# The Economic Effects of Initial Quota Allocations on Carbon Emissions Trading in China

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**ABSTRACT**

The emissions trading scheme has recently become an important emissions reduction mechanism in China. The initial quota allocation is one of the key points in its design, which includes the initial quota allocation criterion and allocation method. In this paper, we analyze the regional macroeconomic impacts of emissions trading in China under different quota allocation criteria and allocation methods using a multiregional computable general equilibrium (CGE) model. The results show that the Ability-to-Pay criterion is better than the other criteria, as it can lead to fewer macroeconomic costs and welfare losses; narrow the economic gap between the eastern, central and western regions; and guide investment into the western regions. Comparing free allocation and auction, it is determined that free allocation leads to lower macroeconomic costs, while auction is better at adjusting the industrial structure. This indicates that a hybrid allocation method is preferable.

**Keywords:** Initial quota allocation, Criterion, Methods, CGE, Macroeconomic cost

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## 1. INTRODUCTION

Along with the rapid economic growth, China has been the largest emitter of greenhouse gas in the world. To combat climate change and accelerate the transition to a low-carbon economy, at the 2009 Copenhagen Summit, the Chinese government committed to the reduction of its carbon intensity by 40–45% from 2005 levels by 2020. In 2011, the State Council of China introduced a set of explicit carbon intensity reduction targets for each region by 2015, compared to 2010 levels, in the Twelfth Five-Year Plan (see Appendix Table A1). To achieve this commitment, seven trading pilots have been established and trials were started in 2013, which are expected to inform a national wide carbon market (Jotzo and Löschel, 2014).

In theory, the emissions trading scheme is a market-based cost-effective reduction mechanism. It allows extra emissions cutbacks and the selling of superfluous quotas to obtain trading benefits in regions that have a lower marginal abatement cost (MAC), while regions with a higher MAC avoid too high abatement costs by buying quotas. This can reduce the total abatement cost

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of the society as a whole (Marshall, 1998; Montgomery, 1972; Tietenberg, 1985). Unlike a carbon tax, the emissions trading scheme uses a quantity cap on emissions rather than price intervention, and therefore has a more explicit reduction effect. It not only has the advantage of being cost-effective, but can also reduce the disparities among regional economies so as to promote equity and efficiency (Rose, 1992; Rose and Stevens, 1993; Vennemo et al., 2009). However, emissions trading may lead to a related problem known as “carbon leakage” whereby some industries with a high MAC in trading regions may simply transfer to other regions with more lax emission constraints or a lower MAC due to a decline in competitiveness (Böhringer and Rutherford, 2002; Kuik and Hofkes, 2010; van Asselt and Brewer, 2010).

The initial quota allocation is one of the key points in the emissions trading design, and different quota allocations, which include the allocation criterion and allocation method, will affect the distribution of costs across regulated entities (Chen and Wu, 1998; Peace and Juliani, 2009). Currently, as Rose et al. (1998) summarized, the international initial quota allocation criteria are based mainly on three equity types—allocation-based, output-based, and process-based—which comprise nine criteria, namely Sovereignty, Egalitarian, Ability to Pay, Horizontal, Vertical, Compensation, Rawls’ Maximin, Consensus and Market Justice. Some studies have also proposed various allocation principles based on equity among regions (Grubb, 1990; Grubler and Nakicenovic, 1994; Keverndokk, 1995).

Beyond qualitative discussion, quantitative analysis comparing different quota allocation criteria has also been done by some researchers. Rose and Zhang (2004) and Bohm and Larsen (1994) simulated the emissions trading with a nonlinear programming model, while Edmonds et al. (1995) used a bottom-up model that consists of supply, demand, energy balance, and greenhouse gas emissions to evaluate different quota allocation criteria. Nevertheless, there is a lack of macroeconomic analyses of different quota allocation criteria.

In terms of the initial quota allocation method, there are generally two possible options, namely free allocation and auction. Free allocation can be characterized as creating hidden subsidies in emission sectors; it also has the potential to overcompensate in high emission sectors and is not conducive to social investments flowing into low-carbon industry (Xuan and Zhang, 2013). Meanwhile, auction can improve the market efficiency and enhance the emission sectors’ motivation to engage in autonomous reduction. In addition, auction revenue can be recycled in various ways to further promote energy conservation and emissions reduction (Cramton and Kerr, 2002; Goulder et al., 1999).

Although the emissions trading scheme will be cost-effective irrespective of the initial quota allocations, production profits, investment distributions and the industrial structure are quite different under the different allocations (Coase, 1960; Rose and Tietenberg, 1993). Generally, the computable general equilibrium (CGE) model will be used to investigate the economic impact of initial quota allocation method (Edwards and Hutton, 2001; Hübler et al., 2014; Parry et al., 1999). Based on the previous research, we develop a multiregional CGE model that is coupled with an emissions trading model which describes the decision-making process of each trading sector in the emissions trading. This combination captures the connection between the micro decision making of emissions trading sectors and macroeconomic effects of carbon market policy.

China is categorized by a diversity in industrial structure and a spatial heterogeneity of economic development because of its large territory. Therefore, the impact of emissions trading on regional macroeconomies is an important element of the emissions trading mechanism design (He and Li, 2010). Although many studies have discussed the initial quota allocation in China (Wu et al., 2010; Yuan et al., 2013; Zhou et al., 2013), most of which have had a qualitative focus or used an endogenous carbon tax to represent emissions trading, quantitative analyses on regional macroeconomies with in-depth consideration of emissions trading are still rare, and more of such research is needed. Therefore, the model developed in this paper contributes to the literature in developing an emission trading model that depicts the decision-making optimization of trading sectors in each region coupled with a multiregional CGE model.

This paper analyzes the regional macroeconomic impacts of emissions trading in China under different quota allocation criteria and allocation methods with a multiregional CGE model. The remainder of the paper is structured as follows: Section 2 describes the methodology and data used for the model. Section 3 presents the different allocation criteria scenarios and empirical results, while Section 4 presents the different allocation method scenarios and empirical results. Section 5 states the conclusions that have been drawn from the results.

## 2. MODEL AND DATA

For this study, we developed a multiregional Chinese energy–environment–economy CGE model (CEEP Multiregional Energy-Environment-Economy Modeling System, $CE^3MS$), in which the whole economy is divided into provincial regions based on administrative divisions and all regions form a national wide market through labor migration, capital flow, and commodity trading. There are 30 regions[1] and 17 production sectors in each region, including five energy sectors and 12 non-energy sectors (see Appendix Table A2). The model includes 30 regional governments and one central government, and it comprises six modules, as follows: production, commodity trading, institution, labor and capital flow, carbon emissions and trading, and macro-closure. The key features of $CE^3MS$ are outlined below.

### 2.1 The Production Module

The production sectors are perfectly competitive and produce generic commodities with capital, labor, energy and non-energy inputs. In production, energy is treated as a special resource rather than an intermediate input and is combined with value-added as a VA-E bundle. Thus, energy can be substituted for other energy or intermediate input. Electric power production is divided into eight kinds of technologies, as follows: thermal power, natural gas power, oil-fired power, nuclear power, hydro-power, wind power, solar power, and other technologies. In electric power production, coal, petroleum, and natural gas are the raw materials of thermal power, oil-fired power, and natural gas power, respectively, and cannot be substituted. Technical share factors are adopted in the composition of all technologies that can be calibrated in the benchmark. We assume fixed shares of technologies under simulation scenarios as this paper represents a static and short-term analysis.

### 2.2 The Commodity Trading Module

Commodity trading in the model includes import, export, and transfers among regions. The products of sectors in each region not only supply to the local market ($QRD_{j,r}$), but also to other regions in China ($QRRE_{j,r}$) and the rest of world ($QE_{j,r}$), according to the following specification:

1. Tibet is not included due to a lack of available data.

$$QA_{j,r} = \alpha_{j,r}^{cet}\left[\delta_{j,r}^{cet} QDS_{j,r}^{\rho_{j,r}^{cet}} + (1-\delta_{j,r}^{cet}) QE_{j,r}^{\rho_{j,r}^{cet}}\right]^{\frac{1}{\rho_{j,r}^{cet}}} \tag{1}$$

$$QDS_{j,r} = \alpha_{j,r}^{ds}\left[\delta_{j,r}^{ds} QRRE_{j,r}^{\rho_{j,r}^{ds}} + (1-\delta_{j,r}^{ds}) QRD_{j,r}^{\rho_{j,r}^{ds}}\right]^{\frac{1}{\rho_{j,r}^{ds}}} \tag{2}$$

where $\rho_{j,r} > 1$ is the substitution elasticity parameter, $\alpha_{j,r}$ and $\delta_{j,r}$ are the efficiency parameter and share parameter of the CES function. $QA_{j,r}$ is the output of sector $j$ in region $r$, and $QDS_{j,r}$ is the supply in domestic, which includes $QRRE_{j,r}$ and $QRD_{j,r}$.

