An Empirical Emission Analysis Model for Hebei Provincial Industries in China

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Abstract - **With a population of 67 million people, Hebei is one of largest provinces in China, with a rapid growth in economy. The 2005 provincial GDP and industrial value creation increased respectively 3.2 and 1.8 times over the 2000 level, which indicates a fantastic developing speed. However, there is an environmental challenge also has accompanied with economic growth. This challenge is nowadays an urgent issue to deal for further economic development. According to the national 2005 statistics in China, the provincial emissions for industrial wasting gas, CO2, industrial dusts and industrial soot are placed as number 1, 5, 6 and 2 respectively in a national ranking. These ranks indicate a fact of the total emission level is much higher in Hebei province than the rest of China.**

This paper introduces an empirical analysis model for static industrial emissions for Hebei industries. The model consists of a number of measurable variables, such as GDP, industrial value creation, emission coefficient and probability deviations. Based on the available data sourced by provincial and national statistics for industrial outcome, the model is used to analyze the basic structure, mainstream and correlations of total industrial emissions, types of industries and return of investments for emission control and treatment, as well as environmental projects.

The analysis model provides also the fundamental information for decision making process in further investments for industries, macro-level governing of industrial structures, restructuring the provincial industrial sectors and better utilizing of natural resources. The study analysis concluded there is still a need for limitation for total emissions for the provincial industries and the ways for realizing is upgrading of total industrial productivities and efficiencies. Our analysis also recommends more investments for emissions control and treatment projects, as well as restructuring of provincial industries from heavy production based into new innovation based.

Key words - Emission, Empirical analysis, Industrial Waste Gas, Treatment

GENERAL SITUATION OF EMISSION OF INDUSTRIAL WASTE GAS AND OUTPUTS IN HEIBEI PROVINCE

As rest of China, the industry economy of Heibei province has been developed in a very fast speed for the last decades. In 2005, the provincial Gross Industrial Output Value was calculated as 1,100 billion RMB (equal to 143 billion USD) and the Value-added Industry Creation was calculated as 322 billion RMB (equal to 42 billion USD). Both indicators were approximately 3.2 times and 1.8 times respectively than the 2000 levels.

At the same time, this high speed industrial growth has also brought the environment issues companied with the achievement. As environment becomes a global issue for debates and it has huge impact to climate, sustainability, ethics and even legal consequence [1]. The pollution issue is a severe focus and there is indeed a need to reduce the pollutions and in a long term view, eliminate it. To start with, it is necessary to define the measurable variables and standards for pollution measurement. According to the National Bureau of statistics of China's standard criterion, a most common pollution source is defined as industrial waste gas, which includes:

1) Industrial SO_2, measured in cubic meters;
2) Industrial soot, measured in ton;
3) Industrial dust, measured in ton

The total industrial waste gas emission in China for 2005 was measured as 2651.8 billion cubic meters, the volume of emission of industrial SO_2 was amounted to 1.281 million tons, the volume of emission of industrial soot was amounted to 0.56 million tons and the volume of emission of industrial dust amount to 0.713 million tons.

Among these measurements, Hebei provincial industries have occupies national ranking in 1st, 5th, 5th and 2nd places, respectively, see details in Figure 1, 2, 3, 4. According to 2004 Chinese environment statistic annuals, the industrial SO_2 emission intensity is 0.0274 ton/10000 RMB, the industrial soot emission is 0.0122 ton/10000 RMB, the industrial dust emission intensity is 0.016423 ton/10000 RMB, respectively higher than the national average emission 29.9%, 23.2% and 61.4%. The data above indicated that Hebei province is still in the stage of extensive mode of industry economy growth.

The eleventh five-year plan of Hebei province indicated that Hebei should protect environment, build a resource conservation and environment friendly society, insist sustainable development and new industrialization path. In order to realize this object, there is a practical significance to

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do empirical Analysis of Emission and Treatment of industrial Waste Gas of Hebei province.

