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APPLICATION THE OPTIMIZATION MODELS TO ANALYSIS OF THE INDUSTRIAL POLLUTANT EMISSION IN CHINA

An industrial planning is made based on the optimization model. Factor analysis was used to reject relativity among the environmental indicators. Then, thirty nine industries were clustered into four clusters. Lastly, optimization model was used to plan the industrial structure. Adjusting the industrial structure, it is difficult to reduce vast SO_2, smoke, and dust with total industrial output value growth; the air pollutant emission only can be decreased by 10%. The parameters of smoke emission are limited constrains for the optimization. The reasonable and feasible way to solve the problem is to introduce the lower smoke emission technique of the cluster 2 and 4 industries.

1. INTRODUCTION

The research about the inverse U-shaped relationship between environmental damage and economy development is vast but far from conclusive [1]. The empirical studies always focus on the reduced form regressions and try to explain the environmental pollution change with economy development. Economic indicators such as the income, income-squared or GDP, GDP-squared, capture the scale, composition and income effect [2]. At the initial stages of economic development, the increasing scale of economic activity as well as the changing composition from agricultural towards industrial activities generates more pollution [3]. Following the economy development

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and income rise, the demand for environmental quality increases and stringent environmental regulation leads to the replacement of high pollutant emission technologies by less harmful ones [4]. The income and technique always change the industrial structure [5]. Industrial structure, technology, and production scale are the three main factors to reduce the pollutant emission [6].

The results of EKC have shown that economic growth could be compatible with environmental improvement if appropriate policies are taken [7]. Before adopting a police, it is important to understand the nature and causal relationship between economic growth and pollutant emission [8]. Following the population rising and living level improving, expanding the industrial scale is inevitable. It is unreasonable to limit the industrial scale for reducing the pollutant emission. The technological change is usually considered necessary albeit not sufficient condition for a transition to sustainability [9]. It is one of the factors influencing the environmental intensity of production and it is able to reduce the impacts from manufacturing processes [10]. As technological change usually encompasses three major stages (invention, innovation and diffusion, and different actors) [11], technique has not effect for reducing the pollutant emission, in a short time. The adjustment industrial structure is usually known as one of the best way to reduce the pollutant emission.

The aim of this paper is to discuss how much pollutant can be abatement in current condition. In the second part, an optimization model was introduced. In third part, China's 39 industries were classified into four classes according to the results of factor analysis, then, the parameters of the four clusters were used to the optimization model.

2. MODEL FORMULATION

2.1. DATA PRE-PROCESSING

Figure1 shows the processes of data pre-processing. First, thirty nine (shown in Table 1) industries' APEI (atmospheric pollutant emission indicators) were calculated by using the data from the China Statistical Yearbook in 2010. Then, the factor analysis is used to research six APEI ($USDE_i$ (unit sulfur dioxide emission of industry i), USE_i (unit smoke emission of industry i), UDE_i (unit dust emission of industry i), $TSDE_i$ (total sulfur dioxide emission of industry i), TSE_i (total smoke emission of industry i) and TDE_i (total dust emission of industry i), $i = 1, 2, ..., 39$). This six APEI were condensed into 3 factors. And next, the cluster analysis was used to the factor scores. The thirty nine industries were clustered into four types industries. The parameters of four types of industries: unit sulfur dioxide emission of the jth kind industries, $USDE_j^0$, unit smoke emission of the jth kind industries, USE_j^0, unit dust emission of the ith kind industries, UDE_j^0, total sulfur dioxide emission of the jth kind industries, $TSDE_j^0$, total smoke emission of the jth kind industries, TSE_j^0, and total

