

Analytic Expression of Optimal Solution of M&A Matching Based on Fuzzy Number Method

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Abstract: Research on the merger and acquisition matching focuses on strategic matching, organizational matching and resource matching in academic circles, but merger and acquisition matching is more in line with the rational decision from the efficiency and scale, and the existing DEA research has not paid sufficient attention to this topic. In order to increase the flexibility of M&A matching, this paper studies the M&A matching problem from efficiency and scale using DEA model and fuzzy number method, and gives Analytic Expression of Optimal Solution of M&A Matching of two methods. The example shows that the method is feasible and effective and has important practical significance for strategic M&A.

Keywords: DEA Model; Fuzzy Number method; Optimal Solution

I. Introduction

The supply-side structural reform in China focuses on adjusting economic structure, making factors realize optimal configuration, improving economic growth quality and quantity, optimizing industrial structure, improving industrial quality, optimizing product structure, promoting resource integration and realizing optimized resource configuration and optimized regeneration^[1-3]. The strategic mergers and acquisitions is the important measure to boost industrial restructuring and optimization, realize optimized resource allocation and drive the supply-side reform. In the mergers and acquisitions, the one how to match with the target company is the important problem that should be solved by the acquiring company and the acquired company and the key step whether the mergers and acquisition (M&A) succeeds or not. In this paper, the DEA method was used to put forward to the match and selection problem of acquiring company, acquired company and target company in the strategic mergers and acquisitions, and establish a merger and acquisition (M&A) match strategy on the basis of individual preference. It has the great significance for promoting the supply-side reform. In the M&A, the one how to match with the target company is the important issue that should be solved by the acquiring company and the acquired company and the

key step whether M&A can succeed or not. Enterprise determines the M&A strategy on the basis of its M&A capability and M&A motivation, and determines the merger target range through the due diligence and by combining the enterprise development strategy and the understanding in industry value. An acquiring enterprise has multiple target enterprises, and a target company is the target of multiple acquiring companies; both acquiring company and acquired company made selection based on their own benefits, whichever it is the one to form the enterprise set of the acquiring company or the enterprise set of the acquired company. Obviously, the higher the match degree between the acquiring company and the acquired company is, the better the merger and acquisition result is^[4-5]. Currently, the research on the merger and acquisition match issue concentrates on the strategic match, organizational match and the resource match, Das T K, Teng B introduced firstly the strategic match concept to the merger and acquisition field, and divided the merger and acquisition into the related acquisition and the unrelated acquisition; according to their theoretical analysis on them, the strategic match could enhance the synergistic effect of the enterprises under merger and acquisition, and bring high return on assets and equity returns for the acquirer. For the strategic match in the merger and acquisition activity, Kitching J proposed to pay attention to the strategic correlation of both parties, and the common benefit drive could stimulate both parties to make information and resource integration^[6-7].

More specifically, Schweiger D L, Ivancevich J M pointed out that the correlated merger and acquisition would bring higher profitability than the uncorrelated merger and acquisition; however such conclusion conflicted with the theoretical research; whereas according to the empirical research, the correlated merger and acquisition did not subtract or add the returns. Scholars proposed the organizational match to analyze the compatibility of the organization structure from the aspects of culture, organizational system and human capital. After researched the organizational match in the merger and acquisition activity, Down J W thought the match of the dominant party and the participating party on the aspect of culture and incentive system could decline or enhance the synergistic effect of acquiring

enterprise and acquired enterprise on the aspects of key technology, organizational culture and talent exchange; the organizational match had one-sidedness, requiring to pay attention to the compatibility of organizational structure and make light of the potential value of acquisition objective. Some scholars considered enterprise was the aggregate of resources, the enterprise structure compatibility and the potential value of acquisition object came from the heterogeneity of resources, and the acquisition match was researched from the resource complementarities. Improving efficiency and pursuing scale economy are the important motivations of mergers and acquisitions. Comparing with the potential value of enterprise, structural compatibility and resource complementarity, the enterprise participating in mergers and acquisitions prefers to see whether the post-merger efficiency is damaged and the post-merger scale is overlarger; therefore the one considering the acquisition match from two aspects, namely the efficiency and the scale, is more suitable for the rational decision making of enterprise (Haspeslagh P, Jemison D, 1991).

