Allocation of carbon permits within regions and its regional economy impact:

a multi-regional general equilibrium analysis

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1. Introduction

In the 12th Five-Year Plan of China proposed in 2011, China carried out the target to reduce its economy's carbon intensity by 17 percent by 2015 compared to 2010 levels. To achieve this goal, seven carbon emissions trading pilots have been established to find a way for the unified national carbon trading market. In China, regional differences and interregional economic linkages have played key roles in China's regional economy development and spatial structure formation. To get a national target, each region will have a different contribution. Difference of initial quota allocation and emission reduction cost among provinces in China is the driving force of unified national carbon trading market. The initial quota allocation of carbon permits will have important effects on regional economic development, industrial structure and interregional trading. Therefore, the allocation of the emission reduction target at the provincial level may not only take regional economic development into consideration, but also the regional reduction potential to achieve the goal, while at the same time emphasizing regional equity and a regional development strategy.

CO2 emissions allowance trading is an effective mechanism for emission control, and the initial emission allowance allocation is the key to and premise of this trading. In general, there are various possible allocation schemes. First, the 'grand-fathering' scheme where permits are allocated free in proportion to companies' emissions in a base year, and are resaleable. But such scheme makes more sense where those participating in the scheme are the only ones who face economic penalties for polluting. An alternative is 'benchmarking', where firms are allocated permits according to an emissions target based on a regulator's judgement of best-practice for that industry. This would be fairer in terms of ensuring all that companies pay for carbon use, but difficult to apply in less homogeneous sectors, for example it is rare for emissions trading schemes to allocate permits to new entrants (Tietenberg, 1990). Possibly the fairest method would be the third scheme--a public auction, which would also raise revenues, which would be recycled in various ways. For a global pollutant, such as carbon dioxide, a system of auctionable permits works in many ways like a carbon tax, although it is the total volume, rather than the marginal abatement cost, which is fixed. However, a permit scheme has various advantages, particularly if it allows for international trading. Unlike a carbon tax, permits can be saved for future use which makes sense given that carbon is a long-lasting global pollutant allowing users greater choice over the intertemporal path of consumption, and making possible a futures and options market (Cramton and Kerr, 1998.).

This paper attempts to simulate the unified national carbon trading market through provinces with a multi-regional CGE model in China. It concerns different initial quota allocations and their effect on regional economic. Commonly there are three principles in initial quota allocation: equity principle, auction principle and current production principle. In the model, four scenarios are designed: one is free allocation by grandfathering, that is, a region receives quotas based on historic performance according to equity principle; the second is auctioning of quotas with revenues recycled as lower VAT, this model assumes the government budget balances, so the exact amount rebated in lower VAT will also partly reflect changes in economic output and the tax base; the third is allocation of quotas relative to current production, which means disguised subsidies and will encourage regions to improve production efficiency; the last one is allocation of quotas according to the pre-given emission reduction target in the 12th Five-Year work program of energy conservation and emission reduction, through comparing with other three scenarios, we can evaluate the feasibility of this policy.

2. Literature review: emission quota allocation research

Emissions trading theory has matured in 1980s, and then many studies focus mainly on practice. Montgomery (1972) and Tietenberg (1985) indicated that the emissions trading system is superior to the traditional environmental policy, with the characteristic of controlling pollution at the lowest cost. However, the monopolistic emissions trading market may be even less efficient, compared with the Command-and- Control. Hahn (1984) believed that in the imperfect competitive market, both the trading volume and cost depend on the initial allocation of emissions allowance. In addition, the market power would also influence the design and operation of the emissions trading system (Misiolek and Elder,1989; Svendsen and Morten,2002). Tietenberg (1990) find that it is due to the increased transaction costs caused by the government control. The transaction costs of emissions trading include the costs for negotiation, approval, monitoring, and enforcement. High transaction costs reduce the cost efficiency of emissions trading (Foster and Haln,1995; Stavins,1995). Given the transaction costs existing in emissions trading Stavins (1995), believed that transaction costs will affect the trading system, and thus create a new cost-efficient equilibrium. Therefore, the initial emissions allocation plays an important role in determining the control efficiency. Cason and Gandgadharan (2003) demonstrates Stavins's opinion, and points out the transaction costs will boost the price of an emission permit.

