Supplier Selection models for a Heterogeneous Supply Base

Jishnu Hazra  
Associate Professor  
Indian Institute of Management Bangalore  
Bannerghatta Road, Bangalore, 560 076 INDIA.  
E-mail: hazra@iimb.ernet.in  
Ph: (91 – 80) - 699 3195

B. Mahadevan  
Professor  
Indian Institute of Management Bangalore  
Bannerghatta Road, Bangalore, 560 076 INDIA.  
E-mail: mahadev@iimb.ernet.in  
Ph: (91 - 80) - 699 3275

Abstract

Internet based marketplaces have enabled industrial buyers to locate suppliers from geographically diverse locations. This has resulted in increased variations in certain supplier parameters such as capacity and cost among the participating suppliers. However, the impact of this increased heterogeneity on the procurement practices are not well understood. In this paper we consider three supplier parameters that can affect the price the buyer pays and the number of suppliers that the buyer will select for award of contract. These attributes are capacity, production cost and demand for supplier’s capacity. We show how these parameters impact the price that a supplier quotes. We also show how the buyer will determine the optimum number of suppliers using a reverse auction mechanism when he does not have perfect knowledge of the suppliers’ parameters. Our model suggests that buyers need to adjust some of the input parameters while procuring capacity from a heterogeneous supply base. For instance, buyers need to pre-qualify more suppliers if the supply base has greater heterogeneity.

Keywords: Supply Heterogeneity, Supplier Selection, Electronic Markets

1. INTRODUCTION

Firms competing in the 21st century need to deploy alternative methodologies to improve the responsiveness of supply chains especially when addressing a build-to-order requirement. One of the ways to achieve this is to have contractual agreement with suppliers located worldwide [1]. Consider Li and Fung, a well known build-to-order supply chain integrator operating from Hong Kong. Li & Fung has contractual agreement with multiple mills for weaving and dying of un-dyed yarns in order to improve responsiveness [2]. Contracts provide buyers the required flexibility to handle uncertain demand and permit better capacity planning. Suppliers would also prefer to have contractual agreements with buyers as it could lower their cost due to better capacity planning [3]. Additionally, suppliers derive benefits from better upstream procurement planning.

Consider a typical supply chain management (SCM) strategy of identifying a set of suppliers to contract with. A certain number of suppliers, \( n \), are first pre-selected on the basis of an established process such as RFQ. The \( n \) suppliers are required to participate in a reverse auction in an electronic marketplace. At the end of the auction, contracts are awarded to a sub-set of \( m \), selected suppliers for a period ranging from one to three years on a contract price. The \( m \) suppliers satisfy the demand arising out the contract obtained through the electronic market during the period of contract, in addition to any demand that they have in the traditional market.

An interesting development in the field of SCM is the ability to gainfully exploit the benefits offered by the Internet in effectively deploying SCM strategies. Several studies predicted electronic markets to play a significant role in redefining buyer – supplier relationships [4, 5, 6]. A variety of Business-to-Business (B2B) market places are available today and organizations could put a combination of these to use through an E-procurement plan [7]. E-procurement offers several new advantages to industrial buyers. Many of them stem from the ability to reach a wider set of suppliers than before. For instance, a registered user of Alibaba.com gains access to several thousand trade leads in 27 industry categories and 900 product categories posted by potential buyers and suppliers [8]. The implications of such a dramatic increase in the potential supplier base are not well understood in practice.

An increase in the potential supplier base introduces greater heterogeneity primarily on three dimensions: capacity, cost structure and demand for their capacity in the open market. We investigate the impact of supply base heterogeneity on the size of the supply network and the procurement cost of the buyer. In the absence of this knowledge, organizations will choose to ignore the potentially large supplier base and
continue with their old strategy of selecting suppliers from local markets. Our work is at the intersection of supply contracting literature and Internet applications for procurement. While supply contracting literature addresses various contracting mechanisms employed between a chosen set of suppliers and a buyer, we extend this work by studying the effect of heterogeneous mix of the supply base typical of electronic markets on the basic parameters of contract such as \( n, m \) and price obtained through the electronic market. Earlier studies have neither explicitly acknowledged the increased heterogeneity of the supply base nor analyzed the situation arising out of this. We show how managers could adopt strategies for supplier selection while sourcing from a heterogeneous supply base.

