a result of shipping a larger annual volume on a preplanned schedule. Further cost savings from

single sourcing may be achieved by storing closely together all items meant for a particular buyer. This facilitates an increased familiarity with the items, their locations and destinations, and the handling procedures, on the part of materials handling personnel (Treleven, 1987), which results in increased material handling efficiency. Economies of scale could also result from the indivisibilities of people and facilities. No matter how small the output may be, there is a minimum capacity of people or facilities required. There are also minimum set-up costs of machines, contracts, and services (Nooteboom, 1993) – like the granting of a subsidiary, advisory services, etc.

We incorporate the effect of the economies of scale in our model as follows. Let the unit cost of production be represented by c, which is a function of quantity produced, $c = c(q)$, where q is the quantity produced. The value of q lies between 0 and Q, and depends on the size of the order received from the buyer. This in turn depends on the whether the buyer chooses a single or a multiple source strategy. It is assumed that the function $c(q)$ is strictly decreasing and convex with respect to q, that is $\frac{\partial c}{\partial q} < 0$, and $\frac{\partial^2 c}{\partial q^2} > 0$.

Incorporating Effect of Specific Knowledge

The effect of specific knowledge is modeled as an efficiency gain in terms of cost reduction, as a supplier improves his skills and expertise in production with an accumulation of production experience. A supplier acquires specific knowledge, or learns, in production only if it is awarded the supply contract in part or in full. Hence, the effect of specific knowledge (or learning) is defined as the decline in unit cost with an increase in cumulative uninterrupted production (Nooteboom 1993), conditional on the award of a supply contract. The effect of specific knowledge is distinguished from that of economies of scale in that, the latter depends on current production volume within a period of time, while the effect of specific knowledge depends on accumulated production volume across all periods of time, since the beginning of production. In addition, learning may arise from different activities and on different levels (e.g., in production, marketing, and finance).

We incorporate the learning curve for production labor in our model as follows. Let the cost of labor be represented by L. We can define the cost of labor as a function of cumulative units of production, such that $L = l(z^e)$, where l is the labor cost for the first unit produced, and z is the cumulative number of units produced. The exponent

$e = \dfrac{\log w}{\log 2} \leq 0$ captures the learning effect, where w is the learning rate. Including the learning effect, the cost function c is then re-written as a function of both quantity and accumulated quantity produced, that is $c = c(q, z)$, where the value of z lies between 0 and $2Q$, for our two-period repeated game. As before, we assume that function c, with respect to z, takes a general and regular form, that is $\dfrac{\partial c}{\partial z} < 0$, $\dfrac{\partial^2 c}{\partial z^2} > 0$.

ANALYSIS

In this section, we will examine the impacts of economies of scale, and of specific knowledge, on sourcing strategy.

Impact of Economies of Scale on Sourcing Strategy

We will first consider the case when the buyer uses a single source strategy. Following which, we will examine the case when the buyer follows a multiple source strategy.

Single Source Strategy

Given that the buyer's requirement of Q per period is purchased from a single source, the unit cost of production to the successful supplier is thus $c(Q)$ in each period. In period 1, in bidding to be the single supplier, competition between both potential suppliers results in a price level $P_1 = c(Q)$. As the game is repeated, in period 2, the same price level results, $P_2 = c(Q)$. Hence, the buyer's cost of purchase over periods 1 and 2 is π_b (SS) = $2Qc(Q)$, while the supplier's payoff is π_s (SS) = 0, given that $P_1 = P_2 = c(Q)$. Lemma 1 follows.

Lemma 1: Under a single source strategy, the purchase price to the buyer for each period is $P = c(Q)$.

Multiple Source Strategy

We next examine the case when the buyer uses two suppliers, and splits its purchase contract into two portions, $(1- \alpha)Q$ and αQ, for each period In this case, the supplier who has been awarded a larger portion of the supply contract will benefit from a lower unit cost of production due to the economies of scale effect – that is $c((1- \alpha)Q) < c(\alpha Q)$, if $\alpha < 0.5$, given that $c(q)$ is convex and strictly increasing in q. However, the competitive price level will be such that the supplier awarded the smaller supply contract will charge, $P = c(\alpha Q)$, while the supplier awarded the larger contract will charge a marginally lower price, $P = (c(\alpha Q) - \varepsilon)$, $\varepsilon \rightarrow 0$. Hence, the lemma follows.

