The research on the impact of energy-environment policy on regional development—based on CGE model

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Abstract: In this study, we will focus on studying the impact of energy and environment regulatory on the inter-regional coordinated development from the regional level. Making use of multi-regional energy-economy-environment computable general equilibrium (CGE) model, we will analyze the effect of regional energy regulation in the future. We will research the impact of the carbon emissions trading and other environmental policy on regional economic development and industrial structure. The results show that the regulation of energy and environment can promote regional industry to upgrade and different policies of energy and environmental are needed to implement to mitigate the negative impact on the economy of different regions. In the paper, we expand the traditional regional energy-environmental CGE model tools for providing new quantitative methods to study regional energy and environmental problems in China.

1. Introduction
China's economic and social development faces many prominent problems, such as the restriction of environment and the unbalanced development of regional economics. China's energy resources are mainly concentrated in the north and the west, while economic growth areas are mainly concentrated in the southeast areas. The reverse distribution of economy and resources leads to the pressure of energy transportation. At present, many areas of our country are shortage of water and energy resources. The solution to these issues needs fundamentally change the mode of the regional economy and energy development. The impact of energy and environmental regulation on the economy is not only reflected in the growth rate, but also related to the industrial structure, the people's welfare and other aspects.

Computable general equilibrium model has been widely used in energy and environmental policy simulation. Energy-environmental CGE model is based on a typical economic system, but the energy elements and pollution emissions need to be carefully handled. For the energy-environmental CGE model, it is the core problem that how to embed the energy environment factor into the CGE model. The most of the energy environment CGE model is built up based on the standard CGE model framework by exogenous environment factor, which change the production function or utility function for the feedback the environmental impact of emissions. Roy et.al (1995) [1] broke down the energy-intensive sectors in the model for estimating environmental losses due to carbon emissions from all sectors. He et al. (2010) [2] directly calculated emissions of pollution using fixed emission factors for energy, in order to simulation the impact of environmental taxes on our energy reduction and economic development. In recent years, some scholars have tried to change the model of the basic data set to establish structure-derived type of energy and environmental CGE model. For instance, Gao
Ying et al (2009) [3] transformed the traditional social accounting matrix framework, which is introduced the new accounting accounts, such as resource recovery, pollution control and natural endowment factor, etc. Xie et al(2000) [4] increased the description of the environmental pollution controlling activities in the model, which established pollution control department to simulate the pollution reduction behavior and characterized emission reduction costs of the production department and environmental protection investmen, etc. From the regional level, the influence of various environmental regulations and energy regulation on interregional industry, capital and labor transfer is seldom considered. The few studies systematically consider the effect of the multiple energy regulations and environmental regulations on regional economic coordinated development. Niu Yujing et al (2012) [5] simulated and analyzed the impact of multi-regional carbon tariffs on carbon leakage using the CGE model of the eight regions in the world, introducing the international banking and international transport services and other virtual sectors, etc.

Compared with previous research on the national level of energy and environmental policies [6-10], this paper focuses on the impact of environmental regulation on regional energy trade, financial and human capital flows from the cross-regional level. We simulates the effect of environmental regulation and energy mechanism on regional economic coordinated development. In addition, the paper will enrich and expand the traditional regional energy-environmental CGE model tools for providing new quantitative methods to study regional energy and environmental problems in China.

2. The model and Scenario design

2.1. Multi-regional energy-environment-economy CGE model

We construct a multi-regional resource-economy-environment CGE model, which based on the social accounting matrix of Guangdong, Guizhou and other regions of China in 2007. Three regions have their own production and demand structure, and the regions are interrelated through commodity trade and the flow of production elements. The model includes 28 production departments, which are three resource recovery sector, four pollution control department, four resource sectors and 17 traditional productive sectors, and two types of groups are namely urban and rural, and six kinds of production factors are land, physical capital, environmental capacity of capital, agricultural labor, productive workers and professional and technical personnel.

In order to better characterize all kinds of energy and environmental regulations in the model, considering the energy consumption related to pollutant emissions, the energy and environmental capacity assets are combined to energy-asset beam with the Leontief function. It should be pointed out that any one of the production department has two kinds of treatment methods for pollutants, namely direct control (the goods of the pollution control department as an intermediate input) or buy emission rights. Environmental capacity assets can become capital to bring benefits, which the right of using environmental capacity can be transferred with compensation in the case of emissions trading. The environmental capacity assets become the capital with expected return, which also can be viewed as emission rights of an enterprise through the government auction or free distribution.

