Management Performance Evaluation Method Based on TESUR Model and LOD Theory

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Abstract. This paper proposed a new model named time effect seemingly unrelated regression (TESUR) model. Based on lattice-ordered-decision (LOD), TESUR model can be applied to evaluate the management performance of enterprise, which overcomes the characters of “incommensurability” and “contradiction” among multiple-objectives. The method is verified by evaluating management performances of 8 petroleum enterprises. It is proved to be a relatively objective and effective evaluation method.

Keywords: Performance Evaluation, Time Effect Seemingly Unrelated Regression, Lattice Order Decision

1. Introduction
Improving management performance is the key way for enterprises to develop in the competition. The establishment of a reasonable and effective performance evaluation system can help enterprises to diagnose the problems existing in the current management, and then help them to successfully achieve organizational goals.

Data envelopment analysis (DEA) [1], Artificial neural network (ANN) [2], Balanced scorecard (BSC) [3] and Multi-criteria decision-making (MCDM) [4], etc. are usually used for performance evaluation. With the development of the research, some scholars introduced the concept of Lattice Order Decision (LOD). Wu xiancong et al. for the first time applied the fuzzy multi-objective and multi-level lattice order decision-making method for performance evaluation, selection and ranking of multiple schemes, which made up for the shortcomings of the traditional linear weighted method and provided a new way for performance evaluation [5]. Most performance evaluation methods are single dimensional analysis, which only one cross-section data or time series data be used for analysis and evaluation. The shortcomings of these methods are: first, the rich historical data of enterprises are underutilized to provide more authentic and reliable information; secondly, for some environment-sensitive enterprises, the traditional evaluation methods cannot effectively eliminate the impact of environmental changes (reflected in the correlation of the corresponding period and the time effect) on performance. petroleum enterprise, for example, in the year of higher oil prices, the profit and performance indicators can greatly improve, but the increase is mainly due to the price change which a temporary factors (i.e. the time effect), not the promotion of the management performance. Therefore,
in the performance evaluation of petroleum enterprise, excluding the influence of oil price fluctuations will more accurately reflect the management performance of enterprises.

In view of the above, this paper introduced variable coefficient model of panel data - Seemingly Unrelated Regression (SUR). Considering the Time effect (Time Effects, TE), a TESUR coefficient estimation method is put forward. Then, according to the main indicators reflecting the management performance of the enterprise, the Lattice Order Decision (LOD) was used to rank the performance of the evaluated enterprise. Finally, a group of petroleum enterprises was taken as an example to carry out a case analysis.

2. TESUR model and parameter estimation

2.1. TESUR model.

Based on SUR model, a TESUR model is proposed taking into account temporal effects. Its basic structure is as follows:

\[ y_{it} = X_i \beta_1 + \gamma_t + \epsilon_{it}, \quad i = 1, \cdots, N; t = 1, \cdots, T \]  

(1)

Where, \( \gamma_t \) is the time effect of phase \( t \).

The matrix form of the model is:

\[ Y = \tilde{X} \beta + (I_N \otimes I_T) \gamma + \epsilon \]  

(2)

Where,

\[ Y = \begin{pmatrix} Y_1 \\ Y_2 \\ \vdots \\ Y_N \end{pmatrix}_{NT \times 1}, \quad \tilde{X} = \begin{pmatrix} X_1 & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & X_N \end{pmatrix}_{NT \times NK}, \quad \beta = \begin{pmatrix} \beta_1 \\ \beta_2 \\ \vdots \\ \beta_N \end{pmatrix}_{NK \times 1}, \quad I_N = \begin{pmatrix} 1 \\ \vdots \\ 1 \end{pmatrix}_{N \times 1}, \quad I_T = \begin{pmatrix} 1 \\ \vdots \\ 0 \end{pmatrix}_{T \times 1} \]