The rest of the paper is organized as follows: We begin by motivating the research problem in section 2 with a review of pertinent literature. In section 3 we discuss the issue of supply base heterogeneity and describe the problem. We present the base model in section 4. In section 5 we analyze the three cases of supply base heterogeneity and derive solution procedures for each case. Using the solution procedure, we analyze the problem, and discuss key managerial implications of the study in section 6 and finally conclude the paper in section 7.

2. LITERATURE REVIEW

There are several studies related to contractual agreements between the supply chain members for capacity reservation. Cachon [9] provides an excellent review of the supply chain contract literature. Alternative contract mechanisms have been proposed in the past including quantity flexibility [1], back-up agreements [10], buy-back [11] and pay-to-delay [12]. Serel et al. [3] proposed a contract mechanism in which the supplier offers a portion of her capacity in advance at a cost lower than the market. For additional capacity, the buyer pays at the market price.

The literature in contracting suggests that the mechanism employed for supplier selection, pricing and the number of suppliers are important issues for consideration. In a multiple supplier environment, in addition to the amount of capacity to be reserved, the number of suppliers with whom the buyer has to engage in a contract becomes a decision variable. Moreover, the presence of multiple suppliers will require the buyer to set-up a competitive mechanism for capacity allocation among the selected suppliers.

In the electronics industry large buyers conduct the majority of their transactions through long-term contracts, and use the open markets primarily to buffer supply and demand shocks [13]. Even in the services sector, such as the transportation industry buyers increasingly use reverse auctions to source their transportation needs [14]. Our use of reverse auction for supplier selection in this study has been motivated both by several real life examples and the existing literature in supplier selection.

The buyer in an electronic market essentially faces the issue of supplier selection. Most approaches deal with the supplier selection problem using price, quality and other factors employing either simple weighting scheme of qualitative factors or mathematical programming methods [15, 16]. Weber et al. [17] provides a review of research on supplier selection methods using these approaches. These approaches do not address the problems arising out of information asymmetry.

Furthermore, Elmaghraby [4] reports that there is a paucity of papers that incorporate the informational aspects of the sourcing problem. She identifies several under-researched areas, among them cost structure, asymmetry and unobservability of costs, and variability across the supplier base. Our model address issues that arise from unobservability of certain parameters and stochastic differences across the supplier base.

Moreover, the relationship between capacity and price has not been explicitly considered. In a recent paper, Grey et al. [13] suggested that although suppliers have an option to sell capacity in both the open market and the electronic market, they face different sets of costs. Consequently, suppliers will deploy alternative strategies for pricing their capacity in these markets. In our model, we explicitly model the relationship between price and capacity and its impact on the procurement cost for the buyer. These interrelationships will govern supplier selection.

3. HETEROGENEITY IN SUPPLY BASE

Consider an \( i^{th} \) supplier participating in an electronic market with a finite capacity, \( \mu_i \), and a unit cost of production, \( v_i \). While attempting to sell its capacity in the open market, the supplier will find that the demand is stochastic. Hence the capacity the supplier will be selling in the open market is a random variable \( X \). In this paper, we utilize a uniform distribution \( U(0, b_i) \) to model the demand for the supplier’s capacity in the open market. For the \( i^{th} \) supplier, the vector \( \{\mu_i, v_i, b_i\} \) denotes the supplier parameters for capacity, production cost and the open market demand respectively. We define supply base heterogeneity in an electronic market as the variations among the participating suppliers in the supplier parameters.

Heterogeneity in the supply base was not so much an issue in the pre-Internet era. Typically, due to high search costs, organizations often tended to locate suppliers from local markets and source components. However, B2B electronic
market places have enabled industrial buyers to look for potential suppliers in geographically different markets. For example, an auto-component manufacturing firm located near the city of Bangalore in India could participate in a reverse auction hosted on behalf of an automobile manufacturer to supply components to their Detroit plant provided they pre-qualify. Actively considering such suppliers would mean greater supply base heterogeneity.

