# The economic impact of linking the pilot carbon markets of Guangdong and Hubei Provinces: A Bottom-Up CGE Analysis

Liu Yu[1]  Cai Songfeng[1]  Zhang Yaxiong[1]

(1. State Information Center, Beijing 100045)

**[Abstract]** Controlling greenhouse gas emission is an important task for China to actively address global climate change. In order to achieve the 2015 target of 17% reduction in carbon intensity against 2010 levels, China has adopted a series of market-based policy measures. This paper utilizes SICGE-R-CO2 (The multiregional General Equilibrium model with carbon dioxide emission rights trading module developed by State Information Center) to simulate the mitigation costs and economic influences of Guangdong's and Hubei's independent mitigation efforts and linking cross-provincial carbon trading. It is found out that linking carbon trading market can effectively reduce the mitigation cost of the whole region. Carbon price of Guangdong and Hubei stands at 102.9 RMB/tonne of carbon dioxidene of carbon dioxide and 14.8 RMB/tonne of carbon dioxide and the average emissions reduction cost for the region is 972.4 RMB/tonne of carbon dioxide, if the two provinces take actions independently. However, in a linking carbon market where Guangdong buys from Hubei 23 million tons emission permits (824 million RMB), average carbon price will drop to 35.9 RMB/tonne of carbon dioxide and emissions reduction cost 567.9 RMB/tonne of carbon dioxide. From the perspective of industries, output reduction of high emitters is the main drive for emission reduction, while substitution effect between different fuels is limited. In terms of macro economy, carbon tax and carbon market will exert negative impact on economic growth, especially on investment, and consequent price growth is not large. Although the GDP of Hubei (seller of emission right) suffers larger loss, its welfare will be improved. From the perspective of sectors, industries with high emissions like power, non-metallic mineral products, non-metallic mining and dressing, metal smelting and rolling and chemical industries are heavily affected, but service industry is much more immune. In the last part of the paper, major conclusions are drawn and policy proposals are offered.

**[Key Words]** Carbon Market, Economic Influence, SICGE-R-CO2

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**[About Authors]** Liu Yu (1977—), Heilongjiang Province, research associate at the Policy Simulation Laboratory of State Information Center Economic Forecast Department. E-mail: liuyu@mx.cei.gov.cn. Tel: 010-68557128. Address: No.58, Sanlihe Road, Xicheng District, Beijing, 100045. Zhang Yaxiong and Cai Songfeng are respectively Senior Research Fellow and Research Assistant at the Economic Forecast Department of the State Information Center.

# Ⅰ Research Background

Reducing greenhouse gas emission has become a consensus for countries in the world to address climate change. As the largest emitter and biggest developing country, China faces huge pressure in reducing $CO_2$ emissions. China puts forward the 2020 target of 40% to 45% reduction in carbon intensity against 2005 level, and short-term targets of 16% reduction in energy intensity and 17% reduction in carbon intensity during the 12$^{th}$ Five-Year Plan period. In order to achieve these goals, the 12$^{th}$ Five-Year Plan has made clear provisions for establishing and improving statistical accounting system of greenhouse gas emissions and for setting up a carbon market. In 2012, seven provinces and cities[1] were listed in the pilot program of carbon trading. A regional carbon market is estimated to take form by 2013 and extend to cover the whole country in 2015. It is the first time for China that an official national document has decided to set up a national carbon market, which has fully demonstrated the government's resolution to achieve abatement targets through market mechanism. Therefore, mitigation cost of carbon market and potential economic influences have become a focus of interest for government and academia.

Currently, carbon market in China is steadily progressing; however, relevant research lags far behind. Most available literature focuses on qualitative research, not quantitative calculation or estimation of economic influences. These qualitative researches fall into three categories. First, researches about basic economic theories of carbon trading. Zheng Shuang (2007) analyzes economic principles of carbon market, structure and economic characteristics of international carbon market. Yang Ji (2010) focuses on basic economic theories of carbon market, and puts forward that emission right belongs to environmental property right and that the motivation of carbon trading is transaction cost. Second, study on rules, regulations and suggestions of carbon market. After summarizing different rules of allocating emission rights, some scholars come up with their own approaches (Xu Yugao, 1997; Chen Wenying, 1998;

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[1] In January, 2012,the General Office of the NDRC issued *Notice on Carrying out Pilot Work of Carbon Emission Rights Trading*. Pilot programs will commence in seven provinces and cities (Beijing, Tianjin, Shanghai, Chongqing, Hubei (Wuhan), Guangdong (Guangzhou) and Shenzhen), and they are called “6 plus 1” pilots.

Liu Weiping, 2004). Some other scholars discuss potential problems and development modes of future carbon market (Zhang Fang, 2006; Yu Tianfei, 2007; Jiang Shumin, 2009; Jiang Feng, 2009). Third, research about international practices and experience (Wang Weinan, 2009; Zhou Hongchun, 2009; Han Xintao, 2010; Zou Yasheng, 2011). Based on relevant theories about carbon trading, this kind of research learns from international experience and lessons, with the intention to provide some inspiration for China.

Current quantitative researches mainly focus on economic influences of carbon market on different countries. Mckibbin (1999) utilized global CGE to analyze the impact of carbon trading and concluded that China would suffer the most in global trading. Roman (2008) and Li Jianming (2005) employed CGE respectively to estimate the possible influence on European Union and Russia, and the potentials of Taiwan to participate in international carbon trading. Li Na (2010) used dynamic CGE of China's enormous regions to simulate the influence of uniform and differential tax rates on regional development of China. He Jianwu and Li Shantong (2010) utilized enormous regional CGE to analyze the impact of uniform carbon tax rate on regional economy, industrial structure, $CO_2$ mitigation and regional disparities. Liang Qiaomin and Wei Yiming (2012) used CGE to analyze the distributional influence of carbon tax. Gao Pengfei, Chen Wenying and He Jiankun (2004) made detailed analysis about mitigation cost in China. In addition, using CGE, some scholars made quantitative analysis about economic influences of carbon tax (Wang Can, Chen Jining and Zou Ji, 2005; He Juhuang, Shen Keting and Xu Songling, 2002; Cao Jing, 2009; Zheng Yuxin and Fan Mingtai, 1999).

