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Analysis on Effect Decomposition of Industrial COD Emission

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Abstract

In this paper, which is based on the effect decomposition model of the emission of pollutants, the change of the industrial COD emission is researched, and a quantitative analysis is carried out for the scale effect, structure effect and technology effect of the industrial COD emission change. The driving factors and causes for this kind of change are identified and the contribution of the three kinds of effects on the pollution reduction is analyzed. The results show that the gradually increasing scale effect is a major factor causing increasing stress on the pollution reduction. The structure effect which is overall low indicates that the activities of optimization and adjustment for the industrial structure have no significant effect. The increment of the generalized technology effect is a main reason for the reduction of the pollution emission. Wherein, the upgrading of industrial technology and the development of scale economy make a great contribution to reduction of pollution. It is an important way to realize the target of pollution reduction by using clean technology effect to offset the new emission and reducing the stock with pollution control effect.

Key words: Driving factors; Effects decomposition; Pollution reduction

Foreword

After Grossman and Krueger used the negative scale effect and positive structure effect and technology effect to explain the environmental Kuznets inverse-U-shaped curve for the first time, domestic and foreign scholars have carried out researches on the causes of the pollution change. Generally speaking, in the actual economic activities, the influence of the economic growth on the environment can be decomposed into three kinds: scale effect, structure effect and technology effect. Wherein, the structure change, technology development, the change of demand model and more effective

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laws and regulations are considered as the main causes of decreasing pollution. In the process of economic growth, the change direction of the environmental pollution is the result of the combined action of the three kinds of effects[1].

In the past few years, the decomposition analysis was introduced into the research work to conform the relative importance of various mechanisms, especially the contribution of the structure change on the decreasing pollution. The method of decomposition analysis provides empirical evidence for analyzing the major influence factors of the pollution change and gathers more and more attentions thanks to the decomposition of contributions of the mechanisms on the pollution change. For the basic decomposition mode, the pollution change is decomposed into scale effect resulting from an enlarging economic scale, structure effect resulting from the change of economic structure, and technology effect resulting from the change of pollution intensity of each department. The extended model can further decompose the technology effect into energy components, efficiency and other technology effects. E.g. the method of decomposition was used by de Bruyn to analyze the contributions of the structure change and the environmental policy on the emission change of SO_2 and he thinks the environmental policy was a major factor of decreasing emission of SO_2 in Holland and West Germany in 1980~1990[2]; Selden et al analyze the change of the 6 pollutants defined in Clean Air Act of America in 1970~1990 and think that the structure effect was insufficient to lead a decreasing emission of pollutants. They especially emphasize the key functions of the Clean Air Act in other technology effects [3]. However, there are few records about this in China. Chen Liujun et al use the decomposition model to calculate the scale effect, structure effect, clean technology effect and pollution processing effect in the pollution change in the industry of China. The results show that the scale effect and the structure effect are supposed to increase the industrial pollution in 1992~2000 and the scale effect accounts for the major part; the clean technology effect and the pollution processing effect are supposed to reduce the industrial pollution and the clean technology effect accounts for the major part[4]. The results of the research on the influence on the pollution emission change by Zhou Jing et al show that the scale effect is supposed to improve the amount of pollution emission. The affecting direction of the structure effect and the generalized technology effect is not clear. However, the generalized technology effect plays a decisive role in the pollutant control. A powerful environment policy and management measures can effectively control the pollutant emission [5].

A trial empirical analysis is carried out for the driving force and causes of the pollution reduction based on the decomposition model of effect. In this paper, the decomposition model was used for analysis of the effect of various factors for the pollution change in past few years in China and quantitative decomposition was conducted for the scale effect, structure effect and technology effect of the economic growth to find out the driving causes of economy for the amount change of the industrial COD emission.