3.1. Capacity heterogeneity

The suppliers participating in an electronic market could vary in terms of the installed capacity. Capacity variations are prevalent in every sector of industry and exist for several reasons [18]. Often, firms create entry barriers through capacity build up for strategic reasons. Therefore, capacity choices are often firm level strategic decisions. We therefore assume in our model that capacity is private information known only to the specific supplier. However, we assume that the buyer has subjective belief about the capacity distribution across the suppliers and this is modeled by sampling from a uniform distribution $U(\mu_l, \mu_h)$.

3.2. Cost heterogeneity

There could be significant variations in the unit cost of the capacity offered by suppliers participating in an electronic market. Well known reverse auction sites such as Freemarkets have reported this phenomenon among the participating suppliers in their reverse auctions. Cost differentials occur primarily as a result of variations in input factor cost. Shifting of major manufacturing activities to Pacific Rim countries and China, software development activities to India and textile manufacturing to Latin and central America, South Asia and Pacific Rim countries are attributed to cost structure differentials. Therefore, we model a situation where $v_i$ is uniformly distributed, $U(v_l, v_h)$.

3.3. Demand heterogeneity

In reality, there could be variations among the supply base in the nature and quantum of opportunities available to them in the open market on account of several factors. First the demand for the products offered by the suppliers in their local markets could vary significantly. For instance, among the manufacturers, those in the developed countries are exposed to a greater set of opportunities than those in developing countries. Second, the sector in which the supplier is operating could itself be perceived to be competitive. Sector competitiveness is attributed to the existence of good infrastructure and complementary resources for the industry to grow. Typical examples include BPO service providers in India and semiconductor manufacturing firms in Taiwan. Thirdly, reputation effects contribute to differences in demand in the open market. Software service providers in India experience greater demand than those in ASEAN region. Therefore, between these two categories of suppliers there could be a significant difference in the demand parameter, $b$. We model a situation in which the parameter $b$ varies uniformly between $b_l$ and $b_h$ denoted as $U(b_l, b_h)$.

Before we discuss the heterogeneity problem, we elaborate the supplier selection and procurement issues faced by the buyer in an electronic market. We also formalize the costs faced by a supplier in both the open market and the electronic market and develop the base model for the problem.

4. THE BASE MODEL

Consider an item that a buyer would like to procure from an electronic market for which there are $n$ pre-qualified suppliers available to supply as per specifications. The total amount of capacity the buyer is seeking through the electronic market is denoted by $\Lambda$. In reality, $\Lambda$ would represent the forecasted annual requirement of the buyer, which are made-to-order. Typically, most of the contracts awarded through electronic markets are for a long term of one to two years [19, 20, 21].

We assume that the buyer will allocate the contract to $m$ suppliers through a reverse auction. The salient features of the supplier selection process are as follows: The buyer pre-qualifies $n$ suppliers to participate in the bidding process, through a RFQ, along with reverse auction rules, duration of the bid taking period, and other terms of fulfillment. The buyer will also a priori announce the number of suppliers, $m$ ($1 \leq m \leq n-1$), that will be selected. This is a common practice in reverse auction models where all participating suppliers will know the number of suppliers and quantity allocation before the commencement of the bidding process. In our model the buyer will select $m$ suppliers ($1 \leq m \leq n-1$) that have quoted the $m$ lowest prices and winning bid price is the price of the first rejected supplier. The buyer obtains quote from the participating suppliers in the form of price-capacity curve. The price-capacity curve distribution of the participating suppliers would be the basis for the buyer to allocate the order among the suppliers so as to minimize the total expected cost of the items procured.

In this paper we model a scenario where the buyer will split its requirement equally among $m$ suppliers ($1 \leq m \leq n-1$). Unequal allocation can be modeled using mathematical programming techniques [22] however the price contract is different from ours. In unequal allocation the suppliers will pay different unit price. In this paper all $m$ suppliers, finally
selected, will get an equal allocation of the capacity at the price of \((m+1)\) lowest supplier’s bid. Therefore, the fraction of the capacity awarded to each supplier is \(\frac{\Lambda}{m}\). This practice of splitting the contract into lots and letting the suppliers know about the number of lots \(a \text{ priori}\) is an important operational feature observed in an electronic market [23]. A preliminary qualification for the supplier to be enlisted by buyer is that the supplier’s capacity is at least as large as \(\Lambda\). This is to ensure that in case \(m = 1\) then there is no capacity infeasibility issues. Such pre-qualification conditions are not uncommon [24, 19, 25].

