A SIMULATION TECHNIQUE FOR EVALUATING SUPPLIER CONTRACTS

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ABSTRACT

This paper proposes a decision-making tool for evaluating supplier contracts. The proposed technique takes advantage of the demand and component price forecasting while considering the dynamic nature and uncertainty of these variables. A microeconomic model along with the Monte Carlo simulation is used to evaluate supplier contracts.

INTRODUCTION

In today’s dynamically changing market conditions the issues concerning effective supplier relationship techniques have been of great interest to both researchers and practitioners. Also, the concept of supply chain management as a key to gaining competitive advantage has become popular. It promotes close, long-term relationships with suppliers, as opposed to the traditional view that postulates “arm’s-length” contracts to avoid closer dependence on suppliers. However, more insight research in this area (see Dyer et al. (1998) or Bensaou (1999) for example) indicates that close relationships with suppliers may not be optimal in some cases, as they tend to be costly and hard to terminate if a supplier’s performance is inefficient. In fact, today’s practice tends to be a mixture of close partnerships and arm’s-length relationships. Close partnerships are valuable when dealing with highly customized, strategic parts. In the case of more standardized or commodity-like products, arm’s-length relationships seem to be better for manufacturers as they enable more flexibility in reaction to market changes. Hence, creating an optimal portfolio of contracts in given market conditions becomes a vital issue.

This research attempts to provide a decision-making tool for evaluating supplier contracts. The proposed technique takes advantage of the demand and component price forecasting while considering the dynamic nature and uncertainty of these variables. A microeconomic model along with the Monte Carlo simulation method is used to evaluate supplier contracts.

THEORETICAL BACKGROUND

Arm’s-length contracts vs. strategic partnerships

In recent years, a vast amount of research conducted in the subject of supplier management practices has been focusing on the analysis of outstandingly successful Japanese manufacturing
and supply strategies in comparison with the rest of the world; Langfield (1998). Especially, the successes of Japanese car manufacturers (such as Toyota) were proclaimed to have their source in effective business practices, mainly, in the effective way of managing their suppliers through strategic partnerships. Consequently, the idea of reducing the number of suppliers and moving towards long-term relationships was proclaimed by many researchers to be a good management practice. Indeed, most of the U.S. and European automobile manufacturers aimed at decreasing the number of their direct suppliers and concentrated on building and keeping strategic partnerships. Some researchers, however, noticed discrepancies between the intentions expressed by the managers or trends articulated in business magazines, and the actual policies adopted by managers (see Cohen & Agrawal (1999) or Dyer et al. (1998) for example). Moreover, researchers expressed doubts as to the correctness of the trend of changing supplier management strategies, regardless of other factors that might have a potential impact on supplier relationships decisions; Bensaou (1999); Dyer (1996); Kim & Michell (1999). In fact Dyer, Cho et al. (1998) noticed no difference between arm’s-length contracts and partnerships in American manufacturers except for the length of contracts. They concluded, that there are some conditions under which the strategy of moving towards long-term contracts and reducing the number of suppliers is not always reasonable. On the contrary, short term contracts appear optimal in a wide range of situations.

In the procurement of strategic parts, manufacturers indeed tend to struggle for closer collaboration with their suppliers through effective supply contracts. In this case, strategic partnerships are necessary, as the inputs are usually highly customized and enable differentiating the manufacturer's final product from competitors’ products. The examples of such components in the case of the automotive industry are transmission, air conditioners, body, etc. In the case of more standard components, however, (such as batteries or tires) parts can be purchased from many suppliers and on the spot market. Therefore, the key issue here is flexibility rather than long-term relationships with the suppliers; Bensaou (1999); Martinez-de-Albeniz & Simchi-Levi (2005). Commodity-like products (such as steel, electricity, grain, cotton, or computer memory) do not require customization, thus switching from one supplier to another is relatively simple. Although these products are usually non-strategic, effective supplier management strategies are crucial for manufacturers. The prices of some commodity products (electricity, computer memory) may have a major influence on production costs; Martinez-de-Albeniz & Simchi-Levi (2005). Moreover, worldwide capacity of certain commodities may be limited (e.g. gasoline). It is also vulnerable to unexpected events, such as natural or economic disasters, socio-political changes, terrorism, etc. Therefore, in the environment of uncertainty of supply and demand, the decisions of whether to purchase supply now or wait for better market conditions in the future is important.

**Types of contracts**

As a result of several empirical studies of U.S and Japanese manufacturers (see Bensaou (1999); Dyer et al. (1998); Kim & Michell (1999) for example) it appears that, contrary to previous research, both Japanese and U.S. firms conducted their businesses with a smaller ratio of strategic partnerships than it was commonly believed. Moreover, they frequently engaged in market-exchange relationships. No single type of relationship was found to be inherently superior to others. Therefore, it can be said that the successful supplier relationship strategy requires effective and efficient management of a portfolio of relationships, which should be
adjusted to the specific product, market and supplier conditions; Bensaou (1999); Marquez (2004); Martinez-de-Albeniz & Simchi-Levi (2005).