Lemma 2: When the supply contract is split between two suppliers in the ratio $(1- \alpha)$ to α, then the purchase price to the buyer for each period is P = [Max. $\{c((1- \alpha)Q), c(\alpha Q)\} - \varepsilon]$, $\varepsilon \rightarrow 0$.

Lemma 2 implies that the additional gain in the economies of scale in production, achieved by the supplier who is awarded a larger portion of the supply contract, would not be transferred to the buyer. Instead, the supplier who is awarded the larger contract appropriates the efficiency gains that result from the economies of scale in producing a larger volume. This reflects the opportunistic cost faced by the buyer, when the suppliers are allotted different quantities for production. The final price to the buyer is determined by the production of the less efficient supplier.

To appropriate the efficiency gains from production, and minimize opportunism from the more efficient supplier, the buyer should therefore split the supply contract evenly. Doing so, the buyer would be able to appropriate all efficiency gains due to the economies of scale, as competitive pressure between the two suppliers will result in a price $P = c(\frac{1}{2}Q)$. Proposition 1 thus follows.

Proposition 1: To appropriate all efficiency gains from the suppliers that result from the economies of scale, a symmetric split of the supply contract across all suppliers is optimal.

Proof: From Lemma 2, P = Max. $\{c((1- \alpha)Q), c(\alpha Q)\}$. Hence, when $\alpha = \frac{1}{2}$, P = Max. $\{c((1- \alpha)Q), c(\alpha Q)\} = c((1- \alpha)Q) = c(\alpha Q)\} = c(\frac{1}{2}Q)$, which is the suppliers' unit cost of production. Q.E.D.

Comparing the price outcomes under the single source and multiple source strategies, the effect of the economies of scale clearly favors a single source strategy, which is consistent with the views in current literature. For example, Porter (1980) argued that single sourcing is appealing when the price-quantity influence is substantial.

Proposition 2: Economies of scale favors a single source over a multiple source strategy.

Proof: From Lemma 1, under a single source strategy, is $P = c(Q)$. From Lemma 2, under a multiple source strategy, P = [Max. $\{c((1-\alpha)Q), c(\alpha Q)\} - \varepsilon$], $\varepsilon \rightarrow 0$. Given that $\frac{\partial c}{\partial q} < 0$, and $\frac{\partial^2 c}{\partial q^2} > 0$, $P = c(Q) <$ Max. $\{c((1-\alpha)Q), c(\alpha Q)\}$, as $\varepsilon \rightarrow 0$. Q.E.D.

Impact of Specific Knowledge on Sourcing Strategy

In this section, we examine the impact of both the economies of scale and specific knowledge on sourcing strategies. As before, we will first look at the case of single sourcing, before examining the case of multiple sourcing.

Single Source Strategy

In this case, when the buyer chooses to use only one supplier, the unit cost of production for the successful supplier is $c(Q, z(Q))$ in period 1, which reduces to $c(Q, z(2Q))$ in period 2, due to the effect of specific knowledge acquired over the two periods. In contrast, the unsuccessful supplier would not be able to benefit from such learning effects, and hence its unit cost of production would remain at $c(Q, z(0))$. As in the earlier cases, the competitive price level for supplies would be driven by the least efficient supplier, resulting in $P = c(Q, z(0))$, as $\varepsilon \rightarrow 0$, given that $c(Q, z(2Q)) < c(Q, z(Q)) < c(Q, z(0))$ as $\frac{\partial c}{\partial z} < 0$, and $\frac{\partial^2 c}{\partial z^2} > 0$. This implies that the incumbent supplier would appropriate all gains from the acquisition of specific knowledge, amounting to $Q[2c(Q, z(0)) - c(Q, z(Q)) - c(Q, z(2Q))]$, over the two periods. With the unit cost of purchase remaining at $c(Q, z(0))$ for each period, the total cost of purchase to the buyer over the two periods is therefore $2Q[c(Q, z(0))]$.

Proposition 3a: There exists an economic incentive for suppliers, due to gains from the acquisition of specific knowledge, to maintain a long-term exchange relationship with the buyer.

