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Structural Decomposition Analysis and Evaluation of the Chinese Emission Reduction Policy: Changes in SO_2 Emission from 2001 to 2010

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Abstract: To understand the role of industrial emission in fulfilling the target of total emission reduction, based on structural decomposition analysis, we divided the reduction rate of industrial emission into two parts and found five effects influencing the changes in SO_2 emission reduction. According to 2001-2010 data in China, this study empirically analyzed the main factors of SO_2 emission reduction and explored the main reasons for changes in China's SO_2 emissions. The empirical results show that during such period, the industrial emission is determinant in the reduction rate while the technological effect on the reduction plays a leading role in 2006-2010.

Key words: SO_2 emission, environmental policy, structural decomposition analysis, demand, control policy

INTRODUCTION

Thanks to the contribution of the progress of environmental technology and industrial structure adjustment, China's pollution emissions growth rate has slowed down significantly since the reform and opening policy at the end of 1970s in China. In the "Eleventh Five-Year" periodSO_2 is one of the major pollutants under control policy and pollution abatement of the SO_2 emissions achieved a breakthrough. Industrial SO_2 is the main part of the total SO_2 emissions, accounting for 85% of the total SO_2 emissions in 2010 and the reduction of it is the focus of the official target of SO_2 emission reduction in China. From the perspective of the emission reduction effectiveness and costs, to reduce pollution emission intensity is the fundamental way to solve the environmental pollution. From 1991-2010, the emission intensity of the industrial SO_2 has been reducing and the average annualdeclineis of 8.6%. Industrial emission intensity and emissions per capita show a downward trend; the average annual decline of industrial emission intensity is 10.87% during the "10th Five-Year" and "11th Five-Year" period. Therefore, not only to analyze whether the reduction targets are fulfilled or not is enough, but it is also important to know the emission intensity when analyzing the factors affecting emissions of pollutants.

The literature on SO_2 emissions in China is limited. And these existing mainly focused on the industrial emission reduction, or the factorial changes of the industrial emission intensity. However, when referring to the relationship between the overall emission reduction and industrial emission, there are little of systematic research and deep discussion. For the diverse situations of the provincial fulfillment of the emission reduction tasks in "11th Five-Year" period, this paper explores the following questions. How much industrial emission has contributed to the fulfillment of the entire target" How about the ratio" Employing the structural decomposition methods, attempt to find the factors resulting in the changes in SO_2 emissions and analyze their mechanisms.

MATERIALS AND METHODS

The Structural Decomposition Analysis (SDA) is based on the input-output method. The input-output table describes the structural characteristic of the sub-sector, so the decomposition method provides proper analysis to decompose economic changes into different factors, particularly the analysis of structural changes. Based on such advantage, SDA technique is often used in the decomposition analysis of environmental pollution and the change of energy consumption. Since work on the decomposition of pollutant emissions, a series of research using SDA methods appear. As existing SDA' analysis results showed, the change of pollutant emission could be decomposed into three effects: Scale effect, structural effect and technological effect. Thorough analysis on these three effects' changes could help to explain the mechanism of the potential impact on the environment.

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The scale effect measures the effect of the emissions increase caused by the growth of economic scale. The structure effect measures the change of emissions as all the output's composition has changed their structure. The technical effect measures pollution emission change. As engine and the display of dynamic change in emission intensity, technological innovation, particularly environment protection and energy-saving technology, have significant positive impact on clean production and pollution control. In the developed countries, such as United States, Japan, Britain, etc., there are many factors proposed to control SO_2 emission reduction. The significance ordering of these factors were as follows: Economic restructuring, energy restructuring, environmental policy and technological progress on environmental protection (Li *et al*., 2010). Here, our work will focus on the technical effects and structure effects.