The data envelopment analysis (DEA) is a non-parameter method for analyzing the relative efficiency of the same type of decision-making unit with more inputs and outputs. This method has been used by many scholars for researching the influence of mergers and acquisitions behavior (M&A behavior) on the performance and scale of enterprise; however these researches were only limited to analyze the change of enterprise before and after mergers and acquisitions, they did not involve in the theoretical problems of mergers and acquisitions, such as which enterprise or enterprises will be merged? How about the post-merger efficiency and scale? The ways of merger and acquisition are known, but the evaluation on efficiency and scale is usually made after the mergers and acquisitions are completed, namely such evaluation is a post-merger event. Obviously, the one how to conduct the mergers and acquisitions has the realistic significance and challenge (Cartwright S, Cooper C L, 1995). However, the existing DEA research does not pay enough attention to the subject. In order to add the flexibility of M&A match, this paper adopted the DEA method to research the M&A match from two aspects, *i.e.*: efficiency and scale on the basis of enterprise individual preference (Tao R, Zhang Q Y, 2011).

2. Problem Description

2.1 Precondition Hypothesis

The research object of M&A match is the direct M&A, so the counseling operation provided by investment bank and other intermediary platforms can be used to formulate M&A strategy for enterprise rationally, such as: seeking for the best target party for acquirer; selecting rational acquirer for the target object; preventing from hostile takeover. General speaking, the intermediary agent's service charge, comparing with the assets and funds involved in M&A, is usually less; in view of this

fact, a non-profit-making intermediary agent is hypothesized; it is known as the Hypothesis 1.

The one to pursue M&A synergistic effect is the mostly fundamental motivation of mergers and acquisitions. In view of the differential efficiency theory, the M&A synergistic effect comes from the efficiency variance, for instance, if the efficiency of Company A is higher than that of the Company B, the efficiency of the Company B will be improved to the level of the Company A after both merge; in such case the synergistic effect appears. However if the differential efficiency theory is extended to the extremity, there will be an enterprise with the best management level in the whole society; therefore the M&A match faces with two different and unavoidable issues: (1) there is efficiency variance between both parties; (2) avoiding from overlarger scale when eliminating efficiency variance. Therefore the efficiency variance hypothesis can be made; it is known as the Hypothesis 2. Afterwards, the M&A match method considering the efficiency and the scale can be described.

Hypothesis 1: the intermediary platform relied by M&A match is called as the non-profit-making platform.

Hypothesis 2: the enterprise with the efficiency "1" (there is no space to improve the efficiency) has strong M&A capability, so the enterprise is called as the acquiring party; the enterprise with the efficiency less than "1" (there is the space to improve the efficiency) has the relatively weak M&A capability, so the enterprise is called as the acquired party.

2.2. Thinking Analysis

Assuming there are N enterprises in the market, if taking N as the decision-making unit (DMU), the CCR efficiency of N numbers of DMU can be obtained from the DEA model, namely $\theta = (\theta_1, \theta_2, \dots, \theta_N)$; afterwards, the N numbers of DMU can be grouped in accordance with the value of $\theta_j (j=1, 2, \dots, N)$: the effective DEU with θ_j equaling to 1 is categorized into the acquiring group, it is recorded as $E = (DMU_1, DMU_2, \dots, DMU_t)$; if not, it is categorized into the acquired group, it is recorded as $S = (DMU_1, DMU_2, \dots, DMU_h)$, and $t + h = N$, $E \cap S = \varnothing$, arbitrary acquiring enterprise $DMU_k (k=1, 2, \dots, t)$ and acquired enterprise $DMU_d (d=1, 2, \dots, h)$ are taken as a M&A match combinedly, they are recorded as $DMU_{d \& k}$.

When considering the M&A match of efficiency and scale, if θ_{dk} is the relative efficiency of $DMU_{d \& k} (k=1, 2, \dots, t; d=1, 2, \dots, h)$, and $\theta_{dk} \in (0, 1]$; of which T_{dk} is the returns to scale of $DMU_{d \& k}$ and $T_{dk} =$ (inferior position, neutral position, inferior position); so $\theta_{dk} (k=1, 2, \dots, t; d=1, 2, \dots, h)$ will form the M&A match efficiency matrix θ ; the M&A match returns-to-scale matrix formed by $T_{dk} (k=1, 2, \dots, t; d=1, 2, \dots, h)$ is known as "T". The T_{dk} value of the returns to scale is of three levels, *i.e.*: inferior position, neutral position, inferior position; they belong to the linguistic value information; however the efficiency is the precise figure information.

The different type of information describing the different attributes is called as the mixed attribute information; the common processing methods include the genetic algorithm, fuzzy number method and 2-tuple linguistic method. There is possible to occur the unfeasible M&A match. If the efficiency is effective and the returns-to-scale is of inferior position, the M&A scheme might become the best M&A match; however it is contradictory to the real application. In reality, the one to pursue the return to scale is one of the important motivations of M&A, if the return to scale is of the inferior position after merger is made, it is not acceptable to both parties. Besides, the M&A scheme with the return-to-scale in inferior position and the ineffective efficiency would be accepted by both parties; this is because that the enterprise with the different individual preference can accept the minimum and different M&A efficiency. The problem to be solved by the match method is the one how to make principal match between the acquiring enterprise and the acquired enterprise by using the DEA method by combining the realistic significance of efficiency and return to scale for enterprise on the basis of the different individual preference of different enterprises.

