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Optimization-Based Buyer-Supplier Price Negotiation: Supporting Buyer's Scenarios with Suppler Selection*

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Abstract

Purpose – The paper aims to propose an optimization model for supporting the buyer-seller negotiations. We consider the price, quality, and delivery as evaluation criteria, also recognized as objectives for negotiation.
Research design, data, and methodology – The methodology used in this paper involves the input-oriented DEA with the inverse optimization. Under the existence of several potential suppliers, the price would be considered to be the decision variable to conclude the negotiation so as to meet the desired level of the quality and delivery. The data set for six suppliers with three criteria is examined by the proposed approach.
Results – We present the decision aid model by displaying the price spectrum as the changes of desired output levels. It overcomes the shortcomings from previous researches mainly based on the discrete types of scenario generations. This approach shows that the obtained results help the buyer understand the trade-offs between price and performance when he/she considers the negotiation.
Conclusions – The paper contributes to the numerical models for buyer-supplier negotiation in that the model for the supplier evaluation and selection is closely linked with the model for negotiation. In addition, it eliminates the unrealistic negotiation strategy, and provides the negotiation strategies that the buyer would not shift the burden on suppliers by maintaining the current efficiency.

Keywords: Supplier Selection, Buyer-supplier Negotiation, Inverse Optimization, Data Envelopment Analysis.

JEL Classifications: C51, C52, C61, C67.

1. Introduction

The relationship between all members in a supply chain is critical to business performance of each member. Indeed, the negotiation results in profitability of all supply chain members in that it impacts directly on the supplier's revenues and buyer's costs. It is becoming increasingly important for buyers to maintain a close relationship with the supplier to gain a competitive advantage over competitors. Buyers strive to find their suppliers, as partners, who provide products or services with lower prices and higher quality. Therefore, the supplier selection is undoubtedly one of the most important activities for retaining the profit potentials and enhancing the competitiveness by forcing different companies into price competition.

The negotiation process of contracts generally involves reviewing, planning, and analyzing to achieve acceptable terms and conditions in the form of agreements or compromises(Dobler et al., 1984). Negotiation often leads to a consensus between the two parties, in terms of price, quality, and delivery, which are typically considered as objectives suggested by Dobler and Burt(1996).

Mainly, the supplier evaluation and selection problem is one of the key topics in the field of supply chain management. The most popular tool for supporting the decision on supplier selection is multi-criteria decision

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making(MCDM) approaches. Particularly, data envelopment analysis(DEA), analytic hierarchy process, analytic network process, simple multi-attribute rating technique, genetic algorithm, grey relational analysis and their combinations are mostly used for evaluating potential suppliers. Recently, Chai et al.(2013) provides a comprehensive literature review from 123 journal articles regarding supplier evaluation and selection. In addition to the introduced studies in this review paper, Amin and Zhang(2012) and Jadidi et al.(2014) proposed the supplier evaluation method by using multiobjective optimization techniques, and Aksoy and Ozturk(2011) and Golmohammadi(2011) utilizes artificial neural network models to assess the performance of the suppliers.

Although the supplier evaluation and selection problems have been extensively studied, there is insufficient research on the optimization model for the negotiations. To be compatible with both the supplier selection model and negotiation model, it requires the optimization models for supporting negotiation with the selected or potential suppliers.

As Amid et al.(2009) pointed out, the value of evaluation criteria and constraints are expressed ambiguously such as “very high quality” or “low in price”. This kind of implicit information makes the selection problem even more complicated and hard to solve. However, a buyer has to establish a negotiation strategy that may be put on the negotiation table. Moreover, determining a negotiation strategy should be closely linked with the numerical analysis, used in the supplier evaluation model. If the possible negotiation strategies can be identified based on the buyer’s preference information, which is sometimes implicit, the buyer would consider the trade-offs between criteria. To address this issue, we propose an optimization method for supporting buyer’s negotiation strategies with the potential suppliers. Our approach considers the price, quality, and delivery as evaluation criteria, also recognized as objectives for negotiation. Under the existence of several potential suppliers, the price would be considered to be the decision variable to conclude the negotiation so as to meet the desired level of the quality and delivery.

The remainders of this paper is organized as follows. Section 2 provides a brief summary of relevant literature. Section 3 presents the methodology for supporting the price negotiation. Section 4 presents the application of the method using six suppliers data. Discussions are presented in Section 5. We conclude the paper with Section 6.

2. Supplier Evaluation and Negotiation

2.1. Supplier evaluation and selection

As mentioned in Section 1, a comprehensive review on the supplier evaluation and selection is provided by the review paper, Chai et al.(2013). Readers also can be referred to previous literature such as Weber et al.(1991), Degraeve et al.(2000), De Boer et al. (2001), and Ho et al.(2010). In this section, we review the previous studies under the scheme of DEA methodology, instead of introducing all studies relevant to supplier evaluation and selection.