We begin our analysis of supplier heterogeneity by first deriving the price a supplier is likely to quote in the electronic market if the supplier was awarded a contract. Consider the \(i^{th}\) supplier participating in the electronic market with its vector of supply parameters, viz., \([\mu_i, v_i, b_i]\). While attempting to sell its capacity in the open market, the supplier finds that the demand is stochastic. Hence, the capacity the supplier will be able to sell in the open market is a random variable \(X\). On the other hand, when the supplier enters into a contract with the buyers through an electronic market, her uncertainty of selling the unsold capacity in the open market comes down. Hence, she would prefer to first pledge a certain amount of capacity in the electronic market before facing uncertain demand in the open market.

The random nature of demand in the open market imposes a financial burden on suppliers because of the risk of unsold capacity. We do not consider the cost of unsold capacity because the supplier has already made investment in capacity at the time of decision-making. If the supplier utilizes \(x\) units of capacity for production, then the supplier’s cost is given by \(v_i x\). Finally, the historical price per unit of capacity in the open market is \(P\), which is the average price prevailing in the open market. We assume that this price per unit of capacity is uniform across all suppliers. Such an assumption is common in the literature (see for example [3]).

From the suppliers’ perspective, she will sell her capacity in the open market at a unit price of \(P\). However, since she will face uncertain demand and incur selling costs, she will consider selling some capacity through the electronic market at a lower price, as long as the price differential between the open market and the electronic market is more than the costs incurred in selling additional capacity in the open market. Based on these considerations, we derive the price – capacity curve for a supplier to participate in an electronic market.

The expected profit if the \(i^{th}\) supplier offers her entire capacity in the open market is given by

\[ P(E\{\min(X_i, \mu_i)\}) - v_i (E\{\min(X_i, \mu_i)\}) \]  \hspace{1cm} (1)

The first term in the above expression is the expected revenue earned (\(X_i\) is the amount of capacity she can sell in the open market) and the second term is the cost. The \(E\) in the equation is the expectation operator. The production cost is a function of the number of units produced.

Now suppose the supplier participates in the electronic market and is awarded \(\lambda_i\) units of capacity, in which case she will have to sell \(\mu_i - \lambda_i\) units of capacity in the open market. Her expected profit if she is awarded the contract will be:

\[ P_i(\lambda_i) \lambda_i + P(E\{\min(X_i, \mu_i - \lambda_i)\}) - v_i (\lambda_i + E\{\min(X_i, \mu_i - \lambda_i)\}) \]  \hspace{1cm} (2).

In equation (2), \(P_i(\lambda_i)\) is the price the supplier quotes to the buyer, which is a function of units of capacity, the buyer procures from this supplier. The supplier will accept the contract provided (2) is at least as large as (1). Therefore the price-capacity curve is given by:

\[ P_i(\lambda_i) = \frac{P(E\{\min(X_i, \mu_i)\}) - E\{\min(X_i, \mu_i - \lambda_i)\})}{\lambda_i} \]  \hspace{1cm} (3).

For a demand distribution, \(U(0, b_i)\), where \(b_i > 0\), after simplification we get

\[ E\{\min(\xi, X)\} = \frac{2b_i \xi - \xi^2}{2b_i}, 0 \leq \xi \leq b_i \]

\[ = \frac{b_i}{2}, \xi > b_i \]  \hspace{1cm} (4).

Furthermore, since \(m\) suppliers will be awarded the contract, \(\lambda_i = \frac{\Lambda}{m}\) for the selected suppliers. When \(\mu_i < b_i\), substituting (4) in (3), and replacing \(\lambda_i\) with \(\frac{\Lambda}{m}\), we get after simplification:

\[ P_i\left(\frac{\Lambda}{m}\right) = P - \left(\frac{P - v_i}{2b_i}\right) \left(2\mu_i - \frac{\Lambda}{m}\right) \]  \hspace{1cm} (5).

From equation (5), it is clear that the price quoted by the \(i^{th}\) supplier in the electronic market decreases linearly with the capacity.