Composite commodities will be used for local intermediate input, governmental and household final consumption, fixed assets investment, and inventory. The supply function is represented by the constant elasticity of transformation (CET) function, while the demand function follows the Armington assumption.

## 2.3 The Institution Module

The model assumes that there is no direct linkage between households and the central government. Households' income ($YH_{h,r}$) is composed of labor payment, part of capital compensation, and transfer payments from the local government. Households' consumption of different commodities ($QH_{h,j,r}$) is determined by the Cobb–Douglas function under the principle of utility maximization with budget constraint:

$$Min \quad U_{h,r}(QH_{h,j,r}) = \prod_j QH_{h,j,r}^{\beta_j} \tag{3}$$

$$s.t. \quad \sum_j PQ_{j,r} QH_{h,j,r} = mpc_{h,r}(1-tih_{h,r}) YH_{h,r} \tag{4}$$

where $PQ_{j,r}$ is the price of Armington commodity $j$ in region $r$, $mpc_{h,r}$ and $tih_{h,r}$ are the propensity to consume and individual income tax rate of household $h$ in region $r$.

Regional enterprise income includes capital compensation and local government transfer payments, and then transforms to savings after deducting the enterprise income tax. The income of the central government consists of proportional[2] tax revenues from all regions and the expenditures are transfer payments to regional governments. Regional government income ($YRG_r$) consists of proportional local tax revenues ($TAX_r$), transfer payments from central government ($\overline{transctor_r}$) and auction revenue ($\overline{CP_0} \times \overline{COQ_{tj,r}}$).

$$YRG_r = TAX_r + \overline{transctor_r} + \sum_{tj} \overline{CP_0} \times \overline{COQ_{tj,r}} \tag{5}$$

$$TAX_r = stva \times \sum_j tva_{j,r} \times PVA_{j,r} \times QVA_{j,r} + stih \times \sum_h tih_{h,r} \times YH_{h,r} + stie \times tie_r \times YENT_r \tag{6}$$

2. The proportions of tax allocation (*stva*, *stih*, *stie*) between regional governments and the central government are determined by tax law.

Here, $\overline{CP_0}$ and $\overline{COQ_{tj,r}}$ are the auction price and initial emissions quota of trading sector $tj$ in region $r$. $tva_{j,r}$, $tih_{h,r}$ and $tie_r$ are the tax rates of value added, households income and enterprise income. $QVA_{j,r}$ and $PVA_{j,r}$ are the value added input and price, while $YH_{h,r}$ and $YENT_r$ are incomes of households and enterprise. The expenditures of local government ($ERG_r$) include transfer payments to households ($trans_{h,r}TAX_r$) and enterprise ($TE_r$) and commodity consumption ($PQ_{j,r}QG_{j,r}$):

$$ERG_r = \sum_j PQ_{j,r}QG_{j,r} + \sum_h trans_{h,r}TAX_r + TE_r \tag{7}$$

We assume a fixed share of each commodity ($shrg_{j,r}$) in the total consumption of local government:

$$PQ_{j,r}QG_{j,r} = shrg_{j,r}mpcg_r(YRG_r - \sum_h trans_{h,r}TAX_r - TE_r) \tag{8}$$

where $mpcg_r$ is the propensity to consume of local government and $QG_{j,r}$ is its consumption for product of sector $j$.

## 2.4 The Labor and Capital Flow Module

We assume that wage differences are the main cause of labor migration and that migration is not completely free (Xu and Li, 2008; Li et al., 2009). Therefore, a distortion coefficient is introduced into the labor migration function and the labor market is ultimately balanced by equilibrium of labor supply and demand in each region:

$$QLST = \sum_r QLSR_r \tag{9}$$

$$QLSR_r = \varphi_r^{LR}\left(\frac{WLR_r}{WLL}\right)QLST \tag{10}$$

$$QLSR_r = \sum_j QLS_{j,r} \tag{11}$$

$$QLS_{j,r} = \varphi_{j,r}^{L}\left(\frac{WL_{j,r}}{WLR_r}\right)QLSR_r \tag{12}$$

Here, $QLST$, $QLSR_r$, $QLS_{j,r}$, $WLL$, $WLR_r$, $WL_{j,r}$ are the labor supply and average wage of the whole country, region $r$, and sector $j$ in region $r$, respectively. $\varphi_r^{LR}$ and $\varphi_{j,r}^{L}$ are distortion coefficients that are equal to weighting factors of each region (sector) regarding the average wage of the whole country (the region). The principle of capital flow in the model is similar to labor migration.

## 2.5 The Carbon Emissions and Trading Module

### *2.5.1 The Emissions Trading Model*

When there is emissions trading, each trading sector determines the actual emissions reductions under the objective of minimizing the total cost by comparing its MAC with the carbon price. The equilibrium carbon price, $CP_1$, is decided until the quota market is cleared:

$$Min \quad TC_{tj,r} = C_{tj,r}(\overline{COE}_{tj,r} - COEE_{tj,r}) + CP_1 \times (COEE_{tj,r} - \overline{COQ}_{tj,r}) \tag{13}$$

$$s.t. \qquad \sum_{tj,r} COEE_{tj,r} = \sum_{tj,r} \overline{COQ}_{tj,r} \tag{14}$$

Here, $TC_{tj,r}$ is the total cost of emissions reductions of trading sector *tj* in region *r*, which consists of abatement cost and trading cost. Meanwhile, $C_{tj,r}$ is the abatement cost function that is derived from the basic CE[3]MS by levying a carbon tax without the emissions trading, $\overline{COE}_{tj,r}$ is the benchmark emissions, and $COEE_{tj,r}$ is the actual emissions under the emissions trading. The next item is trading cost, in which $CP_1$ is the equilibrium carbon price.

### 2.5.2 Modeling of Allocation Methods

Free allocation is modelled through two steps in this paper. First, trading sectors need to buy all quotas, so the cost of buying allowances will influence production and reduction directly. Second, they are compensated via a production subsidy that will decrease the cost of capital and labor. (Edwards and Hutton, 2001; Hübler et al., 2014).

Auction will lead to higher production costs compared with free allocation, as there is no production subsidy. The production of each trading sector will minimize the production cost, which includes production input cost, auction cost, and trading cost (or benefits), under a constraint of the CES production function:

$$Min \quad PA_{tj,r}QA_{tj,r} = PINTA_{tj,r}QINTA_{tj,r} + PVAE_{tj,r}QVAE_{tj,r} + \overline{CP_0} \times \overline{COQ}_{tj,r} + CP_1 \times (COEE_{tj,r} - \overline{COQ}_{tj,r}) \tag{15}$$

$$s.t. \qquad QA_{tj,r} = \alpha_{tj,r}\left[\delta_{tj,r}QINTA_{tj,r}^{\rho_{tj,r}} + (1-\delta_{tj,r})QVAE_{tj,r}^{\rho_{tj,r}}\right]^{\frac{1}{\rho_{tj,r}}} \tag{16}$$

Through the adding of the auction cost $\overline{CP_0} \times \overline{COQ}_{tj,r}$ and trading cost (benefits) $CP_1 \times (COEE_{tj,r} - \overline{COQ}_{tj,r})$ to the total production cost, the emissions trading model is integrated with the CGE model. $QA_{tj,r}$ and $PA_{tj,r}$ are the output and product price of trading sector *tj* in region *r*, $QINTA_{tj,r}$ and $PINTA_{tj,r}$ are the intermediate input and price, $QVAE_{tj,r}$ and $PVAE_{tj,r}$ are the VA-E bundle input and price. The model assumes a perfect auction where $\overline{CP_0}$ is equal to the carbon price $CP_1$, which is derived from the emissions trading model.

The local government receives the auction revenue and transfers it lump-sum to enterprise account as a part of the enterprise savings, so that its budget is balanced:

$$TE_r = \overline{transer_r} + \sum_{tj} \overline{CP_0} \times \overline{COQ_{tj,r}} \tag{17}$$

$$ENTSAV_r = (1 - rent)YENT_r + TE_r \tag{18}$$

We choose the saving-driven closure in the saving–investment balance, of which the quantity of commodities for investment is multiplied by a flexible scalar to ensure the equality of investment cost and the savings value (Löfgren et al., 2002). Thereby the auction revenue will be recycled to increase investment cost through enterprise savings ultimately. We assume that auction revenue will

**Table 1: Value of Key Variables in Benchmark**

| Key Variables | Benchmark Value |
|---|---|
| National GDP (Billion Yuan) | 277671 |
| Variation coefficient of regional economy | 0.8155 |
| Welfare (Billion Yuan) | 97718 |
| Share of energy industry output (%) | 8.572 |
| Share of energy-intensive industry output (%) | 19.628 |

be allocated among production sectors through re-investment of the enterprise account. This assumption can keep the tax neutrality. It is a reasonable way to make the two types of initial quota allocation comparable.

