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Applied Imprecise Data Envelopment Analysis for Selecting the Efficient Method of Technology Transfer: Case Study in Automotive Parts Manufacturing Industry Corporation

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Abstract

Today, Technology have an important role in achieving goal of producing and serving organization for increasing productivity and ability level. Every company for achieving technology either should produce it or give it from external source (Transferring). For achieving technology from other company, technologic transferring is done. Transferring of suitable technology is one the most important methods of increasing technology level in this industry; as a result, the importance of paying attention to that is considered from different aspects. In regard to importance imprecise data, the purpose of this thesis is using Imprecise Data envelopment analysis model for selecting the efficiency method for transferring technology.

Keywords: Transferring technology, Data envelopment analysis, Imprecise data

1 Introduction

Technology transfer is the process by which existing knowledge, facilities, or capabilities developed under federal research and development (R&D) funding are utilized to fulfill public and private needs. Technology transfer is a crucial and dynamic factor in social and economic development. Technology has been transferred intentionally or unintentionally. Sometimes, a generator of technology has acquired a competitive advantage by undertaking the dissemination of products, processes and maintenance systems [1]. Machine industry is known and also base on what Peter Drake said as a mother industry in most of country. The effect of this industry among other industry because of existing value in industry production network is at the limit that most of them are considered one of important element for developing. However transferring of suitable technology is one the most important methods of increasing technology level in this industry; as a result, the importance of paying attention to that is considered from different aspects. Therefore certain policies for codify the best method of transforming technology with purpose of increasing interred abilities and specializing economic source of society by interfering appropriate technology for adaptation ability absorption and developing with national conditions is one of important element for national developing that should be considered , in addition to full the gap between available technology, as a several aspects of transferring technology and necessity use of quantity and quality aspects and at the same time, using making decision model that this model should be considered at the same time, is so important. In regard to importance of this subject, the purpose of this thesis is proposed a mathematic model for selecting the efficiency method for transferring technology. In this paper introducing a Data envelopment analysis(DEA) model that can be useful by using that useful quantity and quality variables in selecting transferring technology method is defined without needing to taste devoting base on mathematic aspects in careful selecting transferring technology method. So, in this paper it has been used the imprecise Data envelopment analysis(DEA) with imprecise data, that this model can be useful by using that useful quantity and quality variables in selecting transferring technology method is defined without needing to taste devoting base on mathematic aspects in careful selecting transferring technology method and also for doing making decision of decision makers, the ability for restriction weight should be added to this model. Finally proposing method has been used for selecting transferring technology method, In respect to defined aspects, these methods has been classified to each other, and for every company, the most useful method of transferring and other classifying rank has been defined.

To the best of author's knowledge, there is not any reference that discusses transferring technology method in the presence of imprecise data and weight restrictions.

This paper proceeds as follows. In Section 2 introduces the method that selects the efficient method of technology transfer. A numerical example and concluding remarks are discussed in Sects. 3 and 4, respectively.

2 Proposed model for selecting the efficient method of technology transfer

Data envelopment analysis (DEA) proposed by Charnes et al. [2] (CCR model) and developed by Banker et al. (1984) (BCC model) is an approach for evaluating the efficiencies of decision making units (DMUs). Traditional DEA models such as CCR and BBC models and so on do not deal with imprecise data and assume that all input and output data are exactly known. In real world situations, however, this assumption may not always be true. Due to the existence of uncertainty, DEA sometimes faces the situation of imprecise data, especially when a set of decision-making units (DMUs) contains missing data, judgment data, forecasting data or ordinal preference information[3]. To deal with imprecise data in DEA, IDEA models and methods have been developed. When imprecision is taken into consideration, the associated DEA model becomes nonlinear, which makes its solution procedure difficult [4] . On the other hand, one serious drawback of DEA applications in evaluation efficiency has been the absence of DM judgment, allowing total freedom when allocating weights to input and output data of supplier under analysis. This allows DMUs to achieve artificially high efficiency scores by indulging in inappropriate input and output weights. The most widespread method for considering judgments in DEA models is, perhaps, the weight restrictions inclusion. Weight restrictions allow for the integration of managerial preferences in terms of relative importance levels of various inputs and outputs [5]. The idea of conditioning the DEA calculations to allow for the presence of additional information arose first in the context of bounds on factor weights in DEA's multiplier side problem. This led to the development of the cone-ratio and assurance region (AR) models [5]. In this section, a new pair of AR-IDEA model is introduction, to restrict the flexibility of decision making units (DMUs) in selecting the weights while ordinal and cardinal data are present. Because of final efficiency score for each DMU will be characterized by an interval bounded, "Minimax regret-based approach" (MRA) proposes to rank the decision making units (DMUs). Recently, Wang et al.(2005) developed a new pair of interval DEA models for dealing with imprecise data such as interval data, ordinal preference information, fuzzy data and their mixture. Farzipoor [5] developed this model for considering, weight restrictions and using this model to selection supplier.

