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How Does Environmental Regulation Affect Carbon Emissions?

—Evidence from China

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Abstract

In this paper, the increment of CO_2 emissions from 285 prefecture-level cities in China from 2004 to 2013 is decomposed into scale effect, composition effect and technique effect. Based on the decomposition results, the effects of different environmental regulation on carbon emission increment and its decomposition effect were studied by using multiple regression methods. The results show that carbon emission environmental regulation, sulfur dioxide emission environmental regulation and electricity prices also significantly reduce the city's carbon emissions, in which carbon emission reduction environmental regulation has the best effect, followed by sulfur dioxide emission reduction environmental regulation. Different environmental regulations do not significantly reduce urban carbon emissions in terms of composition effects, and even increase carbon emissions of cities. In addition, the impacts of different environmental regulations on the cities in the two control zones and the non-control zone were studied. Compared with non-control zone cities, environmental regulations for carbon emission and SO_2 have a better effect on carbon emission reduction in cities of two control zones.

Keywords

Environmental Regulation, Chinese Cities, Decomposition, Carbon Emissions

1. Introduction

As the largest developing country in the world, China is currently in the process of rapid industrialization and urbanization. The level of industrialization increased from 36.1% in 1990 to 41.3% in 2011, with an average annual growth of approximately 1%. During the same period, China's urbanization level rose from 26.4% to 51.3%. With rapid industrialization and urbanization, China's economy has achieved rapid growth. However, this rapid growth was followed by an increasing problem of environmental pollution, especially in terms of energy consumption and CO_2 emissions. In terms of emissions, China's total energy consumption increased from 1.62 billion tons of standard coal in 2002 to 4.003 billion tons of standard coal in 2014, with total CO_2 emissions of approximately 10 billion tons. According to statistics, China has become the world's largest energy consumer and CO_2 emitter. In the face of great pressure to reduce CO_2 emissions, the Chinese government has formulated a series of CO_2 emission reduction plans. For example, the Chinese government announced that by 2020, the CO_2 intensity will be reduced by 40% to 45% on the basis of 2005; in 2014, the Chinese government further promised to peak its national CO_2 emissions by 2030. However, CO_2 emissions have great externalities, and it is difficult to achieve China's CO_2 emission reduction plan simply by relying on market adjustments. This reduction requires a series of environmental regulation measurement at all levels of government. For a long time, China has achieved some results through the promulgation of environmental laws and regulations, the development of environmental standards, levying of sewage taxes and fees, and government subsidies. However, China's pressure to reduce CO_2 emissions is still great.

At present, there is great controversy about whether environmental regulation is conducive to achieve CO_2 emissions reduction, and no consistent conclusions have been reached. Schou (2002) presents that the environmental regulation measures adopted by the government are superfluous because with the continuous consumption of fossil fuels, environmental pollution will automatically improve. Sinn (2008) proposed the idea of a "green paradox". It indicates that the implementation of environmental regulations will accelerate the development of fossil energy owners, resulting in oversupply, declining fossil energy prices, increasing demand, and increasing environmental pollution. More scholars agree with the point of "forcing emission reduction" in which appropriate environmental regulation will force enterprises to upgrade industrial structures and technical innovations to achieve the goal of reducing emissions (Ollinger & Fernandez-Cornejo, 1998; Brunnermeier & Cohen, 2003). Is the current environmental regulation in China a "green paradox" or "force effect" on the reduction of the CO_2 emissions?

In addition, cities play an important role in energy consumption and CO_2 emissions. China's total urban energy consumption accounts for 85% of total consumption, which is 18% higher than the world average (China Urban Energy report). The per capita energy consumption ratio between urban and rural areas is 6.8 (Dhakal, 2009). Thus, it can be seen that environmental regulations of CO_2 emissions should be studied at the city level. However, related literatures mainly study the relationship between CO_2 emissions and environmental regulations at the industry, provincial or national level, but rarely at the city level. Finally, most of the existing literatures use single environmental regulation indicators or comprehensive environmental regulation indicators to study the impact on environmental pollution, and rarely consider the heterogeneity of different environmental regulation indicators. Some literatures use a single indicator such as the level of per capita income, the number of environmental regulation laws, and pollution control inputs as environmental regulation indicators, which may have a certain one-sidedness. The comprehensive environmental regulation indicators better reflect the environmental regulation intensity of each region, but the comprehensive environmental regulation indicators can not reflect the heterogeneity impact of different environmental regulation indicators. In addition, a different selection of single environmental regulation index will also affect the size of comprehensive environmental regulation index, which may affect the final research results.

Therefore, the contribution of this paper has three main aspects. First, the study used data from 285 cities in China during the period of 2004-2013. The results included more data than most previous studies at the industry, provincial or national level. In addition, most economic activities and environmental pollution occurred in cities, the use of city-level data increases the accuracy and reliability of the conclusions. Second, this paper breaks down the carbon emissions of 285 cities in China from 2004 to 2013 into three parts: scale effect, composition effect and technique effect, and then deeply analyzes the mechanism of heterogeneous environmental regulation on the carbon emissions of cities through the above three channels. The results of this paper can provide a scientific basis for the selection of government environmental regulation tools. Third, this paper studies the heterogeneity impact of different environmental regulations on cities in two controlled areas and non-two-controlled areas.

The remainder of this paper is organized as follows: Section 2 surveys the relevant literature. Section 3 introduces the data and presents the decomposition method of CO_2 emission in Chinese cities. Section 4 focuses on the effects of formal and informal environmental regulation on the increase in CO_2 emissions and their three decomposition effects. Section 5 concludes.

