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PERFORMANCE ANALYSIS WITH CARBON FOOTPRINTS IN CHINA: CONSIDERING THE INDUSTRY HETEROGENEITY

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Abstract

Environmental pollution is an anthropogenic phenomenon as a consequence of the industrialization process. Therefore, the balance among energy-economy-pollution performance becomes increasingly important. However, industry heterogeneity exists in the economic system, which makes industry performance differences. This paper focuses on the industrial performance evaluation in China based on the green input-output accounting. For the industrial heterogeneity, a four-stage dynamic Malmquist model is used to identify the different industrial transformation paths of energy conservation and emissions reduction. Furthermore, isolated and unilateral performance evaluation leads to over-incentive in the short periods and under-incentive in the long periods. Considering the intertemporal effect, this paper analyzes the dynamic model by incorporating carry-over activities of fixed assets. Hierarchical clustering is conducted to reveal the bottleneck of industrial performance in China. First, the intertemporal utility of fixed assets is gradually ignored. This implicates the industrial performance development gives up long-term growth opportunities for the special benefit of short-term performance. Next, the genuine managerial performance is contained by the uncontrolled industrial resources endowment. Then, attention should be paid on the active vigilance of the tertiary industry while focusing on the performance improvement of high pollution industries. Last, technical corporation and communication among industries should be encouraged..

Key words: accounting industrial performance, energy conservation, emissions reduction, four-stage Malmquist, green input-output

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1. Introduction

Discussion of economy, energy and pollution under sustainability development has received increasing attention with international emission reduction background. From Kyoto Protocol in 1997 to Copenhagen Climate Council in 2009, Pairs Conference in 2015, and Katowice climate conference in 2018, all of the conferences emphasis the importance of energy conservation and emission reduction. During the past thirty years, the annual economic growth rate is 9.8% in China. The annual growth rates of energy consumption and CO2 emission in industry are 6% and 6.3%. However, Chinese industry consumes 67.9% of energy and emits 83.1% of CO2 with an increasing of 40.1% of GDP. Many scholars and policy-makers are aware that the balance among energy-economy-pollution performance becomes increasingly important.

Environmental pollution is an anthropogenic phenomenon with the consequence of the industrialization process. Industry heterogeneity exists in economic system which makes industry performance differences. Heavy industries are always considered as one of the major problems with more energy consumption and carbon emission in general opinion. Heavy metal is often discharged by a number of industries, such as mining, metal plating facilities, tanneries, which can lead to the contamination of freshwater and marine environment (Hlihor and Gavrilescu, 2009). Therefore, the transformation paths of energy conservation and emissions reduction

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should be different with different industries. Since the balance of industry performance can promote the coordinated development of the whole economic system.

For the performance evaluation, previous literatures used Data Envelopment Analysis (DEA). And then, many literatures evaluated the performance based on Malmquist (Qin et al., 2019). However, some evaluation variables not only take effect in one period, but also have a long-term effect, such as fixed assets, physical capital stock. Tone and Tsutsui (2013) found the traditional Malmquist model didn't explain the long-term effect with a focus on single period. Thus, the traditional Malmquist model cannot make a clear picture of the total factor productivity growth. This leads the performance to over-incentive in the short-term and under-incentive in the long-term.

This paper makes contributions at the methodological and the application levels. First, for the internal relation among industrial value, energy and pollution, a series of green input-output model is built to realize the environment pollution and wastage recycle.

This green accounting is different with the traditional ones because the integrating calculation of energy and pollution indices. Second, this paper incorporated green input-output model into dynamic network Malmquist index considering the intertemporal effect and the linkage defect. Third, considering the sustainability of dynamic, network, and environmental influences, a cluster analysis results the decomposed efficiency scores to distinguish the characteristics of energy performance constrained with environment in Chinese industries. Therefore, the different industrial transformation paths of energy conservation and emissions reduction are recognized as the empirical results.

2. Material and methods

2.1. Conceptual energy-economy-pollution model

Previous literatures focused on the environment performance evaluation by traditional Malmquist. In this paper, all the carry-over activities are defined as dynamic variables which satisfy the general requiremenet. Dynamic variables are not only influence at one period, but also have inter-temporal effect during several periods. Therefore, a conceptual energy-economy-pollution performance model based on dymamic Malmquist is shown in Fig. 1.

Industries are defined as DMUs in Energy-economy-pollution performance evaluation over t (t=1,2,3...) periods. At every period t, DMU produces desirable output Yd and undesirable output Yu by consuming input X (including energy input as EX) with carry-over activity Z. Carry-over activity influences periods t-1, t and t+1. The difference between dynamic Malmquist and traditional Malmquist is the existence of carry-over activities and negative externalities, which is used to evaluate DMUs under a sustainable development view. For empircal analysis, dynamic Malmquist is calculated based on non-oriented and non-radial SBM which allows inputs and outputs for simultaneous and non-proportional changes.