### 2.6 Macro-Closure

The macro-closure in $CE^3MS$ is the savings-driven "neoclassical closure" in which investment is decided by the sum of households, enterprise, government, and foreign savings. In the government balance, all tax rates are fixed and government savings is a flexible residual. Meanwhile, the external balance is a fixed real exchange rate with flexible foreign savings.

### 2.7 Data and Benchmark-Setting

The dataset of $CE^3MS$ is based on the 2007 regional social accounting matrices (SAMs).[3] The emission data are based on the 2008 China Energy Statistical Yearbook and the 2008 Statistical Yearbook of 30 regions, upon which regional industrial carbon emissions in 2007 are calculated according to Intergovernmental Panel on Climate Change (IPCC) method (IPCC, 2006; National Bureau of Statistics of China, 2008). In this paper, eight energy and energy-intensive industries in each region are selected to be emissions trading sectors, namely Coal, Coil, Petro, Chem, Nmm, Metal, Ele, and Gas (Sector codes are defined in Appendix Table A2).

The benchmark of $CE^3MS$ is 2007 without any climate policies, and Table 1 presents the key variables in the benchmark. Under the emissions trading scenarios, a 45% reduction target in national carbon intensity relative to the 2005 level by 2020 is assumed to be the national emissions reduction target. According to Cui et al. (2014), the autonomous decline of national carbon intensity, which is induced by autonomous energy efficiency improvement (AEEI) without any emissions reduction policies, is 29.969% over the period 2007–2020. Considering that the real decrease of carbon intensity during 2005–2007 was about 10.774%, there is still 4.257% of carbon intensity that needs to be reduced. As $CE^3MS$ is a static CGE model, we assume that all reductions are lumped into the year 2007, and therefore yield the absolute emissions reduction target as 271.65[4] Mt $CO_2$. In addition, the quota allocation among sectors in each region is proportional to the benchmark emissions of each sector. We assume no mitigation policy for non-trading sectors.

3. Due to the requirements of research, we expand the sectors and establish a more detailed database based on the 2007 regional SAMs provided by the Development Research Center of the State Council.

4. The benchmark emissions are 6381.30 Mt in year 2007. With the assumption of unchanged GDP, we calculate the absolute emissions reduction as 271.65 Mt under the 4.257% carbon intensity reduction target.

**Table 2: Policy Scenarios of the Five Allocation Criteria**

| Scenarios | Criterion | Criterion Definition and Operational Rule |
|---|---|---|
| Scenario 1 (S1) | Emission Standards | Equity based on consensus, distribute quotas in proportion to GDP |
| Scenario 2 (S2) | Egalitarian | Equity based on egalitarianism, distribute quotas in proportion to population |
| Scenario 3 (S3) | Historic Emission | Equity based on sovereignty, distribute quotas in proportion to emissions |
| Scenario 4 (S4) | Ability to Pay | Equity based on ability to pay, distribute quotas in proportion to reciprocal of per capita GDP |
| Scenario 5 (S5) | National Plan | Distribute quotas according to the Twelfth Five-Year Plan |

**Table 3: Main Index Changes under the Different Quota Allocation Criteria**

| Assessment | Evaluation Index | S1 | S2 | S3 | S4 | S5 |
|---|---|---|---|---|---|---|
| Economy | National GDP change (%) | −0.112 | −0.111 | −0.118 | −0.108 | −0.116 |
| Regional disparity | Variation coefficient | 0.8155 | 0.8155 | 0.8154 | 0.8153 | 0.8154 |
| Welfare | Welfare change (Billion Yuan) | −7.166 | −6.975 | −8.099 | −6.652 | −7.882 |
| Investment | Eastern regions investment change (%) | −0.014 | −0.015 | −0.014 | −0.017 | −0.015 |
| | Central regions investment change (%) | 0.013 | 0.015 | 0.013 | 0.017 | 0.013 |
| | Western regions investment change (%) | 0.031 | 0.034 | 0.034 | 0.037 | 0.035 |

Note: The regional disparity is measured by a variation coefficient, where a smaller variation means less of an economic gap between the regions. Its equation is $\frac{1}{\overline{GDP}}\sqrt{\sum_{r=1}^{R}(GDP_r-\overline{GDP})^2 \Big/ (R-1)}$.

## 3. ALLOCATION CRITERIA SCENARIOS AND RESULTS

### 3.1 Allocation Criteria Scenarios

Based on previous research, this paper focuses on equity criteria that can be quantified in a model. Five kinds of initial quota allocation criteria are chosen (see Table 2) and we compare the macroeconomic impacts of these criteria on the different regions.

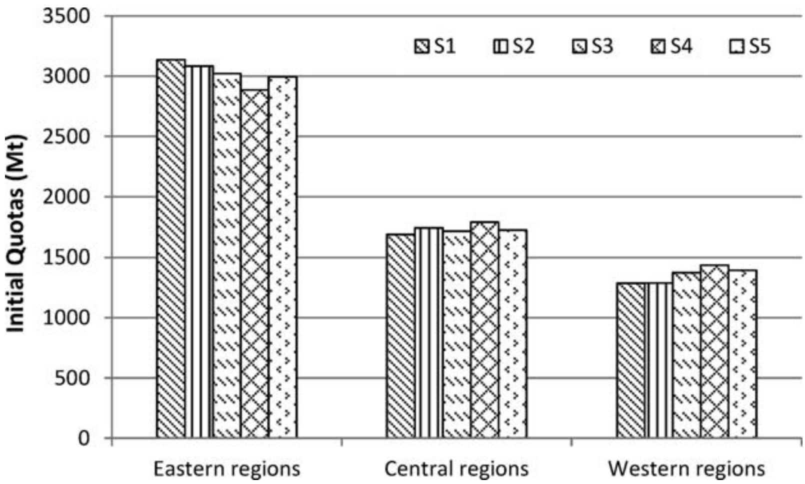
### 3.2 Results

This section explores the macroeconomic effects of the different allocation criteria on regional economies. The main findings of the analysis are presented in terms of regional initial quotas, emissions trading results, gross domestic product (GDP), welfare, and regional investment. In addition, we investigate some key industries in particular regions that are quite significant to local development. The main results are summarized in Table 3.[5]

National GDP and welfare decrease the least under S4, and the corresponding variation coefficient of regional economy is also lower than the others compared with other scenarios. This indicates that, compared with the other four criteria, the Ability-to-Pay criterion (S4) will lead to less macroeconomic costs for the reduction of carbon emissions and narrow the economic gap among the regions. Considering that eastern regions are more developed than central and western regions in China, it is better for regional equity that eastern regions pay more for emissions reduc-

5. The qualitative comparison results of the five allocation criteria under the different allocation methods are the same, so Section 3 lists only the quantitative results of the five allocation criteria under the free allocation method.

**Figure 1: Regional Initial Quotas under the Different Quota Allocation Criteria**




tion. According to five criteria, eastern regions obtain fewer quotas under S4, while the central and western regions obtain more, which will definitely affect the distribution of costs across regions, as quotas actually have values. Compared with the other criteria, the Ability-to-Pay criterion can alleviate the GDP and welfare losses in the central and western regions while increasing the investment in these regions by allocating more quotas to these less developed regions, in order to narrow the economic gap among the regions.

*3.2.1 Regional Initial Quotas*

Figure 1 shows the initial quota allocation results in the eastern, central, and western regions of China under the five allocation criteria. The proportions of initial quotas in the eastern regions under S1 and S2 are 51.34% and 50.45%, which are more than half of the total quotas in China. The quota decreases to 47.22% under S4, which is the least among the five criteria. Meanwhile, the initial quotas in the central and western regions experience an apparent increase under S4 so that the proportion of initial quotas in the western regions increases from 21.04% under S1 to 23.52% under S4. Due to the assumption that regions with a high per capita GDP level have historically spent more on emission permits, the eastern regions should take more reduction responsibility under S4. Thus, under the Ability-to-Pay criterion (S4), the central and western regions will obtain more initial quotas, which can alleviate the emission reduction pressure in these regions.