2. Survey of Related Literature

2.1. Impact of Environmental Regulations on CO_2 Emissions

The effects of environmental regulation on CO_2 emissions are still highly controversial, mainly the controversy between the "green paradox" and "reverse emission reduction". Sinn (2008) first proposed the "green paradox" view that the supply of fossil fuels is limited. When the government adopts environmental regulation policies, fossil fuel owners believe that this policy will damage their own interests, and the owners accelerate the mining of fossil fuels. When sold, fossil fuels are oversupplied in a short period of time, so prices fall and demand rises, which, in turn, accelerates CO_2 emissions. Gerlagh (2011) further proposed a weak green paradox and a strong green paradox and has been widely recognized by the academic community. The weak green public opinion emphasizes the side effects of environmental regulation policies on CO_2 emissions in the short term, while strong green public opinion emphasizes the net present value of losses caused by environmental regulation policies in the long run. Of course, the opposition to the "green paradox" is not overwhelming. Zhang & Wei (2014) believes that with the strengthening of environmental regulations, the impact of the green paradox will be transformed into mandatory emission reduction. Eichner & Pethig (2011) argue that the "green paradox" will disappear when the supply curve of the alternative is tilted upwards. It can be seen that whether environmental regulation is conducive to CO_2 emission reduction is quite controversial among academic circles. This paper examines the relationship between environmental regulation and carbon emission to verify whether the "green paradox" exists in China.

2.2. Selection of Environmental Regulation Indicators

Since the effects of environmental regulation policies are difficult to quantify, and the environmental regulation data at the city level is difficult to obtain, the current selection of environmental regulation indicators varies widely among scholars. Indicators can mainly be divided into the following categories: 1) Measuring the intensity of environmental regulation from the number of environmental regulations (Low & Yeats, 1992). 2) Measuring the intensity of environmental regulation by the proportion of pollution control investment in total cost or total output (Gray, 1987). 3) Using the comprehensive index method to construct a comprehensive indicator of environmental regulation intensity. Goldar and Banerjee (2004) used the growth rate of social education level and the voter turnout rate in parliamentary elections as informal environmental regulation indicators; Langpap and Shimshack (2010) investigated public litigation against environmental pollution and used public supervision and public enforcement as informal environmental regulation variables; when Auffhammer et al. (2016) studied the effect of FDI on CO_2 emission, the study took environmental regulation as a control variable and used electricity price and sewage treatment fees as an environmental regulation index. 4) Using the per capita income level as a proxy variable to measure the intensity of environmental regulation (Antweiler et al., 2001; Mani & Wheeler, 1998). Considering the availability and credibility of data at the city level, this paper selects the reduction of CO_2 targets which is set in the 12th Five-Year Plan, sulfur dioxide emission reductions and urban electricity prices as different environmental regulation variables.

2.3. Scale, Composition, Technique Effects, and Decomposition Methods

Decomposition analysis, as a method to study the characteristics and changing mechanism of interperiod changes, has been widely used in social economic research in recent years. The basic idea of this method is to decompose the change in a certain economic indicator into a variety of driving factors and obtain the respective contribution rates of the driving factors. Currently, there are three main methods for decomposing CO_2 emissions, namely, Kaya identities, LMDI decomposition and STIRPAT models. McCollum & Yang (2009) used Kaya's identity to study the possibility of significantly reducing greenhouse gas emissions from US transportation in the long run. Ang and Su (2016) studied the global power generation from 1990-2013 and the CO_2 intensity in some countries based on the LMDI decomposition method. Lin and Tan (2017) studied the main factors affecting the CO_2 emissions of China's six energy-intensive industries based on Kaya's identity and the LMDI decomposition method. Poumanyvong and Kaneko (2010) used the STIRPAT model to study the effects of urbanization on CO_2 emissions in 99 countries at different stages of development from 1975-2005. Wang et al. (2018) extended the STIRPAT model by adding the proportion of 0 - 14-year-old population and gender factors, and used China's 2006-2015 provincial data to explore the main factors affecting CO_2 emissions.

All three methods are currently used, but each method differs in its applicability to each study. In the use of Kaya's identity, a time-phase analysis of the decomposition factors is required, and the decomposition factors must satisfy the identity; although LMDI can quantify the contribution rate of each influencing factor to the affected object, it cannot study the contribution rate of a single factor. Specifically, when other factors remain unchanged, the contribution rate of a particular factor cannot be studied. The traditional STIRPAT model only includes the three variables of population, technology, and economic development level; it cannot comprehensively analyze the main factors affecting CO_2 emissions. The improved STIRPAT model has no uniform standards and is subjective. This paper decomposes CO_2 emissions into scale, composition and technique effects with reference to the decomposition framework of Shapiro and Walker (2015) (Antweiler et al., 2001; Auffhammer et al., 2016).

First, the scale effect is mainly reflected in the growth of urban output, which has an impact on environmental quality from two aspects. On the one hand, economic growth needs to increase investment and then increase the use of resources; on the other hand, more output will also lead to an increase in pollution emissions. Second, the composition effect refers to a change in CO_2 emissions caused by a change in the industrial structure of a city. In the early years, the industrial structure shifted from primary to energy-intensive heavy industries, resulting in increased emissions, followed by a shift in the economy to green, low-polluting services and knowledge-intensive industries, and reduced energy consumption. The level of CO_2 emissions per unit output decreased, and the quality of the environment improved. The technique effect, which is reflected in the progress of production technology in the process of economic growth in a country, affects the environment by two means. First, when other conditions remain unchanged, technical advancement increases productivity, thereby improving the efficiency of resource use, reducing the input of factors per unit of output, and weakening the impact of production on the environment. Second, environmental technology has been developing and replacing pollution technology, and effectively recycling resources to reduce pollution emissions per unit output.

Through the review of the above literature, we find that at present, in the study of environmental regulation, many scholars only study environmental regulation as a control variable; environmental regulation is rarely studied as an independent variable. Second, most of the existing studies focus on the micro-enterprise or macro-national level, and rarely study environmental regulation and CO_2 emissions from the city level, which is mainly due to the nonavailability of city-level data. Third, existing research rarely explores the effects of different environmental regulations on carbon emission reduction. This paper uses urban-level carbon emission data from 2004 to 2013 and decomposes urban carbon emission, exploring the effects of different environmental regulations on urban carbon emissions and their decomposition effects.