2.2. Basics of four-stage dynamic Malmquist

2.2.1. First stage of dynamic Malmquist calculation

Input x is used to produce desirable output yd and undesirable output yu considering the dynamic variable z at period t. And then, dynamic Malmquist is decomposed into two mutually exclusive and exhaustive components. The decomposition calculation is shown as in Eq. (1).

$$DM = \underbrace{\frac{\overline{D}^{t}(x^{t},z^{t-1},y^{dt},y^{ut},z^{t})}{\overline{D}^{t+1}(x^{t+1},z^{t},y^{dt+1},y^{ut+1},z^{t+1})}}_{①}\underbrace{\left[\left(\frac{\overline{D}^{t+1}(x^{t+1},z^{t},y^{dt+1},y^{ut+1})}{\overline{D}^{t}(x^{t+1},z^{t},y^{dt+1},y^{ut+1},z^{t+1})}\right)\left(\frac{\overline{D}^{t+1}(x^{t},z^{t-1},y^{dt},y^{ut},z^{t})}{\overline{D}^{t}(x^{t},z^{t-1},y^{dt},y^{ut},z^{t})}\right)\right]^{1/2}}_{②}. \quad (1)$$

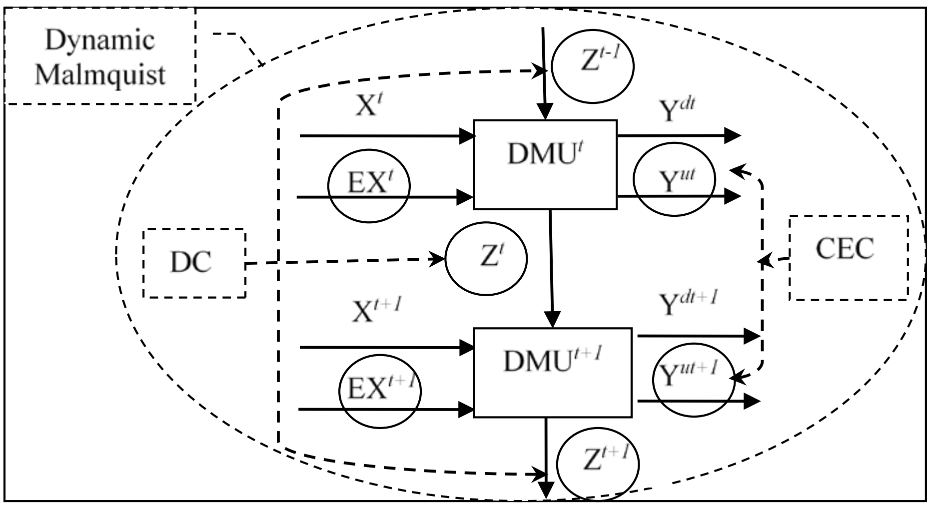


Fig. 1. Energy-economy-pollution performance model

In Eq. (1), part ① indicates that OEC is similar to the catching-up components of the traditional Malmquist. OEC measures the catching-up effect of productivity set with inter-temporal influence between period t and period $t+1$. Part ② indicates that DTC is similar to the frontier-shift components of traditional Malmquist. The index measures the shift of efficient isoquant between period t and period $t+1$.

The catching-up component of dynamic Malmquist is OEC. This can be decomposed into two components. The first component is the product of technical efficiency changes (TEC), as in the traditional Malmquist. And another component is constraint efficiency changes (CEC), which is caused by pollution constraint influence. The decomposition can be shown as Eq. (2).

$$OEC = \underbrace{\frac{\overline{D}^{t}(x^{t}, z^{t-1}, y^{t}, z^{t})}{\overline{D}^{t+1}(x^{t+1}, z^{t}, y^{t+1}, z^{t+1})}}_{③} \cdot \underbrace{\frac{\overline{D}^{t}(x^{t}, z^{t-1}, y^{dt}, y^{ut}, z^{t})/\overline{D}^{t}(x^{t}, z^{t-1}, y^{t}, z^{t})}{\overline{D}^{t+1}(x^{t+1}, z^{t}, y^{dt+1}, y^{ut+1}, z^{t+1})/\overline{D}^{t+1}(x^{t+1}, z^{t}, y^{t+1}, z^{t+1})}}_{④} = TEC \cdot CEC \tag{2}$$

Part ③ in Eq. (1) is TEC proposed by the traditional Malmquist as catching-up component. Similarly, part ④ is CEC. This index shows the catching-up effect on optimal production isoquant with pollution constraint influence. Similar to the traditional Malmquist, TEC can be further decomposed into pure technical efficiency changes (PTC) and scale efficiency changes (SEC).

