Regional Energy/Envionmental Policy and Leakage Effect

---the study based on China's multi-regional CGE model

First version

2008-04-15

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Abstract:

Recently, energy saving/emission reduction has been a very import issue for policy makers and researchers. As a very large country, China's regional policies play an important role in energy saving/emission reduction as well as national-wide policy. Many internatioanl studies has showed unilateral emission reduction policies may result in the "carbon leakage", i.e. emission sources migrate from abating to non-abating countries. Furthermore, some studies pointed out that the leakage is quantitatively significant. In the same way, China's regional energy/environmental policy may also bring on the "emission/energy use leakage" effect among provinces. This paper will use China's multi-regional CGE model to analyze the "emission/energy use leakage" effect due to regional policy.

Key Words: Leakage effect, multi-regional CGE model, energy saving, emission reduction

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Backgroud

Since reform and opening-up, China's economy has maintained rapid growth. China's GDP in 2006 reached 21.0871 trillion yuan, ranking fourth in the world. In 1979~2006, its GDP grew by 12.4 times, with a growth rate ranking first in the world, six percentage points higher than the world's average annual economic growth rate and seven percentage points higher than developing countries. Especially in recent years, economic growth showed a pattern of "high growth, high input, high consumption, high pollution and low efficiency". In 1978-2005, average annual growth rate of energy consumption reached 5.16%; in the period of "11th Five-Year Plan", the growth rate of energy consumption has exceeded the economic growth rate, with an average annual growth rate of 9.9 percent. Especially in 2003 and 2003, the growth rate of energy consumption reached 15.3% and 16.1%, far exceeding the growth rate of GDP. This shows that the high economic growth results in the high energy consumption.

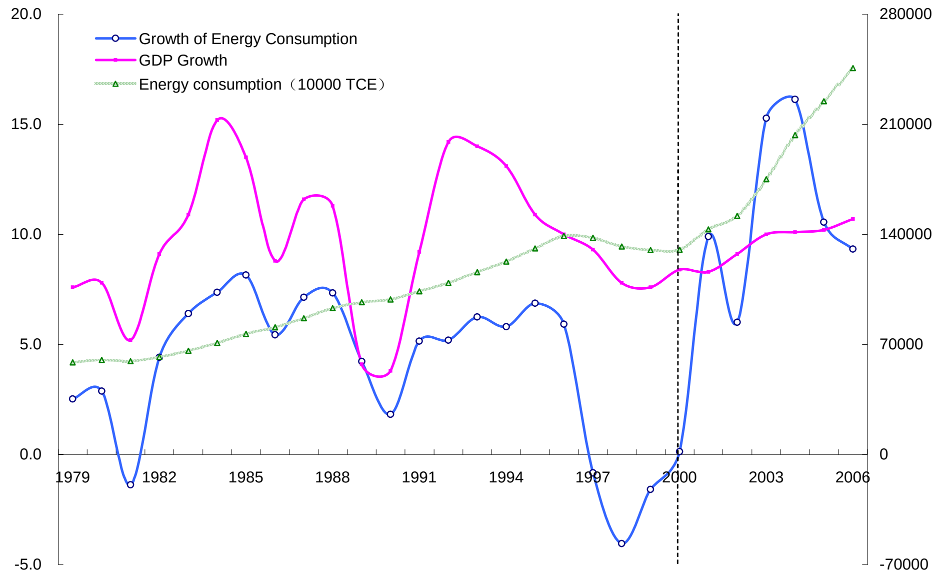

Fig. 1 the GDP growth and energy consumption (1978~2006)

According to the "Initial national communication on climate change of the People's Republic of China," China's greenhouse gas emissions in1994 to 4.06 billion tons in terms of carbon dioxide equivalent, in which carbon dioxide is 3.07 billion tons. According to the preliminary estimates by experts in China, in 2004 China's total greenhouse gas emissions of about 6.1 billion tons of carbon dioxide equivalent, in which carbon dioxide emissions is about 5.07 billion tons. From 1994 to 2004, China's total greenhouse gas emissions increased by 4% per year and the proportion of carbon dioxide in the total emissions increased from 76% in 1994 to 83% in 2004. In 2000, total greenhouse gas emission in China accounts for 14.4% of total world emission, USA for 23.96%. In the period of 1970~2002, the proportion of China's greenhouse gas emission in total wold emission increased by 10 percentage point.