Based on emission dataset from Netherlands and West Germany during 1980~1990, De Bruyn (1997) found that the SO_2 emissions changes were mainly caused by technical effect while the structural effect played a minor role. The technical effect mainly results from three aspects: The structure of energy consumption, energy efficiency and pollution treatment technologies. Similarly, based on the empirical analysis of twelve countries in Asia, Shrestha and Timilsina (1997) found that as the main factor, technological effect, which represented by the energy intensity, affected the strength of SO_2 emissions from power industry. Meanwhile, for the case in America, Selden *et al*. (1999) proved that the structural effect had a very small contribution to the reduction of pollution and the reduction of pollution was mainly caused by the decrease of energy consumption intensity and other technical effects. By means of empirical analysis on CO_2 emissions of OECD countries, Hamilton and Turton (2000) reported that the scale effect was the main reason for emissions growth while technical effects (the energy intensity, the usage of fossil energy and pollution emissions density) were the main reason, leading to the reduction of pollution emissions. Stern (2002) analyzed SO_2 emissions dataset of 64 countries. His result showed, whether pollution increased or not, economies scale and technology effects are the main reason for such dynamic change. Bruvoll and Medin (2003) explained 10 kinds of air pollutant emissions in Norway from 1980-1996 and reported that there were significant positive correlation between energy intensity, technical effect and pollution reduction but the role of structural effect was not significant.

Aiming at current situation of China's environment, more and more scholars conducted various studies on pollution emissions. He (2005, 2006, 2009) had made a series of research work to analyze the factors of China's SO_2 emissions change. She decomposed three effects (economies of scale, structural effects and technological effects) and proved that the impact of trade on emissions depended on two factors: resource endowments and the level of environmental regulation.

Regarding scale effect, most scholars agreed that as one of main reasons, GDP growth led to the increase of SO_2 emissions (Qiu *et al*., 2008; Zeng *et al*., 2009; Zhai and Li, 1998; Zhao *et al*., 2006). Using CGE modeling, during 2001~2010 , the scale effect was the main reason of pollution increase; while the structural effect and the technological effect played a positive role in reducing pollution, but to a less extent (Zhai and Li, 1998). Zhang (2000) improved that during the period of 1980~1997, China's per capita GDP growth and population expansion were the main reasons for pollution increases while the decline of the intensity of energy consumption was related to pollution reduction (Zhang, 2000). Through analysis the relationship between Jiangsu Province's economic activity and pollution emission, (Zhao *et al*., 2006) reported that during the period from 1990-2002, economy structure adjustment and urbanization process are the main factors, leading to an increase in pollution emissions.

For the structural and technological effects, most scholars agreed that the energy structure and energy intensity were the main factors, which affected pollution emission. For example, according to SO_2 emissions data during 1997~2007 pollution emission intensity was mainly caused by the changes in energy intensity and emission coefficient. As the Chinese government paid more attention to the environment protection, from the beginning of the 10th Five-year plan, China's average annual emissions intensity began to decline and the changes in the above factors had exerted effect on emission reduction.

Moreover, structural effect and technical effect are often used to decompose the changes in emission intensity. Then other related factors were proposed, such as economy development level, the clean technology effects, etc. (Wang and Sun, 2010; Wang *et al*., 2008). Yang and Geng (2010) found that, in the economical developed area, especially southeast coastal areas, the industrial pollution emission intensity became less. Such positive relationship between economic opening degree and industrial pollution emission indicated that there was a pollution transfer within China's export-oriented development process. Based on analysis of the "11th Five-year plan" data, Cheng (2011) proved that compared with structural effect, environmental technologies played a major role in the reduction of SO_2

emission. Zeng *et al*. (2009) proved that during the period from 1996-2007, the removal rate of SO_2 efficiency was an important factor for the industrial SO_2 emissions in China. Similarly, thermal power plants, there were many significant factors for the emission reduction of SO_2, such as, coal sulfur content, efficiency of the desulfurization system, desulphurization capability of the newly-increased sets, desulphurization capacity of existing sets and the capacity of the small thermal power plants closed. According to above research results, these authors provided suggestion for fulfilling China's emission reduction targets. These proposals sometimes were inconsistent, but most of them propose solutions from the perspective of technical effects. For example, many results showed that as effective ways to reduce the emissions, improving energy utilization and developing clean technique had played a decisive role in the fulfillment of the industrial SO_2 emission reduction targets.

The existing literatures are restricted to decompose the changes in industrial emission or industrial emission intensity in China. Presently, there is lacking of systematic research on the relationship between the overall emission reduction and industrial emission reduction. Therefore, to explore the reasons for the changes in pollutants emission, we should decompose the changes in various emissions and then analyze the technical indicators about the emission intensity and the emission density. So, we could explore the mechanism how to influence the emission changes hierarchically.