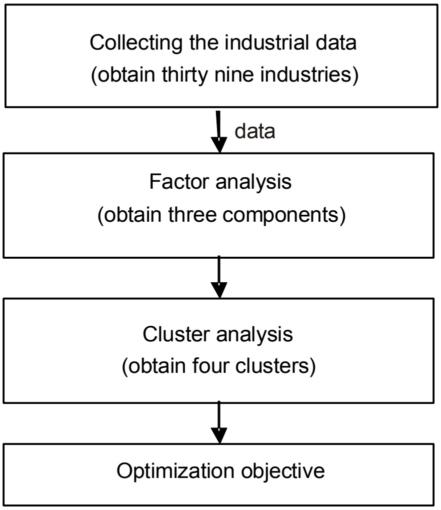

Fig. 1. Primary processes of data preprocessing

Table 1

Industries used for the initial solution

1	Coal mining and processing	21	Medicine manufacturing
2	Petroleum and nature gas extraction	22	Chemical fiber
3	Ferrous metals mining and dressing	23	Rubber production
4	Metals mining and dressing	24	Plastic production
5	Nonmetal minerals mining and dressing	25	Non-metallic mineral production
6	Other metals mining and dressing	26	Ferrous metal smelting and rolling processing
7	Agricultural and sideline foodstuffs processing	27	Non-ferrous metal smelting and rolling processing
8	Food manufacturing		
9	Beverage manufacturing	28	Metal production
10	Tobacco processing	29	Ordinary machinery
11	Textile	30	General equipment
12	Textile clothing, shoes and hats manufacturing	31	Transport equipment
13	Leather furs down and related production	32	Electric equipment and machinery
14	Wood, bamboo, rattan, and brown grass production	33	Other electronic equipment manufacturing
		34	Instruments manufacturing
15	Furniture manufacturing	35	Arts and grafts products and other manufacturing
16	Paper and paper production		
17	Printing industry and recording media	36	Out resource and material reclaim and processing
18	Cultural educational and sports goods		
19	Oil processing, coking and nuclear fuel processing	37	Electric power, heat power production and supply
20	Chemical materials and chemical products manufacturing	38	Fuel gas production and supply
		39	Water production and supply

dust emission of the *j*th kind industries TDE_j^0, $j = 1, 2, 3, 4$ were calculated following the results of the cluster analyses. Last, USDE_j^0, USE_j^0, UDE_j^0, TSDE_j^0, TSE_j^0, and TDE_j^0 were used for the optimization objective.

2.2. OPTIMUM OBJECTIVE

The objective function of single-objective optimization model is to maximize the total industrial output value (TIOV) over a specified planning horizon, and is presented as follows:

$$g_1 = \sum_{j=1}^{4} \mathrm{IOV}_4^0 \tag{1}$$

where g_1 is TIOV, its unit is one billion yuan; IOV_j^0 is the industrial output value of the *j*th kind industries, its unit is also one billion yuan. It is important to note that the above objective function is a linear equation. It is subject to the following constraints.

1. Economic indicators constraints

Industrial output value of each *j*th kind industries should be satisfied by the following inequality:

$$\mathrm{MEIOV}_j^0 \le \mathrm{IOV}_j^0 \le \mathrm{MEIOV}_j^1 \tag{2}$$

where MEIOV_j^0 and MEIOV_j^1 are the minimum expected industrial output value, and the maximum expected industrial output value of the *j*th industry, respectively. Their units are one billion yuan.

2. Atmospheric pollutant emission indicators constraints

The expected emission of total sulfur dioxide (EETSD), the expected emission of total smoke (EETS), and the expected emission of total dust emission (EETD) should be satisfied by the following inequalities:

$$\sum_{j=1}^{4} \left(\mathrm{USDE}_j^0 \times \mathrm{IOV}_j^0 \right) \le \mathrm{EETSD} \tag{3}$$

$$\sum_{j=1}^{4} \left(\mathrm{USE}_j^0 \times \mathrm{IOV}_j^0 \right) \le \mathrm{EETS} \tag{4}$$

$$\sum_{j=1}^{4} \left(\mathrm{UDE}_j^0 \times \mathrm{IOV}_j^0 \right) \le \mathrm{EETD} \tag{5}$$

where $USDE_j^0$, USE_j^0, and UDE_j^0 are the unit sulfur dioxide emission, the unit smoke emission, and the unit dust emission of the *j*th industry, respectively. Their unit is tons per one billion yuan. The unit of EETSD, EETS, and EETD is ton. Equations (3)–(5) are the constraints for sulfur dioxide emission, smoke emission, and dust emission, respectively.