The frontier-shifting component of the new Malmquist is DTC. In the similar way, it can be decomposed into the product of technical changes (TC) as in the traditional Malmquist. And dynamic changes (DC) is of inter-temporal influence from carry-over activities. Eq. (3) shows the decomposition.

Part ⑤ in Eq. (3) is TC proposed by the traditional Malmquist as frontier-shifting component. Similarly, part ⑥ is the DC. This index shows the frontier-shifting effect on optimal production isoquant with the inter-temporal dynamic influence of carry-over activities.

$$DTC = \underbrace{\left[\left(\frac{\overline{D}^{t+1}(x^{t+1}, y^{dt+1}, y^{ut+1})}{\bar{D}^{t}(x^{t+1}, y^{dt+1}, y^{ut+1})}\right)\left(\frac{\overline{D}^{t+1}(x^{t}, y^{dt}, y^{ut})}{\bar{D}^{t}(x^{t}, y^{dt}, y^{ut})}\right)\right]^{\frac{1}{2}}}_{⑤} \cdot \underbrace{\left[\left(\frac{\dfrac{\overline{D}^{t+1}(x^{t+1}, z^{t}, y^{dt+1}, y^{ut+1}, z^{t+1})}{\overline{D}^{t+1}(x^{t+1}, y^{dt+1}, y^{ut+1})}}{\dfrac{\overline{D}^{t}(x^{t+1}, z^{t}, y^{dt+1}, y^{ut+1}, z^{t+1})}{\bar{D}^{t}(x^{t+1}, y^{dt+1}, y^{ut+1})}}\right)\left(\frac{\dfrac{\overline{D}^{t+1}(x^{t}, z^{t-1}, y^{dt}, y^{ut}, z^{t})}{\overline{D}^{t+1}(x^{t}, y^{dt}, y^{ut})}}{\dfrac{\overline{D}^{t}(x^{t}, z^{t-1}, y^{dt}, y^{ut}, z^{t})}{\bar{D}^{t}(x^{t}, y^{dt}, y^{ut})}}\right)\right]^{1/2}}_{⑥} \tag{3}$$

Therefore, dynamic Malmquist index is greater than 1, it suggests progress. If it is less than 1, this suggests regressions. And if it equals to 1, this indicates stable productivity. Thus, the dynamic Malmquist is a more general index than the traditional Malmquist.

2.2.2. Second stage of Tobit model based on panel data

Based on the first stage, slack variables are the result conponents of performance evaluation. Actually, they are influenced by uncontrollable resource endowment variables, internal managerial efficiency and random error in common. In order to eliminate the uncontrollable resource endowment influence, the purpose of second stage is to get the genuine managerial performance. For this purpose, xxTobit is defined which is a extended Tobit model incorporating with SFA considering time shift. The xxTobit model includes three components as Eq. (4).

$$S_i^{i*} = f^{it}(z_i^{it}, \beta^i) + D^i(d_i^i, \delta^i) + v_i^i$$
$$\text{where } S_j^i = S_j^{i*}, \quad if\ S_j^{i*} > 0, = 0, \quad otherwise \tag{4}$$

where the independent variables S_j is slacks ($j=1,2,\ldots,n$), the dependent variables is decomposed into three parts as Eq. (4) which is similar to SFA model. z^i is uncontrollable resource endowment variables ($i=1,2,\ldots,q$), β^i is the parameter vector. The second part $D^i(d_j^i, \delta^i)$ is a DMU dummy part with parameter vector δ^i and a dummy variable d_j. The last one is random error.

2.2.3. Third stage of adjustment and dynamic Malmquist re-calculation

To eliminate the uncontrollable resource endowment influence, the input data in Malmquist calculation are adjusted at the first stage based on Tsutsui and Goto (2009) as shown in Eq. (5).

$$x_j^{ai} = x_j^i + [\max_j\{z_j^i \beta^{i*}\} - z_j^i \beta^i] + [\max_j\{\hat{v}_j^i\} - \hat{v}_j^i] \tag{5}$$

To avoid the irrational DEA scores, performance variables are adjusted by Liu and Tone (2008) as Eq. (6).

$$x_j^{Ai} = \frac{\max_j(x_j^i) - \min_j(x_j^i)}{\max_j(x_j^{ai}) - \min_j(x_j^{ai})}[x_j^{ai} - \min_j(x_j^{ai})] + +\min_j(x_j^i) \tag{6}$$

After using the xxTobit model considering time shift and SFA model to adjust input variables, performances with new data are recalculated using the above equations. Thus, the genuine managerial performance eliminates uncontrollable resource endowment influence and random error.