DECOMPOSITION MODEL

The purpose of this study is to conduct a structural decomposition analysis and evaluate China's emission reduction policy by employing SDA methods. Given a function f (x, y), x and y the two factors, the discrepance could be denoted as $\Delta x \Delta y$. The contribution value and contribution ratio of x, y is as follows:

$$C(\Delta x)=|\Delta x|*\delta*t=\frac{|\Delta x|^2|\Delta y|}{|\Delta x|+|\Delta y|},\quad C(\Delta y)=\Delta y*\delta*t=\frac{|\Delta x||\Delta y|^2}{|\Delta x|+|\Delta y|} \tag{1}$$

$$CR(\Delta x)=\frac{C(\Delta x)}{s}=\frac{|\Delta x|}{|\Delta x|+|\Delta y|},\quad CR(\Delta y)=\frac{C(\Delta y)}{s}=\frac{|\Delta y|}{|\Delta x|+|\Delta y|} \tag{2}$$

Further, given factors $\{x_1, x_2, ..., x_i, ..., x_n\}$, for factor x_i, its discrepance is represented as Δx_i. The contribution value and contribution rates of factor x_i are expressed as follows generally:

$$C(\Delta x_i)=\Delta x_1\Delta x_2\cdots\Delta x_i\cdots\Delta x_n*\frac{|\Delta x_i|}{|\Delta x_1|+|\Delta x_2|+\cdots+|\Delta x_i|+\cdots+|\Delta x_n|},\Delta x_i\neq 0 \tag{3}$$

$$CR(\Delta x_i)=\frac{|\Delta x_i|}{|\Delta x_1|+\cdots+|\Delta x_i|+\cdots+|\Delta x_n|},\Delta x_i\neq 0 \tag{4}$$

Inspired by structural features of pollutant emission, we divide sulfur-dioxide emission into two parts, including industrial emission of sulfur dioxide (referred to as the industrial emission) and living or other sulfur-dioxide emissions (abbr. the life emission). Life emission refers to the net weight of sulfur dioxide emissions from all the social-economic activities and the public facilities. Here, the life emission is mainly related to the scale of population. Therefore, we present an explicit formula for the life emission in the form of an product of sulfur dioxide per capita and total population.

The parameters are described as follows. Given the base period and reporting period t, E, E_1,E_2 represents total emissions, industrial emission and life emission, respectively and $E = E_1+E_2$. Y,Y_1,Y_2 represents GDP, industrial added value and population, respectively. I, I_1,I_2 represents total emission intensity, the intensity of industrial emission, the life of emission intensity, respectively and $I = E/Y$, $I_1 = E_1/Y_1$, $I_2 = E_2/Y_2$; S ($S = Y/Y_1, 0\leq S\leq 1$) denotes the proportion of industry; ϕ ($\phi = E_1/E, 0\leq\phi\leq 1$) represents industrial emission/the total emissions; Δp ($\Delta p_t = I_t/I_0-1$, $\Delta p_t\geq 1$) denotes the growth rate of total emission intensity; Δq_1, Δq_2 represents the industrial added value and the population growth rate respectively, $\Delta q_{1,t} = Y_{1,t}/Y_{1,0}-1$, $\Delta q_{2,t} = Y_{2,t}/Y_{2,0}-1$, $\Delta q_{1,t}\geq -1$, $\Delta q_{2,t}\geq -1$; $\Delta\omega$, represents the industrial added value and the population growth rate, respectively, $\Delta\omega_t = s_t/s_0\geq -1$; $\Delta\theta$ ($\Delta\theta_t = 1-E_t/E_0$, $\Delta\theta_t\leq 1$) represents the growth rate of the total emissions; $\Delta\delta_1$, $\Delta\delta_2$ represents growth rate of the industrial emission intensity and growth rate of the emission intensity of life, respectively:

$$\Delta\delta_{1,t}=I_{1,t}/I_{1,0}-1, \Delta\delta_{2,t}=I_{2,t}/I_{2,0}-1,\quad \Delta\delta_{1,t}\geq -1, \Delta\delta_{2,t}\geq -1$$