5. IMPACT OF SUPPLY BASE HETEROGENEITY
We see from equation (5) that the vector of supplier parameters of the participating suppliers affects the expected unit price that the buyer will pay. In such a situation, a buyer would like to know the relationship between the supplier parameters and the price that the buyer may ultimately fetch from the electronic market. Moreover, the buyer will also be interested in knowing the optimum number of suppliers, \( m^* \), to be selected in such a situation. We analyse the three cases of supply base heterogeneity independently and develop solution procedures to address the above questions.

5.1. Capacity heterogeneity

Buyers could face a situation in which they pre-select suppliers whose cost structures and demand distribution in the open market do not vary significantly. In such a situation, differences exist only in their capacities. We analyze this to understand how it affects the price obtained by the buyer. As in Section 5.1, we assume that the buyer does not know the individual supplier’s capacity but has subjective belief about the capacity distribution across the suppliers and this is modeled by sampling from a uniform distribution \( U(\mu_l, \mu_u) \).

Optimum number of suppliers to allocate the requirement

We know that the buyer obtains quote from the participating suppliers in the form of price – capacity curve. We analyze the problem from the buyer’s perspective by relating the capacity-price curve distribution of the suppliers to its cost minimization function. As the buyer has to announce the number of suppliers that will be selected (that is, \( m \)), it will do in a fashion that will minimize its total expected cost of the items procured. The reverse auction rules have been described earlier in Section 4. The buyer’s problem can therefore be formulated as:

\[
\min_{m \geq 0} \Lambda E(P_{\lbrack m+1 \rbrack}) = \Lambda \min_{m \geq 0} E(P_{\lbrack m+1 \rbrack}),
\]

where \( P_{\lbrack 1 \rbrack} \leq P_{\lbrack 2 \rbrack} \leq \ldots \leq P_{\lbrack m \rbrack} \leq P_{\lbrack m+1 \rbrack} \ldots \leq P_{\lbrack n \rbrack} \)

denotes the order statistics and \( P_{\lbrack m+1 \rbrack} \)

is the lowest bid price amongst the rejected suppliers.

From equation (5), it can be shown that

\[
E(P_{\lbrack m+1 \rbrack}) = P - \left( \frac{P - v}{2b} \right) \left( 2E(\mu_{\lbrack n-m \rbrack}) - \frac{\Lambda}{m} \right).
\]

Using a similar notation for order statistics for the random variable \( \mu \), \( \mu_{\lbrack 1 \rbrack} \leq \mu_{\lbrack 2 \rbrack} \leq \ldots \leq \mu_{\lbrack n \rbrack} \leq \ldots \mu_{\lbrack n-1 \rbrack} \leq \mu_{\lbrack n \rbrack} \).

Substituting \( E(\mu_{\lbrack n-m \rbrack}) = \mu_i + \frac{n-m}{n+1}(\mu_u - \mu_i) \) [26] in the above equation and simplifying we get an expression for expected unit price to be paid by the buyer.

\[
E(P_{\lbrack m+1 \rbrack}) = P - \left( \frac{P - v}{2b} \right) \left( 2\mu_i + \frac{n-m}{n+1}(\mu_u - \mu_i) - \frac{\Lambda}{m} \right) \hspace{1cm} (6).
\]

The buyer’s optimization problem stated above can now be solved by simple calculus and the optimum value of \( m \) can be obtained. The optimum number of suppliers that the buyer will select in a capacity heterogeneous supply base is given by

\[
m^* = \sqrt{\frac{\Lambda(n+1)}{2(\mu_u - \mu_l)}} \hspace{1cm} (7).
\]

The expression for optimum number of suppliers exhibits several properties of interest to the buyer. It is dependent only on total capacity requirement of buyer, the number of participating suppliers and buyer’s knowledge of the range of supplier’s capacity. Interestingly, all these parameters are independent of supplier specific parameters. The only error that buyer can introduce in the computation of \( m^* \) is in the estimation of \( \mu_u \) and \( \mu_l \).