2.2.4. Forth stage of Malmquist hierarchical cluster model

To identify the internal similarity of industries, the result of decomposed efficiency indices is calculated by hierarchical cluster model. This is defined as Malmquist hierarchical cluster model. This model uses centroid cluster to measure the distance among the group centroids as shown in Eq. (7).

$$D_{KL} = ||\overline{X}_K - \overline{X}_L||^2 \quad (7)$$

3. Data expression

3.1. Data of green accounting

The discussion of linkage analysis for human's economic activities, the energy resources and pollution emission under sustainable development has received increasing attention, especially after Japan's nuclear leakage. It is a necessary relationship between economic development and environment control. Nevertheless, traditional input-output accounting is based on marketing principle. This accounting only considers the pure economic system without considering the energy resource and pollution emission influence. Green accounting not only considers the relationship between energy-pollution and economic activities, but also regard for the correlation between stock and flow.

Similar with the traditional accounting, the total value added of sectors are adjusted in Pure Value Tables. Differing from traditional accounting, three energy recovery departments are introduced into the calculation which are coal recovery department, petroleum recovery department and natural gas recovery department. Meanwhile, energy recovery departments are defined as virtual ones to be used rationally and economically. Three pollution abatement departments are waste water abatement department, waste gas abatement department, solid waste abatement department. All the data come from the energy recovery ratio and realization of energy-saving based on the compilation of green input-output accounting.

3.2. Variable selections for dynamic performance

Previous literatures about performance always focused on economic growth. This means they use energy, capital stock and staff resource as inputs to product output value with pollution as outputs(Guo et al., 2011; Meng et al., 2016; Jradi et al., 2018). The carry-over activities and negative externalities are introduced based on non-oriented and non-radial method (Tone, 2001). In the spirit of the literatures, this paper defines the input variables including complete energy, capital stock and staff based on the cost. The desirable output variable is selected as output value based on the revenue.

Then, complete pollution is considered as undesirable out-put. Both of complete energy and complete pollution are from green input-output accounting. Comparing with the indirect energy consumption and pollution emission from traditional input-output accounting, they evaluate more profound and more comprehensive fully considering the mutual influence among sectors. They can also avoid the performance disadvantage of traditional indirect variables.

For the heterogeneity of industries, the results of single period static efficiency comparison among industries are relatively unconvincing (Barrows and Ollivier, 2014; Baldoni et al., 2018; Forslid et al., 2014). However, the correlation between industries is a two-way trading relationship of mutual dependence. Moreover, Malmquist focuses on an industry historical efficiency changes with the frontier of all the industries. So, as to make a comparison from the perspective of its own efficiency changes, the heterogeneity of industry can be ignored. Therefore, forty sectors are defined as DMU in performance evaluation. (Lei and Zhao, 2011).

3.3. Resource endowment variable selection

For the Tobit regression, the uncontrollable resource endowment variables which influence the dynamic performance. The fourteen uncontrollable resource endowment variables are selected from five aspects which are macro-economy, human resource, openness, energy consumption, pollution consumption, and R&B.

For the management ineffectiveness, two dummy variables are defined as D_1 and D_2 for industry classify. When D_1=0 and D_2=0, this means the industry belongs to the primary industry. When D_1=1, D_2=0, this means the industry belongs to the second industry. When D_1=1, D_2=1, this means the industry belongs to the tertiary industry. Therefore, the uncontrollable resource endowment variables which influence the dynamic performance variables as shown in Table 1.

4. Results and discussion

4.1. Dynamic Malmquist decomposed efficiency analysis in China

Based on the first three steps of theoretical part, first, the Malmquist of every industry in China is calculated based on the primary inputs, outputs and dynamic variables. From the results, the original dynamic performance is calculated as ODP as shown in Table 2. Second, the uncontrollable resource endowment variables are defined as dependent variables. They influence the independent variables which are the slacks from the first stage. Then the resource endowment variable influence can be reduced. Third, the new dynamic performance is re-calculate using the new inputs, outputs and dynamic variable as NDP as shown in Table 2.