The model assumes full employment of labor, capital mobility, exogenously given regional environmental capacity capital. Environmental capacity assets can be assumed incomplete or complete flow between the sectors or regions based on the scenario setting, and liquidity depends on the rate of environmental capacity capital return, namely price of emission rights and elasticity of substitution. When the emission trading is not implemented, the model assumes that the supply of environmental capacity is in the form of a constant elasticity function. When the market of emission trading is established, equilibrium equation on emission rights between departments among regions is as follows.

\[ P_{EVr} = \left( \sum_{i} \alpha_{rr}^s PENV_{i,rs} \right)^{-\frac{1}{\sigma_{rr}}} \quad \text{if} \quad \sigma_{rr} \neq \infty \]
\[ TEN_{r} = \sum_{i} EN_{i,rs} \quad \text{if} \quad \sigma_{rr} = \infty \]
Emission rights price of production department in various regions,

\[ EN_{ir}^* = \alpha_{i,r}^{es} T_{ir} \left( \frac{PENV_{ir}}{Pev_{r}} \right)^{\sigma_{ir}} \text{ if } \sigma_{ir} \neq \infty \]

\[ PENV_{ir} = Pev_{r} \text{ if } \sigma_{ir} = \infty \]

Equilibrium conditions of the emission rights market,

\[ EN_{ir}^* = EN_{ir}^d \]

\( Pev_{r} \) Return on environmental assets of region r

\( TEN_{r}^i \) The total amount of all environmental assets of region r

\( PENV_{r}^i \) Prices environmental assets of region r department i

\( EN_{ir}^d \) Demand for environmental assets of region r department i

\( EN_{ir} \) All environmental assets of region r department i

\( \alpha_{i,r}^{es} \) Share parameters of environmental assets supply of region r department i

\( \sigma^{es} \) The sectorial elastic parameters of environmental assets

2.2. Scenario Design

According to IPCC fifth report, in order to achieve the sustainable development of human, the average global temperature rise must be controlled within 2 \(^\circ\)C in 2100. At present, China has become the world's largest carbon emitter. China's carbon emission in 2014 is about 94 billion tons, accounting for 29% of global carbon emissions. To assume the responsibility of emissions reductions, China commits that carbon emissions per unit of GDP in 2030 will be reduced by more than 60% in 2005. This study mainly set four scenarios to analyze the impact of energy and environmental regulations on regional economic development mode. The first scenario of environmental regulation is mainly the establishment of the carbon tax and carbon emissions trading. The second scenario is mainly the energy tax and the limitation energy consumption. Specific design scenarios are shown in Table 1.

| Category | Scenario description |
|----------|----------------------|
| A1: Energy tax | The tax rate of electric power, coal and refined oil is 10%. |
| A2: Limit energy consumption | Reduce energy consumption by 1% of the electricity, coal and refined oil. |
| B1: Carbon tax | The carbon tax is 10% in the final consumption goods of sectors. |
| B2: Carbon tax and Carbon emissions trading | The final goods consumption is levied 10% carbon tax, and establish regional carbon emissions trading market. |

3. The Result

3.1. The impact of environment policy on the regional economy

When the emissions trading market is not established, all regions that levied on the carbon tax, are more dependent on the output effect to achieve the emission reduction targets, so that the actual GDP decreases more than that in the case of the implementation of emissions trading scenarios. Guangdong and Guizhou are affected differently in both environmental policy scenarios due to the different industrial structure. Guangdong Province is based on the manufacturing, where the long-term extensive economic growth makes the local environmental capacity of capital increasingly scarce. If the emission reduction targets are achieved only through a carbon tax (B1), real GDP decline 0.14%, mainly due to carbon tax that increases production costs, reduce profits, and result in shrinking of production scale, the decline in rate of wages, reduce household disposable income. Residents reduce
consumption under the double impact of commodity price and income. Guangdong foreign imports and transferred area decreased, which are affected by the regional demand.