5.2. Cost heterogeneity

In this case, all suppliers are assumed to have similar capacity and demand distribution for their capacity. However, suppliers differ on account of variations in the unit production cost. Retaining the subscript for cost alone in equation (5), we rewrite the price equation as follows:

\[
P_i(\frac{\Lambda}{m}) = P - \left( \frac{P - v}{2b} \right) \left( 2\mu_i - \frac{\Lambda}{m} \right).
\]

As in Section 5.1, we assume that the buyer does not have knowledge of the individual supplier’s production cost but has subjective belief about the capacity distribution across the suppliers and this is modeled by sampling from a uniform distribution \( U(v_1, v_h) \). The expected bid price of the \( (m+1) \) lowest bidder is given by:

\[
E(P_{\lbrack m+1 \rbrack}) = P - \left( \frac{P - E(v_{\lbrack m+1 \rbrack})}{2b} \right) \left( 2\mu_i - \frac{\Lambda}{m} \right).
\]

Using the order statistics for \( v \), we obtain,

\[
E(v_{\lbrack m+1 \rbrack}) = v_1 + \frac{m+1}{n+1}(v_h - v_1).
\]

Substituting \( E(v_{\lbrack m+1 \rbrack}) \) in the above equation we get the expected unit price to be paid by the buyer.
As shown in the previous case, the optimum number of suppliers to be selected could be obtained using simple calculus. It can be shown that the optimum number of suppliers that the buyer will select in a cost heterogeneous supply base is given by:

$$m^* = \sqrt{\frac{\Lambda}{2\mu}} \left( \frac{(P-v)}{(v_h-v_l)} \right) - 1 \right) \frac{(P-v)}{(v_h-v_l)} - 1 \right)$$

(9).

It is clear from equation (9) that as the range of the distribution parameter and the number of pre-qualified suppliers increase, \(m^*\) will increase. However, as in the case of capacity heterogeneity, \(m^*\) is expected to be robust. The expected unit price to be paid by the buyer is given by substituting \(m^*\) in equation (8).

5.3. Demand heterogeneity

We now analyse the third case where the participating suppliers have similar cost structure and capacity. They however, differ significantly in the demand for their capacity in the open market. As in the previous two cases we drop the subscripts for capacity and cost in equation (5) and rewrite the price equation of the supplier as follows:

$$E(P_{m+1}) = P \left\{ P - \left( \frac{m+1}{n+1} \right) \left( \frac{2\mu - \Lambda}{m} \right) \right\}$$

(8).

In order to sharpen the understanding and provide additional insights we perform more analysis of the model behavior using some numerical illustrations. The additional experiments conducted using numerical examples were meant to address the following questions:

(a) What is the impact of supplier parameters and the number of pre-qualified suppliers on the expected unit price that the buyer would pay and on the optimum number of suppliers to be selected for award of the contract?

(b) What is the relationship between the degree of heterogeneity and the number of pre-qualified suppliers on \(m^*\) and on the expected unit price to be paid by the buyer?

By degree of heterogeneity we mean the spread in the distributions of supplier parameters. We have chosen a base case and two levels of heterogeneity for analysis. The details are given in Table 1. Figure 1 is a plot of the expected unit price to be paid by the buyer for the base case scenario for all the four cases of heterogeneity (three independent cases and one involving all the three).
has the optimum number of suppliers to be awarded the contract in each of the four cases for the base case.

### Table 1

<table>
<thead>
<tr>
<th></th>
<th>Capacity</th>
<th>Cost</th>
<th>Demand</th>
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</thead>
<tbody>
<tr>
<td>Base Case</td>
<td>U(120,140)</td>
<td>U(190,210)</td>
<td>U(160,180)</td>
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<td>U(150,190)</td>
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<td>Scenario 2</td>
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<td>U(170,230)</td>
<td>U(140,200)</td>
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<td>P = 300</td>
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<td></td>
<td>b = 170</td>
<td>b = 170</td>
<td>v = 200</td>
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6.1. The Base case scenario

We make several important observations using the results of the base case scenario. First, all the four cases of heterogeneity have similar patterns of impact on both the expected unit price and the optimum number of suppliers to be selected. Second, the expected unit price to be paid by the buyer is convex and decreasing in \( n \), the number of pre-qualified suppliers. It is easy to deduce this in the case of capacity heterogeneity by substituting equation (7) in equation (6), and simplifying it. Clearly, as more number of suppliers is allowed to participate in the electronic market, the buyer discovers better price.

