Impacts of controlling energy consumption quota on regional development in China-a simulation based on a multi-regional CGE model

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**Abstract:** Chinese government is considering a new policy to control energy consumption quota in order to promote economic transition of regional development pattern. However there is a controversy about the new policy because all provinces wish to get much more energy consumption quota. In addition, disaggregation of energy consumption quotas refers to the tradeoff between equity and efficiency. Authors developed a multi-regional CGE model to simulate the impacts of the policy to control energy consumption quotas on regional economy. The results indicate the policy to control energy consumption quota will slow down economic growth of most regions. Disaggregation of energy consumption quotas based on efficiency-first principle will enlarge regional disparity. If the disaggregation gives priority to equity, it has a greater negative impact on national economic growth. A balanced consideration of equity and efficiency is important for disaggregation of energy consumption quotas when the new policy to control energy consumption quota is implemented.

**Key Words：**energy consumption quota; multi-regional CGE model; efficiency-first; equity-first

**1. Introduction**

To change the way of economic development and reducing the energy waste, Chinese government has set targets of a reduction of 16% of energy consumption per unit GDP and non-fossil energy should account for 11.4% of all primary energy sources in the ‘twelfth five-year’ plan. In order to restrain excessive increase of energy consumption and realize the target of energy-saving and emission-reduction, Chinese government has been considering a new energy policy, the control of energy consumption quotas, in the hope of controlling the total energy consumption less than 4.1 billion tce in 2015. Total energy consumption quotas will be allocated among provinces and each province will have own energy consumption quota. However, as there exist obvious disparity of economic development and energy efficiency among regions, how to allocate quotas among regions is very important to Chinese regional economic development in the future. Efficiency and equity are two principles for resource allocation. Equity-first allocation of energy consumption quotas may be good for regional coordinated development while causing some negative impacts on economic efficiency. Efficiency-first allocation of energy consumption quotas may cost less, but it would probably cause large negative impacts on economic development of less developed regions. So, how to manage the trade-off between equity and efficiency is a key problem to allocate energy consumption quotas among regions.

The policy to control energy consumption quotas has never been implemented anywhere before. Its basic idea is very similar to the idea of cap-and-trade of greenhouse gases emissions in that by setting an upper limit for total energy consumption, energy consumption quota is made a scarce resource. At present, there is rather limited research on the proposals for allocating energy consumption quotas among different regions and the impacts of these proposals on economy and environment. However, the researches on the allocation of greenhouse gases emission can be used as sources of references for this subject. The researches related to carbon permits allocation are massive, many of which applied not only to allocate among regions but also to allocate among industries. Such as an allocation of identical emission reduction rate (Grubler et al., 1994), an allocation based on emission per capita (Grubb, 1989), an allocation based on GDP or output (Phylipsen et al., 1998), an allocation based on weighted average value of multiple variables (CO2 emission per capita, GDP, CO2/GDP and GDP per capita) (Phylipsen et al., 1998; Baer et al., 2008), an allocation based on history emission trends (Baumert et al.，1999), an allocation based on emission reduction cost (Den Elzen et al., 2005) and so on. In these allocation proposals, industrial energy utilizing efficiency, CO2 emission per capita and GDP are several core factors. They present basic equity or efficiency principle from different point of views. Besides, there are some comparative studies of different allocation proposals for carbon emission permits using quantitative methods. Most are done from the view of industry, in which different standards and proposals were compared and allocation issues about equity and efficiency among or within industries were addressed (Demailly et al., 2006; Fischer et al., 2007; Sue Wing and Kolodziej, 2008; Quirion, 2009). However, rare researches are dedicated to the impacts of different allocation proposals on regional economy and regional coordinated development.

This paper use scenario analysis method and multi-regional dynamic CGE model to study the policy to control energy consumption quotas. First, a base scenario is simulated to analyze energy consumption demands in separate regions of China and the necessity of implementation of the policy to control energy consumption quotas. Second, total energy consumption quotas are allocated among regions applying different priority principle between efficiency and equity and these allocation proposals are simulated to analyze their impacts on regional development. Last, a further discussion is done trying to find a feasible plan for easing negative effect caused by the control policy in the hope of providing reference for policy makers.