*3.2.2 Emissions Trading Results*

The different allocation criteria lead to quite different initial quotas among the regions, and therefore, quota trading volumes in the regions vary significantly under different allocation criteria (see Figure 2). The results show that regions with a high carbon intensity and large emissions demand, such as Shanxi and Inner Mongolia, need to buy more quotas under S1. Regions with a relatively lower population but large emissions demand, such as Inner Mongolia, Shanghai, and Shanxi, need to buy more quotas under S2. However, trading among regions is not as active under S3 and S5. Most regions are sellers of quotas under S4, while only Shandong, Jiangsu, Guangdong,

**Figure 2: Regional Trading Volumes under the Different Quota Allocation Criteria**

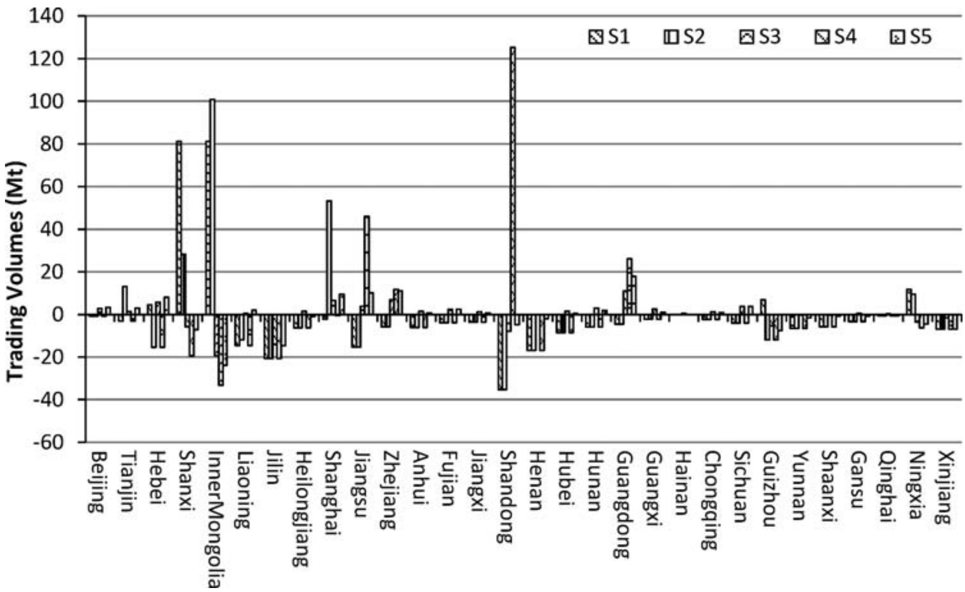
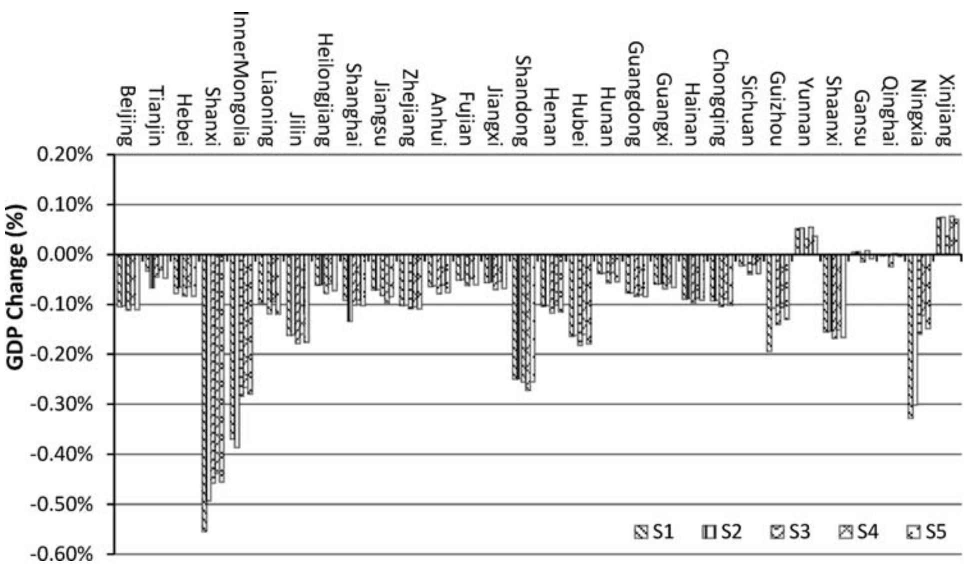



**Figure 3: Regional GDP Changes under the Different Quota Allocation Criteria**

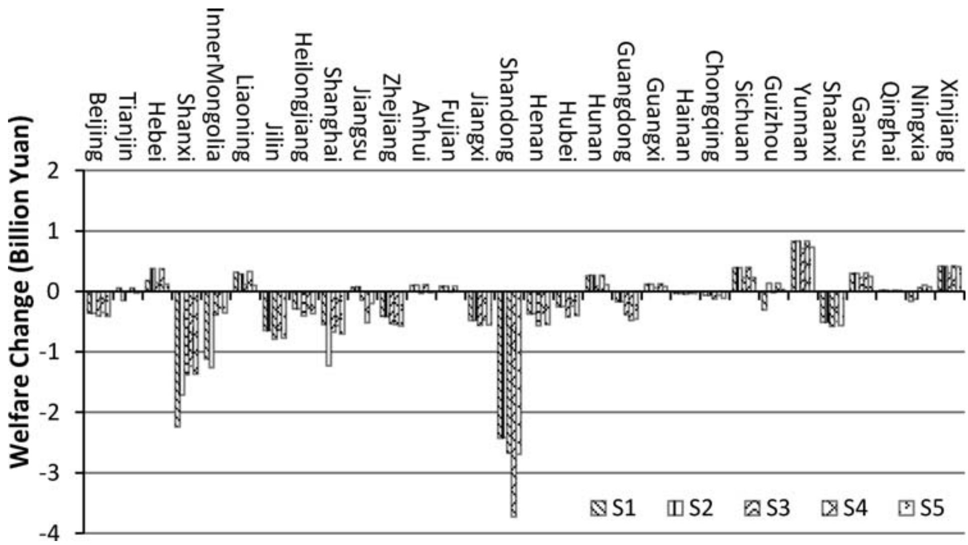



and Zhejiang need to purchase quotas in order to meet the needs of emissions. Shandong, which has the highest emissions under the benchmark, needs to buy a lot of quotas because the quotas it is allocated under S4 are much lower than its emissions demand for production. That indicates significant costs for purchasing quotas under the Ability-to-Pay criterion in Shandong.

*3.2.3 The GDP*

Figure 3 shows the regional GDP changes under the five allocation criteria compared with the benchmark scenario. The decreases of GDP in all regions except Jiangsu, Zhejiang, Shandong,

**Figure 4: Regional Welfare Changes under the Different Quota Allocation Criteria**



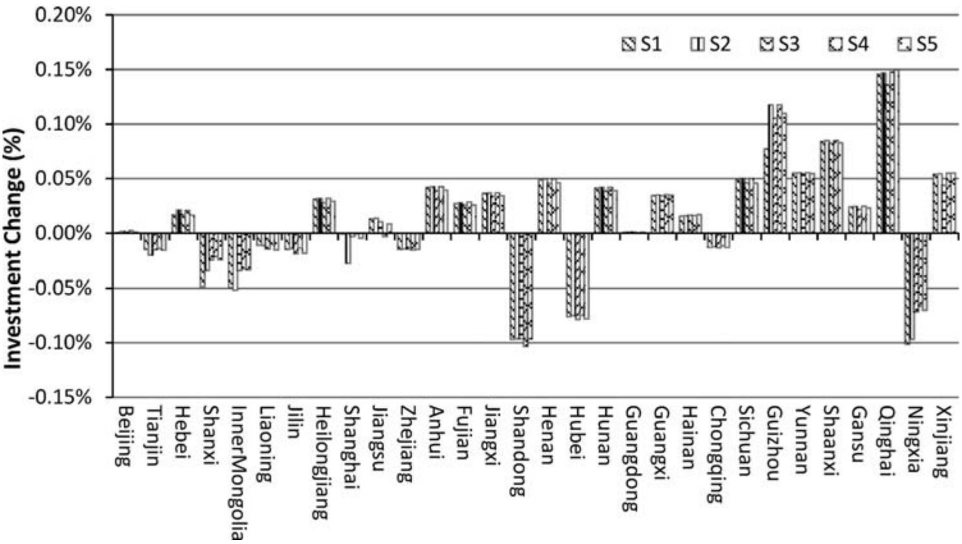

and Guangdong are the least under S4, and vice versa. The main reason for this is that these regions are quota sellers under S4 and can obtain certain economic compensation through sales. This will decrease the production costs of trading sectors in these regions, meanwhile leading to higher rates of capital returns and wages, as well as more economic activities, resulting in less GDP loss. As the Ability-to-Pay criterion is based on the principle that developed regions should take more reduction responsibilities, Jiangsu, Zhejiang, Shandong, and Guangdong are allocated fewer quotas and need to buy quotas to meet their regional emissions demands. Therefore, these four regions face more GDP loss under S4.