3. DEA Model and Methods

3.1. DEA Model

Assuming there are n number of DMU, every DMU has m types of input (it means the DMU may consumes “resources”) and s types of “output (they are the indicators indicating “efficiency” after DMU consumes “resources”); the input data of every DMU can be set as follows: x_{ij} is the input volume of the i type of input for j^{th} DMU, where $x_{ij} \in \mathbb{R}^m_{\geq 0}$; y_{rj} is the input volume of the r type of input for j^{th} DMU, where $y_{rj} \geq 0$; v_i is a measure (or known as “weight”) for i type of input; u_r is a measure (or known as “weight”) for r type input; of which, $i=1,2,\dots, m, r=1,2,\dots, s, j=1,2,\dots, n$. For convenience, order: $x_j = (x_{1j}, x_{2j}, \dots, x_{mj})^T, j = 1,2, \dots, n, y_j = (y_{1j}, y_{2j}, \dots, y_{sj})^T \in \mathbb{R}^s_{\geq 0}, j=1,2, \dots, n, v = (v_1, v_2, \dots, v_m)^T, u = (u_1, u_2, \dots, u_s)^T$.

As for the weight coefficient $v \in E^m$ and $u \in E^s$ (x is the m -dimension real number vector, u is the s -dimension real number vector), so the average index number of efficiency of the j^{th} DMU is:

$$h_j = \frac{\sum_{r=1}^s u_r y_{rj}}{\sum_{i=1}^m v_i x_{ij}}$$

Select appropriate weight coefficient v and u , make

them meet $h_j \leq 1 \quad j = 1, 2, \dots, n$.

When evaluating the efficiency of No. $j_0 (1 \leq j_0 \leq n)$ DMU, the weight coefficient v and u are taken as the variables; the efficiency index of No. j_0 DMU is taken as the objective; the efficiency index of all DMUs, i.e.: $h_j \leq 1 \quad j = 1, 2, \dots, n$ is taken as the constraint, so the following $\lambda^0, s^{-*}, s^{+0}, \theta^0$ model can be established:

$$\bar{P}_{C^2R} \left\{ \begin{array}{l} \max \frac{u^T y_{j_0}}{v^T x_{j_0}} = V_p \\ \text{s.t.} \quad \frac{u^T y_j}{v^T x_j} \leq 1, j = 1, 2, \dots, n, \\ v \geq 0 \\ u \geq 0 \end{array} \right.$$

As a matter of convenience, make this record $(x_0, y_0) = (x_{j_0}, y_{j_0})$; “ \leq ” means every component is less than or equal to; “ \leq^* ” means every component is less than or equal to and one component is not equal to at least; “ \leq^+ ” means every component is less than and is not equal to. The optimum efficiency evaluation number V_p of DMU is unrelated to the input volume x_{ij} and the dimension selection of the input y_{rj} . Since the different dimensions have a multiple change, if the i^{th} input volume under the new dimension is $\delta_i x_{i1}, \delta_i x_{i2}, \dots, \delta_i x_{in}, \quad i = 1, 2, \dots, m$.

And $\rho_r y_{r1}, \rho_r y_{r2}, \dots, \rho_r y_{rn}, \quad r = 1, 2, \dots, s$, Where: $\delta_i > 0, \rho_r > 0, \quad i = 1, 2, \dots, m, r = 1, 2, \dots, s$.

The fractional programming of new dimension is:

$$(P-E) \left\{ \begin{array}{l} \max \frac{\sum_{r=1}^s u_r (\rho_r y_{r0})}{\sum_{i=1}^m v_i (\delta_i x_{i0})}, \\ \text{s.t.} \quad \frac{\sum_{r=1}^s u_r (\rho_r y_{rj})}{\sum_{i=1}^m v_i (\delta_i x_{ij})} \leq 1, j = 1, 2, \dots, n, \\ v = (v_1, v_2, \dots, v_m) \geq 0, \\ u = (u_1, u_2, \dots, u_s) \geq 0. \end{array} \right.$$

If $v = (v_1, v_2, \dots, v_m)^T, u = (u_1, u_2, \dots, u_s)^T$ are the optimum solution of the programming $c^T \bar{x} - \varepsilon \cdot d^T \bar{x} = \min_{x \in R^*} (c^T x - \varepsilon \cdot d^T x)$, so it allows to verify $\bar{v} = (v_1 / \delta_1, v_2 / \delta_2, \dots, v_m / \delta_m)^T, \bar{u} = (u_1 / \rho_1, u_2 / \rho_2, \dots, u_s / \rho_s)^T$

This is another optimal solution of (P-E), and the optimum efficiency average index number before and

after the dimension changes is natural.