**2. Model and Data**

2.1 Basic structure of dynamic multi-regional CGE model in China

The multi-regional CGE model for China in this paper is developed based on single region CGE model. Structures of production sectors are displayed in figure 1 and figure 2. Economic interactions among regions are added, including commodity transactions, investment flows and labor flows among regions. It is assumed in describing commodity transactions that goods from different regions are not fully replaceable, using CES (Constant Elasticity of Substitution) function to specify their relations. When describing investment flows, investment in different regions is decided by logistic function of return on capital and price of capital. Numbers of labor force in different regions, if total labor force of whole country is constant, are decided by average salary of entire country and regional salary distortion factor.

In this multi-regional dynamic CGE model for China, economic growth is driven by endogenous consumption, investment and net export. Residents are categorized into urban and rural ones. Their purchase amounts of different goods are decided by ELES (Extend Linear Expenditure System) consumption function. Tax rates of different regions are exogenous while government consumptions are endogenous and their purchase amounts of different goods are described by C-D (Cobb- Douglas) function. The demands for different investment goods of every industry are described by Leontief function. Inventory investments are set to be constant in the model. Both import and export are endogenous. Exchange rates are exogenous. The ratio of foreign savings in domestic GDP is endogenous. This model is recursive dynamic model. The dynamic process is realized by capital accumulation, labor force increase and technology improvement.

Energy consumption quotas are allocated among regions according to different scenarios. Similar to the treatment of carbon permit (SEO, 1998; Boehringer et al., 1998), unit energy consumption quota is taken as a kind of implicit energy tax and is then added to the price of product of every industrial sector.

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Non-energy 1

Non-energy n

Leontief

Output

Labor-capital-

energy mix

Intermediate input

Leontief

CES

Labor

Capital energy mix

Oil

Gas

Refined oil, coke and fuel gas

CES

Coal

CES

Electricity

Fossil fuel

CES

Capital

Energy mix

Fig. 1 Structure of production sectors (except electricity)

CES

Other power

Capital

Non-energy

Leontief

Output

Labor-capital

mix

Intermediate input

Leontief

CES

Labor

Oil

Gas

CES

Electricity

Fossil fuel

Energy mix

Refined oil, coke and fuel gas

CES

Coal

Thermal power

Fig. 2 Structure of electricity sector

2.2 data

Research center on fictitious economy and data science of Chinese Academy of Sciences has established an Interregional Input-Output Table 2002 for China, including thirty provinces (exclude Tibet, Hong Kong and Taiwan) and sixty sectors. In this table, a 30×60×30×60 matrix of commodity transactions reflects regional commodity usage of intermediate inputs of industries of regions, and a 5× 30×30×60 matrix of commodity transactions reflects regional commodity usage of rural household consumption, urban household consumption, government’s consumption, gross fixed capital formation, and inventory investment. The model here uses it as the basic database.

**3. Scenario design and disaggregation of energy consumption quotas**

3.1 Scenario Design

3.1.1Baseline Scenario

The baseline scenario (S0) discussed here represents the situation in which economics develop normally without constrain of any specific energy consumption control. It means the economic development and industrial structure changes from 2003 to 2015 are mainly driven by the improvement of TFP (total factor productivity), the increase of labor force and capital accumulation. The history values of each regions’ TFP from 2003-2010 are calibrated by the history values of GDPs of each region within that period. Future values of each regions’ TFP from 2011-2015 are calibrated by the ‘twelfth five-year’ planning values of GDPs of each region in that period. Besides TFP, the model also includes the energy efficient improvement, using a constant yearly-increase value of 0.2% of AEEI to represent it. The growth rates of regional labor force from 2003 to 2010 uses the recorded history values while the ones from 2011-2015 are estimated according to the increase trends of regional labor force. Capital accumulation is automatically calculated yearly by the model.

3.1.2 Policy scenarios

Although policy scenarios are all related to the policy to control energy consumption quotas, different scenarios can be designed by different implements of regional disaggregation (Table 1).