Suppose that there are n suppliers (DMUs) to be evaluated which produce multiple outputs *yrj* (r = 1, 2, ..., s), by utilizing multiple inputs *xij* (i = 1, 2, ..., m). Without loss of generality, it is assumed that all the input and output data *xij* and *yrj* (i=1, ..., m; r=1, ..., s; *j=1, ...,* n) cannot be exactly obtained due to the existence of uncertainty. They are only known to lie within the upper and lower bounds represented by the intervals $\left[x_{ij}^L, x_{ij}^U\right]$ and $\left[y_{rj}^L, y_{rj}^U\right]$, where $x_{ij}^L > 0$ and $y_{rj}^L > 0$.

In order to deal with such an uncertain situation, the following pair of linear programming models has been developed to generate the upper and lower bounds of interval efficiency for each DMU [3].

where *jo* is the DMU under evaluation (usually denoted by DMUo); *ur* and *vi* are the weights assigned to the outputs and inputs; θ_{jo}^U stands for the best possible relative efficiency achieved by DMUo when all the DMUs are in the state of best production activity, while θ_{jo}^L stands for the lower bound of the best possible relative efficiency of DMUo. They constitute a possible best relative efficiency interval $\left[\theta_{jo}^L, \theta_{jo}^U\right]$. ε is the non-Archimedean infinitesimal.

In order to judge whether a DMU is DEA efficient or not, the following definition is given.

Definition 1. A DMU, DMUo, is said to be DEA efficient if its best possible upper bound efficiency $\theta_{jo}^{U*} = 1$; otherwise, it is said to be DEA inefficient if $\theta_{jo}^{U*} < 1$.

Restriction weights are represented in the following form:

$$A^+ = (a_i \le \frac{v_i}{v_{+1}} \le \beta_i), \qquad v = (v_j) \in A^+ \tag{1}$$

$$A^- = (\theta_r \le \frac{u_r}{u_{r+1}} \le \zeta_r), \qquad u = (u_j) \in A^- \tag{2}$$

The vectors u and v contain component variables ur and vi, which are to be assigned values that are constrained to lie within restriction weights defined by the sets A+ and A, respectively. where $a_i, \beta_i, \theta_r \zeta_r$represent fixed lower and upper bounds for the ratio of the values associated with input and outputs for DMU j. The linear programming problem for the Restriction weight -IDEA model is then finally given by

$$\begin{array}{l} Max\theta_{jo}^U = \sum_{r=1}^s u_r y_{rj_o}^U \\ s.t. \\ \quad \sum_{i=1}^m v_i x_{ij_o}^L = 1, \\ \quad \sum_{r=1}^s u_r y_{rj}^U - \sum_{i=1}^m v_i x_{ij}^L \le 0, \qquad j = 1, \cdots, n, \\ \quad v = (v_j) \in A^+, \\ \quad u = (u_j) \in A^-, \\ \quad u_r, v_i \ge \varepsilon \qquad \forall r, i. \end{array} \tag{3}$$

$$
\begin{aligned}
& Max\theta^L_{jo} = \textstyle\sum_{r=1}^{s} u_r y^L_{rj_o} \\
& s.t. \\
& \qquad \textstyle\sum_{i=1}^{m} v_i x^U_{ij_o} = 1, \\
& \qquad \textstyle\sum_{r=1}^{s} u_r y^U_{rj} - \sum_{i=1}^{m} v_i x^L_{ij} \le 0, \qquad j = 1, \cdots, n, \\
& \qquad v = (v_j) \in A^+, \\
& \qquad u = (u_j) \in A^- \ , \\
& \qquad u_r, v_i \ge \varepsilon \qquad \forall r, i.
\end{aligned} \tag{4}
$$