According to Chai et al.(2013)’s investigation, DEA is the most commonly used technique for supplier evaluation and selection. DEA is an effective tool in evaluating the performance of a set of decision-making units(DMUs) which consume multiple inputs to produce multiple outputs. An explanation to the traditional DEA approaches is given in the textbook of Cooper et al.(2006). To the best of our knowledge, Weber(1996) is the first to study the supplier evaluation and selection with DEA. Weber(1996) considered the criteria such as unit price, percentage of rejects, percentage of late deliveries, business allocation units, etc. From this work the author emphasized the advantage of the objective methods by supplementing the usual subjective methods. Since Weber(1996) presented a DEA approach for supplier selection based on multiple criteria, a number of DEA approaches have been proposed. Talluri et al.(2006) proposed a chance-constrained DEA approach for uncertain performance measures in the supplier selection problem. Imprecise DEA(IDEA) was also employed to the problem by Saen(2007, 2008). Saen(2007) considered the characteristics of data(cardinal & ordinal). Saen(2008) extended his previous research with imposing weight restrictions, referred to as a assurance-region DEA(AR-DEA). Recently, Falagario et al.(2012) suggested the cross efficiency model for a specific application of public procurement bids.

2.2. Buyer-supplier negotiation using DEA

Numerous researchers have investigated various negotiation models from different points of view for a long time (Pan & Choi, 2016). In the negotiation between the buyers and suppliers, it is very difficult to investigate the data that has to be ideally obtained from both side of suppliers and buyers since all the data might be confidential within the competitive nature. Namely, it is only possible when the data from both sides is available. For example, a price negotiation study is examined by Das and Tyagi(1999), who investigate the negotiation situation where the buyers and suppliers are cooperative. However, it is unrealistic to obtain the data from all the buyers and suppliers in the relevant industry in most cases. Researchers of microeconomics and game theory view a negotiation as a dynamic and incomplete information game, and try to solve the game model under certain specified conditions (Govindan et al., 2012). Zheng and Negenborn(2015) proposed a negotiation model under the assumption that the buyer and the supplier have full information on each others' revenue or cost. This assumption of the proposed analytical model seems to be fair when both parties handle the standard products. However, in many cases in supply chains, since the buyer and the supplier have asymmetric information, it is not easy to analyze the negotiation strategy analytically as well as empirically. Rosato(2017) analyzed sequential negotiation models with considering risk taking tendency. One-side asymmetric information is incorporated for explaining the role of risk aversion, but only a pair of the buyer and supplier is analyzed. From the optimization perspective, Pan and Choi(2016) discussed the price and delivery date negotiation problem under the make-to-order environment. The authors proposed a linear programming model with intelligent algorithms. However, they also considered the model for a buyer-supplier pair, so the negotiation is limited in that a buyer cannot consider the negotiation strategy with the other potential suppliers. Therefore, in order to increase applicability in reality, we narrow down to the scope of the study to the single buyer's negotiation strategy with multiple potential suppliers. In this problem setting, DEA has typically been applied to the buyer's negotiation problem in situations where multiple potential suppliers exist.

Weber and Desai(1996) and Weber et al.(1998) utilized DEA with focusing not only on supplier evaluation but also on negotiation strategy generation. However, those initial approaches only take into account the negotiation strategy with inefficient suppliers based on the benchmark information from the DEA results. Talluri(2002) proposed a buyer-supplier game model using a binary integer programming for evaluating alternative supplier bids. From the buyer's perspective, four variations of the model were proposed to effectively evaluate alternatives based on the ideal targets predetermined by the buyer. Zhu(2004) also developed a buyer-seller game model where the efficiency is maximized with respect to multiple targets set by the buyer. It assumes that the targets set by the buyer do not have to dominate all the suppliers, while the ideal targets of Talluri(2002) dominate all the suppliers. Note that the term "scenario" is used as different meanings between Talluri(2002) and Zhu (2004). In Talluri(2002), scenario represents the negotiation environment that includes the number of inputs and outputs variables and bids. However, Zhu(2004) indicated it to be a strategy that identifies the required input levels to meet the ideal targets of outputs. Also, Talluri et al.(2008) used the term scenario as a possible negotiation strategy that the buyer can undertake, similarly to Zhu(2004). Talluri et al.(2008) provided a input-oriented negotiation model by adopting the multiobjective inverse optimization scheme proposed by Wei et al.(2000). Thus, they can identify required input levels to the predetermined discrete scenarios. Several characteristics of above mentioned studies are summarized in <Table 1>.