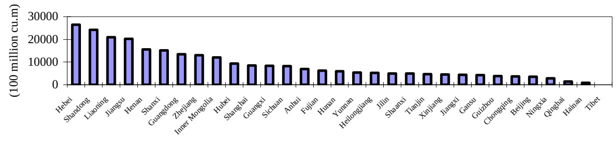

FIGURE 1

Aarrangement of the total volume of industrial waste gas emission in Chinese province (region, city) in 2005

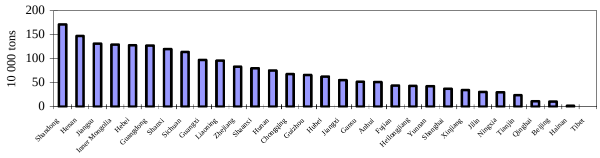

FIGURE 2

Aarrangement of volume of industrial SO2 emission in Chinese province (region, city) in 2005

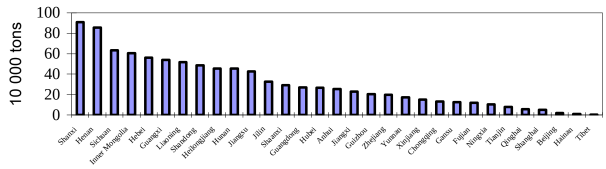

FIGURE 3

Aarrangement of volume of industrial soot emission in Chinese province (region, city) in 2005

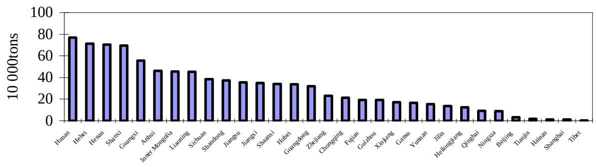

FIGURE 4

Aarrangement of volume of industrial dust emission in Chinese province (region, city) in 2005

EMPIRICAL ANALYSIS OF EMISSION OF INDUSTRIAL WASTE GAS IN HEBEI PROVINCE

Static econometrical model analysis of emission of industrial waste gas

If technical level is constant, the volume of industrial waste gas emission is in direct ratio to Gross Industrial Output Value or Value-added of Industry. So below model of industrial waste gas emission can be established as:

$$Y=\beta 0+\beta 1X1+\varepsilon 1$$

$$Y=\beta 2+\beta 3X2+\varepsilon 2$$

Among:

Y expresses total volume of industrial waste gas emission.

X_1 expresses Gross Industrial Output Value.

X_2 expresses Value-added of Industry.

ε_1 and ε_2 express disturbance.

β_1 is direct emission intensity, it expresses the volume of industrial waste gas emission per industry product produced, reflects the direct emission intensity in industry department producing its products. It is direct-viewing and its physical significance is specific, it is supposed to be a invariable under invariable technical level.

β_3 is Value-added emission intensity, it expresses the volume of industrial waste gas emission per Value-added created. Compare with direct emission intensity, it can reflect the economy benefit of industrial waste gas emission of industry department better. In situation of taking GDP of Value-added caliber as the goal of economy development, there is more pertinence to use Value-added emission intensity to study new industrialization path and environment friendly society. In itself, Value-added emission intensity is direct emission intensity. Its physical significance is less clear than direct emission intensity, which takes Gross Industrial Output Value as foundation, but its economical significance is more important. It is supposed to be a invariable under invariable technical level too.

TABLE I

DATA OF 1995-2005 HEBEI PROVINCE INDUSTRIAL OUTPUT VALUE AND THE VOLUME OF INDUSTRIAL WASTE GAS EMISSION

Year	Gross Industrial Output Value X_1 (100 million RMB)	Value-added of Industry X_2 (100 million RMB)	total volume of industrial waste gas emission Y (100 million cu.m)	volume of emission of industrial SO_2 Y_1 (10000 ton)	volume of emission of industrial soot Y_2 (10000 ton)	volume of emission of industrial Y_3 (10000 ton)
1995	2240.14	701.48	7369.97	94.41	44.56	37.11
1996	2677.71	863.75	7889.48	98.27	43.59	36.17
1997	3014.23	984.19	9064.02	125.19	79.62	98.73
1998	2719.1	889.07	9386.84	119.11	74.72	100.69
1999	2994.58	976.57	9032.33	111.66	71.45	90.69
2000	3426.05	1132.63	9858.27	113.36	67.22	81.27
2001	3766.85	1244.14	11456.79	109.59	55.24	67.3
2002	4294.68	1413.48	12743.32	105.34	54.54	63.02
2003	5708.8	1801.7	16057.46	120.16	54.27	65.87
2004	7846.4	2459.15	21713.71	120.82	53.91	72.06
2005	11007.98	3219	26518	128.1	56.0	71.3

Data source: 1996-2006 Economy annals of Hebei province, National Bureau of statistics of China.