3. Decomposition of Urban CO_2 Emission Variation in China

3.1. Decomposition Framework

According to the decomposition framework of Shapiro and Walker (2015), we decompose the CO_2 emissions changes in Chinese cities into scale, composition and technique effects. Using X_{ct} to represent the total GDP of all industries of city c in year t, θ_{cit} is the share of the output of industry i of city c in year t, and e_{cit} represents CO_2 intensity (total CO_2 emission/GDP), so the total CO_2 emission of city c in year t is

$$P_{ct} = X_{ct} \cdot \sum_i \theta_{cit} \cdot e_{cit} \quad (1)$$

By fully distinguishing Equation (1), the change in CO_2 emissions can be decomposed into the following expressions :

$$\Delta P_{ct} = \Delta X_{ct} \cdot \sum_i \theta_{cit} \cdot e_{cit} + X_{c,t-1} \cdot \sum_i \Delta\theta_{cit} \cdot e_{cit} + X_{c,t-1} \cdot \sum_i \theta_{ci,t-1} \cdot \Delta e_{cit} \quad (2)$$

On the right-hand side of (2), the first part represents the scale effect, which measures the effect of the increase of total economic scale on CO_2 emissions while keeping industrial structure and CO_2 emission intensity unchanged. The second part represents the composition effect, which is used to explain the effect of the industry internal structure adjustment on the CO_2 emission when the economic scale and carbonemission intensity remains unchanged. The last part is the technique effect, that is, keeping the economic scale and industrial structure unchanged, and the influence of CO_2 emission intensity change on CO_2 emissions.

3.2. Data Sources and Description

3.2.1. City-Level GDP Data

This paper constructs the panel data of 285 cities above the prefectural level in China from 2004 to 2013. As of the end of 2014, there were 290 cities above the prefecture level in China. Due to the lack of data in Lasa, Sansha, Bijie, Tongren, and Haidong, the data set of this paper covers 285 cities above the prefecture level (excluding Lasa, Sansha, Bijie, Tongren and Haidong). In this paper, the

GDP data of 285 prefecture-level cities during 2004-2013 are derived from the China Urban Statistical Yearbook, and the provincial GDP deflator is used to convert the cities' nominal GDPs to the base period of 2004.

3.2.2. CO_2 Emissions at the Provincial Level and the Six Basic Sectors

According to the Energy Statistics Yearbook of China, we calculated the energy consumption of provinces and their six basic sectors from 2004 to 2013, including coal, crude oil, gasoline, diesel, natural gas, electricity, etc. Then, according to the conversion factors of energy consumption obtained by IPCC in 2006, the CO_2 emissions of provinces and the six basic sectors were calculated from 2004 to 2013.

3.2.3. Proportion of Cities by Industry

When we calculate the scale, composition and technique effects, we must use the ratio of the urban subsector GDP to the cities' GDPs. The change in the proportion of urban subsector GDP to a city's GDP can reflect the changes in the city's industrial structure. However, there is almost no GDP data in China's urban subsectors. To better reflect the changes in the urban industrial structure, we use the changes in the proportion of employed people in urban subsectors. The employment data of urban subsectors comes from the China Urban Statistical Yearbook. To correspond with the CO_2 emission data of the six basic departments at the provincial level, we have consolidated the employment of 19 industries in the cities according to the six basic departments at the provincial level.

3.2.4. Measurement of Environmental Regulation Intensity

Considering the inevitability and the untrustworthiness of relevant data at the city level, this paper selects the reduction of SO_2 emission formulated by the "Eleventh Five-Year Plan", the reduction of carbon intensity formulated by the "Twelfth Five-Year Plan" and electricity price as different environmental regulation variables. The reduction of carbon intensity and SO_2 are mandatory environmental regulations formulated by the government, which can reflect the intensity of environmental regulations in each province. We assume that the reduction of carbon intensity at the urban level is the same as the reduction of carbon intensity in the province and that the reduction of carbon intensity is used as a direct emission reduction tool. In addition, according to the research method of Chen et al. (2018), the emission reduction of SO_2 in each city is estimated. Considering that reducing SO_2 while reducing carbon emissions, and SO_2 reduction is used as a synergistic emission reduction tool. Finally, urban electricity price is one of the policy tools for attracting investment, which potentially reflects the intensity of urban environmental regulation (Wu et al. 2016). This paper regards electricity price as a comprehensive environmental regulation.

3.3. Decomposition Mode Analysis

Based on the estimates of X_{ct}, θ_{cit} and e_{cit}, we use Equation (2) to decompose, and obtain the average CO_2 emissions of 285 cities from 2004 to 2013, the changes of carbon emission from 2004-2013 and their three decomposition effects. On this basis, we can obtain the change in China's national level of CO_2 emissions from 2004 to 2013 and its three decomposition effects.

Figure 1 is a line chart showing the change in China's CO_2 emissions and GDP from 2004 to 2013. From Figure 1, we can see that with the rapid growth in China's GDP, China's CO_2 emissions have also increased rapidly. From 2004 to 2013, China's GDP increased by 142.39%, and CO_2 emissions increased by 115.87%. In addition, China's CO_2 emissions growth has slowed since 2010, from 11.11% in 2010 to 2.69% in 2013. Figure 2 shows the decomposition effect of China's CO_2 emissions growth from 2004-2013. China's CO_2 emissions increased by approximately 5.812 billion tons in a decade. Among them, while maintaining the industrial composition and production technology in 2004, CO_2 emissions increased by 164.3%, mainly due to the rapid development of China's economy and the rapid growth of fossil energy consumption; in the case of maintaining the same scale of production and production technology in 2004, the industrial composition adjustment in the decade has reduced CO_2 emissions by approximately 9.36%, and the reduction in CO_2 emissions is small. The reason may be that high-energy-consuming enterprises in the eastern region have moved to the central and western regions, so that the composition effects are not significant across the country; while maintaining the same scale of production and industrial composition in 2004, the technical effect of the decade has reduced CO_2 emissions by approximately 39.19%, and the effect is relatively significant.