As seen in <Table 1>, Talluri et al.(2008) only provided the model for handling the interrelationship between inputs and output variables and addressed the question of how much should the input increase to achieve the desired level of outputs without changing the efficiency level. The major advantage of Talluri et al.(2008) is the use of inverse optimization scheme based on the results of DEA. The inverse optimization enables the buyer to consider negotiation strategies with efficient or inefficient suppliers by restricting the current efficiency of suppliers. As Talluri(2002) stated, it is possible that some of the inefficient suppliers perform better over all than some of the efficient suppliers, because, in DEA, an efficient one may excel on only few dimensions but perform poorly on many other dimensions. Therefore, we also use the inverse optimization scheme to expand the alternatives for negotiation.

In addition, all the DEA-based negotiation studies provided negotiation scenarios or alternatives based on the target, which is determined by the buyer or set by the efficient units. While these target setting may seem logical, both methods have disadvantages. First, the target setting by the buyer at a time is very difficult decision making so that the corresponding results may be unacceptable for the buyer. Second, the target set by the efficient suppliers may not provide a satisfactory solution, because efficiency in DEA is a relative measure by only considering under evaluated suppliers, thus it may provide an ineffective negotiation strategy. Therefore, instead of using such methods for setting a target, we provide a inverse programming method for displaying potential negotiation strategies. This approach provides multiple negotiation alternatives by presenting the buyer's desired output levels with the inversely calculated possible input level regarding each supplier.

<Table 1> DEA-based negotiation studies

	Negotiation partner	Target	Scenarios or Alternatives	Interrelationship
Weber & Desai (1996)	Inefficient suppliers	Set by efficient suppliers	Alternative bids by the target	no
Weber et al. (1998)	Inefficient suppliers	Set by efficient suppliers	Alternative bids by the target	no
Talluri (2002)	Inefficient suppliers	Ideal target set of all variables	Alternative bids by the target	no
Zhu (2004)	All potential suppliers	Ideal target set of all variables	Alternative bids by the target	no
Talluri et al. (2008)	All potential suppliers	Best values of some outputs	Discrete cases set by the buyer	yes

3. Methodology

3.1. Inverse optimization using DEA

The inverse optimization using DEA was introduced by Zhang and Cui(1999), and extended by Wei et al. (2000). The inverse optimization provides the clues for supporting decision making as an ex post facto analysis, such that how much increase inputs in order to increase the desired level of outputs with maintaining the current efficiency. Therefore, it compensates the disadvantage of the traditional DEA models which mainly focus on a post-hoc assessment(Lim, 2016). Wei et al.(2000) studied the inverse optimization problem under the output-oriented environment, on the other hand, Talluri et al.(2008) utilized a scenario-based inverse optimization for the buyer-supplier negotiation under the input-oriented environment. We analyze the buyer-supplier price negotiation model restricting input variables to the single input, the price. Since the price as an input variable for suppliers is considered as payment for the buyer, we set the inverse programming with one input variable and multiple output variables. In addition, it is reasonable and desirable to formulate the input-oriented DEA model because the buyer-supplier negotiation focuses on minimizing the price with maintaining current level of the outputs.

Suppose that there are m inputs (i = 1,2,...,m) and s outputs (r = 1,2,...,s) for each DMU j (j = 1,2,...,n). Under the constant returns to scale (CRS) assumption, the input-oriented DEA model can be expressed as follows.

$$\begin{aligned} &\min \theta_o \qquad (1) \\ &s.t. \sum_{j=1}^{n} x_{ij}\lambda_j - x_{io}\theta^o \le 0 \quad i=1,...,m \\ &\quad \sum_{j=1}^{n} y_{rj}\lambda_j - y_{ro} \ge 0 \quad r=1,...,s \\ &\quad \lambda_j \ge 0, j=1,...,n \end{aligned}$$

By the model (1), an efficiency score is generated for a DMU by minimizing inputs with fixed outputs and for each observed DMU. Also, λ_j represents the proportion to which DMU j contributes to construct the composite unit for DMU o. In model (1), θ^o is the efficiency score of DMU o. The composite unit produces inputs that are at most equal to a proportion θ of the inputs of DMU o, with $0<\theta^o \le 1$, and consumes at least the same levels of outputs as DMU o. If $\theta^o<1$, DMU o is inefficient and the parameter θ^o indicates the extent by which DMU o has to decrease its inputs to become efficient. From this model, the efficient and inefficient DMUs are obtained with their efficiency scores. For the buyer-supplier negotiation problem, DMUs are considered to be suppliers. Therefore, 'DMU' and 'supplier' are interchangeably used in this paper.