The programming (\bar{P}_{C^2R}) is a fractional programming; it can be converted into an equivalent linear programming problem by using Charnes-Cooper.

For this purpose, if $t = \frac{1}{v^T x_0}, w = tv, \mu = tu$

$$\text{So: } \mu^T y_0 = \frac{u^T y_0}{v^T x_0}, \quad \frac{\mu^T y_j}{\omega^T x_j} = \frac{u^T y_j}{v^T x_j} \leq 1, j = 1, 2, \dots, n,$$

$$\omega^T x_0 = 1,$$

$$\omega \geq 0, \mu \geq 0.$$

Therefore the following linear rules can be obtained:

$$P_{C^2R} \left\{ \begin{array}{l} \max \quad \mu^T y_0 = V_p \\ \text{s.t.} \quad \omega^T x_j - \mu^T y_j \geq 0, j = 1, 2, \dots, n, \\ \omega^T x_0 = 1, \\ \omega \geq 0, \mu \geq 0. \end{array} \right.$$

The fractional programming (\bar{P}_{C^2R}) and the linear programming (P_{C^2R}) are equivalent, it can be obtained by using the following definitions:

The fractional programming (\bar{P}_{C^2R}) and the linear programming (P_{C^2R}) are equivalent in the following sense:

(1) If v^0, u^0 is the optimal solution of (\bar{P}_{C^2R}), so: $\omega^0 = t^0 v^0, \mu^0 = t^0 u^0$ is the optimal solution of (P_{C^2R}), and the optimal values are equal, where:

$$t^0 = \frac{1}{v^{0T} x_0}.$$

(2) If ω^0, μ^0 is the optimal solution of (P_{C^2R}), so ω^0, μ^0 is the optimal solution of (\bar{P}_{C^2R}), and the optimal values are equal.

If v^0, u^0 is the optimal solution of (\bar{P}_{C^2R}); for the feasible solution that (P_{C^2R}) meets $\omega \geq 0, \mu \geq 0$, it can be understood it is the feasible solution of (\bar{P}_{C^2R}) too,

so (from $\omega^T x_0 = 1$): $\frac{u^{0T} y_0}{v^{0T} x_0} \geq \frac{\mu^{0T} y_0}{\omega^{0T} x_0} = \mu^{0T} y_0$

$$\text{Again: } \frac{u^{0T} y_0}{v^{0T} x_0} = \mu^{0T} y_0 \text{ And } \omega^0 = t^0 v^0 = \frac{v^0}{v^{0T} x_0} \text{ And}$$

$\mu^0 = t^0 u^0 = \frac{u^0}{v^{0T} x_0}$ is the feasible solution of (P_{C^2R});

therefore ω^0, μ^0 is the optimal solution of (P_{C^2R}), and the optimal values of both problems:

$$V_{\bar{P}} = \frac{u^{0T} y_0}{v^{0T} x_0} = \mu^{0T} y_0 = V_p.$$

If ω^0, μ^0 is the optimal solution of (P_{C^2R}), it can be known that $\omega^0 \geq 0, \mu^0 \geq 0$, and they are the feasible solutions of (\bar{P}_{C^2R}). Besides, as for the arbitrary feasible solution v, u , of (\bar{P}_{C^2R}), it can be easily found that: $\omega = tv, \mu = tu$ They are the feasible solutions of (P_{C^2R}) too. Of which: $t = \frac{1}{v^T x_0}$,

$$\text{So: } \mu^{0T} y_0 \geq \mu^T y_0 = \frac{u^T y_0}{v^T x_0}.$$

Due to $\omega^{0T} x_0 = 1$, so

$$\frac{\mu^{0T} y_0}{\omega^{0T} x_0} = \mu^{0T} y_0,$$

Therefore as for the arbitrary solutions v, u of (\bar{P}_{C^2R}), there is:

$$\frac{\mu^{0T} y_0}{\omega^{0T} x_0} \geq \frac{u^T y_0}{v^T x_0},$$

So it is easy to obtain ω^0, μ^0 is the optimal solution of (\bar{P}_{C^2R}); moreover the optimal value of both problems are:

$$V_{\bar{P}} = \frac{\mu^{0T} y_0}{\omega^{0T} x_0} = \mu^{0T} y_0 = V_p.$$

The basic conclusion can be obtained as follows:

If the optimal solutions ω^0, μ^0 of the linear programming (P_{C^2R}) meet $V_p = \mu^{0T} y_0 = 1$, so the DMU j_0 is known as the weak effective DEA (C^2R)

If the optimal solutions of the linear programming (P_{C^2R}) have the following relations, i.e.: $\omega^0 > 0, \mu^0 > 0$

$V_p = \mu^{0T} y_0 = 1$, so the DMU j_0 is DEA effective (C^2R). In this paper, the model was used to make the M&A match research on two aspects, i.e.: efficiency and scale; such application is innovative.