### *3.2.4 Welfare*

The national welfare[6] will decrease by 7.17, 6.98, 8.10, 6.65, and 7.88 billion yuan, respectively, under S1–S5. From the perspective of regional welfare, there are 24 regions (except Hebei, Shanghai, Jiangsu, Zhejiang, Shandong, and Guangdong) that have the least welfare loss (or the most welfare gain) under S4 (see Figure 4). For these regions, the Ability-to-Pay criterion (S4) is the most appropriate. As these regions will have trading benefits through quota sales under S4, which can reduce production costs and increase the rate of capital return and wage, the welfare loss is the least under S4. Hebei has a relatively high welfare gain under S2 and S4 because it obtains more initial quotas and benefits from sales under S2 and S4. Due to the lower population, the initial quotas allocated to Shanghai under S2 are far less than the emissions demand it needs for economic development; thus, it exhibits the largest welfare loss under S2. Jiangsu, Zhejiang, Shandong, and Guangdong have both quickly developing economies and high emissions demands; therefore, lower initial quotas are allocated under S4 and their welfare loss is greater.

6. Welfare change is measured as the Hicksian equivalent variation (HEV), relative to the benchmark.

**Figure 5: Regional Investment Changes under the Different Quota Allocation Criteria**




*3.2.5 Regional Investment*

Figure 5 shows the regional investment change under the five allocation criteria. When comparing the different allocation criteria, Hubei, Ningxia, Shanxi, and Inner Mongolia have the least investment decrease under S4, as they take less reduction responsibility due to a lower economic level, and thus have more quotas under S4. There are eight western regions with low emissions demands that have large investment increases. Most western regions have lower economic development and less historic emissions; thus, their investment increases will be lower under S1 and S3 due to fewer quotas. Overall, the Ability-to-Pay criterion (S4) is more advantageous when it comes to protecting western regions with underdeveloped economies and reducing the impact on the industrialized regions.

*3.2.6 Important Industries in Specific Regions*

Emissions reduction policies will definitely affect energy and energy-intensive industries, as they are target sectors of emissions trading in this paper. Due to resource endowment differences among regions in China, the economic development of certain regions depends on specific energy and energy-intensive industries, which should not be affected too much by emissions reductions. Therefore, we also analyze the impact of the different allocation criteria on the Coal industry in Shanxi, the Metal industry in Hebei, and the Nmm (non-metallic mineral) industry in Shandong.

Under the five allocation criteria, the GDP of Shanxi decreases by about 0.438–0.554% (see Figure 6) and S4 leads to the least decrease. As Shanxi is the region with the second highest carbon intensity, the quotas it obtains under S1 are much lower than required for its actual emissions, and this causes the largest decrease in each index. The result in Figure 6 shows that although emissions trading will cause an output decrease of Coal, it can nevertheless increase the net export of Coal in Shanxi.

**Figure 6: Changes in the Shanxi Coal Industry under the Different Quota Allocation Criteria**

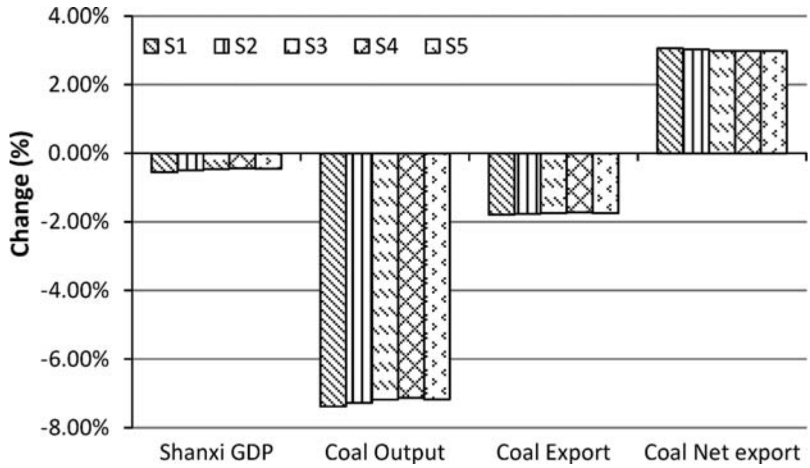
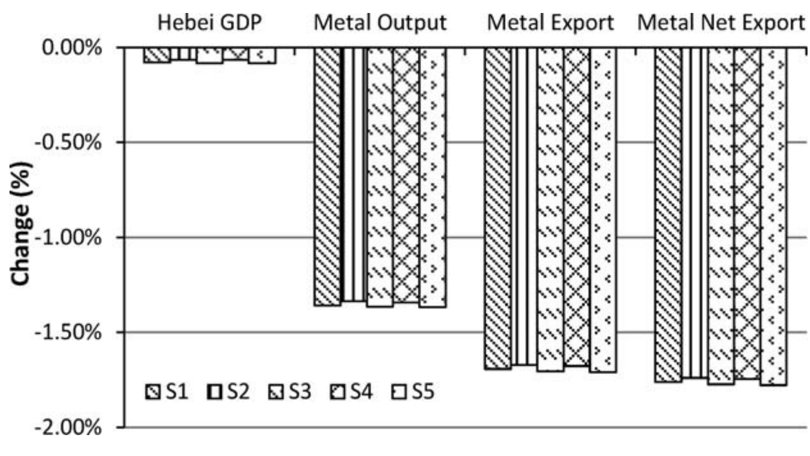



**Figure 7: Changes in the Hebei Metal Industry under the Different Quota Allocation Criteria**




The GDP of Hebei decreases by 0.065–0.084% (see Figure 7) under the five allocation criteria, among which S4 also leads to the least decrease. Hebei is a region with a large population, while its per capita GDP is not very large; thus, the initial quotas allocated are greater under S2 and S4. The Metal industry has been an economic pillar and also a large $CO_2$ emitter in Hebei. As more quotas mean fewer production costs, the Metal output therefore decreases the least under S2 and S4. The decrease in Metal imports in Hebei is about 0.863–0.880%, which is lower than the export decrease, thereby leading to a decrease in net exports. When it comes to reducing the emissions trading impact on the net export of Metal in Hebei, S2 and S4 are the best allocation criteria.

Under the five allocation criteria, the GDP of Shandong decreases by 0.249–0.272% and its output of Nmm decreases by 0.451–0.456%; these parameters both decrease the most under S4 (see Figure 8). The reason for this is that the per capita GDP of Shandong for 2007 is approximately

**Figure 8: Changes in the Shandong Nmm Industry under the Different Quota Allocation Criteria**

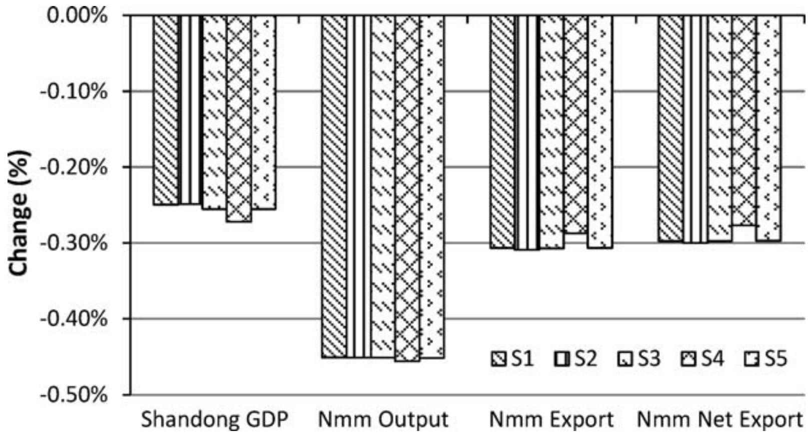



**Table 4: Policy Scenarios of Allocation Methods**

| Scenarios | Scenarios Description |
|---|---|
| Scenario 4_a (S4_a) | Quotas are allocated freely to all trading sectors |
| Scenario 4_b (S4_b) | Quotas are allocated freely to energy sectors while energy-intensive sectors by auction |
| Scenario 4_c (S4_c) | Quotas are allocated by auction to all trading sectors |

Note: We classified Petro and Ele as energy sectors rather than energy-intensive sectors when designing the emissions trading policies in this paper.

the national average, while emissions in Shandong reach 643.12 Mt, which is the highest among all the regions and is far greater than the quotas allocated under S4. However, the export and net export of Nmm both decrease the least under S4. Therefore, considering the impact on import and export of Nmm, S4 is still the best criterion despite the fact that it will cause more GDP loss in Shandong.

In the comparison of the five criteria, the main finding is that the Ability-to-Pay criterion is more advantageous in reducing the emissions reduction pressure in the central and western regions, under which quotas are allocated more to these regions. From the perspective of the macroeconomic effect, the Ability-to-Pay criterion is better, as it brings fewer macroeconomic costs and welfare losses; narrows the economic gap between the eastern, central and western regions; and guides investment into the western region.

## 4. ALLOCATION METHOD SCENARIOS AND RESULTS

### 4.1 Allocation Method Scenarios

To compare the economic effects of the different allocation methods based on the above discussion on the results of the different allocation criteria, this paper sets up three further allocation methods (see Table 4) under the Ability-to-Pay criterion (S4).