1 Structure of Decomposition Method of Effect

Fundamental formula of de Bruyn decomposition model for analysis of change factors of emission of one certain pollutant:

$$E_t = V_t \sum_i S_{it} I_{it} \quad (1)$$

Equation (1) indicates that the change of the pollution emission is from the changes of V_t (scale effect), S_{it} (structure effect) and I_{it} (technology effect). Wherein, E_t is the amount of pollution emission for the industry statistics in the t year, V_t is the industrial added value for the industry statistics in the t year, V_{it} is the industrial added value for the industry i in the t year; E_{it} is the amount of pollution emission for the industry i in the t year; S_{it} is the share of industrial added value for the industry i in the t year ($S_{it} = V_{it}$ $S_{it} = V_{it}/V_t$); and I_{it} is the pollution emission intensity for the industry *i* ($I_{it} = E_{it}/V_{it}$).

Wherein, the scale effect refers to the change of the amount of the pollutants which is caused due to the change of the industrial added value. The structure effect refers to the change of the amount of the pollutants which is caused due to the change of added value share in various industries. Thetechnology effect refers to integration of various factors which cause the change of pollution emission intensity.If sufficient data is obtained, under the basic framework of equation (1), the pollution emission intensity I_{it} can be decomposed further. On one hand, I_{it} depends on the amount of pollution generated in unit. On the other hand, it depends on the emission share of the pollutants generated. E_{it}^* is used to represent the amount of pollutant generated. Additionally, $I_{it}^* = E_{it}^*/V_{it}$ refers to the pollution generation intensity in the industry *i* and $R_{it} = E_{it}/E_{it}^*$ refers to the pollution emission rate in the industry *i*. Clearly:

$$I_{it} = \frac{E_{it}}{V_{it}} = \frac{E_{it}^*}{V_{it}} \times \frac{E_{it}}{E_{it}^*} = I_{it}^* R_{it} \tag{2}$$

A lower I_{it}^* stands for a higher level of cleanliness of the production technology and a lower R_{it} stands for a higher level of pollution control degree.

Put equation 2 into equation 1 and the equation

$$E_t = V_t \sum_i S_{it} I_{it} = V_t \sum_i S_{it} I_{it}^* R_{it} \tag{3}$$

Equation (3) indicates that the change of the amount of pollution emission is caused by the change of V_t (scale effect), S_{it} (structure effect), I_{it}^* (clean technology effect) and R_{it} (pollution processing effect), which separates the contributions of the clean technology and pollution processing on the pollution reduction. The clean technology effect here refers to integration of various factors which cause the change of pollution generation intensity. The pollution processing here refers to integration of various factors which cause the change of pollution emission rate.

The decomposition margin (coupling of the change amount of various factors) shall be processed to classify the change amount of pollution emission. The methods widely used at present include fixed weight method, adaptive weight method (AWD), and method of average distribution of margin. The decomposition method with different layers is adopted in this paper to completely decompose the change of pollution emission or resource consumption. In this method, equation (3) or (4) is considered as a serial decomposition of 3 layers: Layer 1, $E_t = V_t I_t$, the total amount of is decomposed into the industrial added value and macroscopic intensity; Layer 2, $I_t = \sum S_{it} I_{it}$, the macroscopic intensity is decomposed into the industrial composition and intensity of each industry; Layer 3, $I_{it} = I_{it}^* R_{it}$, the intensity of each industry is further decomposed into the pollution generation intensity and pollution emission rate. The method of average distribution of margin is adopted for each layer.