Generally speaking, there are two limitations in current literature. First, most researches are qualitative; quantitative calculation is rather limited. Second, most of the available quantitative research focuses on influences of carbon trading on different countries, but not different regions within a country, let alone different provinces.

Therefore, this paper first constructs an enormous regional CGE of the Year 2007, covering 31 provinces in China. Next carbon tax and cross-provincial carbon trading are added into the model to simulate the influence of Guangdong-Hubei carbon trading on regional economy. Then mitigation cost and economic influence of carbon tax and carbon market are compared.

This paper mainly answers the following questions. Will different mitigation policies have different influences on regional economy? How much will this difference be? Will the mitigation cost under inter-regional carbon trading be lower? What will be the influences of different polices on different industries? Will industries with high energy consumption and high emission suffer more?

This paper is composed of five parts: first, research background; second, introduction of the model and plan; third, $CO_2$ emission in Guangdong and Hubei; forth, simulation results and analysis; fifth, conclusions and policy proposals.

## Ⅱ Introduction of Model and Plan

### 1. SICGE-R-CO2

SICGE-R-CO2 is based on TERM[2] (The Enormous Regional Model), which was developed by Cops (Center of Policy Studies) of Monash University, Australia. The structure is bottom-up. Each province is seen as an individual economy, and is connected with each other by inter-provincial trade, investment and labor flow. Compared with most top-down models, this model can not only analyze the influence on demand side, but also can simulate the impact on supply side. Compared with usual bottom-up structures, this model allows for re-export. This means that imported emission units are not necessarily consumed in the importing province and that exports do not always come from the exporting province. Another feature of the model is that the database is fully automatic so that addition of regions and sectors can be very flexible.

Two major improvements are made to the model. First, updated database. The 2002 input-output table used by the original model can no longer satisfy research need as economy develops and industrial structure changes. Therefore, we use the 2007

[2] Standard TERM is an inter-regional CGE, developed by Professor Mark Horridge and Professor Glyn Wittwer of Cops at Monash University, Australia. Compared with MMRF (Monash Multi Regional Forecasting Model), TERM has a more convenient database and a faster computing speed, so it is well-received in many regions in the world. Till now, TERM has developed different versions for Brazil, Finland, China, Indonesia, South Africa, Poland and Japan.

input-output table of 31 provinces, published by National Bureau of Statistics, to update all the key databases. Second, $CO_2$ emission is added into the model. Since most energy and environment models comprise of only substitution between energy products and emission accounts of $CO_2$, they can only simulate impacts of changes in carbon tax and emission volume. Different from these models, carbon trading is added to analyze the influence of inter-regional carbon market.

## 2. Simulation Plan and Policy Shock

### (1) Simulation Plan

Under the assumption that Guangdong and Hubei meet mitigation targets through carbon market, this research discusses mitigation costs and macroeconomic influences in different scenarios of independent mitigation and common carbon market. Three simulation plans are designed. In all scenarios, actual emission is equal to emission permit. Of course, carbon prices of the two provinces (marginal cost of mitigation) are different in different scenarios. Under inter-provincial trading, mitigation targets can be met through both emission reduction efforts within the province and importing emission rights. Actual emission can be different from emission permit in each of the provinces, but actual emission of the whole region (Guangdong plus Hubei) must be equal to their total permit. Because of free trade between the two provinces, the price of emission rights (marginal cost of mitigation) within the region is the same. Absolute mitigation targets of Guangdong and Hubei are calculated on the basis of their carbon intensity targets during the 12$^{th}$ Five-Year Plan period. Detailed information can be found in the following table.

### (2) Policy Shock

The 12$^{th}$ Five-Year Plan sets relative carbon intensity targets for Guangdong and Hubei. However, SICGE-R-CO2 uses absolute mitigation numbers. So the intensity targets must be transformed into absolute ones using the following formula:

$$T = (BEM2015 - PEM2015) / BEM2015 \quad (1)$$

T stands for absolute mitigation targets in 2015, BEM2015 for benchmark $CO_2$ emission, and PEM2015 for $CO_2$ emission in policy scenario.

$$BEM2015 = EM2010 * (1 + GEM)^5 \quad (2)$$

EM2010 stands for $CO_2$ emission of 2010, and GEM for average annual growth rate of $CO_2$ emission during the 12th Five-Year Plan period.

PEM2015 = BGDP2015 * INTEM2010 * (1 - TINTEM2015 ) (3)

INTEM2010 stands for carbon intensity of 2010, TINTEM2015 for emission intensity of 2015, and BGDP2015 for benchmark absolute value of GDP.

$$BGDP2015 = GDP2010 * (1 + GGDP)^5 \quad (4)$$

GDP2010 stands for absolute GDP of 2010, and GGDP for average annual growth rate of GDP during the 12th Five-Year Plan period.

INTEM2010 = EM2010 / GDP2010 (5)

Substitute (4) and (5) into (3), then substitute (2) and (3) into (1), and formula (6) is formed.

$$T = [(1 + GEM)^5 - ( 1 + GGDP)^5 * ( 1 - TINTEM2015 )] / ( 1 + GEM )^5 \quad (6)$$

As is shown in (6)[3], absolute mitigation targets are affected by three factors. First, growth rate of $CO_2$ emission (GEM), which is positively correlated with absolute mitigation target. Second, growth rate of GDP (GGDP), which is negatively correlated with absolute mitigation target. Third, carbon intensity target (TINTEM2015), which is in positive correlation with absolute mitigation target.