\[ \epsilon = \begin{pmatrix} \epsilon_1 \\ \vdots \\ \epsilon_N \end{pmatrix}_{NT \times 1}, \quad \gamma = \begin{pmatrix} \gamma_1 \\ \gamma_2 \\ \vdots \\ \gamma_T \end{pmatrix}_{T \times 1}, \quad Y_t = \begin{pmatrix} y_{i11} \\ y_{i12} \\ \vdots \\ y_{i1K} \\ y_{i21} \\ y_{i22} \\ \vdots \\ y_{i2K} \\ \vdots \\ y_{iTK} \end{pmatrix}_{T \times 1}, \quad X_t = \begin{pmatrix} x_{i11} \\ x_{i12} \\ \vdots \\ x_{i1K} \\ x_{i21} \\ x_{i22} \\ \vdots \\ x_{i2K} \\ \vdots \\ x_{iTK} \end{pmatrix}_{T \times K}, \quad \beta_t = \begin{pmatrix} \beta_1 \\ \beta_2 \\ \vdots \\ \beta_K \end{pmatrix}_{K \times 1} \]

The error terms of the new model meet the following assumptions:

\[ E \epsilon_i = 0, \quad i = 1, \cdots, N \]

\[ E \epsilon_i \epsilon_j = \sigma^2 I_T, \quad i = 1, \cdots, N; \quad i \neq j \]

2.2. TESUR model parameter estimation.

Based on the principle of covariance estimation, the generalized least square method is used to estimate the parameters. The process of model parameter estimation is as follows:

Firstly, in model (1), for each time point \( t \), divide both sides by \( N \) after summation of \( i \), respectively calculate the mean value of individuals at each time point:

\[ \overline{y_t} = \frac{1}{N} \sum_{i=1}^{N} (x_{it} \beta_t) + \gamma_t + \epsilon_t \]  

(3)

Then, remove the time effect by model (1) minus model (3):
\[ y_u - y_t = X_u \beta_t - \frac{1}{T} \sum_{t=1}^{T} (X_u \beta_t) + \varepsilon_u - \bar{\varepsilon}_t \] (4)

Next, the estimated value of time effect can be obtained by generalized least square method:

\[ \hat{y}_t = \bar{y}_t - \sum_{t=1}^{N} (X_u \hat{\beta}_t) \] (5)

If the total time effect of each year is 0, the intercept of the model can be estimated, i.e

\[
\begin{align*}
\sum_{t=1}^{T} c_t &= 0 \\
\sum_{t=1}^{T} c_t &= 0
\end{align*}
\] (6)

Where, \( c \) is the model intercept, \( c_t \) is the time effect after the restriction condition. Available:

\[
\begin{align*}
\hat{c}_t &= \frac{1}{T} \sum_{t=1}^{T} \hat{y}_t \\
\hat{c}_t &= \bar{y}_t - \hat{c}
\end{align*}
\] (7)

2.3. Lattice order decision method (LOD)

2.3.1 LOD basic idea. Assuming that the problem involves \( i (i = 1, 2, \ldots, m) \) objects and \( j (j = 1, 2, \ldots, n) \) goals, if any two objects have upper and lower definite bounds, then the top element (or the bottom element) is naturally the optimal evaluation object. If the above conditions cannot be met, the positive ideal solution and the negative ideal solution are introduced as virtual evaluation objects, and the top element and the bottom element are respectively regarded to construct a lattice. By comparing the approximate degree of each object with the positive ideal solution and the negative ideal solution, the optimal solution can be judged. The principle of decision making is that the smaller the distance between the scheme and the positive ideal solution while the larger the distance between the scheme and the negative ideal solution, the solution is better \(^7\).