Set the reporting period as zero and the base period as t, we decompose the impact factor of the emission rate:

$$\begin{aligned}
&E_0=I_0Y_0=I_{1,0}Y_{1,0}+I_{2,0}Y_{2,0},\\
&E_t=I_tY_t=I_{1,t}Y_{1,t}+I_{2,t}Y_{2,t}\\
&\Delta\theta_t=1-\frac{E_t}{E_0}=1-\frac{I_tY_t}{I_0Y_0}=1-\frac{I_{1,t}Y_{1,t}+I_{2,t}Y_{2,t}}{I_{1,0}Y_{1,0}+I_{2,0}Y_{2,0}}\\
&=-\frac{(I_{1,t}Y_{1,t}+I_{2,t}Y_{2,t})-(I_{1,0}Y_{1,0}+I_{2,0}Y_{2,0})}{I_{1,0}Y_{1,0}+I_{2,0}Y_{2,0}}\\
&=-\phi_0[(1+\Delta\delta_{1,t})(1+\Delta q_{1,t})-1]-\\
&(1-\phi_0)[(1+\Delta\delta_{2,t})(1+\Delta q_{2,t})-1]
\end{aligned} \tag{5}$$

The above Eq. 5 decomposes the impact, resulting from of industrial emission reduction and life emission reduction. In the last expression of Eq. 5, $-\phi_0\ [(1+\Delta\delta_{1,t})(1+\Delta q_{1,t})-1]$ is the contribution from the change of industrial emission and $-(1-\phi_0)\ [(1+\Delta\delta_{2,t})(1+\Delta q_{2,t})-1]$ is the contribution from the change of life emission.

We decompose the effects:

$$\begin{aligned}\Delta\theta_t = &-\phi_0(\Delta\delta_{1,t}+\Delta q_{1,t}+\Delta\delta_{1,t}\Delta q_{1,t})-\\&(1-\phi_0)(\Delta\delta_{2,t}+\Delta q_{2,t}+\Delta\delta_{2,t}\Delta q_{2,t})\end{aligned} \tag{6}$$

As Eq. 6 represents the decomposition expression, there are the four effects, having effect on the emission reduction, i.e., the industrial capacity of production, the technology improvement, the population scale and the life energy saving.

Further decompose the effects of economic scale and economic structure. The changes of the industrial capacity are related to the total GDP and the changes of industrial proportions. $(1+\Delta q_{1,t}) = (1+\Delta\delta_t)(1+\Delta\omega)_{,t}$ Industrial production growth rate $\Delta q_{1,t}$, economic scale, economic structure, the impact of industrial production can be decomposed as:

$$\begin{aligned}\Delta q_{1,t} = &\left(\Delta\delta_t+\frac{|\Delta\delta_t|\cdot\Delta\delta_t\cdot\Delta\omega_t}{|\Delta\delta_t|+|\Delta\omega_t|}\right)+\\&\left(\Delta\omega_t+\frac{|\Delta\omega_t|\cdot\Delta\delta_t\cdot\Delta\omega_t}{|\Delta\delta_t|+|\Delta\omega_t|}\right)\end{aligned}$$

Combine the Eq. 6, the contribution value of economic scale on the emission reduction is:

$$-\phi_0\left(1+\frac{|\Delta\delta_{1,t}|\cdot\Delta\delta_{1,t}\cdot\Delta q_{1,t}}{|\Delta\delta_{1,t}|+|\Delta q_{1,t}|}\right)\cdot\left(\Delta\delta_t+\frac{|\Delta\delta_t|\cdot\Delta\delta_t\cdot\Delta\omega_t}{|\Delta\delta_t|+|\Delta\omega_t|}\right)$$

The contribution value of economic structure on the emission reduction is: Therefore, the reduction rates of the five effects are decomposed as follows:

$$-\phi_0\left(1+\frac{|\Delta\delta_{1,t}|\cdot\Delta q_{1,t}}{|\Delta\delta_{1,t}|+|\Delta q_{1,t}|}\right)\cdot\left(\Delta\omega_t+\frac{|\Delta\omega_t|\cdot\Delta\delta_t\cdot\Delta\omega_t}{|\Delta\delta_t|+|\Delta\omega_t|}\right) \tag{7}$$

The Eq. 7 includes five factors, affecting the level of emission reduction, i.e., the growth of economic scale, changes in economic structure, technology improvement, population scale growth, life energy saving. By complete decomposition of the reduction rates, the changes in emissions are decomposed to (i) Scale effect, brought about by the GDP growth and population growth, (ii) The structural effect, represented by the proportion of industrial production, (3) The technology effect, measured by the changes in industrial emission and (4) Life energy saving effect, measured by the change in per capita emissions.