Figure 3 is the annual average of CO_2 emissions from 285 cities in China from 2004 to 2013 (unit: 10,000 tons). We can visually see that China's CO_2 emissions show a significant imbalance in regional distribution. According to our calculations, Shanghai's annual average CO_2 emissions ranked first in the country during the past 10 years, exceeding 200 million tons, followed by cities such as

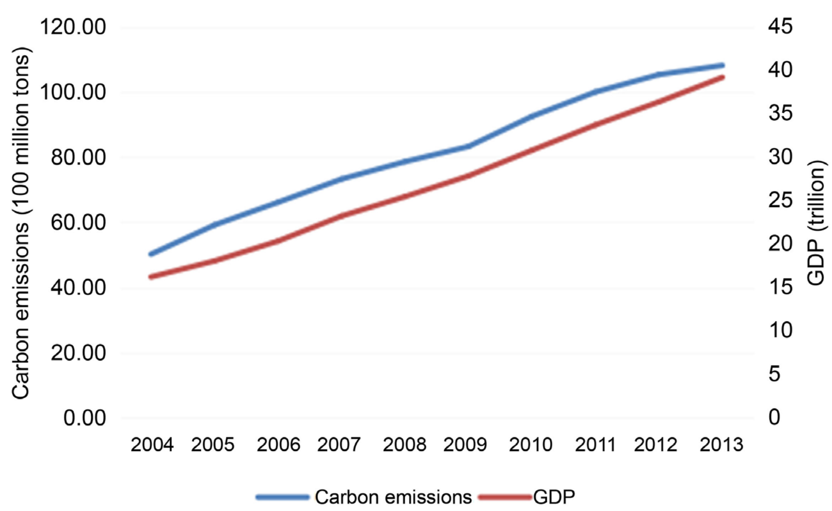

Figure 1. China's CO_2 emissions and GDP from 2004-2013.

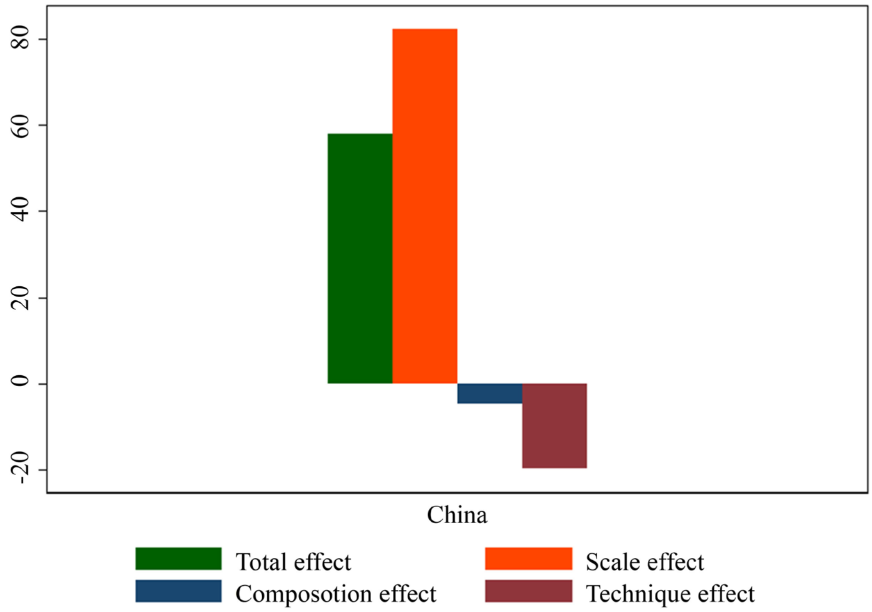

Figure 2. China's CO_2 emission decomposition effect from 2004-2013 (unit: 100 million tons).

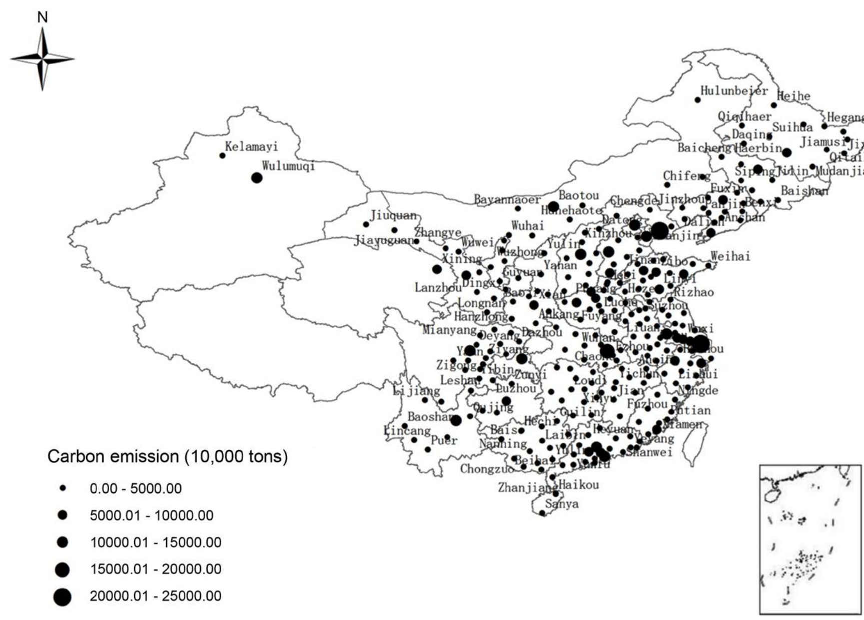

Figure 3. Average CO_2 emissions of Chinese cities from 2004 to 2013 (unit: 10,000 tons).