Therefore, one unified approach that deals with all aspects of the imprecise data and weight restrictions in a direct manner has been introduced. the method of transforming ordinal preference information into interval data and A mini max regret- based approach for comparing and ranking interval efficiency is discussed in the sections,2-1and 2-2.

2.1 The transformation of ordinal preference information

For transforming ordinal preference information into interval data, using following approach. Suppose some input and/or output data for DMUs are given in the form of ordinal preference information .usually, there may exist three types of ordinal preference information: strong ordinal preference information such as $y_{rj} > y_{rk}$ or $x_{ij} > x_{ik}$which can be further expressed as $y_{rj} \ge \chi_r y_{rk}$ and $x_{ij} \ge \eta_i x_{ik}$, where $\chi_r > 1$and $\eta_i > 1$are the parameters on the degree intensity provided by decision makers(DM);weak ordinal preference information such as $y_{rp} \ge y_{rq}$ or $x_{ip} \ge x_{iq}$; indifference, relationship such as $y_{rl} = y_{rt}$ or $x_{il} = x_{it}$. Since DEA model has the property of unit-invariance, the use of scale transformation to ordinal preference does not change the original ordinal relationships and has no effect on the efficiencies of DMUs. Therefore, we may conduct a scale transformation to every ordinal input and output index so that its best ordinal datum is less than or equal to unity and then give an interval estimate for each ordinal datum. No considering the transformation of ordinal preference information about the y_{rj} , $(1, ..., n)$ for example the ordinal preference information about input and other output data can be converted in the same way [3]. For weak ordinal preference information,$y_{r1} \ge y_{r2} \ge ... \ge y_{rn}$, we have the following ordinal relationships after scale transformation:

$$1 \ge \hat{y}_{r1} \ge \hat{y}_{r2} \ge ... \ge \hat{y}_{rn} \ge \sigma_r \tag{5}$$

Where σ_r is a small positive number reflecting the ratio of the possible minimum of

$\{y_{rj} \mid \quad j = 1, ..., n\}$ to its possible maximum. It can be approximately estimated by the decision-maker. It is referred to as the ratio parameter for convenience. The resultant permissible interval for each $\hat{y}_{rj}$ is given by

$$y_{rj} \in [\sigma_r, 1], \quad j = 1, ..., n. \tag{6}$$

for strong ordinal preference information $y_{r1} > y_{r2} > ... > y_{rn}$, there is the following ordinal relationships after scale transformation:

$$1 \geq \hat{y}_{r1}, \quad \hat{y}_{rj} \quad \geq \chi_r y_{r,j+1} \ (j = 1, ..., n-1) \quad \text{and } y_{rn} \geq \sigma_r \tag{7}$$

Where χ_r a preference intensity parameter is satisfying $\chi_r > 1$provided by the decision-maker and σ_r is the ratio parameter also provided by the decision-maker. The resultant permissible interval for each $\hat{y}_{rj}$ can be derived as follows:

$$\hat{y}_{rj} \in \left[\sigma_r \chi_r^{n-j}, \chi_r^{1-j}\right], \quad j = 1, ..., n \quad with \quad \sigma_r \leq \chi_r^{1-j}. \tag{8}$$

2.2 A mini max regret- based approach for comparing and ranking interval efficiency

In the interval efficiency assessment, since the final efficiency score for each DMU is characterized by an in interval, a simple yet practical ranking approach is thus needed for ranking the efficiencies of different DMUs. Here the MRA developed by Wang et al. [3] Is introduced. The approach is summarized as follows:

Let $H_i = \left[a_i^L, a_i^U\right] = \langle m(H_i), w(H_i)\rangle \quad (i = 1, ..., n)$ be the efficiency interval of n DMUs, where $M(H_i) = \frac{1}{2}(a_i^R + a_i^L)$ and $W(H_i\ ) = \frac{1}{2}(a_i^R - a_i^L)$ are their midpoints and widths. Without loss of generally, suppose $H_i = \left[a_i^L, a_i^R\right]$ is chosen as the best efficiency interval. Let $b = \max_{j \neq i}\left\{a_j^U\right\}$. obviously, if $a_i^L < b$, the decision-maker might suffer the loss of efficiency (also called the loss of opportunity or regret) and feel regret. The maximum loss of efficiency he/ she might suffer is given by

$$\max(r_i) = \max_{j \neq i}\left\{a_j^U\right\} - a_i^L = \ \max\{a_j^U\} - a_i^L, \tag{9}$$

If $a_i^L \geq b$, the decision-maker will definitely suffer no loss of efficiency and fell no regret. In this situation, his/her regret is defined to be zero, i.e.$r_i = 0$. combining the above two situation, there is

$$\max(r_i) = \max\left[\max_{j \neq i}(a_i^U) - a_i^L, 0\right]. \tag{10}$$

Thus, the minimax regret criterion will choose the efficiency interval satisfying the following condition as the best (most desirable) efficiency interval:

$$\min_i\left\{\max\left[\max_{j \neq i}(a_j^U) - a_i^L, 0\right]\right\}. \tag{11}$$

Based on the analysis above, the following definition for ranking efficiency intervals is given.

Definition 2: let $H_i = \left[a_a^L, a_a^U\right] = \langle m(H_i), w(H_i)\rangle \quad (i = 1, ..., n)$ be a set of efficiency intervals. The maximum loss of efficiency(also called maximum regret) of each efficiency interval H_i is defined as

$$\begin{aligned} R \quad (H_i) &= \left[\max(a_j^U) - \underset{j\neq i}{a_i^L}, 0\right] \\ &= \max\left[\max\{m(H_j) + w(H_j)\}_{j\neq i} - (m(H_i) - w(H_i)), 0\right], \qquad (12) \\ & i = 1, ..., n. \end{aligned}$$

3 Numerical example

This article's case study is about an 7 Iranian automotive parts manufacturing industry, with respect to attributes including, gain profit, and share of market, which are considered in some sense as outputs, and cost technology transfer and speed technology transfer, which are considered in some sense as inputs. The speed technology transfer share of market and gain profit ,are included as a qualitative input and out put while cost technology transfer will serve as the bounded data output. This qualitative variables is measured on an ordinal scale . In the table1, depicted transfer approach that a corporation can be access (scenario) and in the table 2, show the information comparison among 11, technology transfer approach.

	Merger	Licensing	engineering service	Subcontracting	Equity Investment	T.key	J.V	Alliance	Outsourcing	purchasing machinery	research contract
X1	?	●	?	?	?	?	?	?	?	?	?
X2	?	?	?	?				?	?	?	?
X3	?	?	?	?		?	?			?	
X4	?	?	?	?	?	?	?	?			
X5	?		?	?	?	?		?	?	?	
X6	?	?	?	?			?	?		?	?
X7	?	?	?	?	?	?	?	?	?	?	?

Table.1,: Transfer approach that a corporation can be access

Technology transfer approach	cost technology transfer	speed technology transfer	share of market	gain profit
1. Turn key	[1700,2000]	10	2	4
2. Licensing	[700,1000]	9	8	8
3. Joint Venture	[1000,1200]	11	11	10
4. Alliance	[800,900]	8	10	11
5. Subcontracting	[700,1000]	1	4	7
6. Outsourcing	[1500,2100]	5	5	6
7. Merger	[500,700]	2	9	9
8.Equity Investment	[800,900]	6	7	3
9.purchasing machinery	[500,700]	4	3	5
10.engineering service	[900,1100]	7	6	2
11.research contract	[1500,2000]	3	1	1

Table.2: information comparison among 11, technology transfer approach.