EMPIRICAL STUDY

To decompose the changes in China's sulfur dioxide emissions, the data covers 31 provinces from 2001-2010 (from the 'China Environment Annals'). Industrial value added, population and GDP data are collected from China Statistical Annals. Industrial value added and GDP are calculated at constant prices of 2001. To analyze the change in the emissions at the national level, we examine the reduction effect during 2002~2010. The results are shown in Table 1, Fig. 1, as follows.

As Table 1 shown, more than 90% of the reduction rate can be explained by the scale effect and technical effect. The scale effect plays a dominant role in the increases of the sulfur dioxide emission while the technical effect is the main reason which leads to emission reduction. The working period of the scale and technical effects do not necessarily overlap. The remaining three factors do have some contribution, but comparatively weak.

In the past decade, the scale effect has always been a determinant factor in the increase of emissions. Especially after 2006, the scale effect has not been weakened, but gradually strengthened. In the 11th Five-Year period, the demand and control policy from the central government earnestly were implemented to reduce the pollutant emissions. Surprisingly, the GDP growth has not been weakened but seemed to grow more rapidly. Accordingly, a severe policy of pollution abatement has not shown a negative impact on economic growth.

Technical effects play a leading role in the 11th Five-Year period. In the 10th Five-Year period, the technological effect is the main force of the reduction in emissions. Compared to the scale effect, technical effect contributes less. After 2006, the technical effect became the main reason of emission reduction. It was directly caused by a series of emission reduction policies in the 11th Five-Year policy. In this period, the government conducted a series of measures to reduce emissions from the three main sources: projects, structure and management to reduce emission. In the end of the 11th Five-Year, the nation completed 532 million kilowatts of coal-consuming power plant desulfurization facilities. Desulfurization of thermal power generating capacity increased from 12% in 2005 to 82.6%. Thermal power units of 300,000 kw of electric power industry accounted for the proportion of thermal power installed capacity increased from 47% in 2005 to more than 70%. High

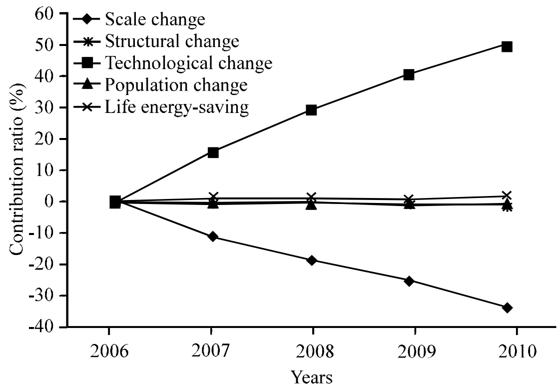

Fig. 1: Different reduction factors' contribution ratio during 2002~2010

Table 1: Effects of SO_2 emissions change decomposition from 2002 to 2010

Years	Economies of scale (%)	Economic structure (%)	Technological progress (%)	Demographic changes (%)	Life energy -saving (%)
2002-2001	-7.01	-0.64	7.86	-0.13	1.01
2003-2001	-15.59	-2.63	6.64	-0.24	1.01
2004-2001	-24.32	-3.57	11.18	-0.36	1.30
2005-2001	-36.12	-3.82	9.01	-0.47	0.52
2006-2001	-47.30	-3.74	16.70	-0.57	2.00
2007-2001	-57.40	-3.78	31.71	-0.67	3.43
2008-2001	-62.82	-3.58	44.56	-0.77	3.44
2009-2001	-67.37	-3.28	55.25	-0.87	2.58
2010-2001	-75.07	-3.72	63.46	-0.94	4.07