Table 1 gives the emissions of major pollutants since 2000. It can be seen that the emission of sulfur dioxide and wastewater are mounting fast, with annual increase of about 5% and 27% in 2000 higher than in 2005. Although COD has declined before 2003, in recent years it is on the rise.

Table 1 the emission of major pollutants since 2000

年份	SO_2 (0.01 Mtons)	wastewater （100 Mtons）	COD (0.01 Mtons)	Soot (0.01 Mtons)
2000	1995	415	1446	1165
2001	1947	433	1405	1070
2002	1927	439	1367	1013
2003	2159	459	1333	1049
2004	2255	482	1339	1095
2005	2549	525	1414	1183

Data Source：China Statistical Yearbook, 2006

China is a very big country, with more than 30 provinces and autonomous regions. Different regions perform differently in terms of natural resources, geographical conditions, infrastructure and economic development. Figure 4 shows per capita GDP and energy intensity (energy consumption unit of GDP) of each province in 2004. The provinces with superior economic development locate in the coastal areas, with highest per capita GDP and lowest energy intensity. Most of the FDI and foreign trade are concentrated in these areas. But relative to inland western region, this area is scarcity of natural resources (such as land, energy, etc.). On the contrary, the central and western regions are rich in resources, but with inferior economic development and highest energy intensity. In Guizhou, Shanxi and Inner Mongolia, energy consumption per GDP is three times higher than the national average. As for analyzing the impact of policies in China,

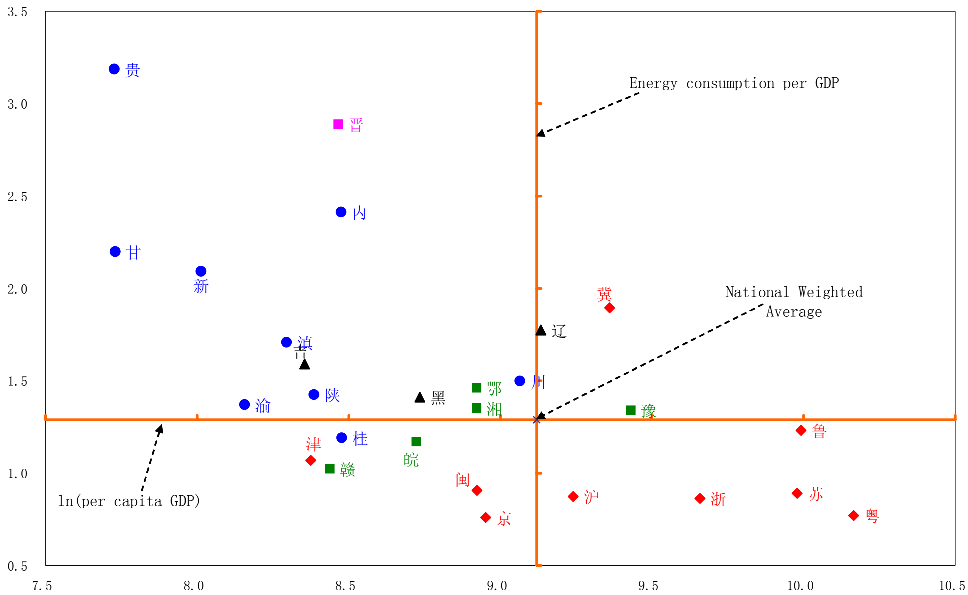

Fig. 2 Per capita GDP and Energy consumption per GDP for each provicne (2004)

regional disparity plays a very import role. Therefore a three regional CGE model is built for the analysis of energy and environmental policies.