Tangshan, Wuhan, Beijing, Tianjin, Chongqing, Nanjing, Wulumuqi, and Shijiazhuang. These cities have the highest CO_2 emissions in the country, with annual average CO_2 emissions exceeding 100 million tons. Figure 4 shows the average annual CO_2 emission intensity of Chinese cities (tons/10,000 yuan) for the period 2004-2013. There are also large regional differences in CO_2 emission intensity in different cities. However, compared with Figure 3, the regional average CO_2 emission intensity is significantly different from the annual average CO_2 emission. Some cities in Ningxia and Shanxi province, the CO_2 emission intensity is

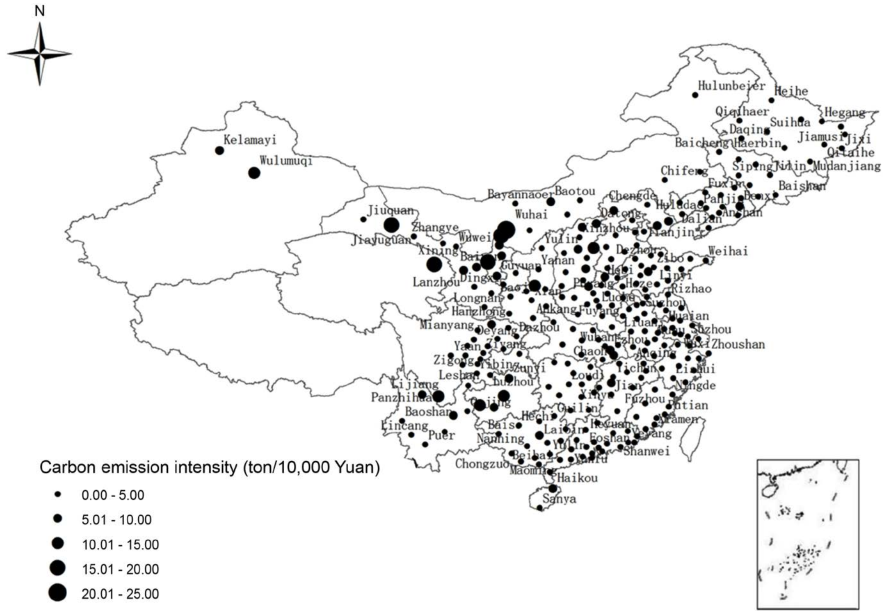

Figure 4. CO_2 emission intensity of Chinese cities from 2004 to 2013 (tons/10,000 yuan).

significantly higher than the national average, close to 10 tons/10,000 yuan GDP. In major cities such as Beijing, Shanghai, and Guangzhou, the CO_2 emission intensity has remained below 2 tons/10,000 yuan GDP from 2004-2013. This finding is because cities such as Beijing, Shanghai and Guangzhou have developed economies and high levels of social development, and regional economic development has a strong spatial agglomeration effect. Therefore, the industrial structure is more reasonable, the CO_2 emission intensity is lower, and the total CO_2 emissions are high; the industrial structure of Ningxia and Shanxi, heavy industry plays a major role, as the main energy output area, the CO_2 emission intensity is high, and the total CO_2 emission is low, which also shows that the industrial sector dominates the CO_2 emissions of Chinese cities.

Chinese cities are characterized by regional disequilibrium in industrialization and urbanization. In the eastern, central and western regions, there are great differences in social and economic development, educational level, environmental management and so on. This study divided 285 cities into the eastern region (101 cities), the central region (100 cities), and the western region (84 cities).

As shown in **Figure 5**, the green bar shows the average growth of urban CO_2 emissions by region from 2004 to 2013. We decompose the growth of average urban CO_2 emissions. The yellow bar corresponds to the scale effect, and the blue bar corresponds to the composition effect. The red bar corresponds to the technique effect.

First, we found that the largest increase in the average CO_2 emissions of regional cities from 2004-2013 was in the eastern region, followed by the western region, and the largest increase in CO_2 emissions due to scale effect was also in the eastern region, followed by the western region. This finding is mainly because the eastern region is the center of China's economy, the GDP of the eastern

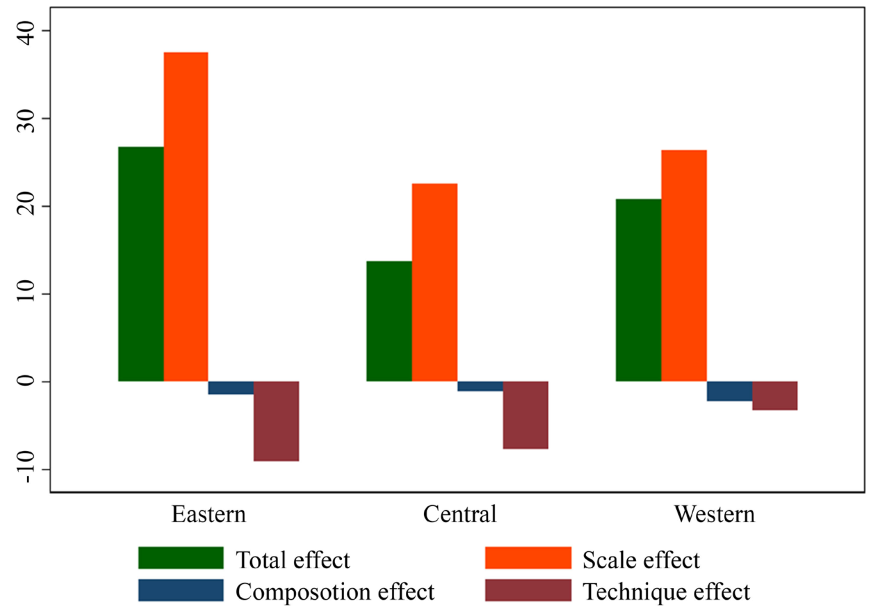

Figure 5. The average CO_2 emission decomposition effect of urban subregions from 2004-2013 (unit: million tons).