Dyer, Cho et al. (1998) and Kim and Michell (1999) examined buyer-supplier relationships of the major Japanese automobile manufacturers and concluded that there was diversity in their supplier practices. Kim and Michell (1999) differentiated contractual and relational supplier bonds as the two opposing strategies. The authors stated that the manufacturing companies chose the suitable strategy depending on the type of supplier organizations they used, relative sales revenues, number of employees, profitability of both buyers and suppliers, and the level of equity held in their suppliers. Bensaou (1999) identified a portfolio of supplier relationships as the way of effective supplier relationship management, based on empirical studies of the practices used by the U.S. and Japanese manufacturers. Apart from strategic partnerships, the author identified three types of relationships: (1) captive buyer, (2) captive supplier, and (3) market exchange. The level of mutual exchange of specific investments was used as a criterion in Bensaou’s study. As each type of the above relationships tends to appear most commonly under the characteristic product and market conditions, Bensaou identified the market-exchange profile as a characteristic for highly standardized products, requiring low levels of customization, low engineering effort, and supplier expertise. Such relationships are characterized by tense climate and mutual distrust. Consequently, in a situation when the fast pace of changes in technology and product design make forecasting and planning hard or even impossible, strategic partnerships are employed.

Marquez (2004), Martinez-de-Albeniz et al. (2005), and Cachon (2004) identified three kinds of contracts: (1) long-term, (2) option, and (3) flexibility contracts. Long-term contracts, also called “forward buy,” “structured” or “commitment contracts,” specify a fixed amount of supply to be delivered at some point in the future. The supplier and the manufacturer must agree on both the price and quantity delivered to the manufacturer.

In the option contract, the manufacturer pre-pays a relatively small fraction of the product price (called “premium” or “reservation price”) in return for a commitment from the supplier to reserve the capacity up to a certain level. The premium is lost if the buyer does not use the option. The buyer can purchase any amount of supply, up to the option level, by paying an additional price for each unit purchased (called “execution price” or “exercise price”) which is settled when the contract is signed. Thus, option contracts reduce inventory risk as they enable flexibility in adjustments to the demand. In this way, the risk is shifted from the manufacturer to the supplier.

In the third type, flexibility contracts, firms agree to supply and purchase within a specific volume and pricing range. A fixed amount of supply is determined when the contract is signed, but the amount delivered to the customer can differ by no more than a certain percentage.

**Modeling Contracts**

The subject literature offers an investigation of the differences between contracting policies of manufacturers that purchase components from external suppliers; see Cachon (2004); Cohen & Agrawal (1999); Li & Kouvelis (1999); Martinez-de-Albeniz & Simchi-Levi (2005); Serel (2001); Tsay & Lovejoy (1999) for example.

Li and Kouvelis (1999) analyzed supply contracts that provide flexibility of the purchase in the context of deterministic demand and random purchase prices. Cohen and Agrawal (1999) introduced an analytical model that evaluated the trade-off between the short term contracts (characterized by flexibility and speculative benefits) and the long-term contracts (providing
advantages of fixed investments, improvement opportunities, and price certainty). Cohen and Agrawal’s model was used to compare the effects of these two contracting strategies on total cost, including purchasing, inventory and shortage costs, incurred by the firm over the length of its entire planning horizon. Upon analyzing various factors, such as fixed investments, the length of the planning horizon, improvement rates for contracts, the decision-makers’ risk preference, and uncertainty in market prices, the authors concluded that although the long-term contracts offer cost improvements, there is a wide range of conditions under which short-term contracts are more cost effective.

Serel (2001) developed analytical models to examine the manufacturer-supplier relationships, analyzing the situation from the perspective of both parties. Serel’s research explored conditions influencing the choice of long- and short-term relationships. The main influencing factors cited are: supplier’s involvement in the product development process, cost and quality of delivered materials, and risk of supply disruptions.

Several researchers took into consideration a possibility of simultaneous use of a portfolio of traditional contracts as an optimal procurement technique; Marquez (2004); Martínez-de-Albeniz & Simchi-Levi (2005). Martínez-de-Albeniz and Simchi-Levi (2005) provided a framework for selecting a set of option contracts for a single component to optimize profits. Marquez (2004) proposed a model to assess the value of a contract portfolio in procurement of strategic commodity-type parts. The author focused on global sourcing as a fundamental strategy in the case of parts that are critical in the production process and which incur high costs if the production is stopped. Setting up a portfolio of contracts for strategic parts ensures the availability of the supply at a competitive price, which provides flexibility necessary in the environment of hard to predict demand and short life cycles of both product and technology.