3. CASE STUDIES BASED ON CHINA'S INDUSTRY

3.1. THE RESULT OF FACTOR ANALYSIS

$USDE_i$, USE_i, UDE_i, $TSDE_i$, TSE_i and TDE_i are selected as APEI in the factor analysis. Thirty nine industries APEI were calculated by using the data from the China Statistical Yearbook in 2010. It is assumed that each industrial output value should be increased by 8%. And $MEIOV_j^0$ is 1.08 of the corresponding industrial output value in 2010.

Table 2

Kaiser–Meyer–Olkin and Bartlett's in test result

KMO	0.572
Approximate Chi-Square	434.960
Degree of freedom	15
Significance	0.000

Table 2 shows the values of KMO and BTS. KMO value, 0.572, means that the degree of common variance among the six APEI was miserable, and if a factor analysis was conducted, the factors extracted would account for a small amount of variance [12].

Table 3

Total variance percentages of the component-rotated values

Component	Eigenvalue a	Variance $a/6\times100$ [%]	Cumulative variable [%]
1	3.501	58.351	58.351
2	1.704	28.404	86.755
3	0.754	12.574	99.329
4	0.028	0.460	99.788
5	0.009	0.147	99.935
6	0.004	0.065	100.000

Table 3 shows the initial solution values of the rotated factors. According to the rule [13] that eigenvalues should be more than one, only factors 1, 2 would be extracted but the third factor was extracted for its eigenvalues is 0.754, and its variance explained was 12.754%. The cumulative percentage of variance explained by these factors was 99.239%, meaning that a considerable amount of the common variance shared by the six APEI could be accounted for by these three factors. Table 3 also showed that component 1, component 2, and component 3 are 58.351%, 28.404%, and 12.754% of the total variance, respectively.

Table 4

Component score coefficient matrix

APEI	SO_2–TSE	Dust	USE
TSDE	0.989836	–	0.123982
TSE	0.961329	0.240576	0.10739
USDE	0.909039	–	0.391463
TDE	0.145342	0.986976	–
UDE	–	0.948753	0.302943
USE	0.282276	0.168411	0.942823

Factors were named by considering that what their variables had in common (Table 4). Factor 1, which had the strongest variation explanation level, includes three APEI ($USDE_i$, $TSDE_i$, and TSE_i) with their factor loads for 0.9090, 0.9898, and 0.9613, respectively. Thus, factor 1 is named as SO_2-TSE. Factor 2, which could be explained 28.404% of total variance, includes two APEI (UDE_i, TDE_i) for their factor loads 0.9488, and 0.9870, respectively. Thus, factor 2 is named as dust. The third factor is USE_i, with its factor loads 0.9428, named as U-smoke.

3.2. THE RESULT OF CLASSIFICATION ANALYSIS

Clustering analysis was applied to the three factors carried out from APEI of the 39 industries. The dendrogram is shown in Fig. 2. The three factor scores of industries examined appeared to cluster four groups, including a different number of objects. The first cluster contained 36 objects, while the second, third, and fourth ones contained only one, respectively. The industries of thirty-seven, six, and twenty-five are second, third, and fourth cluster, respectively. The other industries are the first cluster.

Table 5 shows that, the maximum score of first, second, and third factors of first cluster (the value are 0.7998, 1.0647, and 0.8926) are much smaller than that of the second cluster (the value is 5.7945), the fourth cluster (the value is 5.8788), and the third cluster (the value is 5.8662), respectively. Figure 3 is the three-dimensional image of which the coordinate axes are the first, second and third factor scores, respectively. According to Figure 2 and Table 5, the thirty-nine industries should be clustered into four clusters.