3.2. Negotiation with an efficient DMU

If the buyer wishes to negotiate an agreement with the efficient supplier, which is evaluated through the model (1), we can formulate the following inverse problem to determine a negotiation strategy with the selected supplier.

$$\begin{aligned} &\min \theta_o \qquad (2) \\ &s.t. \sum_{j=1}^{n} x_{ij}\lambda_j - x_{io}\theta_o \le 0 \quad i=1,...,m \\ &\quad \sum_{j=1}^{n} y_{rj}\lambda_j - \beta_{ro} \ge 0 \quad r=1,...,s \\ &\quad \lambda_j \ge 0, j=1,...,n \end{aligned}$$

where $\beta_{ro} = y_{ro} + t(\beta_{ro}^{\max} - y_{ro})$, which represents the increase of output r from current level of each for DMU o. Obviously, $\beta_{ro}^{\max}$ is the maximum value of output r, thus t is a parameter having a value from 0 to 1. Wei et al.(2000) and Talluri(2008) proved the relationship between the model (1) and model (2) under the output-oriented and input-oriented setting, respectively. Similarly, we also consider the following theorem.

Theorem

Suppose that the optimal objective function value of model (1) for DMU o is θ^*=1 and the outputs for this DMU are increased from y_o to β_o, where $\beta_o = y_o + t(\beta_o^{\max} - y_o)$. Then, inputs need to be increased from x_o to $\theta^* x_o$, where θ^* is the optimal value of model (2). That is, the efficiency score of DMU o remains unchanged under the changed input-output setting by varying value of $t \in [0,1]$.

Proof

See Talluri et al.(2008).

This theorem provides the theoretical background for the buyer's negotiation strategy. As t increases, the efficiency remains constant such that the required input level is obtained by the model (2) at any incremental change from y_o.

Suppose that the efficiency of DMU o is θ_o^*=1 and the maximum output targets for negotiation are defined as max $\{\beta_o\}$. If we increase certain amounts of outputs for a particular DMU, the required inputs, α_o, of this DMU can be obtained by the following model.

$$\begin{aligned} &\min \alpha_{1o}, \alpha_{2o}, ..., \alpha_{mo} \qquad (3) \\ &s.t. \sum_{j=1}^{n} x_{ij}\lambda_j - \theta^o \alpha_{io} \le 0 \quad i=1,...,m \\ &\quad \sum_{j=1}^{n} y_{rj}\lambda_j - \beta_{ro} \ge 0 \quad r=1,...,s \\ &\quad \alpha_{io} \ge x_{io} \\ &\quad \lambda_j \ge 0, j=1,...,n \end{aligned}$$

If one of outputs or all outputs are required to increase from y_o to $\beta_o = y_o + t(\beta_o^{\max} - y_o)$, and if the efficiency score remains unchanged at θ_o^*, then the input level of DMU o is determined based on the multiobjective structure. Wei et al.(2000) and Talluri(2008) proposed a multiobjective optimization method with aggregating objective function values under the weighted sum formulation. Interested readers are referred to Hadi-Vencheh et al.(2008) and Jahanshahloo et al.(2015) for more specific efficiency relationship between the model (2) and the multiobjective model (8).

If there is a single input variable, the model (3) becomes a single objective optimization problem. Regarding negotiation in the buyer-supplier relationship, since the price would be a critical criteria for achieving desirable outputs from the buyer's perspective, we set the price as a single output of model (3).

3.3. Negotiation with an inefficient DMU

Talluri(2002) and Talluri et al.(2008) suggested two ways to negotiate with inefficient suppliers. The first strategy is the two-step method that projects inefficient DMU onto the efficient frontier then adopts the method used in the negotiation problem for the efficient DMU case. The second strategy is finding alternative prices for achieving target outputs while maintaining the current efficiency level. However, the first strategy may be fail to project the DMUs onto the efficient frontier. As Zhu(2004) criticized, Talluri(2002)'s model yields an invalid result in proposing negotiation strategies where some or all outputs exceed the realistic maximum target ($\beta_o^{\max}$). Such a problem is also appeared in the study of Talluri et al.(2008). Therefore, we will use the second strategy to avoid the unrealistic results. Also, it gives additional information allowing for supplier's ability in terms of its efficiency. That is, we utilize the model (3) as the case of negotiation with an efficient DMU instead of projecting inefficient one onto the efficient frontier.

Remark

If there are multiple outputs, buyer's preference information on multiple targets is required for finding optimal input level on negotiation. In addition, when multiple inputs are considered for the supplier evaluation, the decision maker (buyer) has to define utility function for input usages or develop an algorithm for finding a compromise solution. Therefore, if such factors exist simultaneously, multiobjective optimization techniques incorporating the decision maker's preference may be a key research topic for the buyer-supplier negotiation. Although we present the model based on the single input case, this type of optimization model will be beneficial for any types of input-output setting.

4. Results

4.1. Negotiation with the efficient DMU

To illustrate the proposed model for obtaining the price negotiation strategy, we use the six suppliers data in <Table 2>. This data have been used in Weber and Desai(1996), Weber et al.(1998), Talluri(2002), Talluri et al.(2008), and Zhu(2004). In the data set, the price is used as the only input. Also, two outputs are used for measuring the quality and the delivery performance, which are percentages of accepted units and on-time delivery. The company is a division of a Fortune 500 pharmaceutical company.