With the decomposition method of different layers, the depth of decomposition layer can be selected according to the data availability. If the data is insufficient, the above-mentioned model can be decomposed just to the second layer and the change of the pollution emission or resource consumption G_{tot} can be decomposed into the scale effect G_{sca}, structure effect G_{str}, and generalized technology effect G_{int}; when the data is sufficient, it can be decomposed to the third layer and the change of the pollution emission or resource consumption can be decomposed into the scale effect G_{sca}, structure effect G_{str}, clean technology effect G_{tec}, and pollution processing effect G_{aba}, as shown in equation (5).Equation (6) and equation (10) are the calculation formulas for the scale effect G_{sca}, structure effect G_{str}, generalized technology effect $G_{int,}$ clean technology effect G_{tec}, and pollution processing effect G_{aba}.

$$G_{tot} = G_{sca} + G_{str} + G_{int} = G_{sca} + G_{str} + G_{tec} + G_{aba} \tag{5}$$

$$G_{sca} = g_V (1 + \frac{1}{2} g_I) \tag{6}$$

$$G_{str} = \sum_i e_{i0} g_{si} (1 + \frac{1}{2} g_{Ii})(1 + \frac{1}{2} g_V) \tag{7}$$

$$G_{int} = \sum_i e_{i0} g_{Ii} (1 + \frac{1}{2} g_{si})(1 + \frac{1}{2} g_V) \tag{8}$$

$$G_{tec} = \sum_i e_{i0} g_{I_i^*} (1 + \frac{1}{2} g_{Ri})(1 + \frac{1}{2} g_{si})(1 + \frac{1}{2} g_V) \tag{9}$$

$$G_{aba} = \sum_i e_{i0} g_{Ri} (1 + \frac{1}{2} g_{I_i^*})(1 + \frac{1}{2} g_{si})(1 + \frac{1}{2} g_V) \tag{10}$$

Wherein, when calculating various effects for the pollution change, $G_{tot} = (E_t - E_0)/E_0$ is the pollution change in the t year compared to the base year. $e_{i0} = E_{i0}/ E_0$ is the pollution share of the industry I in the base year. $g_x = (x_t - x_0)/x_0$ is the change rate of the variable x in the t year compared to the base year. x stands for *V*, *I*, *Si*, *Ii*,*I** and R_i.

2 Selection of Data and Cases

2.1 Data Selection

In this study, the COD emission in 1992~2007 is selected as the object for analysis. The method of dividing the industries into 39 kinds in China Statistical Yearbook 2007 is adopted (in 1992~1996 and 1996~2000, method of dividing the industries into 18 kinds in China Statistical Yearbook was adopted). Eliminating other mining industry, handicrafts and other manufacturing industry without industry representation and resource and material recovery industry without continuous data record in five years, there are 36 kinds of industries for analysis (i = 1,2,…36).

2.2 Selection of Cases

To reflect the regional differences, for the effect decomposition of the total amount of COD emission in regional industries, a developed province, Jiangsu province in the eastern part and Shaanxi in the western part are selected for comprehensive comparison. Because of the data, for the total amount of COD emission in the industry of Jiangsu and Shaanxi, the method of 33 industries is adopted, excluding other mining industry, textile and garment, shoes and hat manufacturing, furniture manufacturing, manufacturing of cultural, educational and sports goods, recycling and disposal of waste, water production and supply industry and other seven industries. The time span started in 2005 and ended in 2006.

All the data required for the effect calculation is from the Annual Environment Report and Statistical Yearbook. Eit is the amount of COD emission in each industry. E_{it}^* adopts the sum of COD emission amount and amount removed in each industry; g_x is the staged change rate in each indication time. Additionally, because the scope of statistics for the industries in the annual environment report does not match that in the statistical yearbook, the data of the pollution emission given just expresses the overall tendency. There might be rise and fall resulting from the adjustment if statistics scope.

3 Effect Decomposition for Total Amount of National industrial COD Emission

3.1 Effect Decomposition Calculation

In order to analyze the variation tendency of each effect of the COD emission, a comparative analysis for the contribution value of each effect is carried out for 1992 ~ 1996, 1996 ~ 2000, 2001 ~ 2007, 2005 ~ 2007, 2005 ~ 2006, and 2006 ~ 2007. The effects of COD emission at different stages are shown in Table 1. The data indicates that the amount of pollution emission does not increase with the economic development of industries in China. Certain achievements have been realized thank to the structure adjustment, technical progress and environmental regulations.