Proof: The competitive price level is $P = c(Q, z(0))$ as $\varepsilon \rightarrow 0$. While, the unit cost of production for the incumbent supplier, due to specific knowledge acquired, are $c(Q, z(Q))$ and $c(Q, z(2Q))$ for periods 1 and 2 respectively. Hence, the payoffs to the incumbent supplier are $([c(Q, z(0)) - c(Q, z(2Q))] + [c(Q, z(0)) - c(Q, z(Q))])Q$, which

can be re-written as $Q[2c(Q, z(0)) - c(Q, z(Q)) - c(Q, z(2Q))]$. For all values of $Q > 0$, $Q[2c(Q, z(0)) - c(Q, z(Q)) - c(Q, z(2Q))] > 0$, given that $\frac{\partial c}{\partial z} < 0$, and $\frac{\partial^2 c}{\partial z^2} > 0$. Q.E.D.

Proposition 3b: Under a single source strategy, the buyer's benefit from the specific knowledge acquired by its incumbent supplier is minimal, as the latter appropriates virtually all gains that result from specific knowledge.

Proof: From Lemma 1, and the proof to Proposition 3a, the competitive price level is $P = c(Q, z(0)$, as $\varepsilon \rightarrow 0$. The buyer's benefit is thus a mere price discount of $\varepsilon \rightarrow 0$, which is minimal. Q.E.D.

While there are obvious benefits to the supplier, when the buyer follows a single source strategy, there are little benefits to the buyer itself. This is due to the opportunistic behavior of the incumbent supplier, who appropriates virtually all gains that result from the specific knowledge acquired in the exchange relationship, instead of transferring any substantial amount of such gains to the buyer. This happens even though supplies are available from competing suppliers in the market. This is because the incumbent supplier, having acquired specific knowledge, has a clear cost advantage over other competing suppliers that it can use to secure repeat supply contracts with the buyer, by offering only a marginal discount.

The motivation for suppliers to seek and to develop lasting exchange relationships is therefore driven by the economic gains associated with the acquisition of specific knowledge. Such economic gains can be so substantial that exchange relationships can be sustained, even though conflicts exist in the relationship (Sriram and Mummalaneni, 1990). Thus, it is important that research works, that attempt to identify the factors that impact exchange relationships, incorporate the underlying economic forces that drive exchange relationships in their studies.

Multiple Source Strategy

We shall now examine if the use of a multiple source strategy would allow buyers to appropriate some of the gains that are derived from the specific knowledge acquired by the suppliers. We shall also focus on situations when buyers optimally split the supply contract symmetrically across their suppliers, as Proposition 1 suggests. With two suppliers, the unit cost of production for each supplier in period 1 is $c(½Q, z(½Q))$, while that in period 2 is $c(½Q, z(Q))$. The symmetric split of the supply contract results in the cost of production being homogenized across suppliers in both periods. This,

together with the competitive bidding between the two suppliers, result in a perfect competition scenario for supplies. As a consequent, the price outcomes are therefore $P_1 = c(½Q, z(½Q))$ in period 1, and $P_2 = c(½Q, z(Q))$ in period 2. Under a multiple source strategy, the buyer thus appropriates all gains that are derived from the specific knowledge acquired by the suppliers.

Proposition 4a: The use of a multiple source strategy, with a symmetric split of the supply contract across the suppliers, allows the buyer to appropriate all gains that result from the economies of scale and the acquisition of specific knowledge by the suppliers.

Proof: Given that $P_1 = c(½Q, z(½Q))$ and $P_2 = c(½Q, z(Q))$, the payoffs to each supplier $\pi_s(\text{MS}) = ½Q\{[P_1 - c(½Q, z(½Q))] + [P_2 - c(½Q, z(Q))]\} = 0$. Whereas, the cost of purchase to the buyer $\pi_b(\text{MS}) = Q[c(½Q, z(½Q)) + c(½Q, z(Q))]$, appropriating all learning gains from the acquisition of specific knowledge, amounting to $\{2Q[c(½Q, z(0))] - Q[c(½Q, z(½Q)) + c(½Q, z(Q))]\}$, which is strictly positive, given that $\frac{\partial c}{\partial z} < 0$, and $\frac{\partial^2 c}{\partial z^2} > 0$. The appropriation of efficiency gains from economies of scale follows from Proposition 1. Q.E.D.

Propositions 3b and 4a are consistent with the view held by Seshadri, *et al,* (1991). They imply that, the possibility of introducing some form of competition between the selected suppliers in order to provide incentives for post-award cost control exists only when multiple suppliers are chosen in the initial process.