<Table 2> Data for suppliers

	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5	Supplier 6
Price ($/units)	0.1958	0.1881	0.2204	0.2081	0.2118	0.2096
% Acceptance	98.8	99.2	100	97.9	97.7	98.8
% OTD	95	93	100	100	97	96

The efficiency calculated by the model (1) is presented in <Table 3>.

<Table 3> DEA results (efficiency and slacks)

Supplier	Efficiency	λ_1	λ_2	λ_3	λ_4	λ_5	λ_6
1	0.9813	0.0000	1.0215	0.0000	0.0000	0.0000	0.0000
2	1.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000
3	0.9177	0.0000	1.0753	0.0000	0.0000	0.0000	0.0000
4	0.9719	0.0000	1.0753	0.0000	0.0000	0.0000	0.0000
5	0.9263	0.0000	1.0430	0.0000	0.0000	0.0000	0.0000
6	0.9264	0.0000	1.0323	0.0000	0.0000	0.0000	0.0000

Since only the supplier 2 is on the efficient frontier, the buyer will choose it as the optimal decision. According to the results shown in <Table 3>, however, its on-time delivery performance is the lowest among six suppliers. Now, let us assume that the buyer wishes to increase the level of delivery performance. In this case, the possible negotiation scenario must involve the trade-off between the price and the delivery performance, and negotiation scenarios have to be prepared based on not violating the current level of efficiency at the same time. The <Table 4> presents the results of the price changes when the level of quality is fixed for supplier 2. Obviously, all the values satisfy the current efficiency.

Table 4> Potential negotiation strategies for supplier 2 (changing OTD)

Scenario	A	OTD	Price
t=0	99.2	93	0.1881
t=0.1	99.2	93.7	0.1895
t=0.2	99.2	94.4	0.1909
t=0.3	99.2	95.1	0.1923
t=0.4	99.2	95.8	0.1938
t=0.5	99.2	96.5	0.1952
t=0.6	99.2	97.2	0.1966
t=0.7	99.2	97.9	0.1980
t=0.8	99.2	98.6	0.1994
t=0.9	99.2	99.3	0.2008
t=1.0	99.2	100	0.2023

A: % Acceptance
OTD: % On-time delivery
Step size OTD: 0.7

Another possible strategy is the consideration of the quality. Assume that the buyer wants to increase the level of quality rather than improving delivery performance. Some scenarios are possible with maintaining efficiency, and corresponding results are shown in <Table 5>.

<Table 5> Potential negotiation strategies for supplier 2(changing A)

Scenario	A	OTD	Price
t=0	99.2	93	0.1881
t=0.1	99.28	93	0.1883
t=0.2	99.36	93	0.1884
t=0.3	99.44	93	0.1886
t=0.4	99.52	93	0.1887
t=0.5	99.6	93	0.1889
t=0.6	99.68	93	0.1890
t=0.7	99.76	93	0.1892
t=0.8	99.84	93	0.1893
t=0.9	99.92	93	0.1895
t=1.0	100	93	0.1896

Step size A: 0.08

As the desired quality level increases, the price increases but the amount of changes are relatively lower than those of delivery performance case. Since the price sensitivity on the changes of quality is less than that on the changes of delivery performance, the buyer may consider simultaneous improvement on the both outputs. The results involving simultaneous proportional changes are presented in <Table 6>.

<Table 6> Potential negotiation strategies for supplier 2 (changing A & OTD)

Scenario	A	OTD	Price
t=0	99.2	93	0.1881
t=0.1	99.28	93.7	0.1895
t=0.2	99.36	94.4	0.1909
t=0.3	99.44	95.1	0.1923
t=0.4	99.52	95.8	0.1938
t=0.5	99.6	96.5	0.1952
t=0.6	99.68	97.2	0.1966
t=0.7	99.76	97.9	0.1980
t=0.8	99.84	98.6	0.1994
t=0.9	99.92	99.3	0.2008
t=1.0	100	100	0.2023

Step size A:0.08; OTD: 0.7

This approach has major two advantages over Talluri et al.(2008)'s study on the interpretation of the results. First, this approach helps the buyer understand the interrelationship between negotiation factors. As described the displayed results in <Table 4>, <Table 5>, and <Table 6>, the potential negotiation strategies with an efficient supplier are provided with changing t. We specify the step size value to show the changes from the current output values to the maximum output targets. Talluri et al.(2008)'s approach also provided similar information with their results, but it is limited in that the results only depend on the predetermined target of the single output. Second, after understanding the trade-offs between the price and each output using the results in <Table 4> and <Table 5>, the buyer can select the promising negotiation strategies considering the sensitivity from the results in <Table 4>, <Table 5>, and <Table 6>. As shown in the fourth column in <Table 4> and <Table 6>, the estimated prices are identical. This implies the price sensitivity of the quality is very low from the specified on-time delivery range (93 to 100). Therefore, the buyer does not need to think the quality when he/she considers the negotiation strategies that improve the delivery performance.