The three regions in this model refer to the Guangdong (GD, Guangdong), Shanxi (SX, Shanxi), and other parts of the country (ROC, the Rest of mainland china). Guangdong Province in the southeast coast and close to Hong Kong and Macao, has a strong geographical advantages. As to international trade and FDI, Guangdong is taking the forefront in the country. Table 1 shows some indicators for the two provinces in 2003. By this table it can be found that Guangdong accounts 34% of the whole country in term of total international trade in 2003. Its foreign trade dependency is about three times higher than national average. Therefore analysis of the impact of globalization of trade, or, in the model of Guangdong Province alone is very necessary.

Table 2 Some indicator for China, Guangdong and Shanxi（2003）

Indicators	Shanxi		Guangdong		China
		% of China		% of China	
Population(10 thousand persons)	3314	2.6	7954	6.2	129227
GDP（0.1 billion Yuan）	2457	2.1	13626	11.6	117252
Per capita GDP (Yuan)	7435	81.7	17213	189.1	9101
Total international trade (10 thousand dollar)	52	0.6	2892	34	8510
Import	37	0.8	1537	35.1	4382
export	14	0.3	1355	32.8	4128
FDI(10 thousand dollar)	21361	0.4	782294	14.6	5350467
Foreign trade dependency	17%	29	176%	292	60%

Note：Foreign trade dependency＝(import +export)/GDP

From an environmental point of view, most of pollutants and energy consumption are closely related. Extremely rich in coal resources, Shanxi Province is called "coal base". According to the Third National Coalfield forecasts in 1995, its coal resource above 2,000m is about 640 billion tons, 16% of the whole country. Its total proved reserves is about 257.8 billion tons, accounting for 27% of the country. According to UNIDO technical Classification (UNIDO, 2003), 44% of manufacturing value added in 2000 in Shanxi Province is from the mining industries and resource-based industries and 61.94% of manufactured exports is the resource-based products. In 2003, the emission of soot per industrial added value is about 5 times of the average national level. Shanxi's economy relies on these energy-intensive industries. This is a reason to choose Shanxi province as a representative region in the model.

The specification of the three regional CGE model

The model we employ in this study is one of the existing DRC-CGE models. The model has 53 sectors, including 10 agricultural sectors, 5 mining sectors, 29 manufacturing sectors, 1 utility sector, and 8 services sectors. There are 3 production factors: land, labor, and capital. Labor is disaggregated into 7 types by occupation. There are 14 representative households by area and income level. Among the factors, labor and capital are used by all sectors, whereas land is used only for agricultural activities.

1. Production and Factor Markets

All sectors are assumed to operate under constant returns to scale and cost optimization. Production technology is represented by a nesting of CES functions. At the first level, firms are assumed to use a composite of primary factors plus energy inputs—that is, value added plus the energy bundle—and other intermediate inputs. At the second level, the division of other intermediate demand is assumed to follow the Leontief specification; that is, there is no substitution among other intermediate inputs. The component of value added plus energy is divided into aggregate labor and energy-capital bundles, which are further split into energy and capital-land bundles. Finally, the energy bundle is made up of seven types of base fuel components, and capital-land is split into capital and land in the agricultural sector.

Agricultural laborers work in the farm sector and production workers work in nonfarm sectors.

This segmented labor market is modeled by incorporating partial mobility using a CET function; that is, this transfer is determined by the relative wage of agricultural and production workers, as well as the constant elasticity of transformation. Otherwise, labor is fully mobile across sectors.

The model distinguishes between old and new capital goods. This assumption of vintage capital allows the substitution elasticity in the production function to differ according to the vintage of capital. The model also includes adjustment rigidities in the capital market. It is assumed that new capital goods are homogeneous and old capital goods supply secondhand markets. The installed old capital in a sector can disinvest when this sector is in decline. The supply curve of old capital is a simple constant elasticity function of the relative rental rates. The higher the rental rate on old capital, the higher the supply of old capital. But the rental rate on old capital is not allowed to exceed the rental rate on new capital. Within sectors, the capital is fully mobile among ordinary firms and export-processing firms.