The real GDP fell 0.11 percent in Guangdong Province when the government levies on carbon tax. Guangdong Province can purchase emission reduction in other provinces to reduce costs due to the establishment of trans-regional emissions trading market, so that Guangdong can alleviate the negative impact of increasing production costs caused by the high local abatement costs. Compared to only establish of trans-regional emissions trading market, so that Guangdong can alleviate the negative impact of increasing production costs caused by the high local abatement costs. Compared to only establish of trans-regional emissions trading market, so that Guangdong can alleviate the negative impact of increasing production costs caused by the high local abatement costs. Compared to only establish of trans-regional emissions trading market, so that Guangdong can alleviate the negative impact of increasing production costs caused by the high local abatement costs. Compared to only establish of trans-regional emissions trading market, so that Guangdong can alleviate the negative impact of increasing production costs caused by the high local abatement costs. Compared to only establish of trans-regional emissions trading market, so that Guangdong can alleviate the negative impact of increasing production costs caused by the high local abatement costs. Compared to only establish of trans-regional emissions trading market, so that Guangdong can alleviate the negative impact of increasing production costs caused by the high local abatement costs. Compared to only establish of trans-regional emissions trading market, so that Guangdong can alleviate the negative impact of increasing production costs caused by the high local abatement costs. Compared to only establish of trans-regional emissions trading market, so that Guangdong can alleviate the negative impact of increasing production costs caused by the high local abatement costs. Compared to only establish of trans-regional emissions trading market, so that Guangdong can alleviate the negative impact of increasing production costs caused by the high local abatement costs. Compared to only establish of trans-regional emissions trading market, so that Guangdong can alleviate the negative impact of increasing production costs caused by the high local abatement costs. Compared to only establish of trans-regional emissions trading market, so that Guangdong can alleviate the negative impact of increasing production costs caused by the high local abatement costs. Compared to only establish of trans-regional emissions trading market, so that Guangdong can alleviate the negative impact of increasing production costs caused by the high local abatement costs. Compared to only establish of trans-regional emissions trading market, so that Guangdong can alleviate the negative impact of increasing production costs caused by the high local abatement costs. Compared to only establish of trans-regional emissions trading market, so that Guangdong can alleviate the negative impact of increasing production costs caused by the high local abatement costs. Compared to only establish of trans-regional emissions trading market, so that Guangdong can alleviate the negative impact of increasing production costs caused by the high local abatement costs. Compared to only establish of trans-regional emissions trading market, so that Guangdong can alleviate the negative impact of increasing production costs caused by the high local abatement costs. Compared to only establish of trans-regional emissions trading market, so that Guangdong can alleviate the negative impact of increasing production costs caused by the high local abatement costs. Compared to only establish of trans-regional emissions trading market, so that Guangdong can alleviate the negative impact of increasing production costs caused by the high local abatement costs.

| Table 2. The effect of environmental regulations on the regional economy (%) |
| --- |
| Carbon tax (B1) | Carbon tax + Carbon emissions trading (B2) |
| | Guizhou | Guangdong | China | Guizhou | Guangdong | China |
| --- | --- | --- | --- | --- | --- | --- |
| Real GDP | -0.03 | -0.14 | -0.06 | -0.03 | -0.11 | -0.05 |
| Total output | -0.12 | -0.24 | -0.10 | -0.10 | -0.19 | -0.08 |
| Resident consumption | -0.04 | -0.03 | -0.05 | -0.03 | -0.02 | -0.04 |
| Investment | 0.00 | -0.29 | -0.01 | 0.00 | -0.23 | -0.01 |
| Export | -0.64 | -0.19 | -0.17 | -0.52 | -0.16 | -0.14 |
| Import | -0.10 | -0.14 | -0.01 | -0.08 | -0.11 | -0.01 |
| Regional transfer-out | -0.21 | -0.15 | - | -0.17 | -0.12 | - |
| Regional transfer-in | -0.08 | -0.25 | - | -0.07 | -0.21 | - |
| Disposable income of rural residents | -0.40 | 0.10 | - | -0.33 | 0.08 | - |
| Disposable income of urban residents | -0.20 | -0.55 | - | -0.16 | -0.45 | - |
| Rural residents’ welfare benefits | -0.02 | 0.00 | - | -0.02 | 0.00 | - |
| Urban residents’ welfare benefits | -0.01 | -0.32 | - | -0.01 | -0.26 | - |
| The average wage rate of agricultural labor | -0.42 | -0.75 | - | -0.34 | -0.62 | - |
| The average wage rate of industrial workers | -0.50 | -0.72 | - | -0.41 | -0.59 | - |
| Technical personnel average wage rate | -0.29 | -0.63 | - | -0.24 | -0.52 | - |
| Return on capital | 0.42 | 0.42 | 0.42 | 0.35 | 0.35 | 0.35 |
| Coal consumption | -1.16 | -1.45 | -0.48 | -0.95 | -1.18 | -0.39 |
| Oil and Gas consumption | -0.62 | -1.58 | -0.34 | -0.50 | -1.29 | -0.28 |
| Thermal power consumption | -1.34 | -1.19 | -0.86 | -1.09 | -0.97 | -0.71 |
| Hydroelectric power consumption | 0.18 | 0.09 | -0.53 | 0.15 | 0.07 | -0.44 |

From the change of industrial structure, the output of the key industries in all regions decreased due to the carbon tax. But the supply output of hydroelectric power increases because the demand for clean energy such as hydroelectric power is increasing due to the decreasing output scale of thermal power supply, and so substitution effect hydropower and thermal power occurs. In the whole country and Guizhou Province, the output of coal mining industry is of the sharpest decline, followed by thermal
power supply, petrochemical and other carbon intensive sectors, while hydroelectricity and other electricity supply industry, social services and other less carbon-intensive manufacturing industries, labor-intensive industries have little impact. In Guangdong province, the decrease of each sector output is smaller than that of Guizhou province, the most significant decline in output is still the coal mining industry.