4.2. Negotiation with the inefficient DMU

Determining the negotiation scenario with an inefficient supplier is also based on the assumption that the current efficiency is not changed, without projecting an inefficient one onto the efficient frontier. Suppose that the supplier 1 is selected as a negotiable unit that has a better performance than the supplier 2 in terms of the delivery. Remind the efficiency is 0.9813 as presented in <Table 3>. We carry out the same analysis to Section 4.1 for supplier 1. The results are shown in <Table 7>, <Table 8>, and <Table 9>.

<Table 7> Potential negotiation strategies for supplier 1(changing OTD)

Scenario	A	OTD	Price
t=0	98.8	95	0.1958
t=0.1	98.8	95.5	0.1968
t=0.2	98.8	96	0.1978
t=0.3	98.8	96.5	0.1988
t=0.4	98.8	97	0.1998
t=0.5	98.8	97.5	0.2009
t=0.6	98.8	98	0.2019
t=0.7	98.8	98.5	0.2030
t=0.8	98.8	99	0.2040
t=0.9	98.8	99.5	0.2050
t=1.0	98.8	100	0.2061

Stepsize OTD: 0.5

<Table 8> Potential negotiation strategies for supplier 1(changing A)

Scenario	A	OTD	Price
t=0	98.8	95	0.1958
t=0.1	98.92	95	0.1958
t=0.2	99.04	95	0.1958
t=0.3	99.16	95	0.1958
t=0.4	99.28	95	0.1958
t=0.5	99.4	95	0.1958
t=0.6	99.52	95	0.1958
t=0.7	99.64	95	0.1958
t=0.8	99.76	95	0.1958
t=0.9	99.88	95	0.1958
t=1.0	100	95	0.1958

Step size A: 0.12

<Table 9> Potential negotiation strategies for supplier 1 (changing A & OTD)

Scenario	A	OTD	Price
t=0	98.8	95	0.1958
t=0.1	98.92	95.5	0.1968
t=0.2	99.04	96	0.1978
t=0.3	99.16	96.5	0.1989
t=0.4	99.28	97	0.1999
t=0.5	99.4	97.5	0.2009
t=0.6	99.52	98	0.2019
t=0.7	99.64	98.5	0.2030
t=0.8	99.76	99	0.2040
t=0.9	99.88	99.5	0.2050
t=1.0	100	100	0.2061

Step size A: 0.12; OTD: 0.5

As presented in <Table 8>, the results show no changes in the price as the changes of the quality. This is because all the solutions are weakly efficient. That is, the buyer can negotiate with supplier 1 in terms of the level of quality without an additional payment. Therefore, the results in <Table 9> have to be revised for displaying potential negotiation strategies by replacing the all the quality values to 100.

5. Discussion

5.1. Managerial implication

At this moment, it is appropriate to consider the implication of our study for the buyers in supply chain. The key contribution of this paper towards managerial practice is that it is intuitively appealing. Our analysis supports the buyer's decision making process in preparing negotiation strategies when the multiple potential suppliers exist. Understanding the trade-offs between the price and the outputs might be the first step of considering negotiation strategies. Based on the presented trade-offs information, more importantly, the buyer can choose the most promising negotiation scenario among the presented possible scenarios. For example, when the buyer takes the supplier 2 as a negotiation partner by improving the delivery performance, the results show that the price sensitivity on the quality is very low. Therefore, the buyer do not need to consider the quality level in this case. Furthermore, the buyer cannot easily determine the desired level of outputs, with considering the price as payment. Therefore, the buyer may not be satisfied with the scenario with the estimated price when the discrete scenario based approach is used. However, the proposed approach gives various potential negotiation strategies attainable with the trade-off information.

The second contribution is that the study provides the link between the methodologies used in the supplier evaluation and negotiation. The decision making on the selecting the negotiation partner has to be based on the evaluation model because the values of criteria used for evaluating suppliers identify the capability of the suppliers. In turn, the same criteria have to be involved in the negotiation as the negotiation factors. For this purpose, DEA and its inverse programming are used as a decision support system.

The third contribution of this study is on the selection of the negotiation partners. Since efficiency in DEA is based on the efficient use of the variables, if some negotiation factors are not measurable, the negotiation strategy with an efficient supplier will not be the effective one. In practice, for example, the expected negotiation time or the negotiation tendency may also be the important factors in the negotiation. Namely, these types of factors may appear to be more effective in determining the potential suppliers. Therefore, by taking into account not only efficient suppliers but also inefficient suppliers as the negotiation partners, the buyer can partially reflect the subjective preferences on above factors.