Table 1 Effect Values of COD Emission Change in 1992~2007 (%)

Year	Gtot	Gsca	Gstr	Gint	Gtec	Gaba
1992~1996	-4.8	44.3	21.3	-70.3	-	-

1996~2000		-3.7	30.6	-5.3	-29.0	-	-
2001~2007		-10.8	191.4	-5.5	-196.7	-176.1	-20.6
Specially	2001~2005	-4.1	107.3	-2.4	-109.0	-103.6	-5.4
	2005~2007	-7.0	48.8	-1.2	-54.6	-45.9	-8.7
	2005~2006	-4.9	22.9	-1.9	-26.0	-21.8	-4.2
	2006~2007	-2.2	25.1	0.7	-27.9	-23.3	-4.6

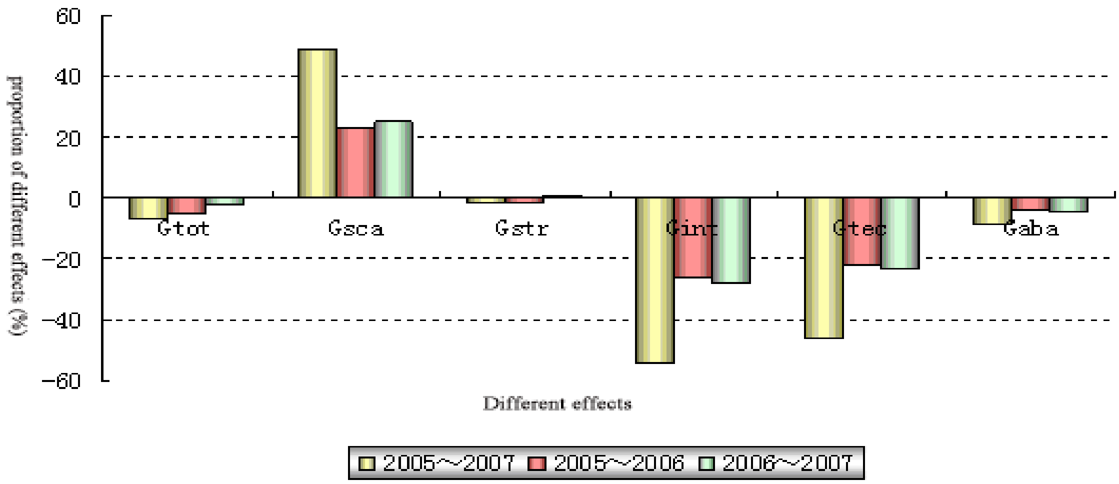

Fig. 1. Effect Decomposition of COD Emission at Different Stages in 2005~2007

3.2 Decomposition Analysis of Effect

As the standard for the industry division in the years above was different from that for 2001~2006, this may have certain influence on the continuity of the data. However, by comparing the change of the effects in the three stages, some rules are found.

Scale effect increasing year by year is the main factor for increasing stress contributing to pollution reduction.

By comparing the scale effects at different stages, it can be found that the scale effect is the main factor for the enhancement of the pollution emission all the time.

The contribution rates of the scale effect in 1992~1996, 1996~2000 and 2001~2007 are 44.3%, 30.6% and 191.4%. During 2001~2007, the stress of the scale effect was obviously greater than that in 1992~2000, which means that the fast economic development brings more and more stress on the environment. The scale effect increased by 2.2% in 2006-2007 compared to that in 2005-2006 and it increased year by year. To realize the goal of pollution reduction in the Eleventh Five-Year Plan, it is more difficult to reduce the amount of new pollutant emission brought by the economic development, compared to reducing 10% of stock.

(2) A generally low structure effect indicates that the result of the optimization and adjustment of industrial structure is not obvious.