**Table 5: The Main Index Changes under the Different Quota Allocation Methods**

| Assessment | Evaluation Index | S4_a | S4_b | S4_c |
|---|---|---|---|---|
| Economy | National GDP change (%) | −0.108 | −0.235 | −0.540 |
| Regional disparity | Variation coefficient | 0.8153 | 0.8157 | 0.8164 |
| Welfare | Welfare change (Billion Yuan) | −6.652 | −29.718 | −94.676 |
| Investment | Eastern regions investment change (%) | −0.017 | −0.004 | 0.000 |
| | Central regions investment change (%) | 0.017 | −0.007 | −0.010 |
| | Western regions investment change (%) | 0.037 | 0.021 | 0.012 |
| Industry structure | Share change of energy industry output (%) | −0.177 | −0.175 | −0.204 |
| | Share change of energy-intensive industry output (%) | −0.020 | −0.033 | −0.008 |
| Carbon leakage | Emissions change of non-trading sectors (Mt) | −10.727 | −11.482 | −16.690 |
| | Emissions reduction contribution of non-trading sectors (%) | 3.95 | 4.06 | 5.71 |
| | Emissions reduction contribution of trading sectors (%) | 96.05 | 95.94 | 94.29 |

## 4.2 Results

This section explores the macroeconomic and sectorial effects of the different quota allocation methods. The main findings of the analysis are presented in terms of emission trading results, GDP, welfare, international trade, and investment. Since not all of the sectors are included in the emissions trading, which may cause a carbon leakage between trading sectors and non-trading sectors, we also focus on the emissions changes in non-trading sectors. The main results are summarized in Table 5.

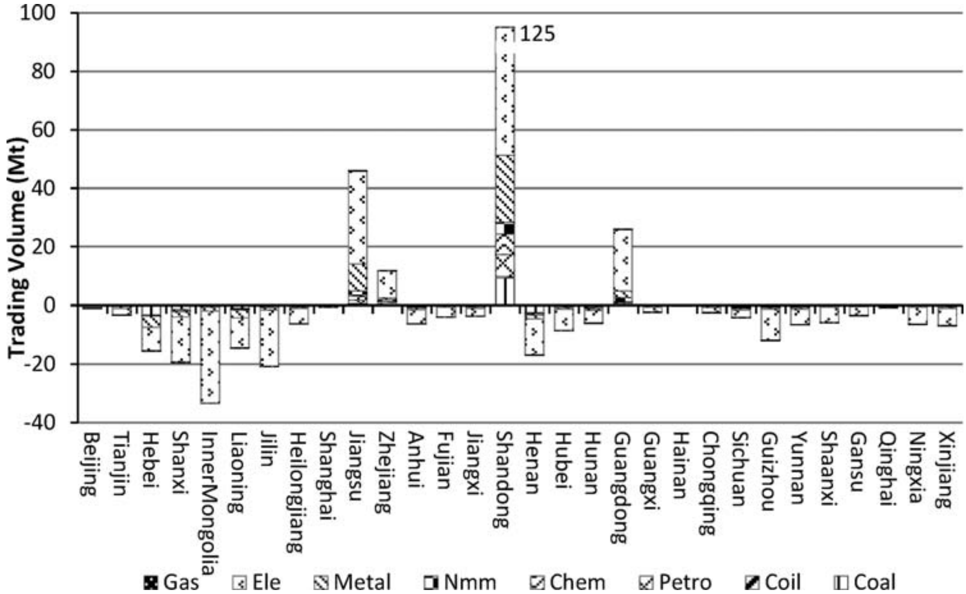
Comparison of national GDP and welfare under S4_a–S4_c indicates that free allocation leads to lower macroeconomic cost. It also improves the investment distribution among regions so as to narrow the economic gap. Compared with free allocation, auction will lead to higher production costs for trading sectors as they need to buy initial quotas. This will affect the output and increase the producer price of trading sectors, which also means lower rates of capital returns and wages because of the substitution of energy, capital, and labor. Therefore, households' consumption, social investment, and other related economic activities will be lower, leading to a lower GDP and more welfare losses. On the other hand, to keep the tax neutrality and consider the reality in China, we assume the auction revenue will be transferred to enterprise account as its savings rather than returned to households. Under this assumption of recycling approach, it is concluded that free allocation leads to results in lower macroeconomic cost.

In the benchmark scenario, the shares of energy and energy-intensive industries in industry structure are 8.752% and 19.628%, respectively. Both see declines under S4_a–S4_c, which indicates a transition from energy-intensive industries to less intensive industries under the emissions trading scenarios. As auction will directly increase the production cost and affect the output, S4_a is better for protecting energy output when the quotas are free. The output of energy-intensive industries will decrease more under S4_b and S4_c when there is an auction. However the share of energy-intensive industries decreases the least under S4_c compared with other scenarios. This is mainly due to the extension of auction coverage, where all trading sectors are faced with auction. This significantly affects the total industry output as the production costs increases, which leads to a slight decrease in the energy-intensive industries' share. Therefore, S4_b is the best for industry structure adjustment, as it causes a lower energy output decrease while resulting in a greater reduction in energy-intensive industries' output.

### *4.2.1 Emissions Trading Results*

Figure 9 shows the equilibrium results of emissions trading when the carbon price is about 29.56 yuan/ton and the total trading volume is 209.11 Mt. There are four regions in which all the

**Figure 9: Regional Trading Volumes under the Different Quota Allocation Methods**



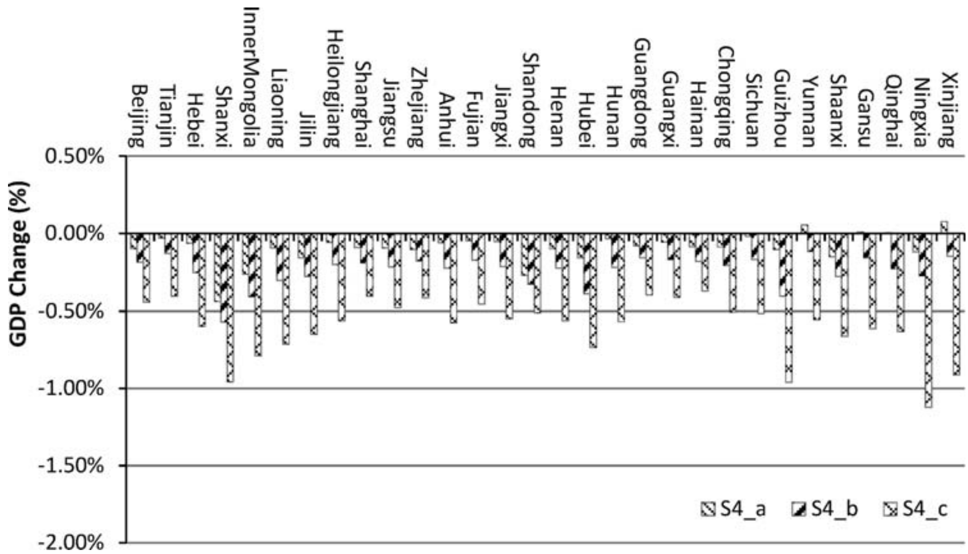

trading sectors need to buy quotas, namely Shandong, Jiangsu, Zhejiang, and Guangdong, most of which are eastern coastal regions with rapid industrial development and a higher MAC. Shandong is the largest buyer, as its real emission is 505.02 Mt $CO_2$, while it only obtains 379.82 million units of initial quotas (one unit quota is equivalent to a ton of $CO_2$ emissions permits). Thus, Shandong needs to buy about 125.20 million quotas, of which the Ele sector is the main buyer, with purchases accounting for 58.83%. Western regions such as Qinghai, Ningxia, and Xinjiang with their lower MAC values, will be net quota sellers.

If we look further into the sectors, we can find that for both sides of trading, the Ele sector is the most important participator followed by the Metal sector. The electric power industry is both an important energy conversion industry and the main greenhouse gas emission source, and the power structure is still dominated by thermal power with large coal input in China. Electricity generated by thermal power in 2007 accounted for about 82.98% of the total power output, coal consumption used by thermal power accounted for about 51.59% of the total national coal consumption, and the $CO_2$ emissions of the Ele sector accounted for 54.90% of the total emissions in China. Moreover, sectors in the different regions exhibit great disparities in terms of mitigation potential; for example, the Ele sector in Guangdong needs to buy 21.03 Mt, while the Ele sector in Inner Mongolia can sell a superfluous volume of 31.45 Mt, which indicates that the MAC of the Ele sector in Guangdong is much larger than that of Inner Mongolia.