The allocation of emissions is the basic premise of emissions trading, which decomposes the total emission allowance to each pollution source according to some rule. There are three major criteria or methods of allowance allocation: auction, criteria exogenous to the firm receiving the permits, and output-based allocation (Boemare and Quirion,2002; Persson et al.,2006). Grandfathering is the most common criterion in practice (Cramton and Kerr, 2002). However, grandfathering has two negative effects: it reduces the incentive of regulated firms to develop environmental innovations to reduce the value of the permits, and it creates a bias against new firms entering the product market (Boemare and Quirion, 2002; Howe, 1994; Milliman and Prince,1989). Lord Marshall's report (Marshall, 1988) said that a permit scheme is that potential international trading could allow extra cutbacks in pollution to be made in those countries which have the lowest marginal abatement costs, and sold to countries with higher marginal abatement costs. In theory, this should reduce the total abatement cost. There is a considerable literature on both the theory and practice, for example Parry et al. (1997) estimated that the costs of reducing US emissions by 10% were more than three higher under a grandfathered permit system than with a carbon tax, due to the inability to recycle revenue. Smith (1998) quotes a study by Ballard et al. (1985) estimating that tax receipt in the USA had a deadweight welfare cost of 20-50% at the margin, and discussed the potentially large revenues involved in carbon taxes, and the fact that grandfathering means the loss of the possibility of recycling these to reduce the welfare distortions. Cramton and Kerr (1988) pointed to the likely costs of political lobbying and legal challenges to any system which allocates permits free to some firms but not others.

The three allowance allocation methods, auctions–in theory –are considered to be the most cost effective (Cramton and Kerr,2002). Researchers suggest that the auction method is the most cost-efficient method, by which its revenue can be used to cut pre existing distortion taxes (Fullerton and Metcalf,2001; Goulder etal.,1999). The emissions-based free allocation is thereby more costly than the output-based allocation rule, since it distorts firms' choice of both output levels and emissions rates (e.g. Böhringer et al., 1998; Böhringer and Lange, 2005). Goulder et al. (1999) have also shown that the efficiency of pollution abatement can be improved in the second-best world if revenues from auctioning are used to reduce pre-existing taxes. A related but distinct concern that is intended to be tackled by means of free allocation is the risk of carbon leakage which refers to the relocation of emissions from abating to non-abating countries instead of their reduction (Böhringer and Rutherford, 2002; Kuik and Hofkes, 2010; van Asselt and Brewer, 2010).

With the deteriorating environmental contradiction in China, more attention has been paid to emissions trading and discussion of Chinese emissions trading with the total amount control (Lin,1990; Ma and Du,1999; Wang and Yang,2002) and the initial allocation of emission permits (Yang and Fu,2002; Shi and Huang,2005), which is regarded as a solution to the emission reduction. Raufer and Li (2009) hold that emissions trading market designs based upon US or European approaches are not necessarily relevant for the conditions found in China, and proposes a three-component air quality management approach of emissions trading program. Studies on China’s emissions trading are fruitful, especially, some papers are mostly focused on the power industry analysis, for example Chang and Wang (2010) indicated that the power industry often has numerous other policy objectives, therefore, the design and implementation of an emissions trading program in the sector have to give consideration to the compatibility of existing industrial policies. Lin et al.(2011) studied focus on the SO2 emissions trading in the power industry in Fujian province in China, compared four different allocation methods for sulphur dioxide allowance. Liu et al. (2012) examined the performance of the Jiangsu SO2 emission trading market under different allowance allocation methods and transaction costs.

The remainder of the paper is structured as follows. Section 3 and 4 describe the methodological approach and the data used for the multi-regional CGE model in China with 4 kinds of initial quota allocation scenarios. Section 5 presents empirical findings on the different initial quota allocations and their effect on regional economic in 30 provinces, and addresses the issues of alternative model specification and sensitivity analysis. Section 6 concludes.

3. Description of multi-regional CGE model

For this study we build a multi-regional computable general equilibrium (CGE) model, which includes 30 regions in China and 21 sectors in each region. Through labor flow, capital flow, energy flow and commodity trade, 30 regions form a unified domestic market. There are 2 production factors: labor and capital, and 2 representative households by area: urban and rural. The multi-regional CGE model is comprised by production block, trade block, institution block, flow block, emission block and system constraint block. The key features of the model are outlined below.

3.1 Production block

In the production, we treat energy as a special resource rather than an intermediate input and combine it with value-added as KLE bundle. In this model, there are five types of energy, namely coal, crude oil and natural gas, petroleum products, gas and electricity. Thus, for each sector ($j=1,\ldots,I,\ i=j$) in each region ($r=1,\ldots,R,\ s=r$), gross output (QA_{jr}) are produced using inputs of labor (L_{jr}), capital (K_{jr}), energy (E_{jr}) and intermediate input ($INTA_{jr}$):

$$QA_{jr}=CES_{jr}(KLE_{jr}(L_{jr},K_{jr};E_{jr}),INTA_{jr}) \tag{1}$$

We use constant-elasticity-of-substitution (CES) functions to characterize the production technologies and nesting structures for production of all industries. All industries are characterized by constant returns to scale and are traded in perfectly competitive markets.