Main sources of data are as follows. The 8% and 10% average annual growth rates of GDP (GGDP) in Guangdong and Hubei come from *12th Five-Year Plan* of the two provinces. Carbon intensity targets (TINTEM2015) come from *Working Plan of Controlling Greenhouse Gas Emissions during the 12th Five-Year Plan Period*, which was issued by State Council. Carbon intensity of Guangdong and Hubei is estimated to drop by 19.5% and 17% respectively. Growth rate of $CO_2$ emission (GEM) is calculated in later part of the paper. Due to lack of $CO_2$ emission data of each province, we assume that growth rate of $CO_2$ emission is equal to that of energy consumption. The latter can be calculated on the basis of energy consumption elasticity (energy consumption growth rate = GDP growth rate*energy consumption elasticity, under the assumption that energy consumption elasticity during the 12th

[3] An underlying assumption in this formula is that percentage variation of GDP before and after 2015 is minor enough to be neglected.

Five-Year Plan period is the same as that of 2010). Energy consumption elasticity of 2010 is calculated on the basis of energy consumption growth rate and GDP growth rate in 2010. Results are shown in Table 1 and Table 2.

**Table 1 Carbon emissions growth rate of Guangdong and Hubei in baseline scenario from 2010 to 2015 (%)**

| | Energy consumption elasticity of GDP in 2010 | GDP growth rate | Energy consumption growth rate | Carbon emissions growth rate |
|---|---|---|---|---|
| Guangdong | 0.79 | 8.00% | 6.35% | 6.35% |
| Hubei | 0.80 | 10.00% | 7.97% | 7.97% |

Data source: calculated by the author

**Table 2 the estimation of total quantity reduction target of guangdong and hubei in 2015(%)**

| | average growth rate per annum of GDP in the 12th Five-Year Plan period | average growth rate per annum of carbon emissions in the 12th Five-Year Plan period | Intensity reduction target in 2015 | total quantity reduction target in 2015 |
|---|---|---|---|---|
| Guangdong | 8% | 6.35% | 19.5% | 13.07% |
| Hubei | 10% | 7.97% | 17% | 8.90% |

Data source: calculated by the author

According to our estimation, during the 12$^{th}$ Five-Year Plan period, Guangdong needs to reduce 13.7% of its carbon emission. Since emission in 2007 is 311 million tons (400 million tons in 2010[4]), Guangdong needs to reduce emissions of 40.64 million tons (52.13 million tons) in 2015. Mitigation target of Hubei is 8.9% in the same period. Since its emission in 2007 stands at 265 million tons (382 million tons in 2010), Hubei needs to reduce emissions of 23.62 million tons (34.02 million tons) in 2015.

## Ⅲ $CO_2$ Emission of Guangdong and Hubei in 2007

### 1. Emission Database

[4] Total energy consumption (10,000 ton standard coal) can be calculated on the basis of GDP (100 million yuan) and energy intensity (standard coal/10,000 yuan) of the two provinces from 2007 to 2010. Growth rates of energy consumption of Guangdong and Hubei during the same period are 28.7% and 44.3% respectively. It is assumed that $CO_2$ emission grows at the same rate. So 2010 emissions of Guangdong and Hubei are 400 million tons (4=3.11*(1+28.7%)) and 382 million tons (3.82=2.65*(1+44.3%)).

Emission database of SICGE-R-CO2 mainly comes from 2007 input-output table of 31 provinces and 42 sectors, published by National Bureau of Statistics, and emission factors of IPCC. Instead of emissions from end use, this database deals with emissions from direct production processes. Moreover, two special cases are taken into consideration. First, simple processing of energy products like coal washing does not produce emissions, and is treated differently. Second, energy conversion like the transformation from coal to coking coal involves more conversion than combustion. So the issue of combustion ratio is rather relevant, and it is the same with the transformation from crude oil into refined products. This paper refers to domestic research on conversion coefficient in combustion to deal with this issue.

## 2. $CO_2$ Emission of Guangdong and Hubei in 2007

In 2007, Hubei produces 265 million tons carbon dioxide, of which 249 million tons (93.8%) come from production processes. Only 6.2% comes from private consumption. Coal and oil products generate a large proportion of emission (180 million tons, 69.8% and 73.25 million tons, 27.6% respectively). The 6.99 million tons emission from natural gas only accounts for 2.6%. However, emission from natural gas accounts for 32.4% of private consumption, much higher than oil products (Table 3). This is because residents rely heavily on natural gas for cooking, heating and washing in daily life.

Emissions in Hubei are heavily concentrated in heavy chemical industries with high energy consumption. The five largest emitting industries are metal smelting and rolling (50.77 million tons), production and supply of power and heat (46.55 million tons), non-metallic mineral production (42.82 million tons), chemical industries (36.71 million tons) and transportation and warehousing industries (24.74 million tons). All of these are typical energy intensive heavy chemical industries. $CO_2$ emission of these five industries accounts for 81% of the total, and the share of the top ten industries reaches 91%. In conclusion, $CO_2$ emission in Hubei is highly concentrated (Table 3).

**Table 3 Carbon dioxide emissions of Hubei in 2007（unit：10 thousand ton）**

| sectors | coal | Refined oil | Natural gas | total |
| --- | --- | --- | --- | --- |

| | | | | |
|---|---|---|---|---|
| Smelting and Rolling of Metals | 4384.6 | 679.5 | 12.9 | 5076.9 |
| Production and Supply of Electric Power and Heat Power | 4635.8 | 14.7 | 4.8 | 4655.3 |
| Manufacture of Nonmetallic Mineral Products | 3961.5 | 302.2 | 18.5 | 4282.2 |
| Chemical Industry | 2712.2 | 931.9 | 27.2 | 3671.3 |
| Traffic, Transport and Storage | 38.8 | 2434.7 | 0.0 | 2473.5 |
| Construction | 279.3 | 348.9 | 0.0 | 628.3 |
| Agriculture | 116.0 | 387.1 | 5.4 | 508.5 |
| Hotels and Catering Services | 255.4 | 172.8 | 12.7 | 440.9 |
| Manufacture of Foods and Tobacco | 189.5 | 239.0 | 2.2 | 430.7 |
| Manufacture of General Purpose and Special Purpose Machinery | 152.4 | 193.8 | 41.1 | 387.3 |
| **Sum of top ten( A0 )** | 16725.5 | 5704.6 | 124.7 | 22554.8 |
| **Other sectors( A1 )** | 800.8 | 1502.6 | 44.5 | 2347.8 |
| **Total emission from industry( A=A0 + A1 )** | 17526.3 | 7207.2 | 169.2 | 24902.6 |
| **Private emission ( B )** | 985.0 | 118.1 | 529.7 | 1632.8 |
| **total ( A + B )** | 18511.3 | 7325.3 | 698.8 | 26535.4 |