Moreover, we also know from the expressions for \( m^* \) and the numerical and simulation analyses that an increase in \( n \) in turn increases \( m^* \). In reality, there could be realistic limits up to which one could increase the number of pre-qualified suppliers. We have not modeled explicitly the cost of pre-qualifying, coordinating and transacting with each supplier and therefore, we obtain this result. A better understanding of this aspect helps the buyer in arriving at an appropriate value of \( n \).

6.2. Effect of degree of heterogeneity

What is of particular interest to practicing managers is the effect of degree of heterogeneity. Figures 2 – 4 have plots for the three cases of heterogeneities under varying degrees of heterogeneity. Table 2 also has data on the optimum number of suppliers for the three cases of heterogeneity for varying degrees of heterogeneity. These results point to two key messages.

Irrespective of the type of heterogeneity, we see that as the degree of heterogeneity increases, \( m^* \) becomes smaller. Increased heterogeneity indicates that the participating suppliers differ significantly. For instance, a higher capacity heterogeneity would mean that we are likely to have in our pool of pre-qualified suppliers those with higher capacity than others. Clearly, such suppliers will quote a lower price and the buyer gets the benefit of sourcing more capacity from that supplier before considering the next supplier. One can make similar arguments for the other two cases of heterogeneity. One implication of this result is that buyers in general are likely to benefit from greater heterogeneity of the supply base.

![Figure 1](image-url)
### Table 2
Optimum number of suppliers for the base case and the other scenarios

<table>
<thead>
<tr>
<th>n</th>
<th>Simulation</th>
<th>Capacity Heterogeneity</th>
<th>Cost Heterogeneity</th>
<th>Demand Heterogeneity</th>
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<td>Base Case</td>
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<td>SC2</td>
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<tr>
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SC1 = Scenario 1; SC2 = Scenario 2.

### Figure 2
Effect of degree of capacity heterogeneity on expected unit price

![Figure 2](image-url)
Figure 3
Effect of degree of cost heterogeneity on expected unit price

Figure 4
Effect of degree of demand heterogeneity on expected unit price
Since $m^*$ is likely to be smaller as degree of heterogeneity increases, does that mean that a buyer can pre-qualify fewer suppliers? Figure 2 – 4 amply clarify this point. One can observe that unlike the other two scenarios, in the case of greater degree of heterogeneity the number of pre-qualified suppliers has the most significant impact on the expected unit price. The possibility of obtaining a lower price from a supplier base that is highly heterogeneous happens only when there is a relatively large pool of pre-qualified suppliers. This could be explained by the fact that merely having a distribution with greater spread will not fetch the buyer several suppliers with low cost (in the case of cost heterogeneity) or several suppliers with high capacity (in the capacity heterogeneity) or several suppliers with low demand in the open market (in the case of demand heterogeneity). It requires that relatively a large sample of suppliers is pre-qualified from this distribution to participate in the auction. The implication of this for practice is that if the supply base is expected to be more heterogeneous, then there is a motivation for the buyer to pre-qualify more suppliers. On the other hand, if the supply base is likely to be more or less homogeneous, then fewer suppliers need be pre-qualified, thereby saving other costs related to pre-qualification.

7. CONCLUSIONS

The advent of Internet based market places has resulted in newer opportunities for industrial buyers to locate suppliers from far off and hitherto unknown places. While such a move is generally welcome, the implications of this development are not well understood. In this paper, we have defined supply base heterogeneity on the basis of variations in the capacity, cost and open market demand of the participating suppliers in an electronic market. Using a reverse auction mechanism for supplier selection and award of contract, we have modeled the supply base heterogeneity problem. The solution procedures and numerical examples that we have developed indicate that buyers in general are likely to benefit from greater heterogeneity in the supply base. However, in order to extract maximum benefit, buyers need to pre-qualify more suppliers to participate in the auction.

The proposed work could be extended in several ways. In the current model, we have not explicitly modeled the costs of pre-qualification and transacting with selected suppliers. Incorporating this will provide additional insights to the problem. Furthermore, the relationship between cost and capacity has not been considered in this study. It will be worthwhile to study the impact of this correlation on the supply base heterogeneity and on the decision variables.

REFERENCES