2.3.2. LOD basic steps.

Step1: For the evaluation involving \( i (i = 1, 2, \ldots, n) \) objects and \( j (j = 1, 2, \ldots, n) \) goals, the evaluation value of the \( i \) object of the \( j \) goal will be taken as \( x_{ij} \), so the evaluation vector of the evaluation object is:

\[ X_i = [x_{i1} \ x_{i2} \ \ldots \ x_{in}] \]

The evaluation vector constitutes the evaluation matrix \( X^j \) as follows:

\[ X = [X_1 \ X_2 \ \ldots \ X_m]^T \]

Step2: According to the lattice order decision theory, the maximum value \( x^+_j \) corresponding to each evaluation target constitutes \( X^+ \):

\[ X^+ = [x^+_1 \ x^+_2 \ \ldots \ x^+_n] \]

The minimum value \( x^-_j \) corresponding to each evaluation target constitutes \( X^- \):

\[ X^- = [x^-_1 \ x^-_2 \ \ldots \ x^-_n] \]

With positive ideal solution \( X^+ \) as the top element and negative ideal solution \( X^- \) as the base element, the lattice is constructed. Moreover, the priority relationship among each object is
investigated and the Hasse diagram is drawn. Suppose the better evaluation objects under the positive ideal solution are, in turn, \( C_1, C_2, \ldots, C_k (1 \leq k \leq m) \).

Step 3: Determine the difference between the evaluation object \( C_i (i = 1, 2, \ldots, k) \) and the positive ideal solution \( X^+ \):

\[
D_i^+ = \sqrt{\sum_{j=1}^{n} [d(x_{ij}, x_j^+)]^2}
\]  

(8)

Step 4: Determine the difference between evaluation object \( C_i (i = 1, 2, \ldots, k) \) and negative ideal solution \( X^- \):

\[
D_i^- = \sqrt{\sum_{j=1}^{n} [d(x_{ij}, x_j^-)]^2}
\]  

(9)

Step 5: Determine the comprehensive difference of evaluation object \( C_i (i = 1, 2, \ldots, k) \):

\[
D_i = p \frac{D_i^-}{D} + (1 - p) (1 - \frac{D_i^+}{D}), \quad i = 1, 2, \ldots, k
\]  

(10)

Step 6: The decision-maker selects the optimal evaluation object according to the size of \( D_i \) \((i = 1, 2, \ldots, k)\); where, \( d(x, y) \) represents the Minkowski distance between \( x \) and \( y \), \( p \) is the optimistic coefficient, and the decision-maker can take different values according to the actual situation[8].

3. **Evaluation algorithm design**

In this paper, the profit as the dependent variable of the model, choose profitability, operation capacity, growth ability, debt paying ability as explanatory variables. Through TESUR model, coefficient of the four indicators can be obtained as management performance evaluation value. Then, rank the evaluation value of the four indicators by using the theory of lattice order. The steps of the above are as follow:

Step 1: Collect the indicators of four aspects: profitability, operation capacity, growth ability and debt paying ability of the evaluation object. Extract the first principal component of each type of indicators, and take the four principal components as the evaluation value of the four indicators;

Step 2: Calculate the coefficients of the four indicators, and obtain the estimated value of the time effect according to equation (5);

Step 3: According to the TESUR regression coefficient, obtain the indicators coefficient \( x_i = (x_{i1}, x_{i2}, \ldots, x_{in}) \) of each enterprise, and constitute the evaluation object;

Step 4: According to the basic steps of LOD, obtain the comprehensive difference \( D_i \) of the evaluation object;

Step 5: The decision maker ranks the evaluation objects according to the size of \( D_i \) \((i = 1, 2, \ldots, k)\) and selects the optimal evaluation object.

4. **The example analysis**

The petroleum industry is special, and the performance indicators of petroleum enterprise are sensitive to the economic environment, especially the oil price. When evaluating petroleum enterprise, excluding the influence of oil price on performance can make the results more accurately. The change of market environment represented by oil price has an effect on all enterprises simultaneously, which is shown as correlation and time effect. Taking an example, using TESUR and LOD methods to take 8 petroleum enterprises as objects, and makes an analysis from four aspects of their profitability, operating capacity, growth capacity and debt paying capacity.

4.1 **Data collection**
This paper collected the relevant data from 2003 to 2011. Profitability include: net profit margin on sales, profit margin of main business, return on assets, return on investment; Growth capacity indicators include total asset growth rate, net profit growth rate, main business revenue growth rate; Operating capacity indicators include total asset turnover, current asset turnover, fixed asset turnover, deposit turnover, accounts receivable turnover; Debt paying capacity include current ratios, quick ratios, asset-liability ratios, interest payment multiples, and long-term liabilities to working capital ratios. These petroleum enterprise have a long and normal operating history.