Although, by following a multiple source strategy and splitting the supply contract equally among the suppliers, the buyer is able to appropriate all gains that result from the economies of scale and the acquisition of specific knowledge, achieved by the suppliers, its cost of purchase may not be minimized. This is because, in splitting the contract, the efficiency gains from economies of scale are reduced, as production volume for each supplier becomes smaller. Hence, there is a tradeoff between greater economies of scale when using one supplier, against the appropriated gains that result from the acquisition of specific knowledge by suppliers when using two suppliers. Viewed in another way, the use of a multiple source strategy to insure against potential opportunistic behaviors by suppliers carries a cost in reduced economies of scale.

Proposition 4b: Although, by following a multiple source strategy and optimally splitting the supply contract, the buyer can appropriate all gains due to the acquisition of specific knowledge from the suppliers, the cost of purchase is minimized only if the condition that $[c(\frac{1}{2}Q, z(\frac{1}{2}Q)) + c(\frac{1}{2}Q, z(Q))] < 2[c(Q, z(0))]$ *is satisfied.*

Proof: From the proof to Proposition 3a, under a multiple source strategy, the cost of purchase to the buyer π_b (MS) = $Q[c(\frac{1}{2}Q, z(\frac{1}{2}Q)) + c(\frac{1}{2}Q, z(Q))]$. From the proof to Proposition 2a, the competitive price level is $P = c(Q, z(0))$ for each period, under a single source strategy. Hence, π_b (SS) = $2Q[c(Q, z(0))]$. π_b (MS) - π_r (SS) = $Q[c(\frac{1}{2}Q, z(\frac{1}{2}Q)) + c(\frac{1}{2}Q, z(Q))] - 2Q[c(Q, z(0))] < 0$, only if $[c(\frac{1}{2}Q, z(\frac{1}{2}Q)) + c(\frac{1}{2}Q, z(Q))] < 2[c(Q, z(0))]$. Q.E.D.

In Proposition 4b, the left side of the condition, that is $[c(\frac{1}{2}Q, z(\frac{1}{2}Q)) + c(\frac{1}{2}Q, z(Q))]$, reflects a reduction in cost due to acquisition of specific knowledge, when a multiple source strategy is used. While the right hand side of the condition – that is $2[c(Q, z(0))]$, reflects a reduction in cost due to economies of scale, when a single source strategy is used. Hence, whether a single source or a multiple source strategy minimizes a buyer's cost of purchase depends on the tradeoff between the gains due to economies of scale and that due to acquisition of specific knowledge by the suppliers. From Proposition 4, the corollary thus follows.

Corollary 1: A single source strategy is preferred over a multiple source strategy only if the gains due to economies of scale outweigh that due to the acquisition of specific knowledge by the suppliers.

From Proposition 4b, a surprising result is that, over the long term, with an accumulation of specific knowledge such that the efficiency gains associated with it is large, a multiple source strategy clearly dominates a single source strategy. This is in clear contrast to the common view that a single source strategy is favored when contracting parties take a long-term perspective.

Corollary 2: In the long run, in terms of cost minimization, a multiple source strategy is a dominant strategy over a single source strategy.

IMPLICATIONS AND DISCUSSIONS

Parties in exchange relationships have been advised to forgo individual short-term gains, and to take a long-term perspective instead, in following a single source strategy. The rationale for such advice is based on the efficiency gains that result from the

economies of scale and the acquisition of specific knowledge, which take time to materialize. Such advice implicitly assumes that an equitable sharing of the efficiency gains would be the natural outcome in long-term exchange relationships. While it is true that a single source strategy has the advantage of maximizing gains due to the economies of scale, a surprising result is that a buyer gains only minimal benefits that result from the acquisition of specific knowledge by the incumbent supplier (Proposition 3b). This is due to the opportunism of the incumbent supplier, who is able to appropriate virtually all gains that result from its acquisition of specific knowledge precisely because the knowledge acquired is specific to itself.

Whether a buyer or a supplier appropriates a large part of the efficiency gains due to the acquisition of specific knowledge by the latter depends on the sourcing strategy chosen by the former. A single source strategy results in the incumbent supplier appropriating all efficiency gains that result from its acquisition of specific knowledge (Proposition 3b), while a multiple source strategy results in the buyer appropriating all such gains (Proposition 4a). Economies of scale and acquisition of specific knowledge by a supplier thus have opposing effects on sourcing strategy.