Table 1. Resource endowment variables with special significance in SEA

Variable	X_1	X_2	X_3	L_1	L_2	Y_1	Y_2
Business index	*	*	*	*	*	*	*
Gross output rate		*				*	
Fixed asset rate				*	*		
Finance aid				*	*		
Average wage			*				
Woman staff rate			*				
Education level	*	*	*			*	*
Import & export rate		*				*	
Gas rate	*						
Coal rate	*						
Waste water rate							*
Waste gas rate							*
R&B invest	*	*		*	*	*	*
R&B staff			*				

Table 2. The industries of DMUs in dynamic performance evaluation

Num.	ODP	NDP	***Industry***	***Num.***	ODP	NDP	***Industry***
DMU1	0.71	1.00	Agriculture	DMU21	1.24	1.00	Production of Gas
DMU2	0.82	1.53	Mining of Energy	DMU22	1.32	1.51	Production of Water
DMU3	0.84	1.14	Mining of Non-Energy	DMU23	1.39	1.00	Construction
DMU4	0.89	0.91	Manufacture of Foods and Tobacco	DMU24	1.40	9.17	Transport and Storage
DMU5	0.91	2.18	Manufacture of Textile	DMU25	1.43	4.99	Post
DMU6	0.92	0.82	Manufacture of Furniture	DMU26	1.51	0.70	Information Transmission
DMU7	0.93	1.16	Papermaking, and Printing	DMU27	1.54	1.58	Wholesale and Retail Trades
DMU8	0.96	1.21	Processing of Petroleum, Coking, and Nuclear Fuel	DMU28	1.60	1.02	Hotels Services
DMU9	1.00	1.55	Chemical Industry	DMU29	1.60	1.00	Financial Intermediation
DMU10	1.00	0.66	Manufacture of Nonmetallic Mineral Products	DMU30	1.69	1.33	Real Estate
DMU11	1.00	1.44	Smelting and Rolling of Metals	DMU31	1.69	0.85	Business Services
DMU12	1.00	1.55	Manufacture of Metal Products	DMU32	1.73	1.22	Research and Development
DMU13	1.02	0.75	Manufacture of General Machinery	DMU33	1.76	0.60	Comprehensive Services
DMU14	1.05	1.41	Manufacture of Transport Equipment	DMU34	1.85	2.44	Management of Environment
DMU15	1.11	1.14	Manufacture of Electrical Machinery	DMU35	1.94	3.65	Services to Households
DMU16	1.15	0.73	Manufacture of Communication Equipment	DMU36	1.98	1.98	Education
DMU17	1.17	0.65	Manufacture of Machinery for Cultural	DMU37	2.11	1.58	Health, and Social Welfare
DMU18	1.19	1.68	Manufacture of Artwork	DMU38	2.18	3.57	Culture, and Entertainment
DMU19	1.19	1.00	Waste Industry	DMU39	3.07	0.70	Public Management
DMU20	1.23	2.55	Supply of Electric and Heat Power				

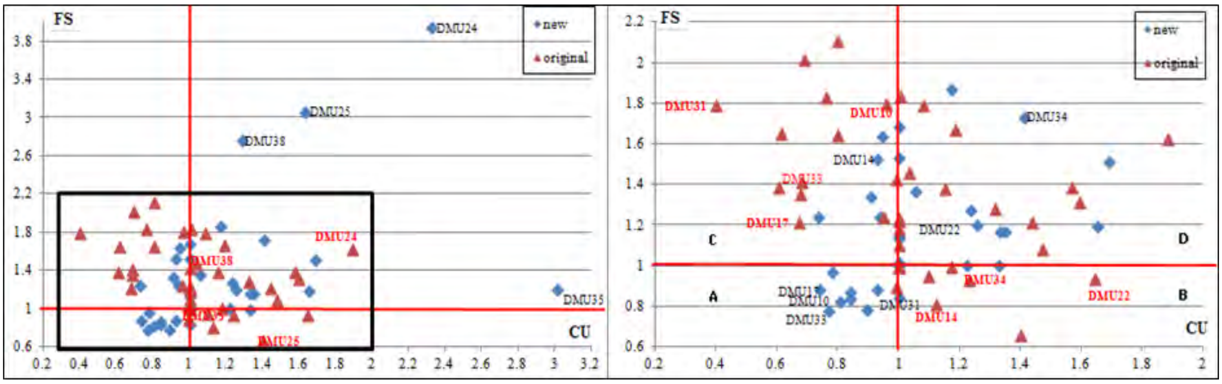
Based on the traditional Malmquist decomposition, the catching-up effect (CU) is as horizontal axis. And the frontier-shifting effect (FS) is as vertical axis to compare the original dynamic performance and the new dynamic performance as shown in Figs. 2-3. The left chart is the whole chart. The right side is the part chart of the black framework in the whole chart. From the whole chart, the differences of every industrial performance are large after getting rid of the influence from the resource endowment variables. This indicates that the uncontrolled resource endowment variables cover up the performance of some star industries. Definitely, after getting rid of the influence from the resource endowment variables, either from OEC or DTC, DMU24(Traffic, Transport and Storage), DMU25(Post), DMU35(Services to Households and Other Services) and DMU38(Culture, Sports and Entertainment) have much more advantage from the original dynamic performance. For example, the OEC of DMU 24 from original dynamic performance is 1.885. while, that of new original dynamic performance is 2.236.