Data source：SICGE-R-CO2 database

The situation in Guangdong is similar to Hubei except for consumption (Table 4). There are two consumption differences between Guangdong and Hubei. First, Guangdong is a developed province in the southeast coastal area, with its per capita income twice as much as that of Hubei[5]. High income has driven the demand for cars and oil products. Of private consumption of Guangdong, 8.97 million tons $CO_2$ emissions come from oil products, while the number for Hubei only stands at 1.18 million. On the contrary, Hubei consumes much more coal than Guangdong (Hubei, 9.85 million tons; Guangdong, 5.671 million tons) since many Hubei households depend on coal for cooking and heating. Second, high household consumption in Guangdong has led to larger emission. In 2007, emission from private consumption in Hubei only totaled 6.99 million tons, while that of Guangdong reached 32.5 million, 4.7 times as large. In addition, higher consumption emission in Guangdong has contributed to larger total emission. In 2007, total consumption in Guangdong reached 311 million tons, higher than that of Hubei by 45.26 million. 70% is generated from consumption.

[5] Per capita GDP (current price) of Guangdong and Hubei is 33151 yuan and 16206 yuan, and national average is 20169 yuan. From *2008 China Statistical Yearbook*.

**Table 4　Carbon dioxide emissions of Guangdong in 2007（unit：10 thousand ton）**

| sectors | coal | Refined oil | Natural gas | total |
|---|---|---|---|---|
| Production and Supply of Electric Power and Heat Power | 11514.8 | 1205.2 | 150.7 | 12870.8 |
| Manufacture of Nonmetallic Mineral Products | 2711.5 | 412.8 | 462.4 | 3586.7 |
| Chemical Industry | 530.7 | 1290.5 | 662.7 | 2483.9 |
| Smelting and Rolling of Metals | 1540.0 | 354.0 | 213.5 | 2107.5 |
| Traffic, Transport and Storage | 0.9 | 1988.0 | 0.3 | 1989.2 |
| Papermaking, Printing and Manufacture of Articles for Culture, Education and Sports Activities | 1091.1 | 92.1 | 43.6 | 1226.9 |
| Manufacture of Textile | 514.0 | 72.4 | 25.3 | 611.8 |
| Manufacture of Foods and Tobacco | 375.8 | 54.3 | 19.8 | 449.9 |
| Extraction of Petroleum and Natural Gas | 73.4 | 340.3 | 0.6 | 414.3 |
| Manufacture of Textile Wearing Apparel, Footwear, Caps, Leather, Fur, Feather(Down) and Its products | 52.7 | 201.1 | 134.1 | 387.9 |
| **Sum of top ten( A0 )** | 18405.0 | 6010.6 | 1713.2 | 26128.7 |
| **Other sectors( A1 )** | 374.7 | 1558.0 | 673.4 | 2606.1 |
| **Total emission from industry( A=A0 + A1 )** | 18779.7 | 7568.6 | 2386.5 | 28734.9 |
| **Private emission ( B )** | 567.1 | 896.7 | 863.3 | 2327.0 |
| **total ( A + B )** | 19346.8 | 8465.3 | 3249.8 | 31061.9 |

Data source：SICGE-R-CO2 database

# Ⅳ Results and Analysis

## 1. Distribution of Emission Reductions

Table 5 shows distribution of emission reductions in different scenarios (Simulation 1, Simulation 2 and Simulation 3). If the province works independently, all reductions are carried out within the province. If inter-provincial trading is allowed, mitigation targets can be achieved through both “domestic mitigation” and “purchase of emission rights”. Negative value under domestic mitigation stands for emission reductions within the province, and negative (positive) value under purchasing emission rights stands for seller (buyer) of emission rights. Sum of these two values should be equal to the mitigation target.

Table 5 demonstrates that if no link is allowed, Guangdong and Hubei can only achieve their 13% and 8.9% emission reduction targets within their respective territory. In link scenario, Guangdong will buy emission rights from Hubei, as mitigation cost in Guangdong is higher. Of the 13% reduction target of Guangdong, 5.7% is carried out within Guangdong and 7.3% is achieved through purchased emission units. The actual emission reduction of Hubei will reach 17.5%, 8.6% higher than the 8.9% target. And the surplus will be exported to Guangdong. In a word, carbon trading will create a new approach for the two provinces in reducing emissions.

**Table 5 Carbon dioxide emissions reduction and emissions right price of Guangdong and Hubei in different ways in Twelfth Five-Year period**

| Reduction ways and price | Simulation 1（no link） | Simulation 2（no link） | Simulation 2（link） | |
|---|---|---|---|---|
| | Guangdong | Hubei | Guangdong | Hubei |
| Reduction by itself（%） | -13 | -8.9 | -5.7 | -17.5 |
| Buying emission right（%） | 0 | 0 | -7.3 | 8.6 |
| emissions right price（RMB/tonne of carbon dioxide） | 102.9 | 14.8 | 35.9 | 35.9 |

Data source：SICGE-R-CO2 simulation result

## 2. Price of Emission Rights (Marginal Cost of Mitigation)

As is shown in Table 5, price in Simulation 2 (Independent mitigation of Hubei) is only 14.8 RMB/tonne of carbon dioxide, the lowest in three scenarios. Since Hubei's 8.9% mitigation target is lower than Guangdong's 13%, mitigation cost of Hubei will be consequently lower[6]. Price of emission rights in Guangdong (Simulation 2) is 102.9 RMB/tonne of carbon dioxide, obviously higher than that of Hubei. And in Simulation 3 (Guangdong-Hubei carbon market) the price is 35.9 RMB/tonne of carbon dioxide. Therefore, carbon market can effectively reduce mitigation marginal cost (price of emission rights) of the whole region, an important policy inspiration. In theory, the more participants in carbon trading, the lower the marginal cost of mitigation will become.