4.2 The evaluation process

The method of combination of TESUR and LOD mentioned above was used for evaluation. The specific steps are as follows:

Step1: Conduct principal component analysis on the indicators of the four aspects, extract one principal component as a comprehensive indicator of the four capabilities, and obtain the indicator data of the four aspects of the 8 petroleum enterprises in the past ten years.

Step2: Use Eviews software \(^9\) to process the data, estimate the model according to the estimation method proposed in this paper, obtain the estimation result of coefficient, and calculate the time effect value of each year. The coefficients of the four indicators of 8 petroleum enterprises are summarized as evaluation objects.

Step3: Calculate the maximum set Max as the positive ideal solution and the minimum set Min as the negative ideal solution according to the 8 evaluation objects, draw the Hasse diagram, as shown in figure 1:

![Figure 1. Hasse Figure.](image)

Step4: The difference between the evaluation object \(C_i\) and the positive ideal solution \(D_i^+\) and the difference between \(C_i\) and the negative ideal solution \(D_i^-\) are calculated according to the maximum set Max and minimum set Min and the formula (8) and (9):

\[
D_i^+ = 1.516586, D_i^- = 1.184532; \quad D_3^+ = 1.794206, D_3^- = 0.91629;
\]
\[
D_4^+ = 1.83413, D_4^- = 0.726983; \quad D_4^+ = 1.399494, D_4^- = 1.282648;
\]
\[
D_5^+ = 1.712652, D_5^- = 1.344838; \quad D_5^+ = 1.915351, D_5^- = 1.700485;
\]
\[
D_6^+ = 2.314823, D_6^- = 1.69545; \quad D_6^+ = 0.817096, D_6^- = 1.708183.
\]

Step5: Find the distance between the positive and negative ideal solutions as \(D = 2.962324\), take \(p = 0.5\), and find the comprehensive difference \(D\) between the evaluation object and the positive and negative ideal solutions according to formula (10):
$D_1 = 0.443954; \quad D_2 = 0.35182; \quad D_3 = 0.313129; \quad D_4 = 0.480278; \quad D_5 = 0.437918; \quad D_6 = 0.463734; \quad D_7 = 0.396308; \quad D_8 = 0.650403.$

Step 6: According to the result of $D_i$, the ranking of evaluation objects is:

$D_8 > D_4 > D_5 > D_7 > D_3 > D_2 > D_1$

That is, the performance ranking of 8 petroleum enterprise $C_8 > C_4 > C_5 > C_6 > C_7 > C_3 > C_2 > C_1$.

At the same time, we extracted the fixed time effect value from the results from 2002 to 2011 and compared it with the trend of crude oil price from 2002 to 2011, as shown in Figure 2. It can be seen that the trend of time effect is roughly the same as that of crude oil price from 2002 to 2011, indicating that the time effect eliminated in this method mainly comes from the fluctuation of oil price.

![Figure 2. Time effect versus oil price trend chart](image)

5 Conclusion
A stable operation of the enterprise will accumulate a large amount of historical data, the effective use of these historical data can provide more valuable information for the enterprise. In this paper, the TESUR model and LOD theory are used to evaluate the performance of enterprises, which has the following characteristics: First, take full advantage of the panel data, introduce SUR model into the management performance evaluation system, and consider the correlation of the corresponding period; second, the TESUR model considering time effect was proposed to eliminate the influence of time effect in the evaluation, so as to make the evaluation more objective and accurate. Third, the lattice order theory is introduced to rank, which overcomes the characteristics of "contradiction" and "incommensurability" among multiple objectives.

Acknowledgments
This work is supported by the National Key Research and Development Program of China under Grants No.2019YFF0216801, the National Social Science Fund Major Project (Research on demand analysis and demand model construction of NQI in industrial development).

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