region accounted for 51.2% in 2013, which determines the rapid growth of CO_2 emissions in the eastern region; while the western region mainly undertakes the industrial transfer of the eastern and central regions, the economy of the western region is still dominated by extensive economic development, which is accompanied by high consumption and high emissions. In terms of composition effects, we find that the composition effects of the western region have the greatest negative impact on CO_2 emissions, followed by the eastern region, while the central region is least affected by composition effects. On the other hand, in the three regions, the most obvious effect of the technical effect on CO_2 emissions is in the eastern and central regions, with absolute values accounting for 18.91% and 24.65%, respectively, while the western proportion is only 10.19%. This finding is mainly because the eastern and central regions have a strong economic base and more investment in emission reduction technologies. In addition, the eastern region has always been at the forefront of reform and opening up, with a strong economic base and industrial supporting capacity. Compared with the western region, the eastern region absorbs and digests the international advanced technology earlier, which is the source of the innovation driving development of our country. However, the western region is constrained by the level of economic development, and technical progress is mainly achieved by undertaking industrial transfer. Therefore, the technical effect in the western region is relatively small.

China's cities are characterized by regional imbalances in terms of industrialization and urbanization, and there are also large differences in the intensity of environmental regulation between cities. In 1998, China officially established SO_2 controlling and acid rain controlling zone. If a city is classified into two control zones, stricter environmental regulations will be adopted to reduce pollutant emissions, especially SO_2. Among the 285 cities studied in this paper, there are 156 cities in two control zones, including not only 4 municipalities, 21 provincial capitals, but also four special economic zones including Shenzhen, Zhuhai, Shantou, and Xiamen. Compared with non-control zone, the two control areas have a large population, developed industries and strong economic strength. There are 129 cities in non-control zone, and the environmental regulations adopted are relatively weak.

As shown in Figure 6, we find that the increase of CO_2 in the cities of the two control zones and the non-control zone are caused by the scale effect. The increase of CO_2 in the two control zones is nearly twice that of the city in the non-control zone, which also indicates that economic growth is the main reason for the increase in urban carbon emissions. In addition, the composition effect and technique effect reduce the urban carbon emission in the two control zones and non-control zone, but the effect of composition effect and technique effect are more significant in the two control areas. The carbon emission reduction caused by the composition effect is nearly 5 times of that of cities in non-control zone, and the carbon emission reduction caused by the technique effect is nearly 7 times of that in cities in non-control zone. This also proves that strict environmental regulation measures adopted by the two control zones, such as the collection of SO_2 sewage charges and the installation of SO_2 removal facilities, have promoted the industrial restructuring and production technology innovation of enterprises.

4. Analysis of the Regression Results

4.1. Analysis of Urban Regression Results

This paper studies the effects of formal and informal environmental regulation

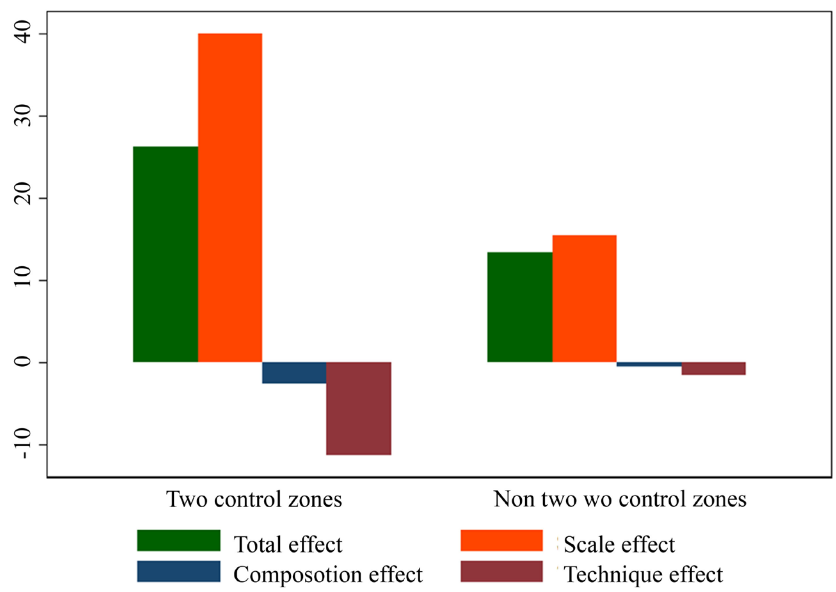

Figure 6. Average carbon emissions and their decomposition effects in two control zones and non-control zones from 2004-2013 (units: million tons).

on CO_2 emissions and three decomposition effects using urban data from 2004 to 2013 in China. Since the three decomposition effects are relative to the increase in CO_2 emissions, our equations take the form of first-order difference. Another first-order difference can also eliminate the instability of urban data caused by time changes, making the results more credible. In the model, the dependent variable ΔY_c has four meanings, which are the scale effect, the composition effect, the technique effect, and the CO_2 emission difference. ΔCO_2 is the reduction of carbon intensity, ΔSO_2 is the reduction of SO_2 emission, and ΔEprice is the industrial electricity price. X is the control variable and dummy variable, which mainly includes the difference of GDP, the difference of share of FDI in GDP and the ratio difference between the secondary industry and the tertiary industry. The dummy variables are the eastern region, the central region, and the western region; ε_c is the error term.

$$\Delta Y_c = \alpha_1 + \alpha_2 \cdot \Delta CO_2 + \alpha_3 \cdot \Delta SO_2 + \alpha_3 \cdot \Delta \text{Eprice} + \alpha_4 \cdot X + \varepsilon_c \quad (3)$$

Table 1 reports the estimated results of OLS. We can see that ΔCO_2 has the

Table 1. Effects of environmental regulations and FDI on CO_2 emissions and the three decomposed effects (OLS).