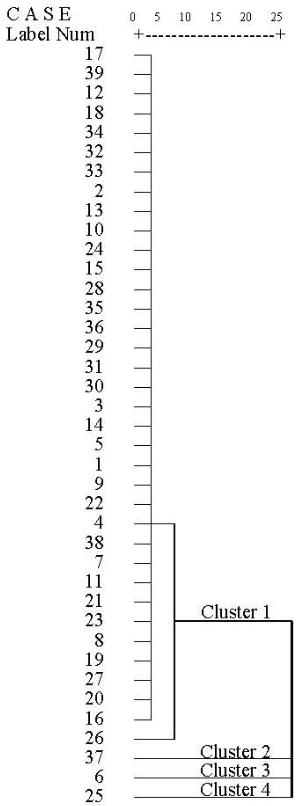

Fig. 2. Dendrogram of clustering analysis

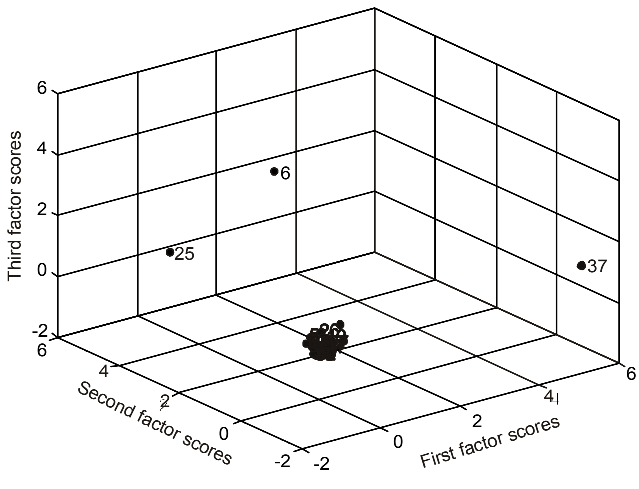

Fig. 3. Graphic model of three factor scores

Table 5

Factor scores of each industry

Industry	SO_2–TSE	Dust	USE	Industry	SO_2–TSE	Dust	USE
1	–0.18818	0.23064	–0.15174	21	–0.2034	–0.23528	–0.15137
2	–0.24712	–0.2225	–0.27114	22	–0.09427	–0.2911	0.02858
3	–0.25432	0.01518	–0.05374	23	–0.23703	–0.23326	–0.16828
4	–0.02259	–0.2068	–0.0105	24	–0.26342	–0.21406	–0.29976
5	–0.26363	0.00376	0.17418	25	0.67304	5.86617	–0.047
6	–1.08584	0.11396	5.87876	26	0.79981	1.06465	–0.51103
7	–0.12162	–0.21477	–0.24051	27	0.15643	–0.10483	–0.14941
8	–0.17208	–0.24489	–0.09271	28	–0.25116	–0.19649	–0.29073
9	–0.16731	–0.25907	0.02378	29	–0.24537	–0.15481	–0.3162
10	–0.27218	–0.21043	–0.28962	30	–0.25908	–0.17376	–0.30998
11	–0.05797	–0.23644	–0.18088	31	–0.24843	–0.16446	–0.33523
12	–0.27378	–0.21128	–0.31127	32	–0.27627	–0.20759	–0.332
13	–0.26591	–0.21701	–0.26978	33	–0.27833	–0.204	–0.33531
14	–0.27467	–0.11044	–0.09481	34	–0.28509	–0.20708	–0.32949
15	–0.28687	–0.20553	–0.28999	35	–0.29274	–0.15443	–0.30882
16	0.20497	–0.36384	0.62092	36	–0.28857	–0.17793	–0.30801
17	–0.28248	–0.2116	–0.31294	37	5.79451	–1.00357	0.89256
18	–0.28528	–0.20687	–0.32434	38	–0.25459	–0.20516	0.01872
19	0.1795	0.04549	–0.04975	39	–0.28676	–0.21071	–0.31455
20	0.47807	–0.07985	–0.18659				

3.3. THE RESULT OF THE OPTIMIZATION MODEL

According to the results of factor analysis and cluster analysis, the parameters (shown in Table 6) of USDE_j^0, USE_j^0, UDE_j^0, MEIOV_j^0, and MEIOV_j^1 were calculated[1]. When the output of cluster 1, 2, 3 and 4 industries increase by one billion yuan, their sulfur dioxide emission will be added by 122.31, 2790.45, 775.95, 646.13 tons, respectively. Similarly, the smoke emission of cluster 3 is 1399.86 tons, which is 316.45 tons more than the total smoke emission of cluster 1, 2, and 4. The dust emission of cluster 1, 2, 3, and 4 are 32.76, 2.01, 443.59, and 1243.94 tons, respectively. MEIOV_j^0 is limited to 80% of industrial output value in 2009. The minimum expected of cluster 1, 2, 3, and 4 industries are 39201.000, 2674.800, 1.112, and 1987.500 billion yuan.