3.2 Trade block

The products (QA_{jr}) of sectors in each region not only supply to local market (QRD_{jr}), but also to other regions in China ($QRRE_{jr}$) and export market (QE_{jr}). As the same, demands (QQ_{jr}) of intermediate and final consumption commodities are differentiated among local market (QRD_{jr}), other regions domestically ($QRRM_{jr}$) and import (QM_{jr}). Both of the total supply and demand of good j in region r is CES composite of domestic variety and foreign variety, and domestic variety is represented by nested CES function. The supply function follows CET (constant-elasticity-of-transformation) function and demand function follows the Armington assumption as follows:

$$QA_{jr}=CES_{jr}(QDS_{jr},QE_{jr}) \tag{2}$$

$$QDS_{jr}=CES_{jr}(QRRE_{jr},QRD_{jr}) \tag{3}$$

$$QQ_{jr}=CES_{jr}(QDC_{jr},QM_{jr}) \tag{4}$$

$$QDC_{jr}=CES_{jr}(QRRM_{jr},QRD_{jr}) \tag{5}$$

QDS_{jr} is the supply of good j in region r to domestic market and QDC_{jr} is the demand of good j in region r from domestic market.

3.3 Institution block and flow block

In the institution block, there are 30 regional governments and one central government in the model, tax income is allocated to regional governments and central government according to certain proportions.

In the flow block, we depict the labor migration, capital flow and energy flow among regions. We assume wage difference is the main cause of labor migration, and it decides the migration amount through a distortion coefficient. After the migration among the regions, for each region, we use a CES function to allocate the labor to sectors with an objection that minimize the labor cost in each region.

$$MigL_{rs} = f(WLR_r, WLR_s, \overline{TL}_r) \tag{6}$$

$$WLR_r = CES_r(WLR_{1r}, \ldots, WLR_{jr}) \tag{7}$$

$MigL_{rs}$ is the labor migration amount from region r to s, $\overline{TL}_r$ is the labor endowment of region r before migration, WLR_r is the wage level of region r, and WLR_{jr} is the wage level of industry j in region r. The handling of capital and energy are similar to labor.

3.4 Emission block

We calculate the carbon emission by carbon intensity and the output value of each region. Carbon intensity is an exogenous variable which is from emission amount in benchmark year. It is also an integrated coefficient according to emission of 13 energy types when we calculate the benchmark emission, for different scenarios we can change it.

$$EMISS_r = ems_r \times GDP_r \tag{8}$$

$EMISS_r$ is the total carbon emission of region r, ems_r is the carbon intensity, GDP_r is the gross domestic product of region r.

4. Data and policy scenarios

The data set of this model is based on the 2002 China inter-regional input-output table published in the book of Input-output model and economic link between Chinese provinces. Carbon emission data is based on data from China Energy Statistical Yearbook and Provincial Statistical Yearbook of 30 provinces.

We design three scenarios to compare the economic impact of different approaches to allocate initial quota in each region. For these three scenarios, the total quotas are the same, 85% of the benchmark emission, i.e. total emission will be reduced by 15%.

Scenario 1: quotas are allocated freely by grandfathering, that is, a region receives quotas based on historic performance according to equity principle, we collect the historic data from year 1987 to 2001 due to that Hainan has been an independent province since 1987.

Scenario 2: allocation of quotas is relative to current production, which means disguised subsidies and will encourage regions to improve production efficiency.

Scenario 3: quotas are allocated according to the pre-given emission reduction target in the 12th Five-Year work program of energy conservation and emission reduction. Through comparing with other three scenarios, we can evaluate the feasibility of this policy.

5. Numerical results

China is characterized by significant regional heterogeneity in energy use, labor and capital demand, carbon emissions, and carbon emission intensity as described above. So we anticipate that policy impacts will vary across provinces, and also expect different responses under the four scenarios modeled. Below we analyze the impact of different initial quota allocations on carbon emissions, GDP per capita and welfare outcomes at the provincial level.

5.1 Carbon emission

Figure 1 shows the carbon emission in the baseline without reduction and under the four scenarios. It shows that in the baseline, the developed regions in coastal area and regions which are industrial aggregations hare large amount of carbon emission, such as Shandong, Jiangsu, Guangdong and Hebei. Carbon emission in Shandong is the largest among all regions, about 9.9% of national carbon emission. In scenario 1 and scenario 2, GDP is the main standard to allocate the initial quota, so it can be obviously seen that developed regions get more emission quotas and the carbon emission doesn’t change much compared with the baseline, such as Jiangsu, Guangdong, Zhejiang. In general, based on equity principle, the larger the historical or current emissions, the greater the emission rights available, and therefore developed regions will receive more carbon emission quotas in scenario 1 and 2. Regions with high emission but not so high GDP get more reduction in scenario 1 and 2. Compared with other scenarios, quota allocation under scenario 3 seems more average among all regions.