According to data of 1995-2005 Gross Industrial Output Value, Value-added of Industry, the total volume of industrial waste gas emission, industrial SO_2 emission, industrial soot emission and industrial dust emission in Hebei province (Table 1), we used Eviews3.1 to regression analysis, the output result can be seen in Table 2 and Table 3. So we can establish below regression models respectively:

$$Y = 2.27579215*X1 + 2544.658171 \quad (1)$$

$$Y = 7.910243885*X2 + 1546.977184 \quad (2)$$

TABLE 2
EVIEWS3.1 OUTPUT RESULT

Variable	Coefficient	Std. Error	t-Statistic	Prob.
X1	2.275792	0.087106	26.12682	0.0000
C	2544.658	452.8716	5.618940	0.0003
R-squared	0.986987	Mean dependent var		12826.38
Adjusted R-squared	0.985541	S.D. dependent var		6181.451
S.E. of regression	743.2922	Akaike info criterion		16.22302
Sum squared resid	4972349.	Schwarz criterion		16.29537
Log likelihood	-87.22662	F-statistic		682.6107
Durbin-Watson stat	1.891782	Prob(F-statistic)		0.000000

TABLE 3
EVIEWS3.1 OUTPUT RESULT

Variable	Coefficient	Std. Error	t-Statistic	Prob.
X2	7.910244	0.206975	38.21829	0.0000
C	1546.977	332.7740	4.648732	0.0012
R-squared	0.993876	Mean dependent var		12826.38
Adjusted R-squared	0.993196	S.D. dependent var		6181.451
S.E. of regression	509.9003	Akaike info criterion		15.46927
Sum squared resid	2339985.	Schwarz criterion		15.54162
Log likelihood	-83.08100	F-statistic		1460.637
Durbin-Watson stat	2.260545	Prob(F-statistic)		0.000000

We test the sample regression equation (1), (2):

Test of Economical significance: $\hat{\beta}_1=2.275792>0$, $\hat{\beta}_3=7.910244>0$, they express the volume of industrial waste gas emission is in direct ratio to Gross Industrial Output Value or Value-added of Industry, so the expression of regression coefficient accords with economy theory and experience expectation.

Test of goodness of fit: according to Table 2 and Table 3, R-squared ① = 0.986987 , R-squared ② = 0.993876 , Adjusted R-squared① = 0.985541 , Adjusted R-squared② = 0.993196, result indicate that 99% of total sum of squares are explained by sample regression line, only 1% is not explained, obviously, the goodness of fit of sample regression model is very high.

T test: given significance level $\alpha = 0.05$, we check t distributing table on degrees of freedom $\nu = 11-2=9$, gain $t_{0.025}(9) = 2.26$, according to table 2 and table 3, $t_0=5.618940>t_{0.025}(9)$, $t_1=26.12682> t_{0.025}(9)$, $t_2=4.648732> t_{0.025}(9)$, $t_3=38.21829> t_{0.025}(9)$, so regression coefficients of two model have significance and are not equal to zero, model should contain absolute term, X_1 and X_2 have significant effect on Y respectively.

According to above test, these two models are relatively good.

Static econometrical models of emission of industrial waste gas reflects the relation between total volume of industrial waste gas emission and Gross Industrial Output Value, the relation between total volume of industrial waste gas emission and Value-added of Industry. Direct emission intensity and Value-added emission intensity both have significance, and $\hat{\beta}_3 > \hat{\beta}_1$, they indicate that the treatment level of total volume of industrial waste gas emission hasn't been improved essentially from 1995 to 2005 in Hebei province , that economical benefit of industrial waste gas emission is low.

Dynamic econometrical model analysis of emission of industrial waste gas

If technical level is variable, direct emission intensity and Value-added emission intensity will change. According to Table 1, we can calculate annual direct emission intensity of industrial SO_2, industrial soot and industrial dust from 1995 to 2000 (Figure 5). The below dynamic econometrical model of emission of industrial waste gas can be established:

$$Yi=Ci+f_{1i}(q)X1+\varepsilon_i \quad (i=1,2,3) \quad (3)$$

$$Yi=Ci+f_{2i}(q)X2+u_i \quad (i=1,2,3) \quad (4)$$

Among: i=1,2,3 expresses the dynamic econometrical model of emission of industrial SO_2, industrial soot and industrial dust respectively in the model.

Y_i expresses the volume of emission of different kind of industrial waste gas.

X_1 expresses Gross Industrial Output Value.

X_2 expresses Value-added of Industry.

ε_i and u_i express disturbance.