[1] USDE_j^0 is calculated by Sulfur Dioxide Emission of Cluster j divided by corresponding industrial output value in 2010; USE_j^0 is calculated by Smoke Emission of Cluster j divided by corresponding industrial output value in 2010; UDE_j^0 is calculated by Dust Emission of Cluster j divided by corresponding industrial output value in 2010.

Table 6

USDE, USE, UDE, and IOV for the four clusters

Parameters	Cluster 1	Cluster 2	Cluster 3	Cluster 4
$USDE^0_i$ (Tons per one billion yuan)	122.31	2790.45	775.95	646.13
USE^0_i (Tons per one billion yuan)	46.63	664.42	1399.86	372.36
UDE^0_i (Tons per one billion yuan)	32.76	2.01	443.59	1243.94
$MEIOV_i^0$ (one billion yuan)	39201.00	2674.8	1.112	1987.5
$MEIOV_i^1$ (one billion yuan)	infinite			

Table 7

The result of optimization for twenty-seven kinds of reduction targets combinations

Com-bination	Reduction targets [%]			Optimized objective (one billion yuan)					Pollutant emission [tons]		
	SO_2	Smoke	Dust	TIOV	IOV_1	IOV_2	IOV_3	IOV_4	SO_2	Smoke	Dust
1	0	0	0	6.7×10^4	6.3×10^4	2.7×10^3	1.2	2.0×10^3	1.6×10^7	5.4×10^6	4.5×10^6
2	0	0	10	5.9×10^4	5.4×10^4	3.2×10^3	1.1	2.0×10^3	1.7×10^7	5.4×10^6	4.2×10^6
3	0	0	15	5.2×10^4	4.6×10^4	3.5×10^3	1.2	2.0×10^3	1.7×10^7	5.3×10^6	4.0×10^6
4	0	10	0	5.6×10^4	5.1×10^4	2.7×10^3	1.1	2.0×10^3	1.5×10^7	4.9×10^6	4.1×10^6
5	0	10	10	5.6×10^4	5.1×10^4	2.7×10^3	1.1	2.0×10^3	1.5×10^7	4.9×10^6	4.1×10^6
6	0	10	15	5.1×10^4	4.6×10^4	3.0×10^3	1.1	2.0×10^3	1.5×10^7	4.9×10^6	4.0×10^6
7	0	15	0	5.0×10^4	4.5×10^4	2.7×10^3	1.1	2.0×10^3	1.4×10^7	4.6×10^6	4.0×10^6
8	0	15	10	5.0×10^4	4.5×10^4	2.7×10^3	1.1	2.0×10^3	1.4×10^7	4.6×10^6	4.0×10^6
9	0	15	15	5.0×10^4	4.5×10^4	2.7×10^3	1.1	2.0×10^3	1.4×10^7	4.6×10^6	4.0×10^6
10	10	0	0	5.8×10^4	5.3×10^4	2.7×10^3	1.1	2.0×10^3	1.5×10^7	5.0×10^6	4.2×10^6
11	10	0	10	5.8×10^4	5.3×10^4	2.7×10^3	2.7	2.0×10^3	1.5×10^7	5.0×10^6	4.2×10^6
12	10	0	15	5.1×10^4	4.6×10^4	3.0×10^3	10.3	2.0×10^3	1.5×10^7	4.9×10^6	4.0×10^6
13	10	10	0	5.6×10^4	5.1×10^4	2.7×10^3	1.1	2.0×10^3	1.5×10^7	4.9×10^6	4.1×10^6
14	10	10	10	5.5×10^4	5.1×10^4	2.7×10^3	1.4	2.0×10^3	1.5×10^7	4.9×10^6	4.1×10^6
15	10	10	15	5.1×10^4	4.6×10^4	3.0×10^3	1.1	2.0×10^3	1.5×10^7	4.9×10^6	4.0×10^6
16	10	15	0	5.0×10^4	4.5×10^4	2.7×10^3	1.1	2.0×10^3	1.4×10^7	4.6×10^6	4.0×10^6
17	10	15	10	5.0×10^4	4.5×10^4	2.7×10^3	1.1	2.0×10^3	1.4×10^7	4.6×10^6	4.0×10^6
18	10	15	15	5.0×10^4	4.5×10^4	2.7×10^3	1.1	2.0×10^3	1.4×10^7	4.6×10^6	4.0×10^6
19	15	0	0	5.1×10^4	4.6×10^4	2.7×10^3	1.1	2.0×10^3	1.4×10^7	4.7×10^6	4.0×10^6
20	15	0	10	5.1×10^4	4.6×10^4	2.7×10^3	1.6	2.0×10^3	1.4×10^7	4.7×10^6	4.0×10^6
21	15	0	15	5.1×10^4	4.6×10^4	2.7×10^3	17.8	2.0×10^3	1.4×10^7	4.7×10^6	4.0×10^6
22	15	10	0	5.1×10^4	4.6×10^4	2.7×10^3	1.1	2.0×10^3	1.4×10^7	4.7×10^6	4.0×10^6
23	15	10	10	5.1×10^4	4.6×10^4	2.7×10^3	1.1	2.0×10^3	1.4×10^7	4.7×10^6	4.0×10^6
24	15	10	15	5.1×10^4	4.6×10^4	2.7×10^3	1.1	2.0×10^3	1.4×10^7	4.7×10^6	4.0×10^6
25	15	15	0	5.0×10^4	4.5×10^4	2.7×10^3	1.1	2.0×10^3	1.4×10^7	4.6×10^6	4.0×10^6
26	15	15	10	5.0×10^4	4.5×10^4	2.7×10^3	1.1	2.0×10^3	1.4×10^7	4.6×10^6	4.0×10^6
27	15	15	15	5.0×10^4	4.5×10^4	2.7×10^3	1.1	2.0×10^3	1.4×10^7	4.6×10^6	4.0×10^6