[6] Generally speaking, marginal mitigation cost is determined by two factors. First, economic structure, such as the ratio of energy intensive and emission intensive industries. Second, mitigation target. Ambitious targets entail higher mitigation costs.

## 3. Average emissions reduction Cost

Table 6 shows the average emissions reduction cost of Guangdong and Hubei, which is used to estimate the consequent economic loss (actual GDP loss and cost (income) of buying (selling) emission rights).

Generally speaking, carbon market can reduce average cost of the whole region (Guangdong and Hubei). In no link scenario, average emissions reduction cost of the region is 972.4 RMB/tonne of carbon dioxide, while in trading scenario the cost drops to 567.9 RMB/tonne of carbon dioxide. The emissions reduction cost of each tonne of carbon dioxide reduces by 404.5 yuan, a 40% decrease. Therefore, Guangdong-Hubei carbon market can dramatically reduce the average mitigation cost of the whole region.

Emissions reduction costs of the two provinces are sharply different. If link is allowed, average cost in Guangdong will drop from 1342.7 RMB/tonne of carbon dioxide to 479.14 RMB/tonne of carbon dioxide, which is lower than the regional average of 567.9 RMB/tonne of carbon dioxide. In link scenario, part of reductions in Guangdong are achieved through imported emission rights, and the ratio of domestic mitigation decreases from 13% to 5.7%, so actual loss of GDP is reduced too. In general, reduced GDP loss is larger than the cost of purchasing emission costs, so inter-provincial carbon trading will help reduce mitigation cost for Guangdong. However, it is quite different for Hubei, where the cost of mitigation, if trading is conducted, will increase from 310.5 RMB/tonne of carbon dioxide to 706.3 RMB/tonne of carbon dioxide, which is higher than the regional average of 567.9 RMB/tonne of carbon dioxide. There are two reasons. First, mitigation cost of Hubei is relatively low, so Hubei would reduce more emissions than required by the target in order to sell some emission rights (Table 6). Second, in trading scenario, price of each ton of $CO_2$ emission will increase dramatically from 14.8 RMB/tonne of carbon dioxide to 35.9 RMB/tonne of carbon dioxide. Although Hubei gets some income from carbon trading, it’s not enough to compensate the loss of the whole economy.

**Table 6 Average cost of carbon dioxide emissions reduction in Guangdong and Hubei in**

**different ways in Twelfth Five-Year period**[7]

| | Guangdong | | Hubei | |
|---|---|---|---|---|
| | No link | link | No link | link |
| （1）total reduction cost（million Yuan） | 54513.5 | 19450.8 | 7328.9 | 16668.4 |
| Real GDP loss | 54513.5 | 18626.5 | 7328.9 | 17492.7 |
| Expenditure for buying emission right | 0.0 | 824.3 | 0.0 | -824.3 |
| （2）total CO2 emission reduction（million Ton） | 40.6 | 40.6 | 23.6 | 23.6 |
| Self-abatement | 40.6 | 17.6 | 23.6 | 46.6 |
| Purchased-abatement | 0.0 | 23.0 | 0.0 | -23.0 |
| （3）Average abatement cost（RMB/tonne of carbon dioxide） | 1342.7 | 479.1 | 310.5 | 706.3 |
| （4）Carbon trading area（Guangdong and Hubei） | No link | | link | |
| Average abatement cost（RMB/tonne of carbon dioxide） | 972.4 | | 567.9 | |

Note：Positive emissions purchase expenditure represents purchasing emissions right, Positive emissions purchase expenditure represents selling emissions right.

Data source：SICGE-R-CO2 simulation result

## 4. Mitigation of Different Industries

Since most emissions of Guangdong and Hubei come from industries, it is necessary to make some detailed analysis about the key industries.

Hubei needs to reduce 23.62 million tons of $CO_2$ to meet the target in $12^{th}$ Five-Year Plan. Most reductions come from industries (21.15 million tons, 89.6%), and only a small part from private consumption (2.47 million tons, 10.4%). As is shown in Table 7, 97 % industrial reductions (20.50 million tons) are concentrated in the top ten emitting industries. Therefore, a clear analysis of these ten industries will ensure a comprehensive understanding of Hubei’s mitigation.

Industrial emission reductions are usually conducted in two ways: reducing output (output effect) and replacing energy products (substitution effect). First, output effect. Reduced output would lead to smaller energy demand, which will decrease carbon emissions. Second, substitution effect. Carbon tax or market-based mitigation mechanism will lead to changes in relative prices of different energy products, which will contribute to substitution between energy products. Since different energy

[7] This table has four components: first, total mitigation cost, including actual GDP loss and cost of purchasing emission rights; second, abatement amount, including domestic mitigation and imported emission units; third, average mitigation cost of each province (total provincial cost/abatement amount); forth, average mitigation cost of the whole region (total regional cost/regional abatement amount).

products have different emission intensities, substitution effect will indirectly reduce total emissions of industries.

As can be seen in Table 7, output effect will generate 12.15 million tons reductions (59% of the total 20.25million) in the top ten industries of Hubei, while substitution effect contributes 8.35 million (41%). The former is slightly larger than the latter. Therefore, emission reductions of Hubei mainly come from reduced output of energy intensive industries.

However, it is not the same for every single industry. Substitution effect takes the dominant role in 5 industries, including metal smelting and rolling, chemical industry, construction industry, accommodation and catering industry, food manufacturing and tobacco processing. In particular, substitution effect takes a much more critical role than output effect in the last two industries. It should be pointed out that output and substitution have opposite effects in agriculture. On one hand, increased output will lead to higher emission (output effect). On another hand, since agricultural activities rely more heavily on coal than natural gas and oil products, carbon tax will motivate more use of natural gas and oil products. So changes in energy structure will reduce emissions (substitution effect).