The structure effect is low generally. In spite of efforts to strengthen the adjustment for the internal products as well as the scale and structure in some industries, overall optimization for the industrial structure is not realized and it changes over and over again. The structure effect was positive in 1992~1996 and after that period, it was a smaller negative value. This means that the structure change in the industry in China leads to pollution reduction. However, the environment factor was not the start point for the adjustment of industrial structure. In 1992~1996, the effect of the structure adjustment on the pollution reduction was positive. Namely, the structure adjustment was going in the direction in favor of the enhancement of COD. The influence of the structure effect on the pollution emission change in 1996-2000 was greater than that in other years and it was -5.3%. But the structure effect in 2001-2005 decreases compared to 1996-2000 and it was -2.4%. For the active implementation of financial policy, when the speed of the economic development remains at a high level, the heavy pollution industry is also developing very fast. For the financial income distribution mechanism after the system of tax distribution, the local governments lean to projects with more profit and tax. However, these projects have greater pollution on the environment, which may be the reason for the unsuccessful of the implementation of optimization for the industrial structure. By comparing the contribution rates of structure effect in 2001~2005 and in 2005~2006, it can be obtained that the total value of the structure effect was -2.4in the Tenth Five- Year while the contribution of the structure effect reaches up to -1.9 in 2006. This means that the contribution rate of the structure effect tends to increase in the three effects in the wake of implementation of pollution reduction and other measures and the increasing strength of structure adjustment. The role of the structure effect in one year was almost the same with that in the Tenth Five-Year. However, the structure effect was supposed to be 0.7% in 2007. This means that there was no further optimization for the economic structure in 2007. What's more, it develops in the direction against pollution reduction, which brings more stress on the pollution reduction.

From this we know that, a certain period is necessary for the adjustment of industrial structure and it is very difficult. In the past few years, although a series of measures, such as the structure pollution reduction have been implemented, the true optimization is not realized for the industrial structure. From the share of industrial added value in the manufacture of paper and paper products, agricultural food processing industry, chemical raw materials and chemical products manufacturing, textile industry and beverage manufacturing, which accounting for more than 70% of the COD emission amount, we can see that it was 18.1% in 2001, 17.7% in 2005, 17.4% in 2006 and 17.7% in 2007. No great change has taken place in the industrial structure of China. The share of the industrial added value increases in 2007 compared to that in 2006 and it decreases to the level in 2005. This the main reason for the positive structure effect. As there is no supporting policy for the structure adjustment in China, it is difficult to implement it and then much is said but little is done. No positive result is achieved. The adjustment of industrial structure mainly adopts administrative measures, involving business failure, personnel placement and reduction of local tax revenue. There are disadvantages, such as short-term, phased and easy rebound, as well as possibility of pollution transfer. Although some enterprises with heavy pollution are shut down during the implementation of the pollution reduction measures, the fast development and space transfer of the industry do not prompt the substantial change of the industry structure. Besides the small capacity units plant that is shut down, it is short of compensation policies for the elimination of industry. In addition, because of the randomness of industrial policy, the policy for some industries lack of long-acting mechanism, which also leads to a higher implementation cost of the industrial structure adjustment. In this situation, the emission amount of both the two main pollutants decreases, further indicating that the work of the pollution reduction has achieved marked results.