$f_{1i}(q)$ expresses direct emission intensity, it is the function of current year investment amount q of treatment project of industrial waste gas. $f_{2i}(q)$ expresses Value-added emission intensity, it is the function of current year investment amount q of treatment project of industrial waste gas too.

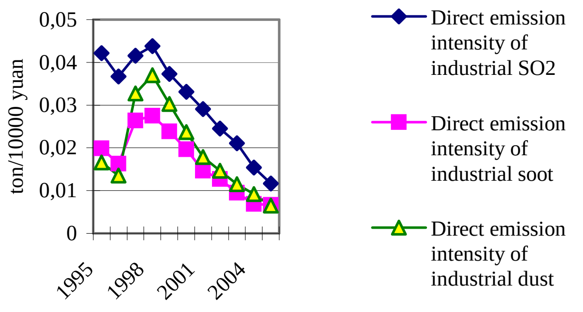

FIGURE 5
1995 2005 DIRECT EMISSION INTENSITY OF INDUSTRIAL WASTE GAS IN HEBEI

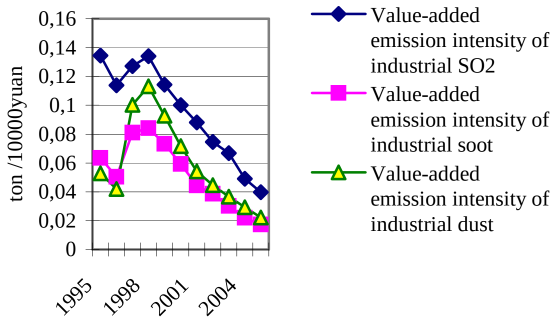

Figure 6

1995 2005 VALUE-ADDED EMISSION INTENSITY OF INDUSTRIAL WASTE GAS

We can get differential from both sides of equation (3) and equation (4):

$$\Delta Y_i = f'_{1i} \Delta q + f_{1i}(q) \Delta X_1$$

$$\Delta Y_i = f'_{2i} \Delta q + f_{2i}(q) \Delta X_2$$

X_1 and X_2 are exogenous variables, the tendency of f_{1i} and f_{2i} are mainly consistent as well as the tendency of emission intensity of three kind of waste gas according to Figure 5 and Figure6, so we will take $f_{11}(q)$ for instance to analysis in following text.

According to data of Hebei province 1995-2004 direct emission intensity of industrial SO_2 and current year investment amount q of treatment project of industrial waste gas (Table 4), we can establish following model of direct emission intensity:

$$f_{11} = C_{10} + C_{11} q + v$$

Among : v expresses disturbance

We used Eviews3.1 to regression analysis, the output result can be seen in Table 5, establish below regression model:

$$f_{11} = -3.984559717e\text{-}07 * q + 0.04676837655$$

TABLE 4

HEBEI PROVINCE 1995-2004 DIRECT EMISSION INTENSITY OF INDUSTRIAL SO2 AND CURRENT YEAR INVESTMENT COST Q OF TREATMENT PROJECT OF INDUSTRIAL WASTE GAS

Year	current year investment cost q of treatment project of industrial waste gas (10000RMB)	direct emission intensity of industrial SO_2 f_{11} (ton/10000RMB)
1995	16031.4	0.042144687
1996	14245.3	0.036699269
1997	28589.5	0.041532995
1998	12854.2	0.043804935
1999	32805.6	0.037287366
2000	33590.6	0.033087667
2001	34443.8	0.029093274
2002	46612.8	0.024528021
2003	53370.1	0.021048206
2004	86490.6	0.015398144

TABLE 5

EVIEWS3.1 OUTPUT RESULT

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Q	-3.98E-07	6.19E-08	-6.433060	0.0002
C	0.046768	0.002579	18.13533	0.0000
R-squared	0.838005	Mean dependent var		0.032462
Adjusted R-squared	0.817756	S.D. dependent var		0.009673
S.E. of regression	0.004129	Akaike info criterion		-7.964539
Sum squared resid	0.000136	Schwarz criterion		-7.904022
Log likelihood	41.82269	F-statistic		41.38426
Durbin-Watson stat	1.857251	Prob(F-statistic)		0.000202

Test of Economical significance: C_{11} = -3.984559717e-07<0, expresses with investment cost increase 10,000RMB, technical level will be enhanced, as a result, the direct emission intensity of industrial SO_2 will reduce -3.984559717e-07. It accords with economy theory and experience expectation.