Table.1 Policy scenarios design

|  |  |
| --- | --- |
| Scenarios | Description |
| Efficiency-first  （S1） | The allocation indicator is comprised of efficiency and equity indicators, and the former kind account for 80%, and the latter kind account for 20%. |
| Equity-first  （S2） | Efficiency indicators account for 20%, and equity indicators account for 80%. |
| Efficiency and equity of same importance  （S3） | Efficiency indicators account for 50%, and equity indicators account for 50%. |

3.2 Disaggregation of energy consumption quotas

Due to the differences of converting coefficient, the sum of all individual regions’ energy consumption is not exact same as national energy consumption. Take the data of 2010 for example, the sum of all regions’ energy consumption is 3.89 billion tce, which is 1.2 times as much as that of the country. Considering this factor, the sum target of all regions’ energy consumption quotas should be adjusted based on the target of national controlling quota. Using 1.2 as the multiply factor, the sum target of regions’ energy consumption quotas in 2015 is set to be 4.92 billion tce (national quota is 4.1 billion tce), which is 1.02 billion tce larger than that of 2010.

The principle and indicators for disaggregation of energy consumption quotas used in the paper can be summarized in table 2. The equity indicator is defined as the geometry average of reciprocals of energy consumption per capita and GDP per capita. The efficiency factor is defined as the geometry average of reciprocals of energy consumption per industrial value added and its variation trend. Energy consumption per capita, GDP per capita and energy consumption per industrial value added of each region are derived from statistic data in 2010, while the average change trends of energy consumption per industry add-value of each region is calculated by related data of the latest 5 years. All indicators are normalized to between 0 and 1. Based on the weight value for efficiency and equity indicators specified in table 1, energy quota allocation of different policy scenarios can be calculated.

Table.2 Principle and indicators for energy consumption quotas’ allocation

|  |  |  |  |
| --- | --- | --- | --- |
| Principle | Factors | Indicators | Explanation |
| Equity | Level of energy consumption and room for its future development | Energy consumption per capita ,and GDP per capita | More energy consumption per capita now means more responsibility for energy saving, so quota allocated will be less. More GDP per capita now means more room for future development, so quota allocated will be more. |
| Efficiency | Energy efficiency level and its potential | energy consumption per industry add-value and its variation trend | Less energy consumption per industrial value added now means high efficiency, so deserving more energy consumption quota. High speed of decrease of energy consumption per industrial value added means more potential in energy saving, so quota allocated will be less. |

**4. Results**

4.1 Baseline Scenario results and necessity of controlling energy consumption

Total energy consumptions of all regions will increase fast and reach about 5.59 billion tce in 2015 in baseline scenario (S0). According to government’s controlling target, total energy consumptions of all regions will not exceed 4.92 billion tce in 2015. So there will be a gap of 0.67 billion tce of energy consumption between that in baseline and controlling target (Figure 3). In baseline scenario, reduce rate of energy intensity will be 10.57% in 2015 compared with in 2010, and non-fossil energy proportion will be 10.84% in 2015, which could not achieve 16% reduction of energy intensity target and 11.4% of non-fossil energy proportion target of the ‘twelfth five-year’ energy plan (Figure 4). In order to change the way of economic development and achieve targets of the ‘twelfth five-year’ energy plan, China need to control energy consumption quota to relieve the trend of swift growth of energy consumption.

Figure 3. Energy consumption of all regions in baseline scenario and in government’s controlling target

Figure 4. Reduce rate of energy intensity and non-fossil energy proportion in 2015 in baseline scenario and in government’s controlling target of the ‘twelfth five-year’ plan

4.2 Policy scenarios results

4.2.1 Effects on energy saving and CO2 emission reduction

Under all policy scenarios (S1, S2 and S3), total energy consumptions of all regions are all controlled at 4.92 billion tce in 2015. But total CO2 emissions of all regions are not same under S1, S2 and S3 scenarios, from about 10.3 to 10.5 billion tones, which are about 1.2-1.4 billion tones reductions compared with that in S0 scenario (Figure 5). Reduce rate of energy intensity and CO2 emission intensity during 2010-2015 will greatly increase and non-fossil energy proportion in 2015 will exceed 11% under S1, S2 and S3 scenarios (Figure 6). So controlling energy consumption quota will on the whole achieve targets of the ‘twelfth five-year’ energy plan.