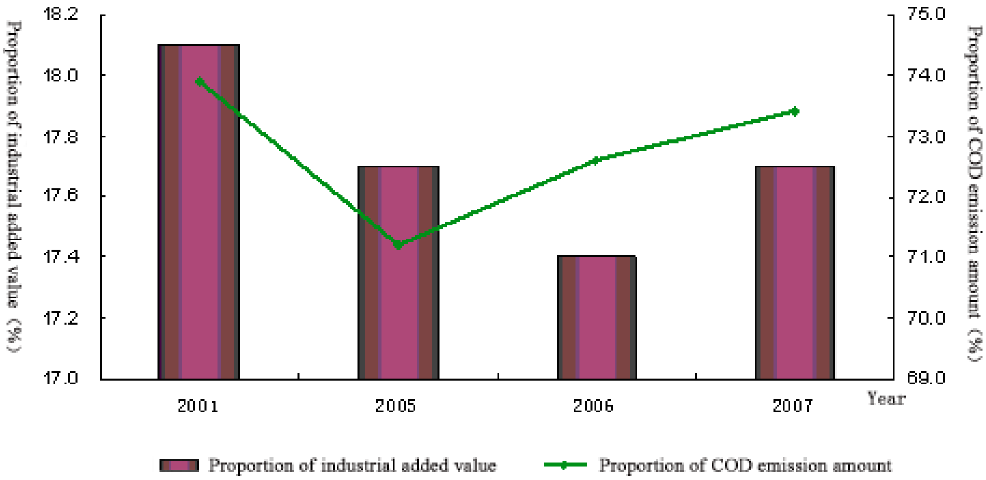

Fig. 2. Comparison of Industrial Added Value and COD Emission Amount in Five Heavily Polluting Industries

(3) The generalized technology effect increasing year by year is the main reason for the reduction of pollution emission.

The generalized technology effect can just offset the influence of the industrial scale in 1996~2000 and 2001~2006. In 1992~1996, the technology effect was much larger than the influence of the scale effect. Both in 2005-2006, and 2006-2007, the generalized technology effect exceeds the influence of the scale effect. This means that the generalized technology was the main factor for the distribution on the pollution reduction. The generalized technology effect comprehensively reflects the achievement of the pollution reduction measures. Keeping a strong generalized technology effect means constantly improvement of cleanliness of the production technology or enlarging the investment on the pollution processing. This needs a more severe environment policy to stimulate enterprises or local governments to take these measures. This means that the marginal benefit of pollution reduction becomes smaller with the development of the technologies and enhancement of the pollution processing level.

Additionally, the further decomposition of the generalized technology effect means that the clean technology effect is greater than the pollution processing effect. This means that in the two policies, reducing the pollution generation (reducing the resource consumption) and strengthening pollution control (or cyclic utilization), people tend to select the former one, or by closing down backward enterprises, or setting up the large while shutting down the small ones. The development of the scale economic brings a decreasing amount of pollution reduction. The pollution processing effect plays a certain role in promoting the clean technology effect. This may also means that the effect of adopting clean technology is more obvious than investing on the pollution processing equipment (cyclic utilization equipment). Additionally, it indirectly means that the environment supervision needs to be strengthened. External supervision is necessary for improving the pollution processing level.

(4) The upgrading of the industrial technology and development of scale economics make great contribution on the pollution reduction.

The clean technology effect reflects the change of the pollutant generation intensity brought by the upgrading of the industrial technology and development of scale economics.

The clean technology effect is the main strength in the generalized technology effect, accounting for about 85% in it. From the view of annual comparison, the clean technology shall be increasing year by year. By comparing the clean technology effect and the scale effect in the past few years, we can find that the scale effect was 22.9% and the clean technology effect was -21.8% in 2005-2006; the scale effect was 25.1% and the clean technology effect was -23.3% in 2006-2007. The clean technology effect can basically offset the influence of the scale effect on the pollution emission. That is to say, reduction of the new pollutants brought by the economic development is mainly realized by the clean technology effect. It is an important way to expand capacities without increasing emissions through the upgrading of the industrial technology and development of scale economics and closing down the backward enterprises.

The comprehensive comparison between the structure effect and the clean technology effect indicates that, though the implementation of the pollution reduction does not bring obvious optimization to the industrial structure, the upgrading of the industrial technology and development of scale economics is prompted by setting up the large while shutting down the small ones and closing down the backward enterprises with the goal of protecting the environment. Reduction of pollution generation intensity of the industrial under the existing structure is realized, which makes for the pollution reduction.