In the single-objective optimization model, EESD, EES, EED, $MEIOV_j^0$, and $MEIOV_j^1$ are the constraints; the TIOV is the objective function. The feasible region, which varying with the constraints, determines the result of optimization. In order to get really optimum results, three pollutant reduction targets (0%, 10%, and 15%) were set, and there are twenty seven combinations (Table 7). The TIOV of combination 1, 2, 4, 5, 10, 11, 13, and 14 are 67168.65, 58738.84, 55517.41, 55517.42, 57706.42, 57669.68, 55517.41 and 55497.15 billion yuan, respectively, which are more than 54831.14 billion yuan (the TIOV in 2009). The TIOV of the other combinations are all lower than 54831.14 billion yuan.

If the emission of SO_2, smoke, and dust are not limited (as combination 1 shown), the TIOV is 67168.65 billion yuan, which will increase by 22.50% compared with the TIOV in 2009. If only the emission of SO_2, or smoke, or dust is limited to 90% of its emission in 2009 (as combination 10, 4, and 2 shown), the TIOV are 57706.42, 55517.41, and 58738.84 billion yuan, respectively. Compared with the TIOV in 2009, the TIOV are increased by 5.24%, 1.25%, and 7.13%, respectively. If both the emission of smoke and dust, or SO_2 and dust, SO_2 and smoke are limited to 90% of their emission in 2009 (as combination 5, 11, and 13 shown), the TIOV are 55517.42, 57669.68, and 55517.41 billion yuan, which are increase by 1.25%, 5.18%, and 1.25%, respectively. If all of the emission of SO_2, smoke, and dust are limited to 90% of their emission in 2009 (as combination 14 shown), the TIOV is 55497.15 billion yuan, which increase by only 1.21%.