**Table 7 Hubei carbon emissions in different scenarios in 2007 (unit: ten thousand tons)**

| Sectors | Baseline | Emission reduction in link scenario | | | | link scenario |
|---|---|---|---|---|---|---|
| | | output effect | substitution effect | Total reduction | surplus | Total reduction |
| Smelting and Rolling of Metals | 5076.9 | -324.4 | -390.3 | -714.8 | 4362.1 | -1364.8 |
| Production and Supply of Electric Power and Heat Power | 4655.3 | -357.1 | -79.3 | -436.3 | 4219 | -934.5 |
| Manufacture of Nonmetallic Mineral Products | 4282.2 | -338.3 | -86.9 | -425.2 | 3857 | -900.2 |
| Chemical Industry | 3671.3 | -134.4 | -167.1 | -301.5 | 3369.8 | -618.6 |
| Traffic, Transport and Storage | 2473.5 | -35.4 | -0.8 | -36.2 | 2437.3 | -84.4 |
| Construction | 628.3 | -12.8 | -22.3 | -35.1 | 593.2 | -72.1 |
| Agriculture | 508.5 | 2.1 | -3.1 | -1.0 | 507.5 | -1.9 |
| Hotels and Catering Services | 440.9 | -4.5 | -75.9 | -80.5 | 360.4 | -120.0 |
| Manufacture of Foods and | 430.7 | -1.3 | -6.0 | -7.3 | 423.4 | -15.9 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Tobacco | | | | | | |
| Manufacture of General Purpose and Special Purpose Machinery | 387.3 | -9.3 | -2.9 | -12.2 | 375.1 | -26.9 |
| **Sum of top ten** | 22554.8 | -1215.4 | -834.7 | -2050.1 | 20504.7 | -4139.5 |

Data source：SICGE-R-CO2 database

Guangdong needs to reduce 40.64 million tons of $CO_2$ to meet the target in 12th Five-Year Plan. Most reductions come from industries (36.18 million tons), and only a small part from private consumption (4.46 million tons). As can be seen in Table 8, emissions in Guangdong are also rather concentrated in certain industries. So the top ten industries will be discussed in detail.

Different from Hubei, output effect takes a absolutely dominant role in the top ten industries. 71% of the total 33.77 million tons reductions are achieved through output effect (23.81 million tons), and the rest 29% (9.96 million) by substitution effect. However, it is not the case with every industry. Substitution effect plays a critical part in six industries, including metal smelting and rolling, chemical industries, textile, paper-making and printing, clothes, leather and down manufacturing, food manufacturing and tobacco processing industries. Over 80% reductions of the last three industries benefit from substitution effect. But since these three industries take only a small proportion of total abatement, output effect is still dominant in general.

**Table 8 Guangdong carbon emissions in different scenarios in 2007 (unit: ten thousand tons)**

| Sectors | Baseline | Emission reduction in link scenario | | | | link scenario |
|---|---|---|---|---|---|---|
| | | output effect | substitution effect | Total reduction | surplus | Total reduction |
| Production and Supply of Electric Power and Heat Power | 12870.8 | -1567.7 | -259.2 | -1826.9 | 11043.9 | -692.0 |
| Manufacture of Nonmetallic Mineral Products | 3586.7 | -430.8 | -212.6 | -643.3 | 2943.4 | -278.6 |
| Chemical Industry | 2483.9 | -97.6 | -130.8 | -228.4 | 2255.5 | -91.4 |
| Smelting and Rolling of Metals | 2107.5 | -153.0 | -163.8 | -316.8 | 1790.7 | -128.6 |
| Traffic, Transport and Storage | 1989.2 | -58.3 | -1.5 | -59.8 | 1929.4 | -20.6 |
| Papermaking, Printing and Manufacture of Articles for | 1226.9 | -36.6 | -126.0 | -162.6 | 1064.3 | -72.3 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Culture, Education and Sports Activities | | | | | | |
| Manufacture of Textile | 611.8 | -14.5 | -28.3 | -42.8 | 569 | -17.1 |
| Manufacture of Foods and Tobacco | 449.9 | -6.6 | -29.8 | -36.4 | 413.5 | -15.3 |
| Extraction of Petroleum and Natural Gas | 414.3 | -12.7 | -0.2 | -12.8 | 401.5 | -4.4 |
| Manufacture of Textile Wearing Apparel, Footwear, Caps, Leather, Fur, Feather(Down) and Its products | 387.9 | -3.2 | -43.6 | -46.8 | 341.1 | -24.2 |
| **Sum of top ten** | 26128.7 | -2380.9 | -995.9 | -3376.8 | 22751.9 | -1344.4 |

Data source：SICGE-R-CO2 database

Due to space constraints, emission changes of the two provinces in trading scenario are not discussed here. In fact, carbon trading will only lead to fewer emission reductions in Guangdong and more in Hubei, without substantial structural changes.

## 5. Macroeconomic Influence

Link Carbon trading market will impose more negative influence on the GDP of Hubei than Guangdong (Table 9). But Guangdong will suffer more in no link scenario, where the GDP of Guangdong and Hubei will reduce by 2.13% and 1.13% respectively. This is because the larger share of energy intensive industries and more ambitious abatement target have increased the marginal cost of mitigation in Guangdong. When Guangdong purchases emission rights from Hubei to relieve mitigation pressure, its GDP will only drop by 0.76%. However, Hubei’s DGP will drop by a larger number of 2.57% since the impact of excessive mitigation cannot compensate the income from selling emission permits.

Link Carbon trading market will improve the welfare for the residents in both Guangdong and Hubei. Although Hubei’s DGP suffers loss in Link Carbon trading market, consumption will increase from -0.05% to 0.02%. Since revenues from carbon tax and emission rights improve residents’ income, consumption will increase consequently[8]. Guangdong’s consumption will also rise in Link Carbon trading

[8] TermCo2 assumes that government balance sheet remains the same and that all carbon revenue is used for direct subsidy for consumers. Of course, there are also other possible assumptions like reducing indirect consumption tax,

market from -0.31% to -0.19%. Although subsidies for residents decrease in Guangdong, purchased emission rights will help create more jobs (no link, -1.40%; link, -0.48%). As the positive influence of employment exceeds that of subsidies, welfare for Guangdong will also improve.