energy consumption and high emission industries such as steel, cement, coking and papermaking, alcohol, MSG, etc., eliminate backward production capacity all over to complete the task. During this period, the central government invested more than 100 billion RMB for the 'three systems' and the environmental regulatory capacity building to support the national pollution reduction. Therefore, in the 11th Five-Year period, due to the degree of improvement of clean energy, industrial emission intensity decreased quickly. It played a crucial role in emission reduction of major pollutants, which effectively reduced the increase in sulfur dioxide emissions. Structural effect compared with other factors presented repeated fluctuations. In Table 1, compared with 2001 dataset, the structural effects repeat between growth and reduction. In 2006, the contribution value of structural effect to the emission reduction is -4.48%, reaching the culmination. After 2008, the structural effect is gradually weakened. But in 2009 it even increased the emissions. In the past decade, China had made some achievements on economy restructuring and changing patterns of development, but the tendency of the economic structure towards heavy industry had not been effectively resolved, comparably. Currently the secondary industry is still a dominant force in China's economic development. Its proportion is not only much higher than 20-30%, the level of the Western developed countries, but also significantly higher than the average level of moderately developed countries. Within the secondary industry, the proportion of heavy and chemical industries is about 60%, still dominant and has maintained a rapid growth trend. Although the elimination of backward production capacity has accomplished in the initial period, if the economic structure and extensive mode of growth do not change in the short term, the road of reduction of pollution would be more difficult.

In Table 1, the influence of structure effect on the reduction of emissions was increasing. This difference shows that in the 11th Five-Year period, the national policy that the pollution abatement is applied to force structural adjustment has worked in a certain degree.

The impact of life emission on emission reduction is limited but basically its trend is more stable. The increase of population to play a role in the increase in emissions and the level of this effect is increasing. The life energy-saving effects on the emission always play a certain role in the reduction. This trend reflects the gradual improvement of the level of clean energy of those years. Combined the above analysis, economical scale and technology effects are the main reason for China SO_2 emission change. That is consistent with the analysis of prior research results. The difference is, we found, in 10th Five-Year and 11th Five-Year period, the determination factor of the reduction rate is the major industrial emission. In contrast, the influence of the life energy-saving impact on the emissions of sulfur dioxide on the emission reduction is small. Among them, the population growth has played a negative and the level is increasing. This gradually enhanced the role of the life energy-saving effect on the reduction of sulfur dioxide emissions.

In reducing emissions of major pollutants, China brings some effective mechanism to the target responsibility system. SO_2 emission reduction targets are broken down to local governments and the six major thermal power enterprises. During the execution of governments at all levels, some often lack the determination and action and ohters also cover the increasingly serious environmental pollution with the economic development of the surface prosperity. Reduction of work pressure is likely to tighten after loose, even some become heavier after the completion of the emission reduction targets ahead of schedule. We attempt to find out whether the target responsibility system has formatted a Long-term mechanism throughout the whole county, or simply in order to complete the task assigned by the State.

Table 2: Annual changes of SO_2 emissions effect through decomposition (2002-2010)

Years	Economies of scale (%)	Economic structure (%)	Technological progress (%)	Demographic changes (%)	Life energy-saving(%)
2002-2001	-643.86	-59.18	722.00	-11.59	92.63
2003-2002	69.91	17.59	11.50	0.95	0.05
2004-2003	182.64	23.32	-102.39	2.23	-5.80
2005-2004	74.44	1.71	17.91	0.73	5.21
2006-2005	662.53	10.51	-504.51	5.09	-73.62
2007-2006	-243.15	-11.03	332.74	-1.51	22.95
2008-2007	-132.21	-3.33	236.71	-1.14	-0.03
2009-2008	-153.74	0.18	271.00	-1.57	-15.87
2010-2009	-657.50	-74.62	737.38	-4.42	99.16

Contribution rate equal to the contribution value divided the reduction rate

Table 3: Annual changes the effect of sulfur dioxide emissions from decomposition (2002-2010)