4. DISCUSSION

It is difficult to reduce vast SO_2, smoke, and dust (15% of total in 2009) with TIOV growth. It is urgent to reduce the unit pollutant emission by technological innovation. Although, the overall technical level of industry has been greatly improved in line with the developments in science and technology since the Reform and Open Policy in 1978, the use efficiency of raw material is lowest among the major industrialized countries in high pollutant emission industries such as other metals mining and dressing industry, Non-metallic mineral production industry, and electric power, heat power production and supply industry [14]. The direct way to close the technical gap is to lower the tariff on importing advanced technologyies which can encourage companies to introduce it. But, developing education and applying the result of scientific researches to industrial production are the long-term planning for improving our technology [14].

The combinations 4, 5, 13, and 14 have two things in common. One is that their reduction targets of smoke is 10%, the other is that their optimization objective (TIOV) are close to 55, 500 billion yuan. Similarly, the combinations 2, 10, and 11 also have two things in common. Except the targets of smoke is 0%, the optimization objective (TIOV) are close to 57, 700 billion yuan. So, it can be thought that the reduction targets of smoke is the limiting constrains. The way to remove the limited constrains, is to shrink the parameter of smoke emission according to introduce the lower smoke emission technique.

Form Table 6, it is known that the USE^0_i of cluster 1, 2, 3, and 4 are 46.63, 664.42, 1399.86, and 372.36 tons per one billion yuan. On the surface, it is most reasonable to decrease the USE_3^0. The $MEIOV_3^0$, 1.112 billion yuan, far below the other minimum expected industrial output value, and the total smoke emission of cluster 3 is very little. As $MEIOV_1^0$ is 46.63 tons per one billion yuan, it is infeasible in technically and economically as the bottleneck of technology. So, the reasonable and feasible way to solve the problem is to introduce the lower smoke emission technique of the cluster 2 and 4 industries (i.e. non-metallic mineral production industry and electric power, heat power production and supply industry).

Industrial structure change, the same as the technical innovation and production scale change, is the possible way to reduce pollutant emission [15, 16]. From the result of optimization objective, it is known that readjusting the industrial structure can reduce the emission of SO_2, smoke, and dust about 10% with economic growth. Under the existing circumstances, if the reduction target is higher than 15%, it is not possible to keep economic growth, continuously. Industrial structure, technology, and production scale are the three main factors to reduce the pollutant emission. Following the population rising and living level improved, the demands of industrial production have been increasing rapidly. Thus it is unreasonable to reduce the pollutant emission by reducing scale of production. Readjusting the industrial structure can only reduce pollutant emission within a small extent (in this case, it is about 10%). The most reasonable way to reduce the pollutant emission is to lower the parameters of USE_2^0 and USE_4^0 by the technical innovation.

5. CONCLUSIONS

From the results and discussion, it can be concluded that it is unreasonable to decrease the pollutant emission by dwindling the scale of industrial production. Reducing the pollutant emission by adjusting the industrial structure is based on the innovation technology. After adjusting the industrial structure, it is necessary to lower the parameters of optimization by innovation technology in some industry.

Now, the air pollutant emission can only be decreased by 10% by adjusting the industrial structure. The parameters of smoke emission are the limited constrains for the optimization. The reasonable and feasible way to solve the problem is to introduce the lower smoke emission technique of the cluster 2 and 4 industries (i.e. non-metallic

Mineral Production industry and electric power, heat power production and supply industry).