After getting rid of the influence from the resource endowment variables, most industries are distributed in A part and D part. Comparing with that, no industries in A part are in original dynamic performance. This indicates that the uncontrolled resource endowment variables cover up the performance of some industries which have lower dynamic managerial performance, such as DMU10(Manufacture of Nonmetallic Mineral Products), DMU17 (Manufacture of Measuring Instrument and Machinery) and DMU33 (Comprehensive Technical Services). This phenomenon reveals the original performance evaluation make the chance of free rider and the status of artificial harmonious.

For the individual industry, the original C part turns into the new A part for lower new DTC. Such as DMU17(Manufacture of Measuring Instrument and Machinery, DTC_{new}=0.884) and DMU33 (Comprehensive Technical Services, DTC_{new}=0.779). This proves the free rider in original performance evaluation again. The original B part turns into the new D part for higher new DTC. Such as DMU22 (Production and Distribution of Water, DTC_{new}=1.204) and DMU34 (Management of Water Conservancy, DTC_{new}=1.730). This reveals these industries break the limitation of resource endowment variables. Their own decomposed efficiency indices promote the dynamic performance. For the decomposed efficiency indices of the new evaluation, the trend of DTC is lower and that of OEC is slightly up. Since the average of DTC is 1.324, while, that of OEC is 1.153. Except the hidden star industries as DMU24 (Traffic, Transport and Storage) and DMU25(Post). This indicates that the influence of uncontrolled resource endowment variables cannot be ignored. Besides that, the influence of resource endowment variables is different from that of managerial control. However, the influence of resource endowment variables should get rid from the dynamic performance. This is the purpose of the managerial dynamic performance evaluation by getting rid of the uncontrolled resource endowment variables.

4.2. Dynamic cluster analysis in China

The dynamic energy-economy-pollution performance prefers to evaluate the control managerial performance getting rid of uncontrolled environment variable influence. However, for identifying the performance with the decomposed efficiency indices, the Chinese industrial dynamic energy-economy-pollution managerial performance and their decomposed efficiency indices are calculated.



(a) (b)