2. Foreign trade and inter-regional trade (domestic trade)

The rest of the world supplies imports and demands exports. Given China's small trade share in the world, import prices are exogenous in foreign currency (an infinite price elasticity). Exports are demanded according to constant-elasticity demand curves, the price elasticities of which are high but less than infinite.

Agents are assumed to regard domestic products and imports as imperfect substitutes, that is, the Armington assumption (Armington 1969). A three-level nesting CES aggregation function is specified for each Armington composite commodity. At the top level, agents choose a mix of domestic aggregated goods and import aggregates, determined by cost minimization and the degree of substitutability. At the second level, the domestic aggregate goods is further split into local goods and outside goods from other regions; at the third level, outsides goods from other regions is further split into goods from other domestic regions. As well as the specification of import, a three-level nesting CET function is specified for each commodity exported and soled in local market and other domestic regions.

3. Income Distribution and Demand

Factor income is distributed to firms, households, the government, and the extra-budget public sector. Capital revenues are distributed among households and firms. Firm income equals a share of gross operating surplus minus corporate income taxes paid to government and profits distributed to households that own shares. Another part of net company income is allocated to extra-budget public sectors as fees. Retained earnings—that is, corporate savings for new investment and capital depreciation replacement—equals a residual of after-tax income minus the distributed profits and fees.

Household income consists of labor earnings and returns to capital and land. Additionally, households receive transfers from the government and the rest of the world. All import and export quota rents are also allocated to households. Household disposable income equals total household income less taxes. Household disposable income is allocated to goods, services, and savings. Households maximize utility using the extended linear expenditure system (ELES), which is an extension of the Stone-Geary demand system. Saving enters the utility function, which is evaluated using the consumer price index. Social consumption and investment final demand follow a fixed share expenditure function.

The government collects taxes from firms, households, and the foreign sector (import tariffs), and it transfers money to the household sector and purchases public goods. Extra-budget public sectors collect fees from enterprises and households. Their incomes are allocated to consumption and saving. The consumption of extra-budget public sectors and government spending constitute one type of final demand, that is, public consumption.

4. Emission

We model emissions to air of the four air pollutants particulate matter (PM_{10}), SO_2, NO_x and VOC; and the greenhouse gases CO_2, CH_4 and N_2O. In this three regions CGE model, the total amount of a given polluting emission takes the following form:

$$E = \sum_i \sum_j \alpha_{i,j} C_{i,j} \quad + \quad \sum_i \beta_i XP_i \quad + \quad \sum_j \gamma_j XA_j$$

where i is the sector index, j the consumed product index, C intermediate consumption, XP output, XA final consumption, α_{ij} the emission volume associated with one unit consumption of product j used by sector i; β_i the emission volume associated with one unit production of sector i. γ_j the emission volume associated with one unit consumption of product j in final consumption .Thus, the first two elements of the right-hand side expression represent supply-related emissions, the third one final-demand-related emissions.

5. Macroeconomic Closure and data

Real government spending is exogenous in the model. All tax rates and transfers are fixed, whereas real government savings is endogenous. The total value of investment expenditures must equal total resources allocated to the investment sector: retained corporate earnings, total household savings, government savings, and foreign capital flows. In this model, aggregate investment is the endogenous sum of the separate savings components. With foreign saving set exogenously, the equilibrium would be achieved through changing the relative price of tradables to non-tradables, or the real exchange rate.

This model is calibrated to the 1997 three regional Chinese Social Accounting Matrix (SAM) developed from the1997 national and regional input-output tables.

The leakage and policy scenarios

Although there are energy policies/environmental policies very early, the analysis of energy and environmental policies has become popular since the signing of the Kyoto Protocol. People are concerned about not only the effect of energy and environmental policy on the countries, but also the impact of them on the trading partners of these countries. The study of “Leakage effect” comes of this. “Leakage effect” refers to that emission sources migrate from abating to non-abating countries. From a global point of view, leakage effect of environmental policy comes mainly from two resources: First, when an abating country carries out environmental policies, such as imposing pollution tax, it will lead to the increase of price and the decline in demand of pollution-intensive products. In addition, it will weaken competitive advantage of pollution-intensive products for this country in the international market and it will result in the decrease in exports and increase in imports. Finally this will simulate the production of these goods of its trading partners and increase pollution emission in these countries. In summary, from a global perspective, the expected effect of environmental policies is offset by this effect in terms of reductions of pollution emission. This effect is commonly known as "relocation effect". Secondly, the reduction in demand for pollution-intensive products will lead to the price decline of these products in the international market. The reduction in the prices will eventually stimulate demand for these products in non-abating countries. This effect will also offset the expected effect of environmental policy, which is usually called as "rebound effect".