Given that, under a single source strategy, the incumbent supplier appropriates virtually all efficiency gains that result from its acquisition of specific knowledge, a buyer thus has little economic incentives to maintain a long-term exchange relationship with a single incumbent supplier. Hence, contrary to conventional wisdom that a long-term perspective favors a single source strategy, Corollary 2 shows that, in the long run when efficiency gains due to specific knowledge is substantial, a multiple source strategy is the dominant one.

On the other hand, a supplier has economic incentives to maintain a long-term exchange relationship with a buyer. This is because a supplier will be able to gain a competitive advantage over other competing suppliers, through the acquisition of specific knowledge, and also profit from this advantage. Hence, Proposition 3a confirms Treleven's (1987) argument that suppliers could benefit from a single source arrangement. However, the source of such benefits lies in the acquisition of specific knowledge by suppliers, rather than the altruistic sharing of benefits by parties in cooperation.

Table 1 illustrates the payoffs to the buyer and the suppliers, under the single and the multiple source strategies, and taking into consideration the effects due to the economies of scale and the acquisition of specific knowledge by suppliers.

Table 1: Impact of economies of scale and specific knowledge on buyer's and supplier's payoffs, under a single and a multiple source strategy

Sourcing Strategy	Supplier's Price	Buyer's Cost of Purchase	Supplier's Profits
Single Source	$P_1 = P_2 = c(Q, z(0))$	$2Q[c(Q, z(0))]$	$\{2Q[c(Q, z(0))] - Q[c(½Q, z(½Q))] - Q[c(½Q, z(Q))]\}$
Multiple Source	$P_1 = c(½Q, z(½Q))$ $P_2 = c(½Q, z(Q))$	$\{Q[c(½Q, z(½Q))] + Q[c(½Q, z(Q))]\}$	0

From Table 1, it is clear that a multiple source strategy is useful in appropriating all efficiency gains from the suppliers, and hence is effective as a check against suppliers' opportunism. Proposition 3b highlights the risk of a single source strategy in that the incumbent supplier will gain an advantage over other competing suppliers in terms of specific knowledge, but need not transfer any significant amounts of the gains that result from specific knowledge to the buyer. A multiple source strategy reduces this risk. As shown in Proposition 4a, conditioned on an equal split of the contract, a buyer is able to enjoy the efficiency gains that result from the economies of scale and the acquisition of specific assets by the suppliers, by following a multiple source strategy. The drawback here is that a multiple source strategy reduces the benefits from the economies of scale. Hence, it may not be the best strategy in terms of minimizing the cost of purchase to the buyer (Proposition 4b). The choice between single and multiple sourcing depends on the tradeoff between the gains from the economies of scale and that from specific knowledge (Proposition 2 and Corollary 1).

In addition, when using multiple sourcing, a buyer has to ensure that efficiency gains in economies of scale and in the acquisition of specific assets are distributed across suppliers such that their cost of production is equalized (Proposition 1). Otherwise, as described in Lemma 2, the price charged to the buyer would be higher, as the competitive price level depends on the supplier who is less efficient.

LIMITATIONS AND CONCLUSIONS

In this paper we examine the impact of the economies of scale and specific knowledge on sourcing strategies, by following a game theoretic approach. We show that a multiple source strategy is effective in curbing opportunistic behaviors by suppliers. A multiple source strategy can therefore be a viable alternative to internalization to bring production in-house in order to control suppliers' opportunism, as TCA typically prescribes. Following a game theoretic analysis, we are also able to identify more precisely the conditions when a single source strategy is favored over a multiple source strategy, and vice versa. We illustrate how the concept of specific knowledge can be formalized using a game theoretic approach, and hence provide a means for future attempts in formalizing TCA arguments. This will help to increase the rigor of the TCA approach. Future research can empirically verify the propositions presented in this paper.

There are several limitations in our analysis that are worth noting. We have not considered product quality. With an increase in the acquisition of specific knowledge, product quality can be improved. Hence, if quality is a significant factor, it can favor a single source strategy at the risk of increasing suppliers' opportunism. Secondly, we do not consider reputation effects, which may punish players who behave opportunistically. In addition, we have also assumed that the suppliers possess the same technology and learn at the same rate. However, if the suppliers learn at different rates, then the results may be modified. Finally, the issue of collusion has been omitted. This may have an impact of the analysis as well, but given that collusion is illegal in certain countries, this is a reasonable omission. The effects of these limitations on the results presented in this paper are left for future research.

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