SYMBOLS

EKC – environmental Kuznets curves
KMO – Kaiser–Meyer–Olkin
BTS – Bartlett's test of sphericity
TIOV – total industry output value, one billion yuan
TSDE – total sulfur dioxide emission, tons
TDE – total dust emission, tons
TSE – total smoke emission, tons
OVI_j – output value of the *j*th kind industries, one billion yuan
OVI_j^0 – output value of the *j*th kind industries, one billion yuan
$MEOVI_j^0$ – minimum expect of output value in the *j*th kind industries, one billion yuan
$MEOVI_j^1$ – maximum expect of output value in the *j*th kind industries, one billion yuan
$USDE_i$ – unit sulfur dioxide emission in industry *i*, tons per one billion yuan
SDE_i – unit smoke emission in industry *i*, tons per one billion yuan
USE_i – unit dust emission in industry *i*, tons per one billion yuan
TSE_i – total smoke emission in industry *i*, tons
$TSDE_i$ – total sulfur dioxide emission in industry *i*, tons
TDE_i – total dust emission in industry *i*, tons
$USDE_j^0$ – unit sulfur dioxide emission in the *j*th kind Industries, tons per one billion yuan
USE_j^0 – unit smoke emission in the *j*th kind Industries, tons per one billion yuan
UDE_j^0 – unit dust emission in the *j*th kind Industries, tons per one billion yuan
$TSDE_j^0$ – total sulfur dioxide emission in the *j*th kind industries, tons
TSE_j^0 – total smoke emission in the *j*th kind industries, tons
TDE_j^0 – total dust emission in the *j*th kind industries, tons
EETSD – expected emission of total sulfur dioxide, tons
EETS – expected emission of total smoke, tons
EETD – expected emission of dust, tons

REFERENCES

[1] RAM E., JAMES S., *The environmental Kuznets curve when the environment exhibits hysteresis*, Ecol. Econ., 2007, 64 (1), 204.
[2] HARBAUGH W.T., LEVINSON A., WILSON D.M., *Reexamining the empirical evidence for an environmental Kuznets Curve*, Rev. Econ. Stat., 2002, 84 (3), 541.
[3] DINDA S., *Environmental Kuznets curve hypothesis: A survey*, Ecol. Econ., 2004, 49 (4), 431.
[4] EDWARD B.B., *Poverty, development, and environment*, Environ. Dev. Ec., 2010, 15 (6), 635.
[5] BRUNO M., TOM V., MARC D.C., T*he EKC for* SO_2*: Does firm size matter?*, Ecol. Econ., 2006, 59 (4), 451.

[6] GROSSMAN G.M., KRUEGER A.B., *The inverted-U: What does it mean*?, Environ. Dev. Ec., 1996, 1 (1), 119.
[7] AMY K.R., ROBERT K.K., *Is there a turning point in the relationship between income and energy use and/or carbon emission?*, Ecol. Econ., 2006, 56 (2), 176.
[8] ANDREONI J., LEVINSON A., *The simple analytics of the environmental Kuznets curve*, J. Public Econ., 2001, 80 (2), 269.
[9] DENG S.H., ZHANG J., SHEN F., GUO H., LI Y.W., XIAO H., *Relationship between industry structure, household-number and energy consumption in China*, Energ. Source, Part B, 2011, DOI: 10.1080/15567249.2010.533330.
[10] FRONDEL M., HORBACH J., RENNINGS K., *End-of-Pipe or Clearer Production? An Empirical Comparison of Environmental Innovation Decisions Across OECD Countries*, Bus. Strategy Environ., 2007, 16 (8), 571.
[11] GONZÁLEZ P., *The empirical analysis of the determinants for environmental technological change: A research agenda*, Ecol. Econ., 2009, 68 (3), 861.
[12] OCAL M.E., ORAL E.L., ERDIS E., VURAL G., *Industry financial ratios-application of factor analysis in Turkish construction industry*, Build. Environ., 2007, 42 (1), 385.
[13] THOEFNER M.B., ERSBOLL A.K., JENSEN A.L., HESSELHOLT M., *Factor analysis of the interrelationships between clinical variables in horses with colic*, Prev. Vet. Med., 2001, 48 (3), 201.
[14] ZHANG J., DENG S.H., SHEN F., YANG X.Y., LIU G.D., GUO H., LI Y.W., XIAO H., ZHANG Y.Z., PENG H., ZHANG X.H., LI L., WANG Y.J., *Modeling the relationship between energy consumption and economy development in China*, Energy, 2011, 36 (7), 4227.
[15] JOSHUA F., *Is there an "animal welfare Kuznets curve"?*, Ecol. Econ., 2008, 66 (2), 478.
[16] ZHANG J., LIU G.D., GUO H., LIU L., DENG S.H., *A theoretical basis for the relationship between the industrial pollutant generation, abatement, emission and economy*, Clean Techn. Environ. Policy, 2012, DOI: 10.1007/s10098-012-0536-8.