All macroeconomic indicators (except for consumption) of Hubei will worsen in link scenario, while Guangdong has a totally different situation where all indicators improve. The following part will focus on explaining the common logic in three Simulations. As the results show, carbon market will increase prices of energy products (electricity price in particular), and other prices will rise accordingly, so CPI will rise slightly. Carbon tax will increase the cost of business, and ROI will decrease accordingly (especially for capital intensive high emitting industries), so investment and capital will all worsen. Compared to provinces without mitigation tasks, real wages decrease, so some labor force will migrate to provinces without mitigation tasks. And then employment will drop in mitigating regions. But the spillover effect of labor force to the non-mitigating provinces is positive. Increased prices make commodities less competitive in international market, so exports will suffer. And the decreased import results from contracted demand of the whole economy.

**Table 9 the macroeconomic influence of carbon trading market in Guangdong and Hubei (%)**

| | Guangdong | | Hubei | |
|---|---|---|---|---|
| | No link | link | No link | link |
| GDP | -2.13 | -0.76 | -1.13 | -2.57 |
| Private consumption | -0.31 | -0.19 | -0.05 | 0.02 |
| Investment | -3.41 | -1.27 | -1.93 | -4.29 |
| Export | -0.74 | -0.23 | -0.64 | -1.39 |
| Import | -1.57 | -0.57 | -1.74 | -3.92 |
| CPI | 0.37 | 0.11 | 0.09 | 0.17 |
| Employment | -1.40 | -0.48 | -0.52 | -1.15 |
| Capital | -2.74 | -1.01 | -1.75 | -3.92 |

Data source：SICGE-R-CO2 simulation

## 6. Impact on Industries

Table 10 shows changes of industrial output and emission intensity in different

reducing tax on new energies and balancing government account. But it is believed that direct subsidies for consumers are more realistic.

scenarios. Industries in Guangdong suffer less in link scenario, but it is the opposite for Hubei. It is found out that in different situations development trends are quite similar. Simulation results reveal that most industries are negatively impacted and the degree of impact is in positive correlation with $CO_2$ emission intensity[9]. Some emission intensive industries are severely affected, like power, non-metallic mineral products, metal smelting and rolling and chemical industries.

There are also some industries whose emission intensities are not consistent with output changes. Some industries with low energy intensity suffer greater output loss. These industries include construction, real estate, metal mining and dressing, supply of natural gas and water and some other service industries in Guangdong. According to different courses, these industries can be divided into three categories.

First, fallen macroeconomic demand (income effect). Take Guangdong's construction sector for example, which is taken as investment goods in most cases. Since total investment decreases in this region, demand for construction also falls. Meanwhile, decreased consumption lead to fallen output in other service industries, of which more than a half comes from private consumption. The share of private consumption and investment in Guangdong's real estate reaches 60% and 17% respectively, so these two factors bring quite a shock.

Second, domino effect of the industrial chain. 70% output of metal mining and dressing industry in Guangdong is used for metal smelting and rolling. So the demand of the latter industry has a direct influence on the former one. Since metal smelting and rolling is quite energy intensive, emission reduction reduces quite a share of its output. Therefore, decreased output in downstream industry (metal smelting and rolling) will lead to less demand for upstream production (metal mining and dressing).

Third, substitution effect. Since Guangdong's natural gas and water are mainly supplied to other provinces, increased prices resulting from carbon tax will make these products less competitive in the competition with other provinces. And they may be replaced by less expensive supply from other regions.

There is another emission intensive industry which suffers little output loss, such

[9] $CO_2$ emission intensity (ton/10,000yuan) = total output value / total $CO_2$ emission

as transportation and warehousing industries of Hubei. They are not for direct use but for inter-regional trade flow. Simulation results show that decrease in trade flow is minor, so carbon tax will have little impact on the output of these industries.

In addition, not all industries are negatively affected, and even some enjoy moderate output increase. Agriculture, education and public administration in Guangdong will benefit, as they barely consume energy products. On another hand, mitigation efforts will reduce labor price, so these labor intensive sectors will benefit. It is the same for agriculture and public management in Hubei.