3.2 M&A Fit Methods

As for arbitrary M&A match, if its return to scale is in inferior position, both parties have a lower preference a for the M&A. If $a < 1$, so the higher efficiency earning is used as the compensation; in other words, the efficiency of repelling such M&A has higher upper limit θ^u , whereas the a value will increase as θ^u value reduces. If $a = \theta^u$, and if the return to scale is in natural position, both parties have no interest loss, so they hold the natural

position for the M&A. If the M&A preference is 1, the M&A scheme shall depend on the efficiency and benefits of the MYA. If the return to scale is diminishing, both parties have higher preference b for the M&A scheme. If $b > 1$, the higher the preference is, the higher the possibility to accept the lower M&A efficiency and benefit is; in other words, the lower limit of accepting M&A efficiency θ^L is lower; it is inversely proportional to b and θ^L ; so $b = \frac{1}{\theta^L}$ and the M&A

match preference function can be defined as follows:

Definition 1: Let θ_{dk}^U ($0 < \theta_{dk}^U \leq 1$) is the upper efficiency limit of $DMU_{d\&k}$ repelling M&A, θ_{dk}^L ($0 < \theta_{dk}^L \leq 1$) is the lower efficiency limit of $DMU_{d\&k}$ accepting M&A, so the M&A fit scheme preference function f can be defined on the return-to-scale matrix T .

Definition 2: let M_{dk} is the comprehensive income of M&A match $DMU_{d\&k}$; according to the efficiency and scale information aggregation, the information aggregation formula is $M_{dk} = \theta_{dk} * f(T_{dk})$; if $M_{dk} < 1$, the M&A scheme is the obsolete disadvantaged match; if $M_{dk} = 1$, the match scheme is the considerable neutral match; if $M_{dk} > 1$, the scheme is the retained advantaged match.

Definition 3: let θ_{dk}^B act as the amiable cross efficiency of M&A $DMU_{d\&k}$, if the value of the cross efficiency θ_{dk}^B of the advantaged M&A scheme and the neutral match scheme $DMU_{d\&k}$ is neutral, the value of the cross efficiency θ_{dk}^B of the disadvantaged M&A scheme is 0, and $\overline{\theta^B}$ is the feasible M&A match scheme (including advantaged M&A scheme and neutral M&A scheme), *i.e.*: θ_{dk}^B .

Proposition 1: if T_{dk} = "Inferior", the M&A match $DMU_{d\&k}$ is an inferior match; it is unrelated to the upper efficiency limit of θ_{dk}^U of repelling M&A.

Demonstration: If T_{dk} = "Inferior", $f(T_{dk}) = a$ and $\theta_{dk} \leq 1$, and $a < 1$, so $M_{dk} = \theta_{dk} * f(T_{dk}) = \theta_{dk} * a < 1$

According to the Definition 2, it can be known that the scheme $DMU_{d\&k}$ is the obsolete inferior match scheme; moreover it is unrelated to the upper efficiency limit θ_{dk}^U of the repelling M&A.

Proposition 2: if T_{dk} = "Neutral", and if $\theta_{dk} = 1$, so $DMU_{d\&k}$ is neutral match; if not, it is the inferior match.

Demonstration: if T_{dk} = "Neutral", $f(T_{dk}) = 1$, so $M_{dk} = \theta_{dk} * f(T_{dk}) = \theta_{dk}$; moreover $\theta_{d\&k} \leq 1$, so if $\theta_{dk} < 1$, $M_{dk} < 1$, it can be known that $DMU_{d\&k}$ is the obsolete inferior match scheme in accordance with the Definition

2; therefore if $\theta_{dk} = 1, M_{dk} = 1$, it can be known that $DMU_{d\&k}$ is the considerable neutral match scheme in accordance with the Definition 2.

Proposition 3: if T_{dk} = "Inferior" and $\theta_{dk} = 1$, the match scheme is the superior match; if not, it depends on the match preference function value θ_{dk}^L ; if $\theta_{dk} > \theta_{dk}^L$, so the match is the superior match; if $\theta_{dk} = \theta_{dk}^L$, so the scheme is the neutral match; if not, it is the inferior match.