Fig. 2. Comparison of resource endowment variables influence

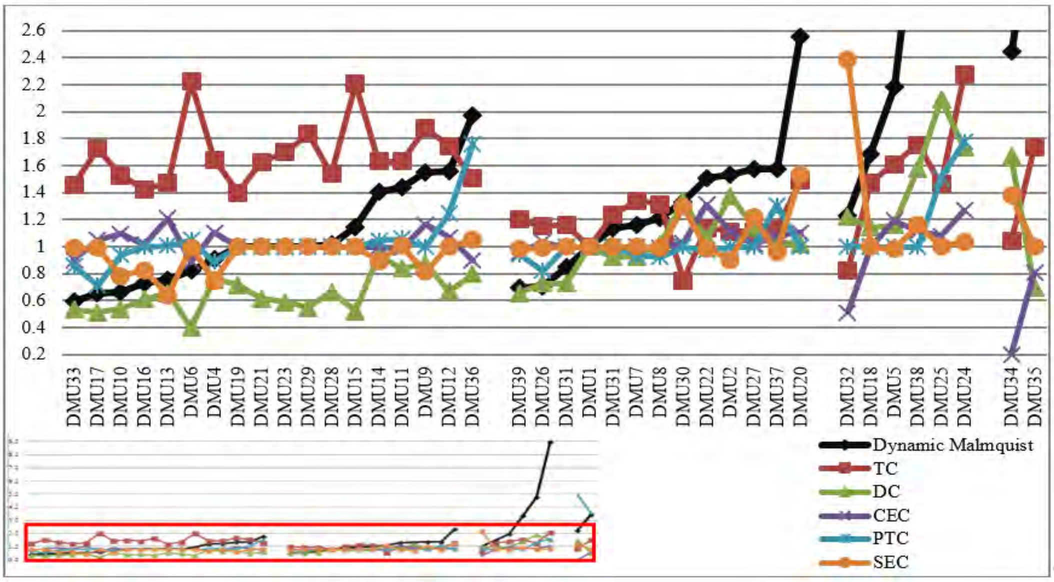


Fig. 3. Decomposed Efficiency Indices of DMPI Model in Dynamic Performance

Then, hierarchical cluster analysis classifies the different characteristics of 39 industries using five aspects which include carry-over activities, negative externalities, technical changes, scale efficiency changes, and pure technical efficiency changes. Five decomposed efficiency indices, DC (Dynamic Efficient Change), CEC (Constraint Efficiency Change), TC (Technical Change), SEC (Scale Efficiency Change) , and PTC (Pure Technical Efficiency Change), stand for the five aspects. Using the decomposed efficiency indexes, 39 industries are classified into four clusters using hierarchical cluster analysis as shown in Fig. 3. Incorporating with the internal characters, the essences of every cluster as shown in Table 3. Based on the results of cluster analysis, the decomposed performance indices of 39 industries are classified in four clusters as shown in Fig. 3. The left part of the figure is the whole tendency chart. The main part of the Fig. 3 is the red framework of the whole tendency chart. Overall. TCs of most industries play a main role in dynamic managerial performances. This indicates current human resource and advantage technology promote the dynamic managerial performances. However, most industries have disadvantage of dynamic effect. The DCs of most industries are lower than 1 which proves the disadvantage again.

Definitely, the first cluster is called as TCI for TC ($TC_{average}$=1.68) taking an absolute role in dynamic managerial performance. The second cluster is called as SAI for the dynamic managerial performance, which is the result of combine action from multiple decomposed efficiency indices. The third cluster is named as DCI for DC ($DC_{average}$=1.49) taking an absolute role in dynamic managerial performance. Other decomposed efficiency indices of this cluster also promote the performance. So the industries of this cluster have a good performance. The fourth cluster is named as PTCI for PTC ($PTC_{average}$=4.42) taking an absolute role in dynamic managerial performance. The typical traditional advantages promote the performances of industries at the leading position among that of other industries. Therefore, dynamic progress gradually becomes the main direction of dynamic managerial performance improvement. The comparatively primary catching-up level such as scale efficiency changes and pure efficiency changes are gradually mature. So larger enhance of catching-up level is comparatively difficult.

4.2.1. TCI (Technical progress cluster)

Almost half of the industries belong to this cluster. Except for DMU29 (Financial Intermediation), DMU28 (Hotels and Catering Services), DMU36 (Education), and DMU33 (Comprehensive Technical Services), all the fourteen industries belong to secondary industry. And then, most of them are manufacturing industry. The main character of this cluster is that, TCs have a leading position comparing with that of other clusters. However, DCs prevent the dynamic managerial performances of this cluster for the lower average efficiency ($DC_{average}$=0.653). This means for those industries, especially for manufacturing industry, advantage technology and science management promote the performance. Meanwhile, they ignore the intertemporal effect of special variables. The restraining influence of increasingly ignored intertemporal effect will grow with the increasing performance. This phenomenon reveals that these industries pay much attention on pursuing the short-term profit. Moreover, little advantage of pollution control and stagnant scale advantage prevent the performance neither. With this background, the differences among the industries of this cluster are from PTC. Comparing with other clusters, the advantage of this cluster is traditional TC ($TC_{average}$=1.68). In the meantime, comparing each other DMU inside this cluster, the better DMUs have advantage on traditional PTC. However, with the sustainable strategy background, only the traditional advantage cannot keep a leading position in the future. Thus, traditional advantages maybe become obvious flaw. Therefore, this cluster should keep the traditional advantages while making effort to control the pollution efficiency and intertemporal effect.

4.2.2. SAI (Synthetic action cluster)

One third of industries belong to this cluster. This cluster includes all the energy industry such as DMU8 (Processing of Petroleum, Coking, Processing of Nuclear Fuel) and DMU2 (Mining and Processing of Energy), but except DMU21 (Production and Distribution of Gas). The major characteristic of this cluster is that the decomposed indices are relatively stable.

No obvious advantage or disadvantage indices comparing with other clusters. The dynamic managerial performance is the synthetic action of five decomposed indices which indicates this cluster has no obvious advantage or disadvantage.

The middle level performance makes this cluster be conservative. The performances of DMU26 (Information Transmission, Computer Services and Software), DMU31 (Leasing and Business Services) and DMU39 (Public Management) are lower than 1. This indicates they regress in performance evaluation. This phenomenon reveals that the tertiary industries have good future in energy and pollution control.

Table 3. Four clusters of dynamic managerial performance

NO.	***Abbreviation***	NDP	***DTC***	***OEC***	***Norm***
(I)	TCI	1.07	1.08	0.97	Technical progress group
(II)	SAI	1.29	1.14	1.11	Synthetic action group
(III)	DCI	3.80	2.39	1.44	Dynamic progress group
(IV)	PTCI	3.04	1.47	2.21	Pure technical efficiency change improved group

However, the ignored degree of intertemporal effect is obvious. DMU1 is the only industry whose composed indices are all stable. It is always on the optimal frontier, but no advantage for itself.