5.2. Methodological implication

The proposed method overcomes flaws resulted from previous study, Talluri et al.(2008), in several ways. First, we do not use the projection method, which is studied by Talluri et al.(2008) for negotiation with inefficient suppliers. Since the projection provides unrealistic results in terms of the level of outputs, the approach by maintaining the current efficiency of the supplier is proposed and examined in a similar way to the negotiation with the efficient supplier case. Second, the proposed method does not require strictly defined target value of outputs. Instead, the maximum possible values of outputs guide the price level for negotiation. Third, the proposed method enables the buyer to identify the trade-offs with the inputs and outputs, ultimately, it helps him/her decide moderate price with the selected negotiation strategy.

6. Conclusions

6.1. Summary

The supplier evaluation and selection problem has been a critical issues in the research field of the distribution and supply chain management. The MCDM approach is known as the most popular tool for supporting the decision making for handling this issue. Especially, various DEA methods have been extensively examined, but there is insufficient research on the optimization model for the negotiations. The negotiation has to be closed linked with supplier evaluation and selection in terms of the use of methodology. Therefore, in this paper, we suggest the inverse optimization scheme for supporting negotiation with the selected or potential suppliers determined a priori by DEA. The proposed approach considers the price, quality, and delivery as evaluation criteria, also recognized as objectives for negotiation. For the inverse optimization, the price is considered as the decision variable that has to be estimated for concluding the negotiation. To show the applicability of the suggested approach, we provide two negotiation situations where the buyer is willing to negotiate the efficient supplier and inefficient supplier. The results regarding both an efficient supplier and an inefficient supplier are presented.

6.2. Future studies

Some of the further research opportunities are as follows. First, the negotiation decision aid method using the inverse programming takes into account the single input case. However, the multiple inputs might be involved in some supplier selection and negotiation problems, so an extension of the method considering multiple inputs is required. Second, as remarked in Section 3.3, the decision maker's preference information needs to be incorporated for the consideration for multiple outputs systematically. The multiobjective optimization can be classified into three approaches, which are prior, progressive, and posterior, according to the timing of the decision maker's preference articulation. From this point of view, our method can be seen as a posterior articulation approach. However, the method for selecting the most preferred strategy among the decision alternatives is not provided, although the potential negotiation strategies are displayed. The posterior approach providing the method for selecting the most preferred negotiation strategy is urgently needed. Developing systematic approaches that treat the preference information on the negotiation factors may provide more practical implications for the buyers.

References

Aksoy, A., & Ozturk, N. (2011). Supplier selection and performance evaluation in just-in-time production environments. *Expert Systems with Applications*, *38,* 6351-6359.

Amid, A., Ghodsypour, S. H., & O'Brien, C. (2009). A weighted additive fuzzy multiobjective model for the supplier selection problem under price breaks in a supply chain. *International Journal of Production Economics*, *121*(2), 323-332.

Amin, S. H., & Zhang, G. (2012). An integrated model for closed-loop supply chain configuration and supplier selection: Multi-objective approach. *Expert Systems with Applications*, *39*(8), 6782-6791.

Bragli, M., & Petroni, A. (2000). A quality assurance-oriented methodology for handling trade-offs in supplier selection. *International Journal of Physical Distribution and Logistics Management*, *30*(2), 96-111.

Browning, J. M. (1990). Purchasing and Materials Management: Text and Cases. *Journal of Purchasing & Materials Management*, *26*(3), 42-44.

Chai, J., Liu, J. N., & Ngai, E. W. (2013). Application of decision-making techniques in supplier selection: A systematic review of literature. *Expert Systems with Applications*, *40*(10), 3872-3885.

Cooper, W. W., Seiford, L. M., & Tone, K. (2006). *Introduction to data envelopment analysis and its uses: with DEA-solver software and references.* New York: Springer Science & Business Media,

Degraeve, Z., Labro, E., & Roodhooft, F. (2000). An evaluation of vendor selection models from a total cost of ownership perspective. *European Journal of Operational Research*, *125*(1), 34-58.

De Boer, L., Labro, E., & Morlacchi, P. (2001). A review of methods supporting supplier selection. *European journal of purchasing & supply management*, *7*(2), 75-89.

Dobler, D. W., Lee, L. J., & Burt, D. (1984). *Purchasing and materials management: Text and cases.* New York: McGraw-Hill.

Dobler, D. W., & Burt, D. N. (1996). *Purchasing and supply management: text and cases* (6th ed.). New York: McGraw-Hill.

Falagario, M., Sciancalepore, F., Costantino, N., & Pietroforte, R. (2012). Using a DEA-cross efficiency approach in public procurement tenders. *European Journal of Operational Research*, *218*(2), 523-529.