*4.2.2 The GDP*

With regard to the three different allocation methods, the changes in regional GDP compared with the benchmark are shown in Figure 10. The national GDPs decrease by 0.108%, 0.235%, and 0.540% under S4_a–S4_c, respectively, which indicates that free allocation leads to lower macroeconomic cost. As can be seen, the GDPs in Yunnan, Gansu, Qinghai, and Xinjiang exhibit slight increases of 0.001–0.076% under S4_a, which means that when the initial quotas are free,

**Figure 10: Regional GDP Changes under the Different Quota Allocation Methods**




these regions will experience macroeconomic benefits. Quota sale regions such as Shanxi and Inner Mongolia can obtain revenues by selling superfluous quotas in the trading due to a MAC that is lower than the carbon price. However, the results show that trading benefits cannot cover the macroeconomic loss caused by excessive reduction in these western and less developed regions.

When there is an auction, the negative impacts on all regions gradually increase. Compared with free allocation, the higher production costs of trading sectors under auction will not only affect the output of trading sectors, but will also reduce the economic activities in regions with lower rates of capital returns and wages. All regions experience GDP decreases when an auction exists (S4_b and S4_c), and the negative effects in quota sale regions are also more apparent. For example, the GDP decreases by 1.124% under S4_c in Ningxia, while it decreases by 0.122% under S4_a. Compared with auction, free allocation is therefore more conducive to economic development in the western regions.

*4.2.3 Welfare*

National welfare is estimated to reduce by 6.65, 29.72, and 94.68 billion yuan under S4_a–S4_c, respectively. Compared with S4_c, free allocation can be taken as hidden compensation to trading sectors; thus, the welfare loss caused by the labor price decrease is less under S4_a (see Figure 11). Auctions will directly increase the production cost of the trading sectors, which will eventually transfer to households via lower wages and higher commodity prices. Therefore, the welfare losses of households will be greater.

Labor-intensive regions such as Shandong, Shanxi, and Shanghai will experience more welfare losses, while welfare in Yunnan, Xinjiang, Gansu, and Sichuan will exhibit a slight improvement under S4_a. When there is an auction, all regions experience a welfare loss, particularly in the eastern coastal regions and central regions with intensive labor. Welfare in these regions is more sensitive to the production cost increase because of a higher MAC and intensive labor. Overall,

**Figure 11: Regional Welfare Changes under the Different Quota Allocation Methods**

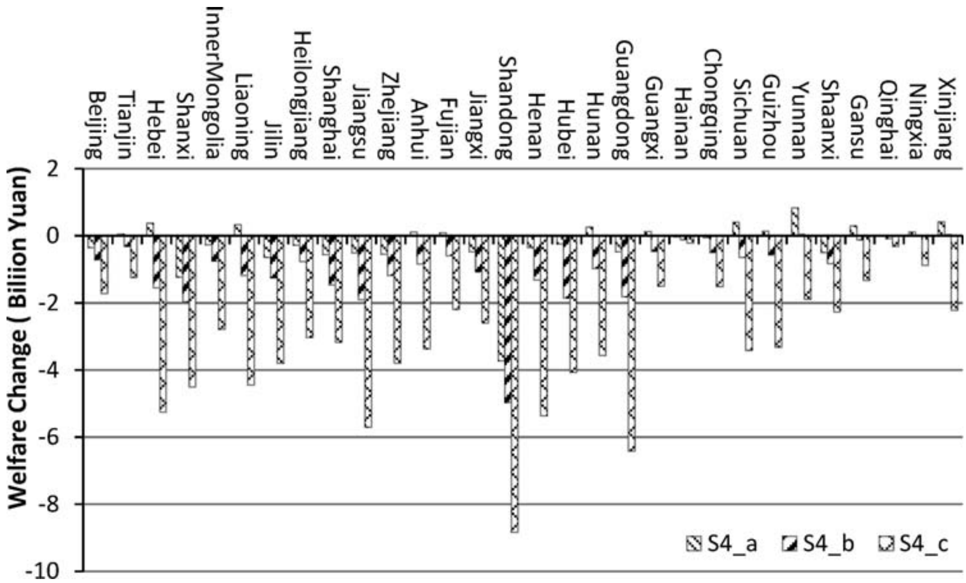



**Table 6: Industry Export and Import Changes under the Different Quota Allocation Methods (%)**

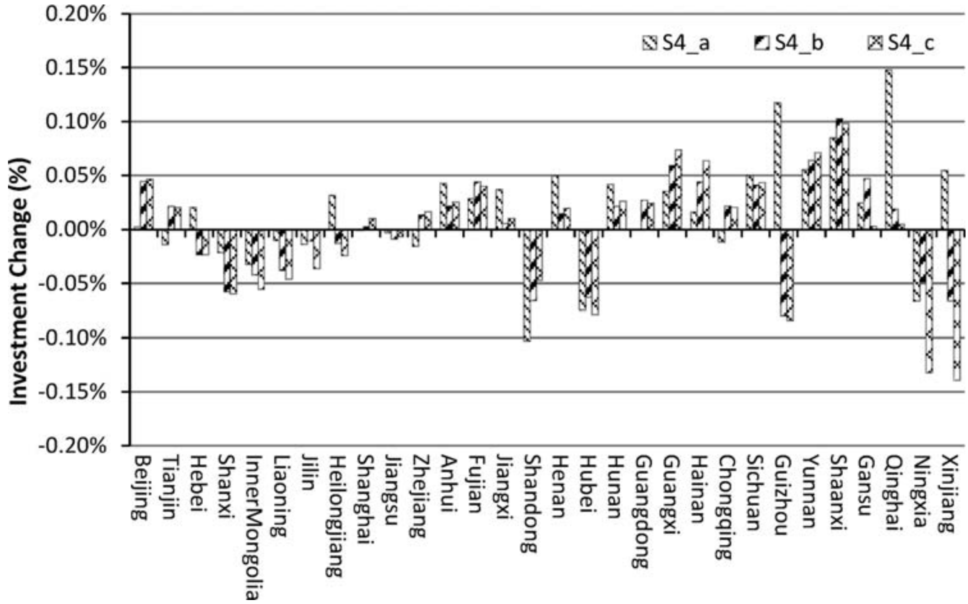
| | Export | | | Import | | | Net Export | | |
|---|---|---|---|---|---|---|---|---|---|
| Sector | S4_a | S4_b | S4_c | S4_a | S4_b | S4_c | S4_a | S4_b | S4_c |
| Agri | −0.13 | −0.31 | −0.85 | −0.25 | −0.37 | −0.64 | 0.32 | 0.41 | 0.53 |
| Coal | −1.11 | −1.20 | −1.87 | −5.33 | −5.54 | −5.73 | 6.04 | 6.28 | 6.38 |
| Coil | 0.40 | 0.39 | 0.21 | −4.11 | −4.36 | −4.87 | 4.44 | 4.70 | 5.24 |
| Mine | −0.10 | −0.10 | −0.15 | −1.97 | −2.09 | −2.06 | 2.38 | 2.53 | 2.49 |
| Fpap | −0.17 | −0.24 | −0.49 | −0.35 | −0.57 | −1.03 | −0.12 | −0.15 | −0.34 |
| Petro | 0.76 | 0.90 | 0.65 | −1.95 | −2.09 | −2.20 | 7.90 | 8.63 | 8.47 |
| Chem | −0.49 | −0.56 | −0.71 | −0.44 | −0.57 | −0.80 | 0.02 | 0.62 | 1.55 |
| Nmm | −0.63 | −0.85 | −1.00 | 0.04 | 0.18 | 0.28 | −0.78 | −1.07 | −1.28 |
| Metal | −1.17 | −1.67 | −1.82 | −0.06 | 0.10 | 0.07 | −9.42 | −14.80 | −15.79 |
| Omf | −0.37 | −0.47 | −0.62 | −0.33 | −0.38 | −0.49 | −0.51 | −0.78 | −1.09 |
| Ele | −4.68 | −4.66 | −5.70 | 2.20 | 2.04 | 2.05 | −4.90 | −4.67 | −5.11 |
| Gas | −1.61 | −1.62 | −2.49 | −1.87 | −2.16 | −2.89 | 2.22 | 2.87 | 3.40 |
| Cons | −0.11 | −0.17 | −0.27 | 0.03 | 0.10 | 0.16 | −0.13 | −0.30 | −0.48 |
| Trans | 0.03 | 0.03 | −0.09 | −0.84 | −0.99 | −1.22 | 1.59 | 1.86 | 1.93 |
| Wsale | 0.05 | 0.05 | −0.08 | −0.70 | −0.92 | −1.30 | 0.24 | 0.30 | 0.24 |
| Esta | 0.13 | 0.20 | 0.16 | −0.38 | −0.53 | −0.82 | 0.44 | 0.63 | 0.74 |
| Ots | −0.11 | −0.24 | −0.59 | −0.32 | −0.42 | −0.62 | 0.82 | 0.56 | −0.47 |
| Total | −0.34 | −0.45 | −0.64 | −0.71 | −0.78 | −0.95 | 0.73 | 0.50 | 0.25 |

the welfare loss of all regions under S4_c is more than two times the welfare loss under S4_a, which indicates that the negative effect of auction on welfare is significant.