**Forecasting in Procurement Decisions**

The importance of forecasting in the decision-making process is questioned neither by researchers nor by practitioners. Utilizing the demand and sales forecasts is a common business practice and one of the key components in planning and operating functions in many firms. Extensive literature reviews of the empirical studies devoted to forecasting practices may be found in Klassen (2001), Mady (2000) or Sethi et al. (2004). These reviews indicated that the vast majority of studies took into consideration demand or sales forecasts, paying little or no attention to the usefulness of the component price forecast; see also Marquez (2004); Sethi et al. (2004); Tsay & Lovejoy (1999).

The decision to enter a long-term contract depends on the nature of the market and on the decision-maker’s risk attitudes. When the market conditions for components are evolving (non-stationary) over the length of the planning horizon, long-term contracts may not prove beneficial at the beginning of the planning horizon, even for risk-averse managers. It may be better to delay the decision to switch to a long-term contract until more price fluctuations have been observed. Thus, a ”wait-and-see” strategy may be best suited in this case. Therefore, forecasts of market conditions, i.e., the fluctuations of market prices over the planning horizon, constitute an important input to the supply manager’s decision-making process.

**RATIONALE**

In our research we concentrate on utilizing the component price forecast in managing supplier contracts. We attempt to verify the hypothesis, that contracting decisions may be facilitated with
the reliable forecast of the component prices. Based on the forecast, the decisions about the types of contracts to sign may be made and the production costs may be reduced. When optimizing contracting decisions most researchers use a deterministic approach and develop linear programming models. Yet, the majority of real-life problems are not linear. Moreover, they are stochastic in nature, which frequently makes models non-solvable with the analytical methods. Our research moves from the deterministic toward the stochastic approach, thus considering all key variables as random variables characterized by particular distribution parameters.

We use the Monte Carlo simulation method to evaluate the contracting decisions. In the context of supplier relationships several attempts were made to incorporate simulations in analyzing contracting strategies. Martinez-de-Albeniz and Simchi-Levi (2005) used the Monte Carlo simulation method to estimate the distribution of profit for each of the contracts and to support the hypothesis that the analyzed portfolio of contracts has the largest expected profit. Similarly, Marquez (2004) used the simulation model to select a suitable portfolio of contracts with suppliers and to compare this proposal against a forward contract, and against an option contract that could be alternatively signed with the supplier.

A TECHNIQUE FOR THE EVALUATION OF SUPPLIER CONTRACTS

Material cost is one of the most important factors in procurement decisions. Each of the components of the final product contributes to the total material cost in a different way, as each of them is acquired from a different supplier and has a different price. Thus, the problem is to select one set of supplier contracts such that the total material cost is minimized. The method for evaluating supplier contracts developed in this study is based on the assumption that both the demand for the final product and the component price can be predicted for any given point in the planning horizon. The problem is based on considering a number of scenarios of contract sequences for the set of parts comprising the final product. The set of available contracts for each component is known. This means that the manufacturer may choose the sequence and types of contracts from a number of alternatives offered by the supplier within the time horizon. Out of the available contracts, the manufacturer builds a sequence of contracts for each part. All contract parameters, such as contracted price, payment terms, etc., are known at the beginning of the horizon. Numerous scenarios may be considered. The total number of possible scenarios depends on the number of parts which constitute the final product and the number of possible contract sequences for each component. At the end of the planning horizon the total cost of materials per unit of the final product is computed. This can be done using the production function. The optimal scenario is the one with the minimal cost.

While creating the technique for evaluating supplier contracts the following assumptions were made:

1) Contracts guarantee unlimited quantities of components for a fixed price throughout the length of the contract.
2) Contracts allow for flexibility of deliveries.
3) Manufacturers aim at maintaining minimal inventory of components.
4) Demand must be met.

Below we give a formal description of our proposed approach to evaluating supplier contracts.
DETERMINISTIC MODEL