Golmohammadi, D. (2011). Neural network application for fuzzy multi-criteria decision making problems. *International Journal of Production Economics*, *131*, 490-504.

Govindan, K., Diabat, A., & Popiuc, M. N. (2012). Contract analysis: A performance measures and profit evaluation within two-echelon supply chains. *Computers & Industrial Engineering*, *63*(1), 58-74.

Hadi-Vencheh, A., Foroughi, A. A., & Soleimani-damaneh, M. (2008). A DEA model for resource allocation. *Economic Modelling*, *25*(5), 983-993.

Ho, W., Xu, X., & Dey, P. K. (2010). Multi-criteria decision making approaches for supplier evaluation and selection: A literature review. *European Journal of operational research*, *202*(1), 16-24.

Jadidi, O. M. I. D., Zolfaghari, S., & Cavalieri, S. (2014). A new normalized goal programming model for multi-objective problems: A case of supplier selection and order allocation. *International Journal of Production Economics*, *148,* 158-165.

Jahanshahloo, G. R., Soleimani-Damaneh, M., & Ghobadi, S. (2015). Inverse DEA under inter-temporal dependence using multiple-objective programming. *European Journal of Operational Research*, *240*(2), 447-456.

Li, G. D., Yamaguchi, D., & Nagai., M. (2008). A grey-based rough decision-making approach to supplier selection. *International Journal of Advanced Manufacturing Technology*, *36,* 1032-1040.

Lim, D. J. (2016). Inverse DEA with frontier changes for new product target setting. *European Journal of Operational Research*, *254*(2), 510-516.

Liu, J., Ding. F. Y., & Lall, V. (2000). Using data envelopment analysis to compare suppliers for supplier selection and performance improvement. *International Journal of Supply Chain Management*, *5*(3), 143-150.

Pan, A., & Choi, T. M. (2016). An agent-based negotiation model on price and delivery date in a fashion supply chain. *Annals of Operations Research*, *242*(2), 529-557.

Rosato, A. (2017). Sequential negotiations with loss-averse buyers. *European Economic Review*, *91,* 290-304.

Saen, R. F. (2007). Suppliers selection in the presence of both cardinal and ordinal data. *European Journal of Operational Research*, *183*(2), 741-747.

Saen, R. F. (2008). Supplier selection by the new AR-IDEA model. *The International Journal of Advanced Manufacturing Technology*, *39*(11), 1061-1070.

Talluri, S. (2002). A buyer-seller game model for selection and negotiation of purchasing bids. *European Journal of Operational Research*, *143*(1), 171-180.

Talluri, S., & Sarkis, J. (2002). A model for performance monitoring of suppliers. I*nternational Journal of Production Research*, *40*(16), 4257-4269.

Talluri, S., Narasimhan R., & Nair, A. (2006). Vendor performance with supply risk: a chance constrained DEA approach. *International Journal of Production Economics*, *100*(2), 212-222.

Talluri, S., Vickery, S. K., & Narayanan, S. (2008). Optimization models for buyer-supplier negotiations. *International Journal of Physical Distribution & Logistics Management*, *38*(7), 551-561.

Weber, C. A., Current, J. R., & Benton, W. C. (1991). Vendor selection criteria and methods. *European journal of operational research*, *50*(1), 2-18.

Weber, C. A., Current, J. R., & Desai, A. (1998). Non-cooperative negotiation strategies for vendor selection. *European Journal of Operational Research*, *108*(1), 208-223.

Weber, C. A., Current, J., R., & Desai, A. (2000). An optimization approach to determining the number of vendors to employ. *International Journal of Supply Chain Management*, *5*(2), 90-98.

Weber, C. A. (1996). A data envelopment analysis approach to measuring vendor performance. *Supply Chain Management: An International Journal*, *1*(1), 28-39.

Weber, C. A., & Desai, A. (1996). Determination of paths to vendor market efficiency using parallel coordinates representation: a negotiation tool for buyers. *European Journal of Operational Research*, *90*(1), 142-155.

Wei, Q., Zhang, J., & Zhang, X. (2000). An inverse DEA model for inputs/outputs estimate. *European Journal of Operational Research*, *121*(1), 151-163.

Zhang, X. S., & Cui, J. C. (1999). A project evaluation system in the state economic information system of china an operations research practice in public sectors. *International Transactions in Operational Research*, *6*(5), 441-452.

Zheng, S., & Negenborn, R. R. (2015). Price negotiation between supplier and buyer under uncertainty with fixed demand and elastic demand. *International Journal of Production Economics*, *167,* 35-44.

Zhu, J. (2004). A buyer-seller game model for selection and negotiation of purchasing bids: extensions and new models. *European Journal of Operational Research*, *154*(1), 150-156.