Demonstration: if T_{dk} = "Inferior", $f(T_{dk}) = b$, so $M_{dk} = \theta_{dk} * f(T_{dk}) = \theta_{dk} * b$. Moreover $b = \frac{1}{\theta_{dk}^L}$, so

$$M_{dk} = \frac{\theta_{dk}}{\theta_{dk}^L};$$

additionally $\theta_{dk} \leq 1$, so if $\theta_{dk}^L \ll \theta_{dk} \leq 1$, $M_{dk} > 1$, it can be known that $DMU_{d\&k}$ is the intentionally retained superior match scheme in accordance with the Definition 2; therefore if $\theta_{dk} = \theta_{dk}^L$, $M_{dk} = 1$, In accordance with the Definition 2, it can be known $DMU_{d\&k}$ is the considerable neutral match scheme; therefore if $\theta_{dk} < \theta_{dk}^L$, $M_{dk} < 1$, it can be known that $DMU_{d\&k}$ is the obsolete inferior match scheme in accordance with the Definition 2.

3.3 Match Process

The M&A match contains three steps:

Step 1: Grouping. In accordance with the CCR efficiency, N numbers of enterprises will be grouped, *i.e.*: the enterprise with the CCR efficiency equaling to 1 is grouped into the acquiring group, if not, the enterprise is grouped into the acquired group.

Step 2: Feasible M&A match screening: obtain the relative efficiency matrix θ from the model (1), determine the return-to-scale matrix T according to the model (3), constrain concurrently the lower efficiency limit θ_{dk}^L of the M&A accepted by both parties is constrained. In accordance with the Proposition 1, 2 and 3, the good or bad M&A scheme in the M&A match matrix can be determined through θ, T and θ_{dk}^L ; afterwards, the feasible M&A match can be screened out.

Step 3: Optimal M&A match decision. Determine the cross efficiency matrix $\overline{\theta^B}$ of feasible match in accordance with the Definition 3, and construct the match optimization model on the $\overline{\theta^B}$, *i.e.*:

$$\begin{aligned} & \max \sum_{d=1}^h \sum_{k=1}^t \theta_{dk}^B x_{dk} \\ & s.t. \sum_{k=1}^t x_{dk} \leq 1, k = 1, 2, \dots, t \\ & \sum_{d=1}^h x_{dk} \leq 1, d = 1, 2, \dots, h \\ & x_{dk} = 0 \text{ or } 1 \end{aligned}$$

The target function of the model is linear, the
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constraint condition can determine the non-void bounded of its feasible domain; if the feasible domain is non-void bounded, it is assured to find the optimal solution for the linear programming problem in a summit point of the feasible domain; therefore the model has the optimal solution.

4. Model Application Case Analysis

The new energy utilization history of China can be traced back to the methane gas utilization in 1950s; however in China the new energy industry has only received its scaled development in recent years. Currently there are more than 130 listed new energy companies. Relative to the developed countries, the new energy industry in China started its development later, so it is accompanied with the backward technology and low overall industrialization degree, and thence it is urgent to merger and reorganize the new energy industry so as to improve the competitiveness of the whole industry. Moreover, China has rich natural resource advantages and the huge market demands; if there are available supporting policies, the new energy will become the

investment hot spot, and its technical utilization level will be progressively improved. In this industry, there is huge M&A space.

How to make the M&A match for the listed new energy company? it can be illustrated by two methods: Select 20 listed new energy companies, take them as 20 DMUs; ensure every DMU contain five inputs x_1, x_2, x_3, x_4, x_5 and two outputs y_1, y_2 ; where the input – output is defined as follows: x_1 : labor force output; x_2 : fixed-capital output; x_3 : total assets; x_4 : operating expenses; x_5 : technological development expenses; y_1 : net profit; y_2 : energy supply volume. Data source: WIND information base.

Method 1: M&A match process

Step 1: divide 20 listed energy companies into two groups according to their CCR efficiency (see Table 1), *i.e.*: (1) acquiring group (DMU₁, DMU₃, DMU₄, DMU₅, DMU₆, DMU₈, DMU₁₀, DMU₁₄, DMU₁₅, DMU₁₉); (2) acquired group (DMU₂, DMU₇, DMU₉, DMU₁₁, DMU₁₂, DMU₁₃, DMU₁₆, DMU₁₇, DMU₁₈, DMU₂₀).

Table 1. CCR Efficiency of 20 Listed Chinese New Energy Companies

DMU1	DMU2	DMU3	DMU4	DMU5	DMU6	DMU7	DMU8	DMU9	DMU10
0.9986	1	0.8967	1	1	1	0.9873	1	0.9978	0.9986
DMU11	DMU12	DMU13	DMU14	DMU15	DMU16	DMU17	DMU18	DMU19	DMU20
0.9968	1	0.9885	1	1	0.8637	0.9786	0.6543	1	0.9769

Step 2: determine the relative efficiency matrix θ of M&A match according to the model (1) (see Table 2); determine the return-to-scale matrix T of M&A match according to the model (3) (see Table 3); in this example, if the θ_{dk}^L of arbitrary M&A match is 0.6, the good or

bad M&A scheme can be judged through θ, T and θ_{dk}^L in accordance with the Proposition 1, 2 and 3; determine the good or bad M&A scheme through θ, T and θ_{dk}^L , see Table 4 as follows:

Table 2. Relative Efficiency Matrix (θ) of M&A Match

	DMU1	DMU3	DMU4	DMU5	DMU6	DMU8	DMU10	DMU14	DMU15	DMU19
DMU2	0.7896	1	0.8795	0.8897	0.8973	0.8794	0.7968	0.7947	1	0.8969
DMU7	0.9876	0.9974	0.8975	0.9828	1	0.9756	0.9984	0.8756	1	1
DMU9	0.9683	1	0.9567	0.9357	1	0.9875	0.9684	0.8896	1	1
DMU11	0.9354	1	0.9785	0.9657	1	0.9165	0.9145	0.9831	1	1
DMU12	0.8796	1	0.9867	0.9375	1	0.8673	0.8891	0.9456	1	1
DMU13	0.9843	1	0.9781	0.9680	1	0.9147	0.9602	0.9063	1	1
DMU16	0.8731	1	0.8834	0.9601	1	0.9364	0.8798	0.8634	1	0.9934
DMU17	0.8897	1	0.8986	0.9976	0.9912	0.9671	0.9561	0.8697	1	1
DMU18	0.8354	0.9934	0.8613	0.9182	1	0.8794	0.8672	0.8437	1	0.9634
DMU20	0.8679	0.9987	0.8891	0.9683	1	0.9861	1	0.8793	1	1

Table 3. Return-to-Scale Matrix (T) of M&A Match

	DMU1	DMU3	DMU4	DMU5	DMU6	DMU8	DMU10	DMU14	DMU15	DMU19
DMU2	Decreasing	Decreasing	Unchanged	Unchanged	Unchanged	Increasing	Decreasing	Increasing	Decreasing	Decreasing

DMU7	Decreasing	Unchanged	Unchanged	Unchanged	Unchanged	Decreasing	Decreasing	Increasing	Unchanged	Unchanged
DMU9	Decreasing	Decreasing	Decreasing	Decreasing	Decreasing	Decreasing	Decreasing	Increasing	Unchanged	Increasing
DMU11	Decreasing	Decreasing	Decreasing	Decreasing	Decreasing	Decreasing	Decreasing	Increasing	Unchanged	Unchanged
DMU12	Increasing	Unchanged	Decreasing	Increasing	Decreasing	Decreasing	Decreasing	Unchanged	Increasing	Decreasing
DMU13	Decreasing	Unchanged	Unchanged	Unchanged	Unchanged	Unchanged	Unchanged	Increasing	Decreasing	Increasing
DMU16	Decreasing	Unchanged	Unchanged	Unchanged	Unchanged	Unchanged	Unchanged	Decreasing	Increasing	Unchanged
DMU17	Decreasing	Decreasing	Unchanged	Decreasing	Increasing	Decreasing	Decreasing	Increasing	Decreasing	Unchanged
DMU18	Decreasing	Unchanged	Decreasing	Decreasing	Decreasing	Decreasing	Decreasing	Unchanged	Unchanged	Decreasing
DMU20	Decreasing	Unchanged	Unchanged	Unchanged	Unchanged	Unchanged	Unchanged	Increasing	Unchanged	Unchanged

Table 4. Goodness or Badness of M&A Match When $\theta_{dk}^L = 0.6$

	DMU1	DMU3	DMU4	DMU5	DMU6	DMU8	DMU10	DMU14	DMU15	DMU19
DMU2	Inferior	Inferior	Neutral	Neutral	Neutral	Superior	Inferior	Superior	Inferior	Inferior
DMU7	Inferior	Neutral	Neutral	Neutral	Neutral	Inferior	Inferior	Superior	Neutral	Neutral
DMU9	Inferior	Inferior	Inferior	Inferior	Inferior	Inferior	Inferior	Superior	Neutral	Superior
DMU11	Inferior	Inferior	Inferior	Inferior	Inferior	Inferior	Inferior	Superior	Neutral	Neutral
DMU12	Superior	Neutral	Inferior	Superior	Inferior	Inferior	Inferior	Neutral	Superior	Inferior
DMU13	Inferior	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Superior	Inferior	Superior
DMU16	Inferior	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Inferior	Superior	Neutral
DMU17	Inferior	Inferior	Neutral	Inferior	Superior	Inferior	Inferior	Superior	Inferior	Neutral
DMU18	Inferior	Neutral	Inferior	Inferior	Inferior	Inferior	Inferior	Neutral	Neutral	Inferior
DMU20	Inferior	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Superior	Neutral	Neutral