Figure 5. Energy consumptions and CO2 emissions of all regions in 2015 in different scenarios

Figure 6. Reduce rate of energy intensity and CO2 emission intensity, and non-fossil energy proportion in 2015 in different scenarios

4.2.2 Impacts on regional development

Impacts of different allocation of energy consumption on provincial economy are displayed in table 3. Simulation results show that, in equity-first scenario (S1) ,GDP growth rates of Beijing, Tianjin, Hebei, Shanghai, Jiangsu, Zhejiang, Jiangxi, Henan, Guangdong, Guangxi and Shannxi are higher than those in S0 scenario and equity-first allocation is benefit for these regions. Especially some east regions, for example Beijing, Tianjin, Shanghai, Jiangsu and Zhejiang, with higher energy efficiency and economic strength, can get a little GDP increase by resources restructure across regions under the policy to control of energy consumption quotas.

However, GDP growth rates of Chongqing, Sichuan, Yunnan, Guizhou, Gansu, Qinghai, Ningxia, Xinjiang, Shanxi, Liaoning, Jilin, Shandong, Hubei, Hunan, Hainan and Anhui in equity-first scenario (S1) are lower than those in S0 scenario. Especially Sichuan, Yunnan, Guizhou, Gansu, Qinghai, Ningxia, Xinjiang, with lower energy efficiency and economic strength, will suffer heavily under the policy to control of energy consumption quotas. That means although the loss of national GDP would be minimal, the negative impacts on central and west area will be most severe. This will lead to larger disparity in regional economy (Table 4). In equality-first scenario (S2), the loss of GDP growth rates of most central and west regions will be smaller than ones in S1, except for Chongqing, Qinghai and Xinjiang. While the loss of growth rates of GDP in east developed area, such as Beijing, Tianjin, Shanghai, Jiangsu, Zhejiang and Guangdong, will be larger than those in S1. This means in S2 scenario, the disparity of regional economic development is eased to some extent, although the overall national GDP loss is a little larger than in S1. In S3 scenario, the GDP variation of each region lies between the value in S1 and S2.

Additionally, whether in S1, S2 or S3, the GDP losses of Chongqing, Guizhou, Shanxi, Jilin, Qinghai and Ningxia provinces are fairly large. Their yearly GDP growth rates will drop as much as over 1% compared to the baseline scenario. These central and west provinces are either base of energy production or less-developed area and they will face a big challenge to ease the negative impacts caused by the implementation of the policy to control energy consumption quotas.

Table 3. Provincial GDP growth per average year in different scenarios

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Regions | Provincial GDP growth per average year (%) | | | |  | S1-S0 | S2-S0 | S3-S0 |
| S0 | S1 | S2 | S3 |  |
| Beijing | 8.00 | 8.56 | 8.33 | 8.46 |  | 0.56 | 0.33 | 0.46 |
| Tianjin | 12.00 | 12.11 | 11.95 | 12.07 |  | 0.11 | -0.05 | 0.07 |
| Hebei | 8.50 | 8.55 | 8.52 | 8.54 |  | 0.05 | 0.02 | 0.04 |
| Shanxi | 13.00 | 11.32 | 11.47 | 11.42 |  | -1.68 | -1.53 | -1.58 |
| Inner Mongolia | 12.00 | 12.02 | 11.98 | 12.00 |  | 0.02 | -0.02 | 0.00 |
| Liaoning | 11.00 | 10.62 | 10.17 | 10.31 |  | -0.38 | -0.83 | -0.69 |
| Jilin | 12.00 | 10.82 | 11.09 | 10.96 |  | -1.18 | -0.91 | -1.04 |
| Heilongjiang | 12.00 | 12.05 | 11.91 | 11.95 |  | 0.05 | -0.09 | -0.05 |
| Shanghai | 8.00 | 8.44 | 8.32 | 8.40 |  | 0.44 | 0.32 | 0.40 |
| Jiangsu | 10.00 | 10.08 | 9.70 | 9.90 |  | 0.08 | -0.30 | -0.10 |
| Zhejiang | 8.00 | 8.40 | 8.05 | 8.23 |  | 0.40 | 0.05 | 0.23 |
| Anhui | 10.50 | 10.46 | 10.62 | 10.52 |  | -0.04 | 0.12 | 0.02 |
| Fujian | 10.00 | 10.03 | 9.85 | 9.95 |  | 0.03 | -0.15 | -0.05 |
| Jiangxi | 13.00 | 13.21 | 13.76 | 13.53 |  | 0.21 | 0.76 | 0.53 |
| Shandong | 9.00 | 8.83 | 8.56 | 8.68 |  | -0.17 | -0.44 | -0.32 |
| Henan | 9.00 | 9.69 | 9.77 | 9.70 |  | 0.69 | 0.77 | 0.70 |
| Hubei | 10.00 | 9.73 | 9.94 | 9.84 |  | -0.27 | -0.06 | -0.16 |
| Hunan | 10.00 | 9.81 | 9.92 | 9.87 |  | -0.19 | -0.08 | -0.13 |
| Guangdong | 8.00 | 8.39 | 8.18 | 8.33 |  | 0.39 | 0.18 | 0.33 |
| Guangxi | 10.00 | 10.26 | 11.02 | 10.67 |  | 0.26 | 1.02 | 0.67 |
| Hainan | 13.00 | 12.50 | 12.81 | 12.76 |  | -0.50 | -0.19 | -0.24 |
| Chongqing | 12.50 | 8.57 | 8.31 | 8.43 |  | -3.93 | -4.19 | -4.07 |
| Sichuan | 12.00 | 11.75 | 11.91 | 11.86 |  | -0.25 | -0.09 | -0.14 |
| Guizhou | 12.00 | 10.66 | 11.64 | 11.23 |  | -1.34 | -0.36 | -0.77 |
| Yunnan | 10.00 | 9.89 | 10.17 | 10.02 |  | -0.11 | 0.17 | 0.02 |
| Shannxi | 12.00 | 12.34 | 12.41 | 12.38 |  | 0.34 | 0.41 | 0.38 |
| Gansu | 12.00 | 11.06 | 11.82 | 11.12 |  | -0.94 | -0.18 | -0.88 |
| Qinghai | 12.00 | 10.72 | 10.41 | 10.53 |  | -1.28 | -1.59 | -1.47 |
| Ningxia | 12.00 | 10.89 | 11.21 | 11.09 |  | -1.11 | -0.79 | -0.91 |
| Xinjiang | 10.00 | 9.68 | 9.48 | 9.62 |  | -0.32 | -0.52 | -0.38 |