From a global perspective, there are so many studies on the Leakage effect. Pezzey (1992) used the WW-model to find that the leakage in European Community turned out to be 70 percent. Rutherford (1992) found that if OECD increases the emission reduction target from 4 percent to 5 percent of current emissions, there would be no reduction at all of global emissions. McKibbin and Wilcoxen (1995) studied unilateral emission abatement by the Annex I countries in accordance with the Kyoto protocol, and found that the leakage effect was 6 percent. In experiments with GREEN the leakage effect was only 3.5 percent when the OECD carbon dioxide emissions were stabilized at the 1990 level. Cole (2000) showed that an increasingly cleaner composition of the manufacturing sector is responsible, at least in part, for reduced pollution in the developed countries. Muradian et al. (2002) concluded that the industrial world has an ecological trade deficit vis-à-vis the developing world, in the sense that the pollution content in imports tends to be larger than it is in exports. Friedl and Getzner (2003) found the import/ GDP ratio to be significant in explaining CO2 (carbon dioxide) reductions.

As we mentioned in the second section, China contains many provinces. Given the difference of endowment among different regions, the inter-regional economic linkage plays a very important role in the China's economic development. Thus regional energy and environmental policies will bring the so-called "leakage effect." It is very import to correctly understand and measure the "leakage effect" for the design of the energy and environmental policy. This is the goal of this paper. There is very few studies on the domestic "leakage effect" in China. In this paper a three regional computable general equilibrium model is constructed to analyze the "leakage effect" of regional energy and environmental policies.

Table 3 gives the three groups of environmental tax scenarios. In each scenario, tax is imposed on the pollutants (SO2 or CO2) to reduce the emission of pollution by 10% in each region.

Table 3 the scenarios of environmental policies

Scenario	**Description**
E1	A: Impose tax on SO2 in Shanxi to reduce the emission by 10%
	B: Impose tax on CO2 in Shanxi to reduce the emission by 10%
E2	A: Impose tax on SO2 in Guangdong to reduce the emission by 10%
	B: Impose tax on CO2 in Guangdong to reduce the emission by 10%

E3	A: Impose tax on SO2 in ROC to reduce the emission by 10%
	B: Impose tax on CO2 in ROC to reduce the emission by 10%

The result of simulation

Fig.3 shows the effect of SO2 tax on GDP in each region. It is very clear that the impact of the SO2 tax on its respective region is negative. When SO2 tax is only imposed in Shanxi provinces, its GDP will reduce by 0.55% and other two regions will get benefit from this SO2 tax. The similar results will be got for the other two scenarios of SO2 tax. It's should be emphasized that Shanxi and Guangdong will get much benefit from the SO2 tax imposed in ROC. In detail, when a SO2 tax is levied in ROC, the GDP in Shanxi and Guangdong increase by 0.5% and 1.4% respectively. Guangdong gets more benefits than Shanxi. This is consistent with that the dependence of Guangdong on other domestic regions is higher that of Shanxi.