(5) Obvious enhancement of pollution processing effect means that the achievement of the pollution reduction is obvious.

The pollution processing effect reflects the ratio change of the emission amount to the generation amount of the pollutants brought by the engineering pollution reduction, structure pollution reduction,

Compared to 2001~2005, the ratio of the contribution rates of the pollution processing effect to that of the generalized technology effect increases significantly and it tends to increase year by year. The pollution processing effect was -5.4% in 2001-2005. It reached up to -4.2% in 2006 and it was -4.6% in 2007. In 2006 and 2007, the condition of the contribution of the pollution processing was similar with that in the tenth five-year. This means that the capacity and level of the industrial pollution processing are developing stably with the vigorous development of the pollution reduction work. This was the best evidence for the great pollution reduction since 2006.

4 Effect Decomposition for Total Amount of Regional Industrial COD Emission

4.1 Effect Decomposition Calculation

The effect decomposition model is applied with the sample of Jiangsu and Shaanxi to calculate the effects of the change of the total amount of the industrial COD emission in 2005-2006, as shown in Table 2.

Table 2 Effect Comparison of COD Emission Change in 2005-2006 (%)

Province	Gtot	Gsca	Gstr	Gint	Gtec	Gaba
Jiangsu	-11.16	22.83	-1.85	-32.14	-30.15	-1.99
Shaanxi	9.52	34.56	-9.77	-15.27	-1.58	-13.69
Nationwide	-4.9	22.9	-1.9	-26.0	-21.8	-4.2

4.2 Decomposition Analysis of Effect

The calculation results show that the total amount of the COD emission of Jiangsu industry in 2006 declined by 11.16% compared to that in 2005. Wherein, the scale effect was 22.83%, the structure effect was -1.85% and the generalized technology effect was -32.14%, of which the clean technology effect was -30.15% and the pollution processing effect was -1.99%. By comparison, the total amount of the COD emission of Shaanxi industry in 2006 increased by 9.52% compared to that in 2005. Wherein, the scale effect was 34.56%, the structure effect was more obvious, -9.77% and the generalized technology effect was -15.27%, of which the clean technology effect was -1.58% and the pollution processing effect was -13.69%.This shows that the total amount of COD emission in Jiangsu industry decreased, thanks to the great contribution of the clean technology effect. The total amount of COD emission in Shaanxi industry increased, mainly due to the scale effect. The industrial added value increased fast and the generalized technology effect was low on the whole. Wherein, the pollution processing effect accounted for a larger part in the generalized technology effect. However, the clean technology effect was not obvious. Considering the structure effect, it was more obvious in Shaanxi province in 2006. The contribution of the structure adjustment for the pollution reduction was higher than that of Jiangsu.