	Total effect	Scale effect	Composition effect	Technique effect
ΔCO_2	−3.9632***	−2.8831*	1.0429***	−2.1230**
	(1.4694)	(1.5185)	(0.3085)	(0.8954)
ΔSO_2	−3.6204***	−6.6724***	0.8954***	2.1566***
	(1.2316)	(1.2728)	(0.2586)	(0.7505)
ΔEprice	−0.0658**	−0.0722**	−0.0060	0.0125
	(0.0282)	(0.0291)	(0.0059)	(0.0172)
Δfdi/gdp	1.0266*	0.7387	−0.3386***	0.6265*
	(0.5473)	(0.5657)	(0.1149)	(0.3335)
Δgdp	0.0093***	0.0165***	−0.0005	−0.0068***
	(0.0015)	(0.0016)	(0.0003)	(0.0009)
ΔSecond/third	4.7407**	2.7703	−0.6507	2.6211*
	(2.3708)	(2.4501)	(0.4978)	(1.4447)
Eastern	14.0276**	7.4729	0.4000	6.1546*
	(5.6438)	(5.8326)	(1.1851)	(3.4391)
Central	0.3884	2.7125	1.3502	−3.6743
	(4.1098)	(4.2472)	(0.8630)	(2.5043)
Constant	105.5598***	89.9849***	−15.5972***	31.1721**
	(21.6713)	(22.3962)	(4.5507)	(13.2055)
N	285.0000	285.0000	285.0000	285.0000
r2_a	0.3877	0.6111	0.1612	0.4048

Standard errors in parentheses *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

best CO_2 reduction effect, followed by ΔSO_2 and finally ΔEprice. This is consistent with our basic expectations, and it also proves that "green paradox" does not exist in China. The main reason is that ΔCO_2 is a government-special carbon emission regulation policy, and ΔSO_2 a government-specific SO_2 reduction policy, mainly plays a synergistic role in reducing CO_2, whose effect is slightly less than ΔCO_2. ΔEprice, as one of the investment policies of the regional government, plays a potential role in CO_2 reduction. Secondly, in terms of scale effect, ΔCO_2, ΔSO_2 and ΔEprice can significantly reduce urban carbon emissions at the levels of 10%, 1% and 5% respectively. Among them, ΔSO_2 has the best CO_2 reduction effect, followed by ΔCO_2 and ΔEprice. We can see that ΔCO_2 and ΔSO_2 differ greatly in scale effect. The reasonable explanation is as follows: 1) SO_2 reduction policy was implemented as early as 2005, while carbon emission reduction policy was implemented in 2010. SO_2 reduction policy lasts longer and has a better effect. 2) More than 70% of China's SO_2 and CO_2 come from fossil fuels, and the ratio of carbon emissions and SO_2 emissions in the combustion process of fossil fuels exceeds 107. Therefore, the SO_2 reduction policy not only reduces SO_2 emissions, but also significantly reduces CO_2 emissions. Thirdly, from the composition effect point of view, ΔCO_2 and ΔSO_2 both significantly increase the city's carbon emissions at the level of 1%. Although ΔEprice is negatively correlated with urban carbon emissions, the effect is not significant. The possible explanations are as follows: 1) after nearly 40 years of reform and opening up, China has formed an energy-intensive, labor-intensive and pollution-intensive industrial structure. Environmental regulation cannot promote China's industrial restructuring and upgrading in a short period of time. For example, during the 11th five-year plan period, China closed more than 70 million kilowatts of small thermal power units, but at the same time encouraged enterprises to build "high-capacity, low-consumption" thermal power units. 2) As a regional government's regulation policy, electricity prices should not only take into account the role of environmental regulation, but also consider the relationship between power supply and demand, poverty alleviation and other factors. Therefore, the effect of electricity prices on carbon emissions is not significant. Finally, in terms of technique effect, ΔCO_2 significantly reduces urban carbon emissions at the level of 5%, ΔSO_2 significantly increases urban carbon emissions, while ΔEprice has no significant impact on urban carbon emissions. Reasonable explanations are as follows: 1) carbon intensity promotes technical innovation of enterprises, reduces energy consumption intensity, and thus reduces urban carbon emissions, which is consistent with the research conclusions of Jaffe et al. (1995), Lanoie et al. (2011). 2) The increase of the regulation intensity of SO_2 will prompt enterprises to install desulfurization devices, use clean coal and other measures to reduce SO_2. To a large extent, these measures do not improve CO_2 reduction technology, or even produce "extrusion effects" (The company used the funds originally used for technological innovation to purchase desulfurization equipment.), which hinders the technical innovation of enterprises in carbon emission reduction.

Second, from the regression results, we can see that the "pollution haven hypothesis" in China still exists. When FDI increases, urban CO_2 emissions increase, and the increase of CO_2 is mainly through the insignificant scale effects. In addition, in terms of composition effects, FDI inflows reduce urban carbon emissions. The main reason is that FDI mainly flows into the tertiary industry, such as leasing and business services, wholesale and retail, etc. The proportion of FDI in manufacturing has dropped from 70.95% in 2004 to 38.74% in 2013. Finally, FDI significantly increases CO_2 in terms of technique effects. A reasonable explanation is that with the improvement of China's production technology level, the inflow of FDI cannot promote the production capacity of China.

Third, although per capita GDP has a significant positive correlation with CO_2 emissions, economic development reduces CO_2 emissions in terms of composition and technique effects. This is consistent with the government's emphasis on maintaining high-speed economic growth while pursuing green development. When the secondary industry increases compared with the tertiary industry, the CO_2 emissions increase significantly, mainly in the scale effect and technique effect.