3.2. The impact of energy policy on the regional economy
Because of the energy tax, the price of commodity in Guangdong is lower than one of the Guizhou and other regions due to its industrial structure. Exports and regional transfer-out continue to grow, making the local GDP not fall but a slight rise. Guizhou affected more by heavy taxation than Guangdong, and Guizhou’s real GDP falls 0.23% due to the influence by exports and domestic transfer-out. The main reason is that the local economic base is weak, which any shock would have a greater impact on commodity prices and factor returns, and hinders the circulation of commodities and factor mobility between Guizhou and other areas, leading local real GDP subject to greater negative impact.

Under the restriction of total energy consumption, the GDP of Guangdong, Guizhou and the whole country decrease respectively by 1.4%, 5.5% and 3.2%, and the consumption of the residents in these regions decreased respectively by 2.5%, 3.6% and 4.8%. In view of this, mandatory policies of limiting the total amount of energy consumption, such as pulling a switch power brownouts, will lead to the destruction of economic growth and reduction of income. In the production sector, the electricity production, coal mining and supply industry, the oil and gas industry, chemical industry and metal rolling processing industry, belonging to high energy-consuming sector, the outputs decrease respectively by 0.21%, 0.20 %, 0.19%, 0.17% and 0.14%. The results of model are shown in Table 3. In addition, in a general equilibrium framework, limiting the supply of products in the energy sector will directly or indirectly lead to the output amount of upstream and downstream industries, which affect the tertiary industry, such as the retail trade industry, etc.

| Table 3. The impact of energy regulation on the regional economy (%) |
|---------------------------------------------------------------|
| Energy tax(A1) | Limit energy consumption(A2) |
| Radiation control | Radiation control |
| Guizhou Guangdong ROC China | Guizhou Guangdong ROC China |
| Real GDP | -0.002 0.010 -0.014 -0.002 | -0.032 -0.014 -0.049 -0.055 |
| Resident consumption | -0.019 0.012 -0.035 -0.030 | -0.036 -0.025 -0.050 -0.048 |
| Investment | -0.009 -0.012 -0.022 -0.021 | 0.002 -0.287 0.010 -0.007 |
| Export | 0.002 -0.238 0.006 -0.008 | -0.642 -0.190 -0.160 -0.170 |
| Import | -0.233 0.061 -0.027 -0.003 | -0.096 -0.135 0.042 -0.014 |
| Transfer-out | 0.018 0.021 -0.005 0.003 | -0.210 -0.148 -0.212 - |
| Transfer-in | -0.014 0.084 -0.047 - | -0.080 -0.253 -0.148 - |
| Disposable income of rural residents | -0.014 -0.046 0.072 - | -0.398 0.096 -0.003 - |
| Disposable income of urban residents | -0.014 0.004 -0.072 -0.076 | -0.195 -0.548 -0.003 - |
| Welfare income of rural residents | -0.119 -0.204 -0.151 -0.161 | -0.018 0.004 -0.614 - |
| Welfare income of urban resident | -0.001 0.000 -0.157 -0.158 | -0.007 -0.317 -1.420 - |
| The average wage rate (industrial workers) | 0.023 -0.240 -0.030 - | -0.495 -0.719 -0.006 - |
| The average wage rate (technical staff) | -0.082 -0.283 -0.183 - | -0.294 -0.633 -0.005 - |

4. The conclusions and recommendations
All kinds of energy and environmental regulations have some negative effect on the economic development of various regions. The establishment of emissions trading and other market mechanisms has a certain positive effect on alleviating the negative impact on the economy due to emission constraints. We prove that the emission trading is a lower cost pollution control method, which is
helpful to achieve the overall control objectives in the more economical way. In view of the characteristics of high energy consumption and heavy pollution in China, the combination of government measures and market mechanism which establish the perfect emissions trading market, is conducive to economic and social sustainable development.

Our country should balance the local economy with a different environmental tax rate. Due to the unbalanced regional economic situation, Guizhou and other underdeveloped areas in China provide raw materials and primary industrial products with the low added value. While Guangdong and other developed areas in China have developed manufacturers. At the same time, the consumption market is small in Guizhou due to the difference of income, so any shock of tax has a significant negative impact on Guizhou's economy. Therefore, the transfer payment was employed, reduce tax rates and the differential tax system were carried out in western areas, while the central government increase financial aid to the West. Under environmental taxation leverage, the environment is improved due to reduce emissions, while economic disparities between regions are narrowed.

The energy tax and energy consumption will have an important impact on the upstream and downstream industries as well as the income of the residents and the price of consumer goods. Implementation of energy tax reform will increase sector production costs, reduce the total energy consumption, but also indirectly increase the consumer price. In the control of total energy consumption, the government should avoid the phenomenon of capacity constraints such as blackouts, to avoid damage to economic growth.

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