### *4.2.4 International Trade*

Table 6 shows the export, import, and net export changes of the aggregate sectors under S4_a–S4_c. Generally, the total aggregate exports and imports both decrease. We find that exports

**Figure 12: Regional Investment Changes under the Different Quota Allocation Methods**




decrease less under free allocation than under auction due to the existence of hidden compensations. For imports, Coal experiences the most significant imports decrease of 5.33% under S4_a, followed by Coil, with 4.11%. With the extension of auction proportion, further increases in production and living costs lead to a larger decrease in consumption demand, which will cause more of a decrease in imports.

If we look into the sectorial results, the net exports of the Metal, Ele, and Nmm sectors are greatly affected. Metal exhibits the most significant decrease of net exports, at 9.42% under S4_a and expanding to 15.79% under S4_c. This indicates that auction has more of an effect on the net exports of energy-intensive industries. However, with the exception of Ele, all of the energy sectors demonstrate net import decreases to varying degrees (the ratio in Table 6 is changes in net exports, which is in contrast to changes in net imports), with greater decreases under auction. Therefore, compared with free allocation, auction is better at reducing external energy dependence, limiting the export of energy-intensive industries, and promoting industrial structure adjustment.

For the Ele sector, because of the high emissions and large domestic consumption demand, the net import of electricity will increase with decreasing exports and increasing imports under the emission reduction policy. In a comparison of S4_a–S4_c, export and import changes of Ele are all relatively smaller under S4_b, which indicates that a hybrid allocation is better.

*4.2.5 Investment*

The investment changes exhibit spectacular disparities among the regions (see Figure 12). There is a clear indication that the western energy and resource-intensive regions such as Qinghai, Guizhou, and Shannxi have substantial increases in investment. Investments in Shandong, Hubei, and Ningxia experience obvious decreases, and Shanxi, Inner Mongolia, and Jilin also exhibit slight decreases. Economic growth in these regions mainly depends on electric power, iron and steel, and other energy-intensive industries; emissions reduction will increase the production costs and so as to reduce investments in these industries. For Guizhou, Xinjiang, Hebei, and Heilongjiang, expansion of the auction proportion will shift the investment impact from positive to negative; meanwhile, it will also make the investment decrease larger in Shanxi, Inner Mongolia, Liaoning, and Jilin. In total, compared with auction, free allocation is better for the western and less developed resource-intensive regions, as it can direct more investment to these regions and promote local development.

### *4.2.6 Carbon Leakage*

Since emissions-trading policies aim at reducing the emissions of some particular sectors, which may cause a carbon leakage in other sectors, this paper also calculates the emissions of non-trading sectors. The results show that more than 90% of non-trading sectors experience slight emissions reduction under all scenarios. The main reason for this is that the increasing commodity prices of trading sectors will lead to higher production costs of non-trading sectors, as there are input–output linkages among them. When energy-related input cost increases, non-trading sectors will choose to reduce outputs or input more labor and capital as a substitution. Therefore, emissions reductions will also appear in non-trading sectors, even though they have no emissions cap. The total emissions of non-trading sectors will reduce by more than 10 Mt $CO_2$ compared to the benchmark.

The increase of $CO_2$ emissions in a few non-trading sectors is so negligible compared to the negative change in most non-trading sectors that we may conclude that the risk of inter-sectorial carbon leakage under emissions trading is not obvious. However, the international carbon leakage is not discussed in this paper, as the small country assumption is adopted in international trade. The energy-intensive industries in China experience export declines due to emissions reduction; in reality, these industries in other countries may produce more and have higher emissions if there is no emissions constraint in those countries.

## 5. CONCLUSION AND DISCUSSION

Based on the Copenhagen reduction target, this paper analyzed the regional macroeconomic impacts of the national wide carbon market of China under both different allocation criteria and different allocation methods with a multiregional CGE model. Several conclusions emerged from the results of the study:

Initial quotas allocated to the eastern regions represent more than 50% of the total cap under the Emission Standards and Egalitarian criterion; part of the initial quotas will transfer from eastern to central and western regions under the Ability-to-Pay criterion, which can alleviate the emissions reduction pressure in these regions.

In the macroeconomic effects comparison, the Ability-to-Pay criterion is better than the other criteria, as it can lead to lower macroeconomic costs and welfare losses; narrow the economic gap between the eastern, central, and western regions; and guide investment into the western region.

In emissions trading, the eastern coastal and industrial regions with higher MAC levels are the main quota buyers, while the central and western regions with rich energy resources are the main quota sellers. Sectors in different regions have substantial differences in mitigation potential, and the Ele sector is not only the focus of energy saving and emissions reduction, but also an important trader in the carbon market.

Compared with auction, free allocation leads to lower macroeconomic costs and welfare losses, and can narrow the regional economic gap. In addition, it can direct investment to western and less developed, resource-intensive regions. However, in terms of the import and export structure, auction does better at reducing energy dependence and limiting the export of energy-intensive industries, which can accelerate structural adjustment.

A well-designed national wide carbon market should minimize the impact on the macro-economy and welfare, balance regional development, guide investment to energy conservation and emission reduction, and protect less developed but resource-intensive regions while limiting the net export of energy-intensive industries and adjusting the industrial structure. Therefore, according to the comparative results discussed above, we suggest that in the initial period of the national wide carbon market in China, the Ability-to-Pay criterion and a hybrid allocation method—free allocation for energy sectors and full auction for energy-intensive sectors—are preferable.

Based on the current emissions trading pilots, a national wide carbon market will be established as a next step in China. Since the effects of the national wide carbon market on regional economies are quite complex and cannot be detected through the trials of seven pilots, it is necessary to simulate a national wide carbon market to analyze its impacts on all regions before a real carbon market is established. In this paper, we have tried to discuss this issue from the perspective of initial quota allocation. The emissions reduction target of 45% in our paper—translating to 4.26% emissions reduction in the benchmark year 2007—is not very large, and therefore some of the results are not very significant. However, the analysis indeed shows some policy implications in the emissions trading scheme design in China.

It must be clear that it is complex and difficult to say an allocation approach is better than others for the all aspects in the whole economic system. There are many literatures discussing the recycling of auction revenue. Different conclusions might become apparent with alternative ways of revenue recycling (Goulder, 1995; Parry and Bento, 2000). For example, when the revenue is used to reduce tax distortions, the macro economic impact may be more positive, which will involve more complex design. When the revenue is given to residents directly, the welfare may be improved a lot. In this paper, we recycle all auction revenue to the production system through re-investment to keep tax neutrality which is a direct and simple approach. Thus lack of a deep discussion of the revenue recycling is a limitation of our study.

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## APPENDIX A

**Table A1: The Regional Reduction Targets in the Twelfth Five-Year Plan**

| Region | Intensity Reduction (%) | Region | Intensity Reduction (%) | Region | Intensity Reduction (%) |
|---|---|---|---|---|---|
| China | 17 | – | – | – | – |
| Beijing | 18 | Zhejiang | 19 | Hainan | 11 |
| Tianjin | 19 | Anhui | 17 | Chongqing | 17 |
| Hebei | 18 | Fujian | 17.5 | Sichuan | 17.5 |
| Shanxi | 17 | Jiangxi | 17 | Guizhou | 16 |
| InnerMonglia | 16 | Shandong | 18 | Yunnan | 16.5 |
| Liaoning | 18 | Henan | 17 | Shaanxi | 17 |
| Jilin | 17 | Hubei | 17 | Gansu | 16 |
| Heilongjiang | 16 | Hunan | 17 | Qinghai | 10 |
| Shanghai | 19 | Guangdong | 19.5 | Ningxia | 16 |
| Jiangsu | 19 | Guangxi | 16 | Xinjiang | 11 |

**Table A2: Sector Declarations and Descriptions**

| Sector Codes | Description |
|---|---|
| Agri | Agriculture, forestry, animal husbandry and fishery |
| Coal | Coal |
| Coil | Crude oil and natural gas |
| Mine | Mining |
| Fpap | Manufacture of foods, beverage, tobacco, textile, wearing, apparel, leather, wood, paper and publishing |
| Petro | Coking, gas and processing of petroleum |
| Chem | Chemical industry |
| Nmm | Manufacture of nonmetallic mineral products |
| Metal | Manufacture and processing of metals and metal products |
| Omf | Other manufacture |
| Ele | Production and supply of electric, heat power |
| Gas | Production and supply of gas, water |
| Cons | Construction |
| Trans | Transport, storage, post, information transmission, computer services and software |
| Wsale | Wholesale and retail trades, hotels and catering services |
| Esta | Real estate, leasing, business services and financial intermediation |
| Ots | Other services |