**Table 10 the influence of different carbon emission reduction policy on the industry output in Guangdong and Hubei**

| | Guangdong | | | Hubei | | |
|---|---|---|---|---|---|---|
| | Emission intensity（ton/ten thousand Yuan） | No link（%） | link（%） | Emission intensity（ton/ten thousand Yuan） | No link（%） | link（%） |
| Agriculture, Forestry, Animal Husbandry & Fishery | 0.071 | 0.86 | 0.28 | 0.221 | 0.41 | 0.92 |
| Mining and Washing of Coal | 0.000 | -0.77 | -0.74 | 0.929 | -1.77 | -4.37 |
| Extraction of Petroleum and Natural Gas | 0.952 | -3.06 | -1.04 | 1.868 | -0.78 | -1.87 |
| Mining of Metal Ores | 0.218 | -5.42 | -1.99 | 1.773 | -3.21 | -7.30 |
| Mining and Processing of Nonmetal Ores and Other Ores | 4.751 | -12.66 | -4.82 | 1.704 | -2.59 | -5.95 |
| Manufacture of Foods and Tobacco | 0.278 | -1.47 | -0.53 | 0.577 | -0.31 | -0.73 |
| Manufacture of Textile | 0.329 | -2.37 | -0.75 | 0.323 | -0.59 | -1.33 |
| Manufacture of Textile Wearing Apparel, Footwear, Caps, Leather, Fur, Feather(Down) and Its products | 0.155 | -0.82 | -0.24 | 0.351 | -0.37 | -0.81 |
| Processing of Timbers and Manufacture of Furniture | 0.070 | -1.48 | -0.51 | 0.241 | -0.89 | -2.04 |
| Papermaking, Printing and Manufacture of Articles for Culture, Education and Sports Activities | 0.510 | -2.98 | -1.04 | 1.063 | -1.37 | -3.03 |
| Processing of Petroleum, Coking, Processing of Nuclear Fuel | 0.053 | -2.53 | -0.86 | 1.123 | -1.52 | -3.59 |
| Chemical Industry | 0.427 | -3.93 | -1.34 | 4.227 | -3.66 | -8.24 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Manufacture of Nonmetallic Mineral Products | 2.652 | -12.01 | -4.28 | 11.741 | -7.90 | -17.46 |
| Smelting and Rolling of Metals | 0.981 | -7.26 | -2.59 | 7.665 | -6.39 | -14.04 |
| Manufacture of Metal Products | 0.081 | -2.47 | -0.88 | 0.435 | -2.03 | -4.49 |
| Manufacture of General Purpose and Special Purpose Machinery | 0.097 | -3.02 | -1.13 | 0.705 | -2.39 | -5.41 |
| Manufacture of Transport Equipment | 0.044 | -1.99 | -0.73 | 0.251 | -1.34 | -3.07 |
| Manufacture of Electrical Machinery and Equipment | 0.028 | -1.77 | -0.67 | 0.212 | -2.42 | -5.31 |
| Manufacture of Communication Equipment, Computer and Other Electronic Equipment | 0.018 | -0.72 | -0.23 | 0.124 | -0.65 | -1.42 |
| Manufacture of Measuring Instrument and Machinery for Cultural Activity & Office Work | 0.010 | -0.86 | -0.28 | 0.185 | -0.93 | -2.05 |
| Manufacture of Artwork, Other Manufacture | 0.071 | -1.21 | -0.43 | 0.783 | -1.08 | -2.49 |
| Scrap and Waste | 0.034 | -1.66 | -0.62 | 0.541 | -2.02 | -4.41 |
| Production and Supply of Electric Power and Heat Power | 4.656 | -12.18 | -4.48 | 10.469 | -7.67 | -16.77 |
| Production and Distribution of Gas | 0.054 | -6.64 | -2.93 | 0.118 | -0.45 | -1.06 |
| Production and Distribution of Water | 0.039 | -4.04 | -1.35 | 0.153 | -1.42 | -3.00 |
| Construction | 0.074 | -3.41 | -1.26 | 0.424 | -2.04 | -4.62 |
| Traffic, Transport and Storage | 0.911 | -2.93 | -1.01 | 3.211 | -1.43 | -3.33 |
| Post | 0.427 | -1.64 | -0.54 | 0.917 | -0.49 | -1.13 |
| Information Transmission, Computer Services and Software | 0.003 | -1.20 | -0.46 | 0.043 | -0.94 | -2.11 |
| Wholesale and Retail Trades | 0.006 | -1.52 | -0.55 | 0.024 | -0.90 | -2.04 |
| Hotels and Catering Services | 0.140 | -1.60 | -0.57 | 1.466 | -1.03 | -2.27 |
| Financial Intermediation | 0.013 | -1.47 | -0.56 | 0.142 | -0.95 | -2.08 |
| Real Estate | 0.009 | -0.71 | -0.34 | 0.137 | -0.49 | -1.01 |
| Leasing and Business Services | 0.074 | -1.19 | -0.40 | 0.870 | -1.01 | -2.35 |
| Research and Experimental Development | 0.040 | -1.16 | -0.39 | 0.168 | -0.59 | -1.37 |
| Comprehensive Technical Services | 0.052 | -1.42 | -0.54 | 0.151 | -0.76 | -1.78 |
| Management of Water Conservancy, Environment and Public Facilities | 0.031 | -0.80 | -0.30 | 0.036 | -0.13 | -0.26 |
| Services to Households and Other Services | 0.076 | -1.31 | -0.52 | 0.001 | -0.53 | -1.18 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Education | 0.014 | 0.37 | 0.11 | 0.177 | 0.17 | 0.40 |
| Health，Social Security and Social Welfare | 0.049 | -0.66 | -0.24 | 0.137 | -0.36 | -0.83 |
| Culture, Sports and Entertainment | 0.025 | -0.69 | -0.21 | 0.219 | -0.36 | -0.82 |
| Public Management and Social Organization | 0.122 | 0.43 | 0.15 | 0.406 | 0.26 | 0.55 |

Data source：SICGE-R-CO2 simulation

## Ⅴ Conclusions and Policy Proposals

SICGE-R-CO2 is used in this paper to measure mitigation cost and economic influence of linking Guangdong-Hubei carbon market. Following conclusions are drawn after extensive analysis. First, linking Guangdong-Hubei carbon market will dramatically reduce the cost of emission reduction. The more participants in carbon trading, the lower the mitigation cost will be. Therefore, China should actively promote the regional carbon market and list it as a key abatement approach during $12^{th}$ Five-Year Plan. Second, Guangdong and Hubei should focus more on key industries and employ appropriate but different long-term and short-term mitigation measures. Since emissions of the two provinces are highly concentrated, mitigation of the emission intensive industries should be a top priority. In the short term, the major measure should be limiting production capacity of the emission intensive industries, and substitution of high emitting energy products should play a supplementary role. In the long run, price mechanism of energy products should be given full play to restructure energy mix. Meanwhile, two mitigation mechanisms should be effectively connected. Third, carbon trading will have quite different influence on the transaction parties. As buyer of emission rights, Guangdong will enjoy lower mitigation cost in trading scenario, while the cost of Hubei will increase. Due to uneven regional development in China, mitigation cost for enterprises in different regions differ. Therefore, we recommend project cooperation. Enterprises with advanced technologies and equipment and abundant capital in regions of high mitigation cost can invest in less developed areas where mitigation cost is low, which will ensure both economic development and emission reduction. Forth, carbon market is beneficial to industrial restructuring. Energy intensive and emission intensive industries are severely affected but the tertiary industry is to large extent immune. This will help adjust and optimize industrial structure, and transform development pattern.

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