Test of goodness of fit: R-squared = 0.838005 , Adjusted R-squared = 0.817756, indicates the goodness of fit of sample regression model is very high.

T test: given significance level $\alpha = 0.05$, we check t distributing table on degrees of freedom$v$ =10-2=8, $t_{0.025(8)}$ = 2.31,obviously, t_{c1}=-6.433060>2.31,t_c=18.13533>2.31,indicates current year investment amount q of treatment project of industrial waste gas has significant effect on f_{11}direct emission intensity of industrial SO_2.

The same principle may result in, according to data of 1998-2004 Table 1 and Table 4, we can establish following sample regression model of direct emission intensity of industrial soot and industrial dust:

$$f_{12} = -2.902406639e\text{-}07 * q + 0.02883169108$$

$$(-4.219143) \qquad (8.750663) \qquad R2=0.780713$$

$$f_{13} = -3.803355946e\text{-}07 * q + 0.03692335967$$

$$(-3.708096) \qquad (7.516056) \qquad R2=0.733333$$

What dynamic econometrical model analysis of emission of industrial waste gas measures are the alteration of direct emission intensity or Value-added emission intensity caused by alteration of treatment investment cost, the influence on the volume of waste gas emission. According to above analysis, the investment cost of treatment of waste gas has significant influence on waste gas emission intensity. $|C11| > |C13| > |C12|$, Therefore, investment cost have most influence on direct emission intensity of industrial SO2, have certain influence on direct emission intensity of industrial dust, and have less influence on direct emission intensity of industrial soot relatively.

Structure analysis of emission of industrial waste gas

In 2004, among the national industry profession, the first 5 professions of the volume of industrial SO_2 emission are the electric power industry, non-metallic mineral product industry, ferrous metals melting industry, chemical manufacturing industry, non-ferrous metals melting industry; the first 3 professions of the volume of industrial soot emission are the electric power industry, the non-metallic mineral product industry, ferrous metal smelting and the rolling processing industry; the first 2 professions of volume of industrial dust emission are non-metallic mineral product industry, ferrous metal smelting industry.

In 2004, the data of gross value of industrial output in Hebei province and the first 5 industrial professions situation can be seen in table 6, obviously, industry structure of Hebei Province by the high pollution profession primarily, the gross value of industrial output of high pollution professions account for the total output value of entire province industry 47.02%. Industry structure of Hebei Province determines the emission of industrial waste gas volume and composing proportion on certain degree.

TABLE 6
2004 GROSS VALUE OF TOTAL PROVINCE INDUSTRIAL OUTPUT AND THE FIRST 5 INDUSTRY PROFESSIONS IN HEBEI

Grouped by Sector	Gross value of industrial output (100 Million)	Style of industrial waste gas
Province total	7846.4	
Smelting and Pressing of Ferrous Metals	2422.6	SO_2, soot, dust
Manufacture of chemical industry	460.5	SO_2,
Production and Distribution of Electric Power and Heat Power	434.6	SO_2, soot,
Processing of Food from Agricultural Products	388.3	
Manufacture of Non-metallic Mineral Products	372.0	SO_2, soot, dust

EMPIRICAL ANALYSIS OF TREATMENT OF INDUSTRIAL WASTE GAS IN HEBEI PROVINCE

Analysis of Industrial waste gas treatment efficiency in Hebei province

Take 2004 as the example, in Hebei Province, the data of treatment efficiency of industrial waste gas comparing with the national top and average treatment efficiency can be seen in Figure 7, obviously, in Hebei, the rate of emission of industrial soot meeting discharge standard has achieved the domestic advanced level, the rate of emission of industrial SO2 and industrial dust meeting discharge standard is higher than the national average level, but still exists 15.6%and 11.4% disparities with the domestic advanced level respectively.

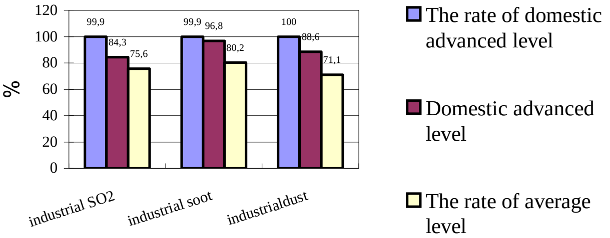

FIGURE 7
2004 THE COMPRAISON OF INDUSTRIAL WASTE GAS MEETING DISCHARGE STANDARD

Analysis of investment of industrial waste gas treatment in Hebei province

In 2004, the data of investment source of treatment project of industrial waste gas in Hebei Province can be seen Figure 8, investment source by the enterprise self-provides and the environmental protection special fund primarily, enterprise self-provides fund is 971 billion RMB (equal to 126 billion USD), which accounts for 74% in total sources, environmental protection special fund is 231 billion RMB (30 billion USD), accounts for 18% in total sources.