Step 3: determine the cross efficiency matrix $\overline{\theta^B}$ of (Table 5); solve the matchable optimal model on $\overline{\theta^B}$. feasible M&A match according to the Definition 3 (see

Table 5. Cross Efficiency Matrix of M&A Match when $\theta_{dk}^L = 0.6$

	DMU1	DMU3	DMU4	DMU5	DMU6	DMU8	DMU10	DMU14	DMU15	DMU19
DMU2	0	0.6985	0	0	0	0	0.6491	0.7819	0	0.8943
DMU7	0	0	0	0	0	0	0	0	0	0
DMU9	0	0	0	0	0	0	0	0.9051	0	0
DMU11	0.5163	0	0	0	0	0	0.6897	0.6015	0	0.8652
DMU12	0.9325	0	0	0	0	0	0.6135	0.8465	0	0.8956
DMU13	0.7614	0.8616	0	0	0.9824	0	0.7635	0.8165	0	0.8357
DMU16	0.8156	0.8952	0	0	0.9102	0	0.7024	0.8167	0	0
DMU17	0	0	0	0	0	0	0.8014	0	0	0
DMU18	0	0	0	0	0	0	0.6354	0	0	0.9164
DMU20	0	0	0	0	0.9861	0	0.8816	0.8165	0	0

If $\theta_{dk}^L = 0.6$, the match results are: DMU1 matches with DMU12, DMU3 matches with DMU16, DMU6 matches with DMU13, DMU14 matches with DMU9, DMU10 matches with DMU20, DMU18 matches with DMU19. In order to illustrate the influence of individual preference on M&A match, $\theta_{dk}^L = 0.9$ and 0.95 are

adjusted as follows: when $\theta_{dk}^L = 0.9$, the match results are: DMU1 matches with DMU12, DMU18 matches with DMU19, DMU6 matches with DMU13, DMU11 matches with DMU14, DMU10 matches with DMU20, DMU1 matches with DMU12, DMU3 matches with DMU16. When $\theta_{dk}^L = 0.95$, the match results are: DMU3 matches with DMU16, DMU6 matches with

DMU13, DMU20 matches with DMU12, and DMU18 matches with DMU19.

Comparing the three groups of match results: if the θ_{dk}^L value varies from 0.6 to 0.9, the cross efficiency of three match schemes are reduced; if the θ_{dk}^L value varies from 0.9 to 0.93, three match schemes are reduced. It is easy find that, the higher the θ_{dk}^L value is, the smaller the target selection scope of both parties is. Therefore, the M&A macro-regulator can control the number of match scheme through the proposed θ_{dk}^L value scope. In the real application, the M&A principal is different, so the θ_{dk}^L corresponding to the M&A match is different too; therefore enterprise can select the appropriate and suitable match target according to its individual preference.

Method 2: Fuzzy number method

In order to embody the advantages of the Method 1, the fuzzy number method is used to study:

M&A match process: convert firstly the return-to-scale matrix (Table 3) of M&A match into the fuzzy number matrix, and then combine with the relative efficiency matrix (Table 2) of M&A match to form the comprehensive income matrix; in order to simplify the operation, the concentration weight is 0.5; finally the model (5) can be used to make the optimal match for the comprehensive income matrix. The optimal M&A results are: DMU3 matches with DMU16, DMU6 matches with DMU13, DMU18 matches with DMU19, DMU10 matches with DMU17, DMU5 matches with DMU20, DMU14 matches with DMU9, DMU14 matches with DMU11, DMU19 matches with DMU12, DMU2 matches with DMU8, DMU4 matches with DMU17.

In accordance with Table 2 and 3, the ones that DMU2 matches with DMU8, DMU5 matches with DMU20, DMU4 matches with DMU17, DMU14 matches with DMU11 are infeasible in the real application. This is rightly because that the four groups of M&A matches have not only the larger scale, but the resource allocation involved in them is waiting for improvement. Therefore the Method 1, relative to the Method 2, has great advantages, such as high flexibility etc.; moreover it can avoid from the difficulty of weight acquisition and the infeasible M&A match.

5. Conclusion

The core of the supply-side structural reform is the strategic adjustment of industrial structure and the industrial upgrade. The strategic M&A has the great and

realistic significance. This paper adopted the DEA method to research the M&A match problems from two aspects, *i.e.*: efficiency and scale, and proposed an individual preference-based M&A match strategy. The empirical research results showed: the strategy is good to use; once the lower efficiency limit of the M&A acceptable to both parties is determined, the feasible M&A match can be screened out according to the post-merger efficiency and return-to-scale. Moreover, the both parties can specify the lower M&A efficiency limit according to their individual preference, and then limit the feasible match scope and realize the win-win between them. This strategy has important practical significance for the strategic M&A and is beneficial for boosting the supply-side reform and industrial upgrade.

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