Table 4. Regional GDP growth per average year in different scenarios

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Regions | Regional GDP growth per average year (%) | | | |  | S1-S0 | S2-S0 | S3-S0 |
| S0 | S1 | S2 | S3 |  |
| East | 8.94 | 9.11 | 8.88 | 9.01 |  | 0.17 | -0.07 | 0.07 |
| Central | 10.69 | 10.67 | 10.82 | 10.74 |  | -0.02 | 0.13 | 0.06 |
| West | 11.40 | 10.55 | 10.78 | 10.66 |  | -0.85 | -0.62 | -0.74 |
| North east | 11.53 | 11.08 | 10.90 | 10.94 |  | -0.46 | -0.64 | -0.59 |
| Average | 9.93 | 9.85 | 9.77 | 9.82 |  | -0.08 | -0.16 | -0.12 |

**5. Conclusions and implications**

According to the simulation results, if the present economic development trend continues, overall volume of energy consumption is growing too fast and by the year 2015 the energy saving goal of the ‘twelfth five-year’ plan cannot be reached. There is necessity for implementation of the control of overall energy consumption quotas.

If efficiency-first allocation is adopted, national economic loss will be minimized. But the central and west area (less-developed region) will suffer most. If equity-first allocation is adopted, negative impacts on the central and west area will be relatively low, although economic efficiency will be lose. If government wants to control both the overall economic loss and regional disparity, the proper solution would be an allocation plan in which efficiency and equity are of same importance.

How to reduce economic losses of the most affected regions? One way is to lower the expected GDP growth rate of these regions to slow down the demand of energy consumption. The target of GDP growth rate of China in the ‘twelfth five-year’ period is 7%. However, several provinces have set their own rates to be higher than 12%. There would be more room for future economic development if GDP growth rates adjusted a little lower. Another way is to change the way of economic development and industrial structure, transferring high energy-intensity industries to low-carbon industries. This transfer is hard for less-developed region and it needs fiscal subsides support from government. However, none of these allocations can be perfect and some regions may suffer a lot under all these allocations. Additional compensation measures should be considered to carry out.

As energy quota is not tradable among regions, the control of energy consumption quotas may be a policy instrument to explore green development for China in short run. But it is not the only and the best policy instrument. For future green development of China in the long run, cap-and-trade for carbon emission may be a better choice than the control of energy consumption quotas as it is benefit for technology improvement, energy substitution and low carbon development.

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