Years	Economies of scale (%)	Economic structure (%)	Technological progress (%)	Demographic changes (%)	Life energy-saving(%)
2002-2001	-643.86	-59.18	722.00	-11.59	92.63
2003-2002	69.91	17.59	11.50	0.95	0.05
2004-2003	182.64	23.32	-102.39	2.23	-5.80
2005-2004	74.44	1.71	17.91	0.73	5.21
2006-2005	662.53	10.51	-504.51	5.09	-73.62
2007-2006	-243.15	-11.03	332.74	-1.51	22.95
2008-2007	-132.21	-3.33	236.71	-1.14	-0.03
2009-2008	-153.74	0.18	271.00	-1.57	-15.87
2010-2009	-657.50	-74.62	737.38	-4.42	99.16

Contribution rate equal to the contribution value divided the reduction rate

Then, the following decomposition is annual emission change from 2002-2010. We analyzed the annual change in the process of emission reduction effects based above years. Results as showed in Table 2.

As shown in Table 2, there is a huge difference between the annual change results from the decomposition and the conclusions in the previous section. Scale effect and technology effect are still the main reason for changes in sulfur dioxide emission. The three other factors also have impacts. In addition to the influence of population growth, the impacts from structural effect and life energy-saving have overlapped.

The scale effect is always the main force of emission reduction, but the direction of its impact is divided into two time periods. From 2003-2006, the scale effect is the main reason for annual emission decreases. After 2007, it becomes the decisive force to increase emissions. Since, 2006, the first year of 11th Five-Year plan, the country has just introduced three measures to reduce emissions. Probably due to the pressure of emission reduction objectives and tasks, local governments have chosen the way to cut capacity in order to obtain emission reduction. With the implementation of the policy of shutting down and desulfurization, the scale effect became normal in 2007.

Technical effect on the emission reduction played a leading role during the 11th Five-Year. In the 10th Five-Year period, the technical effect increased annual emission. While, in the 11th Five-Year period, technological progress was consistent with the dominant emission reduction. Compared to the 10th Five-Year period, the target emission reduction got enough attention. Due to the government focus, the related tasks have been well completed during 11th Five-Year period.

According to above description, it is important for local governments to get the emission reduction methodology guidance so as to complete emission reduction task. During the 11th Five-Year, Ministry of Environmental Protection had issued many guidance documents, for example, 'statistical approach of the total amount of major pollutants emission reduction', 'total allocation guidance of sulfur dioxide', 'the total amount of major pollutants emission reduction accounting rules', to strengthen guidance on pollution reduction.

At the end of S1th Five-Year period, structural effects appeared repeatedly. As shown in Table 3, compared with 2009, since 2010, structural effect had become the dominant reason of emission increases while life and other emissions reduction played an active role in the total amount of major pollutants emission reduction. This denoted that when the emission reduction targets were completed, the economic structure and heavy pollution would rebound.

CONCLUSION

Based on structural decomposition analysis, we evaluated Chinese emission reduction policy and explored the changes in SO_2 emission from 2001-2010. Our empirical research obtained three contributions to SO_2 emission reduction policy:

- Scale effect and technical effect are the main reasons of the change of SO_2 emissions in China. During the 11th Five-Year, the central government forced the local government to reduce pollutant emissions, but GDP growth was not shown to be vulnerable. On the contrary, it has grown more rapidly. Pollution abatement does not have a negative impact on the economic growth
- During the "10th Five-Year" and "11th Five Year" period, the reduction of the industrial emission is the main determinant of the reduction rate. In contrast, the influence of the life emission reduction is weaker. The contribution rates of different factors emission reduction depend on the growth rate and emission structure. Which abatement policy of technological progress and productivity decline leads to more effective emission reduction depends on the growth rate of industrial added value and strength of

industrial emission and it has nothing to do with emission structure. If the growth rate of industrial emission intensity is less than the growth rate of industrial added value, the contribution ratio of technological progress to reduce emissions will be greater. On the contrary, the contribution ratio of productivity decline in emission reduction will be greater

- In the 11th Five-Year period, the technical effect played a leading role in SO_2 emission reduction. Given the emission reduction targets, the provinces in which the industrial emission had a lower proportion of demand a higher level of technological progress and productivity decline. Compared to the 10th Five-Year, during the 11th Five-Year period, as local governments? main task, the target emission reduction had received enough attention and been effectively implemented. It was very important for the provincial governments to obtain the emission reduction methodological guidance so as to achieve the target of SO_2 reducing emissions

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