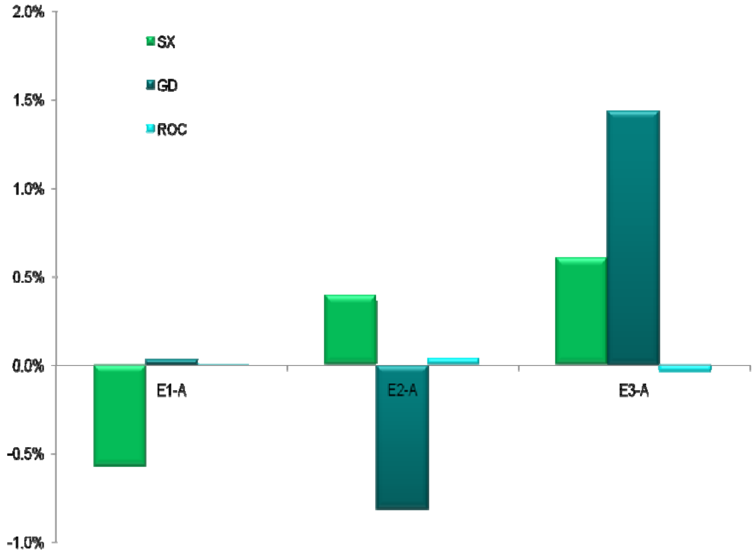

Fig 3 the effect of SO_2 tax on GDP in each province

Fig.3 shows the effect of CO2 tax on GDP in each region. It also can be seen that the impact of the CO2 tax on its respective region is negative. The effect of CO2 tax is larger than that of SO2 tax. When CO2 tax is only imposed in Shanxi provinces, its GDP will reduce by 1.8%. Contrast to SO2 tax, Guangdong will get loss from CO2 tax in Shanxi. The similar results will be got for the other two scenarios of CO2 tax, relative SO2 tax.

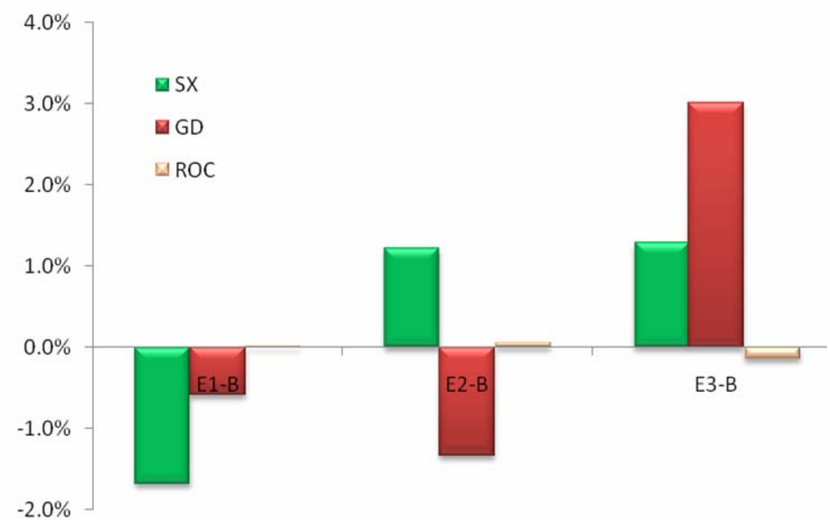

Fig 4 the impact of CO_2 tax on GDP in each province

Figure 5 gives the change of emission of SO2 in each SO2 tax scenario. It renders when SO2 tax is imposed in one region the emission of SO2 in other two regions will increase. Comparative to the abating target, the increase in SO2 emissions is very limited.

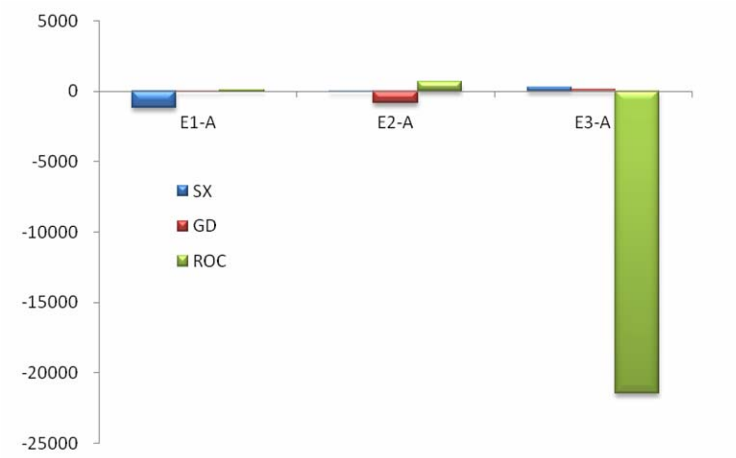

Fig 5 the emission of SO_2 in each scenario

Figure 6 gives the change of emission of CO2 in each CO2 tax scenario. It also denotes when CO2 tax is imposed in one region the emission of CO2 in other two regions will increase. Relative to SO2 tax, the impact of CO2 tax on CO2 emission in other two regions is larger.