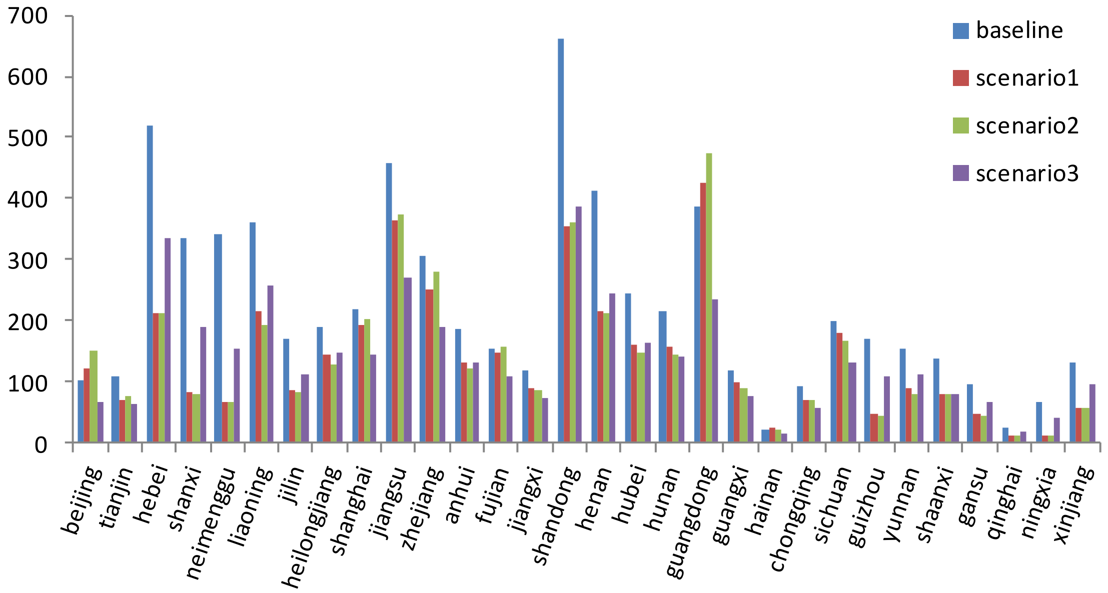

Figure 1 Carbon emission (Mt)

5.2 GDP change

A comparison of the GDP in each region under the four scenarios reveals some significant differences (see Figure 2). It can be seen that three regions with high emission have the greatest GDP change under scenario 2 and scenario 3 compared with baseline and scenario 1, which is Jiangsu, Guangdong and Shandong. It indicates that initial quota allocation considering current output or composite allocation will inspire the economics of developed regions. Some of other regions will have slight GDP decrease under the emission reduction, such as Beijing, Shanghai, Hunan.