4.2. Analysis of Regression Results between Two Control Zones and Non-Control Zone

As shown in Table 2, it can be found that ΔCO_2 significantly reduces urban carbon emissions in both two control zones and non-control zone, but ΔCO_2 has

Table 2. Effects of environmental regulations on CO_2 emissions in two control zones and non-control zone.

	Total effect	Scale effect	Composition effect	Technique effect
		Two control zones		
ΔCO_2	−6.9308*	−4.1531	2.4712***	−5.2489**
	(3.7876)	(4.0269)	(0.7716)	(2.1842)
ΔSO_2	−7.0052***	−6.9702***	1.0736**	−1.1086
	(2.0317)	(2.1601)	(0.4139)	(1.1716)
ΔElectricity price	−0.0754	−0.1357**	−0.0090	0.0693**
	(0.0505)	(0.0536)	(0.0103)	(0.0291)
		Non-control zone		
ΔCO_2	−3.1841***	−3.5355***	0.6832***	−0.3319
	(1.0471)	(0.7673)	(0.2487)	(0.7343)
ΔSO_2	1.3161	−4.5976***	0.6319**	5.2819***
	(1.0719)	(0.7854)	(0.2546)	(0.7516)
ΔElectricity price	−0.0344	−0.0032	−0.0094	−0.0219
	(0.0242)	(0.0177)	(0.0057)	(0.0169)

Standard errors in parentheses $^*p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

a more significant effect in two control zones. ΔSO_2 significantly reduces urban carbon emissions in two control zones, but not in non-control zone. ΔEprice is not significant in both zones. The main reason is that compared with non-control zone, two control zones adopt more stringent environmental regulatory measures and is more thorough in implementing, so ΔCO_2 and ΔSO_2 have more significant effects on urban carbon reduction in the two control zones. Secondly, in terms of scale effect, ΔCO_2 has a more significant effect on carbon emission reduction in non-control zone. ΔSO_2 and ΔEprice have better effects on carbon emission reduction in two control zones. The possible reason is that two control zones have adopted strict regulations on SO_2 reduction for a long time. While closing down enterprises with high sulfur dioxide emission, some enterprises with high carbon emission have also been closed down. Therefore, the carbon emission reduction policy is better for non-control zone in terms of scale effect. This also explains that ΔCO_2 and ΔSO_2 have poor carbon emission reduction effects for two control zones in terms of structural effect. Finally, in terms of technique effects, ΔCO_2 significantly reduces carbon emissions in two control zones, while ΔEprice significantly increases carbon emissions in two control zones. The reasonable explanations are as follows: 1) compared with the non-control zone, the two control zones have adopted more environmental regulation measures, which promoted the technical innovation of enterprises, reduced the SO_2 and reduced the carbon emissions to some extent. 2) The two control zones require power companies to install desulfurization facilities, use clean coal et al., the electricity price of local enterprises has been raised, thus hindering carbon emission technology innovation of enterprises in the two regions.

Different environmental regulations have an emission reduction effect on carbon emissions, which is consistent with the conclusions of existing studies. However, the existing studies mainly focus on the micro enterprises or the national level, and cannot deeply explore the mechanism of environmental regulation affecting carbon emission. In addition, the distribution of carbon emissions in China is very regional and policy-oriented, which cannot be further studied from the micro enterprise and national level. This paper finds that different environmental regulations have different influence mechanisms on carbon emission in the two control zones and the non-control zone, which provides a certain basis for different environmental regulations in different regions.

5. Conclusion

Using data from 285 cities in China from 2004 to 2013, this paper decomposes CO_2 emissions into scale effects, composition effects, and technique effects, enriching our research on CO_2 emissions and their dynamics in Chinese cities. We further analyze the effects of different environmental regulations on CO_2 emissions and their three decomposition effects, and draw the following conclusions: First, carbon emission environmental regulation, sulfur dioxide emission environmental regulation and electricity prices also significantly reduce the city's carbon emissions, among which carbon emission reduction environmental regulation has the best effect, followed by sulfur dioxide emission reduction environmental regulation and electricity price. Second, different environmental regulations do not significantly reduce urban carbon emissions in terms of composition effects, and even increase carbon emissions of cities. Third, in terms of technique effects, environmental regulations for CO_2 have significantly reduced urban carbon emissions, while environmental regulations for SO_2 have increased urban carbon emissions, and the impact of electricity prices on urban carbon emissions is not significant. Fourth, compared with non-control zone cities, environmental regulations for carbon emission and SO_2 have a better effect on carbon emission reduction in cities of two control zones. Based on the above conclusions, we can get the following policy implications:

Fully tap and utilize the effectiveness of environmental regulation policy "forcing emission reduction", promote the adjustment and upgrading of China's industrial structure, encourage the development of carbon emission reduction technology and the development and use of green energy. According to our research, the environmental regulation policy has not promoted the industrial structure adjustment, upgrading, and environmental technology innovation. At present, many enterprises in China have overcapacity, backward technology, and production equipment, and there is no capital and technology for industrial restructuring and environmental protection facilities. While maintaining the moderate intensity of environmental regulation, the government should introduce relevant preferential policies or provide low-interest loans to guide enterprises to carry out technical transformation and environmental production transformation, so as to play the role of "forcing emission reduction" of environmental regulation. In addition, due to the great regional differences in China's economic development and the different industrial structures in different regions and cities, we should be cautious of "one-size-fits-all" when formulating environmental regulation policies, and should make differentiated environmental regulation intensity according to the characteristics of industrial development in different regions or cities. Finally, the government should increase the development and promotion of green energy in terms of policies and funds, such as the use of fuel cell vehicles, wind energy, hydrogen energy, etc., reduce the use of fossil energy, and reduce urban carbon emissions from the root causes.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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