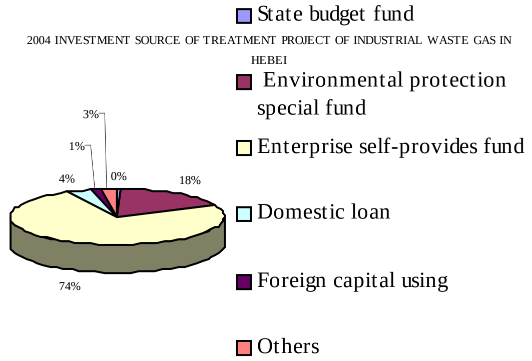

FIGURE 8
2004 INVESTMENT SOURCE OF TREATMENT PROJECT OF INDUSTRIAL WASTE GAS IN HEBEI

From 1995 to2004, the tendency of proportion that investment cost of treatment of industry waste gas investment occupies total investment of pollution treatment in Hebei province can be seen in Figure 9.

In 2004, its proportion increases approximately 28-percentage points comparing to 1995. Obviously, it increases the cost proportion of industrial waste gas treatment investment in the general tendency. This has reflecting in the investment cost, which representing a changeable and dynamic econometrical model analysis of emission of industrial waste gas.

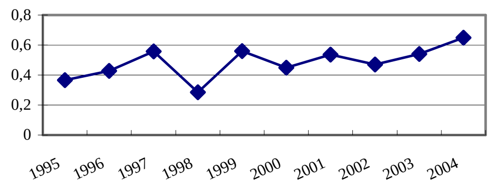

FIGURE 9
1995　2004 THE TENDENCY OF PROPORTION THAT INVESTMENT COST OF TREATMENT OF INDUSTRY WASTE GAS INVESTMENT OCCUPIES TOTAL INVESTMENT OF POLLUTION TREATMENT IN HEBEI

CONCLUSION AND MEASURES

According to the static and dynamic econometrical model analysis of emission of industrial waste gas, the structure analysis of emission of industrial waste gas and the analysis of efficiency and investment of treatment, we can get to draw a conclusion as follow:

1. The current study can be developed and used as a case study for a part of higher education syllabus, such as course in environment management. The definitions in industrial SO_2, measured in cubic meters, versus industrial soot, and industrial dust, both measured in ton can still be an open debate issue for university students, as these definitions and they converting applications toward international standards.
2. The mathematic calculations and modeling of waste emissions are important decision making reasoning and this reasoning has structure and determinism based approach. The good thing with this approach is clear and simple view, the disadvantage is lack of qualitative analysis, so the combination of both is recommended.
3. The treatment level of total volume of industrial waste gas emission hasn't been improved essentially in Hebei province. From now on, controlling total volume should be focused on. In this aspect, the institution of pollution right trade that has been tried out in other province can exert positive effect. So institution of pollution right trade should be pushed in Hebei province.
4. Economical benefit of industrial waste gas emission is low, so we should speed our steps to reform industrial technique then lower the Value-added emission intensity.
5. The emission level of industrial waste gas of Hebei is higher than most other province, but with investment cost increasing, the direct emission intensity of industrial waste gas has been reduced obviously. In order to reduce intensity of pollution emission more, we should insist new industrialization mode of low pollution and increase more investment cost.
6. The industrial structure of Hebei province is industrial structure of high pollution. During and after the eleventh five-year plan, the industrial structure should be adjust gradually, break away from extensive mode of industry economy growth.
7. The total efficiency of treatment of industrial waste gas of Hebei province is better than that of national average efficiency, but hasn't come up with the national advanced treatment efficiency yet. The source of investment of pollution treatment is too centralized.

Seen from the tendency of proportion that investment cost of treatment of industry waste gas investment accounted for total investment of pollution treatment, Hebei province realizes importance of treatment of industrial waste gas more and more. In order to achieve better treatment efficiency, local government should open up the source of investment of pollution treatment, should increase the quantity and proportion of state budget fund, domestic loan and foreign capital using. It is also worth to investigate the international experiences, both in pollution trading [2] and environmental economics [3] so the new economic development is based on environmental thinking.

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