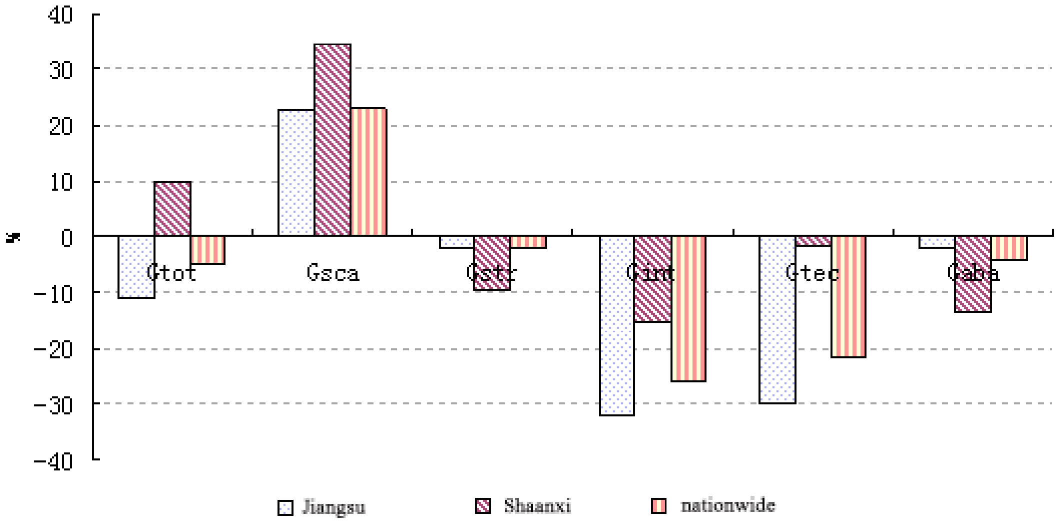

Fig. 3. Decomposition Comparison of Total Amount in 2005-2006

5 Conclusions

The above-mentioned analysis shows that the scale effect is the main reason for the increasing new pollutants and causes increasing stress on the pollution reduction; the generalized technology effect has signality on the reduction of the industrial COD emission amount; the structure effect is low on the whole and it became positive in 2007, which means that no obvious achievement is obtained for the industrial structure. It is difficult to optimize the economic growth with protecting the environment.

By combining with the scale, structure and technology effects from the decomposition of the total amount and from the view of the structure pollution reduction, engineering pollution reduction and management pollution reduction, there is great significance for the structure pollution reduction. The structure pollution reduction plays a role of "multiple enhancement" in the structure effect, clean technology effect and pollution processing effect. There are many medium-sized and small enterprises in China and the pollution concentrates in paper, leather, electroplating, printing and dyeing, cement, brick, coal, nonferrous metals, nonmetallic mineral mining, ferrous metals and other industries with low technical level and difficulty in pollution processing. Preliminarily, the pollution emission of medium-sized and small enterprises accounts for about 50% of the total amount of the industrial pollution emission. For a long time, the medium-sized and small enterprise in China is treated as a special management and service object. The policy of "Those who cause pollution are responsible for the treatment" is adopted for them, which is the same with that for large and medium-sized enterprises. As many medium-sized and small enterprises have weak economic strength and the money for the pollution processing is very limited; as the financing cost and credit risk are high, it is difficult for them to get the funds for the pollution processing; They are often in the dry tree in sharing the environment protection fund from the government, such as special fund for environment protection, grant-in-aid from local governments and other financing arrangement. This severely restricts the pollution processing for the medium-sized and small enterprises. For the enterprises with a large scale, or the medium-sized and small enterprise with a high level of technology, the amount of the pollution emission is relatively low and it is easy to monitor them. For the structure reduction measures for the backward productivity, the amount of the pollution emission can be effectively reduced by closing down backward enterprises, or directly enhancing the pollution processing effect and structure effect. Additionally, the grading of industrial technology and development of scale economics can be prompted and the pollution generation intensity can be reduced as well as the clean technology effect, which plays multiple roles in the pollution reduction.

The clean technology effect is the main strength to offset the amount of the new pollution emission brought by the economic growth. It is an important way to realize the pollution reduction by offsetting the new pollutant and reducing the pollution resource with the clean technology effect and reducing the stock with pollution processing. In 2006 and 2007, the clean technology effect offset more than 93% of bad influence on the scale effect. The upgrading of industrial technology and development of scale economics shall be paid attention to and the backward enterprises shall be closed down to relive the environment stress from the economic growth. It is a key factor for the goal of pollution reduction by upgrading of industrial technology, development of scale economics and reducing the pollutant generation intensity. Based on this, the stock shall be reduced effectively through the engineering pollution reduction, structure pollution, management pollution reduction and other pollution processing measures. Therefore, when developing the clean technology to reduce the new pollutant from the economic growth, it is important guarantee to realize the goal of pollution reduction in the Eleventh Five-year by executing the measures on the pollution reduction. Both of the two above are indispensable.

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