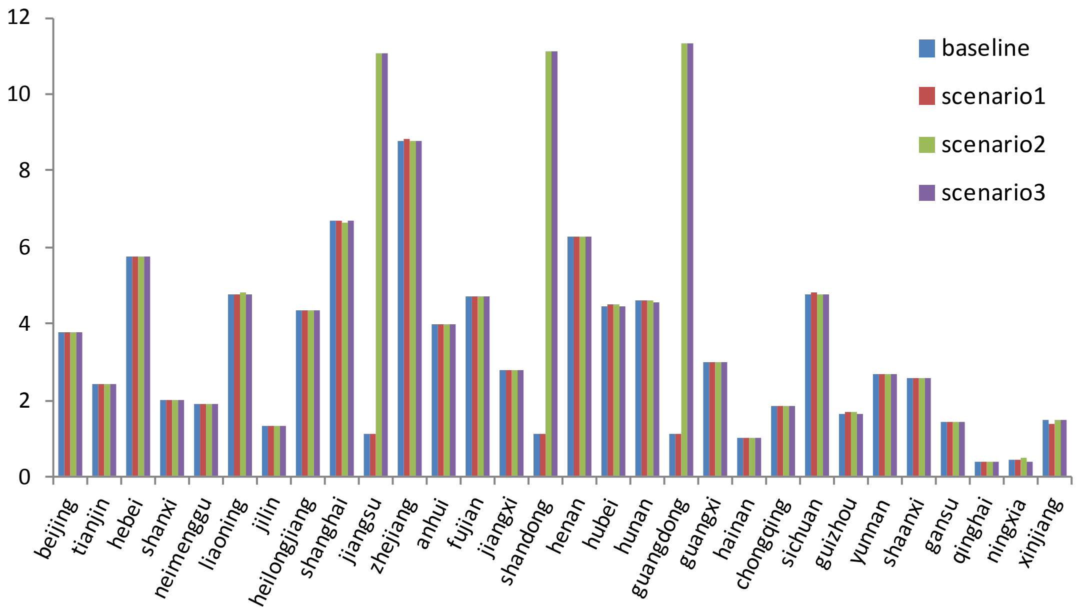

Figure 2 GDP in each region (10^7 yuan)

5.3 welfare outcomes

Figure 3 shows the welfare change of each region under the four scenarios, relative to no carbon reduction scenario. In this paper, welfare change is measured as the equivalent variation of household income relative to the no policy benchmark. Based on the simulation result, we can find that Jiangsu, Shandong, Guangdong, Gansu and Xinjiang will bear a relatively obvious brunt of carbon emission reduction in welfare under scenario 1 and scenario 2. It shows regions which is quite developed or economically backward are much easier to be attacked by emission reduction policy. Nevertheless, welfare outcome of almost all the regions under scenario 3 doesn’t change much. That means the pre-given emission reduction target in the 12th Five-Year work program of energy conservation and emission reduction will not affect residents’ welfare seriously.

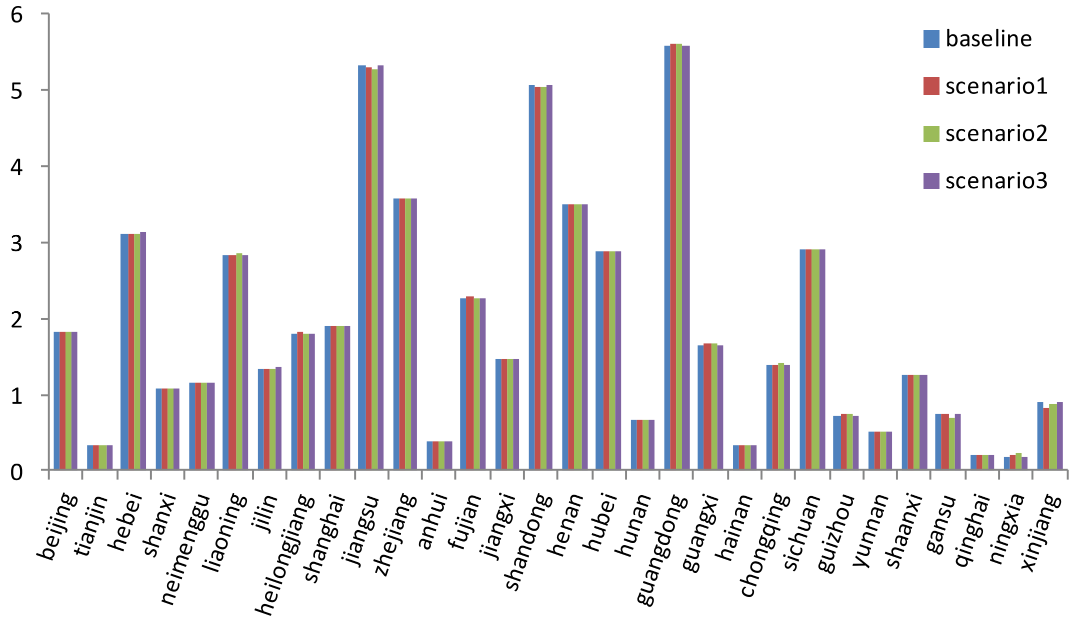

Figure 3 welfare outcomes (10^7 yuan)

6. Conclusions

This paper has described a multi-regional CGE model of China and applied it to assess the impact of four initial quota allocations, which follows rules of grandfathering, auctioning, current production and the pre-given target in the 12th Five-Year work of China. According to the simulation result, this paper can make following conclusions:

1. Under the four scenarios of allocation, developed regions receive more quotas and resources-intensive but no so developed regions get strict reduction and fewer quotas in terms of equity principle (scenario 1 and scenario 2). Quotas are more average in quantity among regions under scenario 3, which is a composite allocation.

2. All the scenarios affect much more on developed regions in coastal area and backward western, especially grandfathering scenario and current output scenario.

3. Comparing with other scenarios, the pre-given target in the 12th Five-Year work of China (scenario 3) has the least affect on economic of regions and is quite prior to the other three allocation policies.

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