4.2.3. Dynamic Progress Cluster (DCI)

This cluster includes six industries such as DMU24 (Traffic, Transport and Storage) and DMU25 (Post). The major characteristic of this cluster is DCs have a leading position for the highest average efficiency ($DC_{average}$=1.487). While TCs promote the performance. The scale changes run in the opposite direction with the performance. This indicates the intertemporal effect of dynamic variable (fixed assets) promotes the performance. Meanwhile, the advantage technology and science management encourage the performance. Thus, the performances of this cluster are higher than that of others.

Especially for DMU24 (Traffic, Transport and Storage) and DMU25 (Post), the higher DCs and TCs promote them to be absolute leaders. DMU32 (Research and Experimental Development) belongs to the marginality of this cluster. It is called as marginality industry based on its characteristic which is slightly different with others. Although the promote index of DMU32 (Research and Experimental Development) is scale effect. It also has the characteristic of this cluster which is larger dynamic progress.

However, the bottleneck of this industry is pollution control and technical regress. This bottleneck also comes from its own industrial characteristic. For the advantage of dynamic progress and technical progress, this cluster is called as a good performance cluster. This advantage will play an important role in the future, especially for DMU24 (Traffic, Transport and Storage) and DMU25 (Post).

4.2.4. Pure Technical Efficiency Progress Cluster (PTCI)

This cluster is a special marginality. This only includes DMU34 (Management of Water Conservancy, Environment and Public Facilities) and DMU35(Services to Households and Other Services). The major characteristic of this cluster is that, PTCs have an absolute leading position comparing with others. And then, the pollution efficiency lags far behind others. This indicates that they are classical traditional industries. And, they belong to the early stage of performance development.

The leading positions of PTCs make these industries with excellent performance for the highest average efficiency ($PTC_{average}$=4.419). However, in the sustainable view, the leading positions cannot be long-term, especially for its regression in pollution control. Therefore, the traditional advantage cannot keep a leading position in the future. Thus, traditional advantages become obvious flaw. So this cluster faces a severe future.

5. Conclusions

Using four-stage Malmquist model and dynamic Malmquist model, this study builds a dynamic energy-economy-pollution Malmquist model incorporating intertemporal effect to measure the managerial efficiency without the influence of local resources endowment. For low-carbon economy, green input-output accounting is incorporated into the new Malmquist model. Therefore, dynamic energy-economy-pollution performance evaluation is constructed to consider the industrial total factor productivity influenced by energy efficiency, economy efficiency and pollution efficiency.

For this purpose, a dynamic Malmquist productivity index with negative externality constraint is considered the intertemporal effect of carry-over activities and the effect of undesirable outputs. Sequentially, the dynamic Malmquist model is applied to analyze a panel data of 39 industries in China based on green accounting. Comparing with the results of traditional performance, the results of dynamic managerial performance reveal the free rider which has been hidden behind the uncontrolled resource endowment influence. This indicates some industries with both good and bad performances are hidden. By hierarchical cluster analysis, some interesting findings about the dynamic performance of every cluster are summarized. For instance, dynamic technical change plays a leading role in promoting dynamic managerial performance. And then, constraint efficiency change keeps a stable trend. Furthermore, the dynamic effect is the largest bottleneck for most Chinese industries.

The empirical analysis shows that all the industries should pay attention on long-term development in energy-economy-pollution allocation. Considering their own industrial characteristics, they should improve the management skill and play a role of high technology input in energy efficiency. In addition, they should pay more attention on high pollution industries and maintain active vigilance on the efficiency of tertiary industries. Finally, the Chinese industries should mainly focus on relative efficiency comparisons among industries instead of absolute quantity control. Meanwhile, technical corporation and communication among industries should be encouraged. Furthermore, green accounting which contains energy, economy and pollution is another way to promote the harmonious development on dynamic energy-economy-pollution performance.

This paper has some implication based on the empirical results of industries performance in China. However, several limitations of this study should be addressed in the future. First, this study considered the intertemporal effect instead of the long-term effect of fixed assets. Further extensions of the Malmquist model are required. Second, this paper defined pollution as the negative output during performance evaluation.

Meanwhile, the negative influences in a multidimensional problem which needs more variables to evaluate. Third, the regression correlation model and difference analysis among cluster variables are necessary before the cluster analysis because of the robustness of multicollinearity. For the further test of the clustering results, a structural model can be introducing. Future studies will develop these limitations to make more comprehensive contributions.

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