Suppose the preference intensity parameter and the ratio parameter about the strong ordinal preference information are given (or estimated) as $\eta 2 = 1.12$ and $\sigma 2 = 0.01$, 2 2 respectively. Using the transformation technique described in previous section, an interval estimate for qualitive factors of each transfer approach can be derived, which is shown in the Table 3 and 4. Therefore, all the input and output data are now transformed into interval numbers and can be evaluated using the pair of AR -IDEA models. According to the decision of DM, the importance of cost must be greater than speed. Assume that cost is twice as important as speed. However, this corporation can be, because we ranking variables in 8 and 11 scale. With considering above information assess efficiency of approach for each corporation. The table5, reports the results of efficiency for each corporation.

Approach	Interval estimate
1	[0.01,0.321]
2	[0.0112,0.360]
3	[0.0125,0.403]
4	[0.014,0.452]
5	[0.0157,0.506]
6	[0.017,0.797]
7	[0.0176,0.567]
8	[0.022,0.71]
9	[0.0247,0.797]
10	[0.27,0.897]
11	[0.031,1]

Table.3, Interval estimate for the 11 approach after the transformation of ordinal preference information

Approach	Interval estimate
1	[0.01,0.45]
2	[0.0112,0.506]
3	[0.0125,0.567]
4	[0.014,0.63]
5	[0.0157,0.71]
6	[0.017,0.797]
7	[0.019,0.89]
8	[0.022,1]

Table.4, Interval estimate for the 8 approach after the transformation of ordinal preference information

Applying Eqs. (3) and (4), the efficiency scores of approach (DMUs) have been presented in Table 5. The result show, merger is the best efficient for All of the corporation.

7	6	5	4	3	2	1	Corporation under evaluation
Merger	Merger	Merger	Merger	Merger	Merger	Merger	Efficient methodof technology transfer
engineering service	Licensing	Sub-contracting	Equity Investment	Licensing	Licensing	engineering service	Preference2
Subcontracting	Subcontracting	Engineering ser-vice	engineering service	purchasing machinery	engineering service	Subcontracting	Preference3
Alliance	engineering service		Licensing	Subcontracting	purchasing machinery	Alliance	Preference4
Outsourcing	Alliance	Alliance	Subcontracting	Joint Venture	Subcontracting	Outsourcing	Preference5
Turn key	purchasing machinery	Equity Investment	Joint Venture	Equity Investment	Alliance	Turn key	Preference6
purchasing machinery	Joint Venture	Outsourcing	Alliance	engineering service	Outsourcing	purchasing machinery	Preference7
Licensing	research contract	Turn key	Turn key	Turn key	research contract	Licensing	Preference8
Joint Venture						Joint Venture	Preference9
research contract						research contract	Preference10
Equity Investment						Equity Investment	Preference11

Table 5: result ranking transfer approach for each corporation under evaluation.

4 Concluding remarks

For achieving a technology, any firm should produce it or gain it from outsources. In gaining technology from other firms, technological corporations should be taken. Scientific approach to the technology transmission is the most important solution in the development path. Because technology transmission, from choice to gaining, suction and adoption, improvement and development stages by having a scientific and conscious approach, it is the most current way to prepare a solid framework to country‘s industrial and economical growth. According to the subject importance and the multi-criteria characteristics of the problem, and choosing an efficient technology transmission method, it is urgent to introduce a model for defining the weights affecting on technology transmission methods, better and more precious. This study aims to choose the most desirable technology transmission method between other proposed methods. The model which has been designed in this research for technology transmission process, is not only for automobile equipment manufacturing industries, but also is for all companies and firms which have the same destination. According to the importance of proposing the qualitative data in choosing the efficient technology transmission method, the DEA method by imprecise data was used. In many ways, decision making variable weights have preference to each other in the decision maker‘s mind, so the weight limitation navigator was added to this model. Finally, this model was used to choose an efficient technology transmission method in the studied firms and the results are surveyed and mentioned later.

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