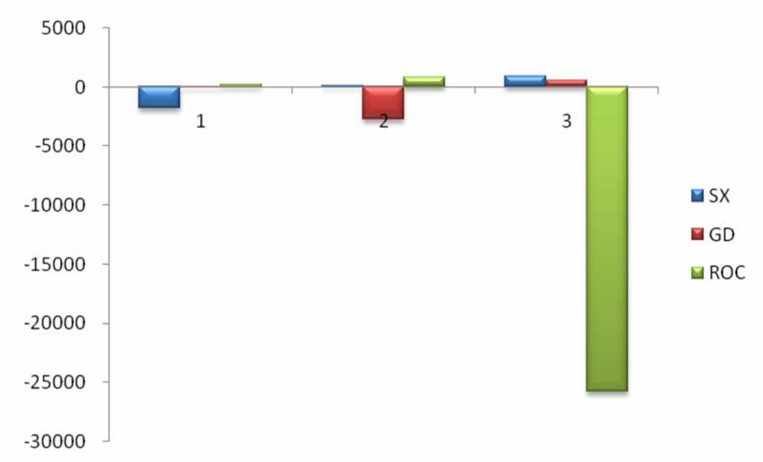

Fig 6 the emission of CO_2 in each scenario

Table 7 gives Leakage effect in all scenarios. Leakage Rate is used here to measure the size of the Leakage effect. Leakage Rate is calculated as the ratio of the additional emissions in non-abating regions to the emission reduction in abating regions. With the data in the figure it can be seen that Guangdong is highest in terms of leakage Rate, Shanxi with secondary leakage rate and ROC with minimum leakage rate. From a regional point of view, highest economic dependence on other domestic regions in Guangdong leads to its largest leakage effect Comparing the two pollution tax, we can find leakage rate for SO2 tax is much higher than that of CO2 tax.

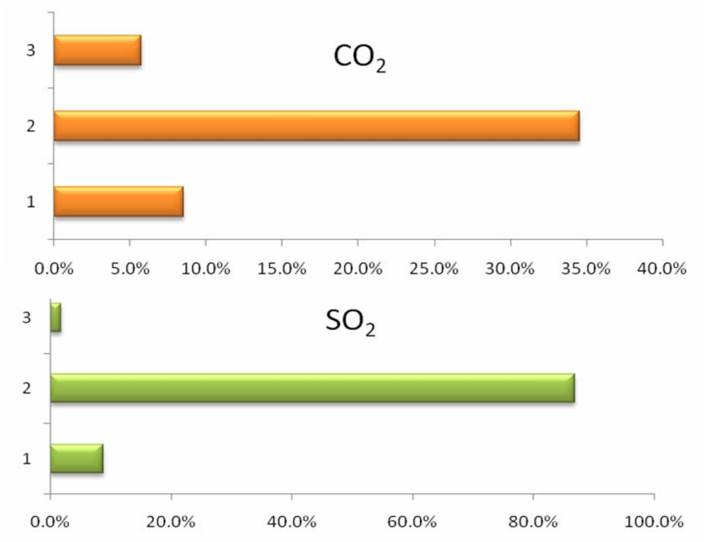

Fig 7 the leakage rate in each scenario

The main conclsion

Based on the analysis in the paper, we can find that:

1. When pollution tax is imposed only in one region, its GDP will decrease. In most of the scenario, other regions will get benefit from this tax.

2. There exits significant leakage effect for regional pollution tax.

3. The leakage effect of SO2 tax is much larger in China than that CO2 tax

4. The higher economic dependence on other domestic regions, the larger its leakage effect.