Let us consider a time horizon $H$ that consists of time granules (e.g. days or weeks) indexed with $i=0, 1, \ldots, n$. Following this notation, $t_0$ denotes the present moment in time, $t_i$ stands for any moment in time and $t_n$ is the end of the horizon. Let us assume that the forecasted demand at $t_i$ is given and denoted by $d_i$. Let us further assume that the final product is composed of $m$ parts, indexed with $j=1, 2, \ldots, m$. Also, the forecasted price of a component $j$ at $t_i$ is given by $p_{ij}$. Let us consider the contracted price of component $j$ at $t_i$ denoted by $c_{ij}$, while $x_j$ will be used to denote the quantity of component $j$ needed to produce one unit of the final product. Then, the total cost of material per unit of the final product at $t_i$ ($COM_i$) is given by:

$$COM_i = d_i \sum_{j=1}^{m} x_j c_{ij}.$$  

Because we assume that the demand must be met, we may denote the quantity of the final product manufactured at $t_i$ as $d_i$. The quantity of the final product manufactured over the horizon $H$ is given by:

$$Q = \sum_{i=0}^{n} d_i.$$  

Further, the total cost of materials over the horizon $H$ is given by:

$$C = \sum_{i=0}^{n} COM_i,$$

and the total cost of materials per unit over the horizon $H$ is:

$$CPU = \frac{C}{Q}.$$  

The objective of our technique is to minimize $CPU$.

Illustrative Example

In order to illustrate the above model let us consider a production process in which a single item is manufactured and a single component is needed to produce a unit of this item. For even more simplicity let us assume that one unit of component is necessary to manufacture one unit of the final product, i.e., $x_j=1$. Let us also consider ten time granules, i.e., $i=0, 1, \ldots, 9$. Demand and component price forecasts are forecasted at each point in time. The manufacturer seeks an optimal trade-off between price and flexibility. Thus, the manufacturer may search for the optimal combination of low price and low flexibility (long-term) contracts, reasonable price and better flexibility (option) contracts, or unknown price and quantity supply but no commitment (spot market). The prices of a long term and a short term contract are 7.5 and 6 respectively. The setting for this example is shown in Figure 1.
The results of computing the above example are presented in Table 1. The best scenario in this example is “B”, in which no contracts are signed over the horizon. Instead, the company’s replenishment procedure is to acquire the component on the spot market.

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Table 1. Sample Evaluation of Supplier Contracts

**Stochastic Model**

Let us now consider a stochastic extension of the proposed model, as most of the real life-problems are stochastic in nature. Therefore, in the proposed technique both the demand forecast and component price forecast are treated as random variables. Parameters of the distributions of these two variables are known based on the available forecasting systems. Let \( v_i \) denote the variance of the forecasted demand of the final product at \( t_i \), and \( \sigma_j \) denote the variance of the
forecasted price of component \( j \) at \( t_i \). As a result, the total cost of materials per unit (\( CPU \)) becomes a random variable. What is more, the distributions of the forecasted component price and demand can change in time, due to the growing uncertainty of the forecast. This phenomenon may be illustrated by a hurricane-path analogy, as presented in Figure 2.

![Hurricane Path Analogy](image)

**Figure 2. Hurricane Path Analogy to the Component Price Forecast**

The longer the time horizon, the less precise is the predicted path, i.e., there is more uncertainty in the forecast. In the context of procurement decisions, if we attempt to predict the component’s price, the time horizon of the forecast significantly affects the forecast’s precision. Assuming that the forecasted price is normally distributed, a short time horizon yields a relatively narrow distribution. As the horizon becomes longer, the distribution becomes more and more disperse. Even in its simplest form the stochastic model is not analytically solvable. Such a complex decision problem, however, may be solved using a simulation approach.

**Monte Carlo Simulation**

The word “simulation” refers to any numerical method meant to imitate a real-life system, especially when other analyses are too complex to be performed. One popular type of simulation is the Monte Carlo Simulation Method, which enables solving a given problem by generating large numbers of pseudo-random instances of the problem.

In the proposed method, a large number of independent and identically distributed instances are randomly generated based on the distributions of the forecasted price and demand. The outcome (\( CPU \)) becomes a random variable. Further, an appropriate statistical analysis of the simulation output may be conducted in order to determine the contract portfolio for which there is a great chance of obtaining the lowest total cost of materials per unit. One example of the statistical analysis which may be employed to differentiate contracts is the analysis of variance (ANOVA). Different scenarios may be compared based on the unit cost of material (\( CPU \)). Once the hypothesis that the scenarios are characterized by different \( CPUs \) is confirmed, post-hoc multiple comparison tests may be used to find the best of the scenarios.

**FINAL REMARKS**

The proposed technique has several simplifying assumptions. Future research will concentrate on extending the method by releasing some of these restrictions. Moreover, the technique will be
extended with the possibility of generating the best possible scenario without any ex ante knowledge about the available types of contracts.
An important part of our future research will be the empirical verification of the proposed model. Thus, empirical data will be gathered from a sample of manufacturing companies that acquire parts from their suppliers through contracts and utilize price and demand forecasting systems. The information collected should relate to all the types of contracts used by manufacturers, their forecast data, material costs, etc. The method may be verified using actual data from the past. If this verification is successful, a new tool to support contracting decisions will become available to business practitioners.

REFERENCES


