The influence of different allowance allocation methods on China’s economic and sectoral development

Tao Pang, Sheng Zhou, Zhe Deng and Maosheng Duan

Institute of Energy Environment and Economy, Tsinghua University, Beijing, People’s Republic of China

ABSTRACT
China launched its national carbon emissions trading scheme (ETS) in 2017. The choice of allowance allocation methods can strongly influence the political acceptance of an ETS by enterprises/sectors that are covered by it. This article builds a computable general equilibrium model to conduct a quantitative analysis of the effects of nine common allowance allocation methods on both the macro-economy and the industries covered by the ETS. The results of the model show that national gross domestic product (GDP) decreases by 0.37–0.44% during the 13th Five-Year Plan period against a backdrop of a 2% annual reduction in carbon emissions from the sectors covered by the ETS compared with the business-as-usual scenario. China’s total emissions drop by 1.71–1.76%. When auctioning and allocation approaches without ex-post adjustment are used, the allowance price is 40–45 yuan/tCO2. When the dynamic allocation methods are used, the allowance price increases to 70–75 yuan/tCO2. Auctioning and allocation approaches without ex-post adjustment exert the same influence on macroscopic indicators (such as GDP and total emissions) and industry indicators (such as output and price). The dynamic allocation methods have a subsidy effect, which can significantly reduce the effect of the ETS on GDP and industry output while significantly increasing the allowance price and decreasing the economic efficiency of the ETS. The cement and steel industries are the most sensitive to the output subsidy effect of the dynamic allocation methods. This article suggests a limit on the use of dynamic allocation approaches to avoid excessively high allowance prices and excessive subsidies for overcapacity industries.

Key policy insights
• Auctioning and one-off allocation purely based on historical data are most economically efficient; dynamic allocation based on updated or actual output data could reduce the impact of the ETS on enterprises’ output, but will increase the allowance price and thus reduce the economic efficiency of the ETS.
• Implementing a national ETS will have limited impact on China’s GDP, but could promote emissions abatement of the whole economy in an efficient way.
• Different allocation methods have almost the same impact on GDP, but the impacts on different sectors are significantly different.

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Allowance allocation; China; emissions trading; national ETS

1. Introduction
China officially launched its national carbon emissions trading scheme (ETS) in 2017. Allowance allocation is one of the core elements in the system’s design. In developing allocation methods under the national ETS, it is important to consider not only general issues, such as economic efficiency and concerns about competitiveness...
of ETS covered sectors, but also special issues related to China’s national conditions, such as the significant uncertainties of economic and industrial development, and heavy regulation of the electricity and heat generation sector.

The allocation approaches under an ETS can be divided into two categories according to whether the entities should pay for the allowances: auctioning and free allocation. Free allocation methods can be categorized according to two criteria. One is based on the period of basic data that is used as a basis for allocation: grandfathering (historical) or dynamic (updated or actual). The other is based on the source of basic data: emissions-based, output-based or input-based. In practice, some naming methods are used because of the specific parameters used in allocation approaches. For example, the benchmarking and historical intensity decreasing methods are both output-based, but the former is based on a given industry’s unified emissions intensity, and the latter allocates allowances based on a given entity’s historic emissions intensity.

Different allocation methods have different influences on the macro-economy and the industries covered by the ETS, thus affecting different stakeholders’ political acceptance of such methods. For example, Bohringer and Lange (2005a) conducted a partial equilibrium model, to compare the cost and efficiency of two allocation methods based on emissions and production, as well their impact on the output and employment of different sectors. They concluded that an emissions-based allocation rule is more costly than an output-based rule in terms of maintaining output and employment in energy-intensive industries. Burtraw, Palmer, Bharvirkar, and Paul (2001) compared the economic efficiency and distribution effects of different allowance allocation methods for the US power industry, emphasizing the advantages of auctioning in terms of efficiency, and quantifying the impact of different allocation methods on energy price, producer profit and asset values. Based on the analysis of a partial equilibrium model, Fischer (2001) indicated that all allowance allocation methods with production-based return imply a subsidy for production, resulting in the need for more effort to reduce emissions intensity for the economy to achieve an emissions control target. These studies make up the theoretical foundation of this present analysis on the economic effect of allowance allocation methods. Taking China’s practical situations in allowance allocation into account, it is also valuable to analyse the effect of different allocation methods.

Owing to China’s fast developing economic circumstances, dynamic allowance allocation with ex-post adjustment is a choice with more political acceptance, in the context of this present phase, when China is moving from its ETS pilots to a national unified ETS. This would mean a flexible emissions cap for the national ETS, which is different from a textbook ETS model, which has a fixed emissions cap (Pang & Duan, 2016). Theoretically, the allocation methods with ex-post adjustment would form a subsidy for enterprises’ emissions or production, thus resulting in a higher cost to achieve a certain emissions control target, which is different from one-off allocation methods including auctioning and grandfathering (Fischer, 2001). Under one-off allocation methods, because free allocated allowances have an opportunity cost (firms that receive allowances can sell them to other firms, so if they choose to emit another tonne of CO₂, they forego what they could earn from selling the allowance), the economic incentives for emissions or production are the same. However, under ex-post allocation methods, the firms would get more allowances if they increase their level of production or emissions, so the incentive to reduce emissions would be distorted. It is therefore of theoretical and practical significance to analyse the effect of allowance allocation methods on the economy and related industries.

This article considers nine possible allowance allocation methods, which have been adopted in China’s seven ETS pilots or schemes in other regions (Pang & Duan, 2016). A dynamic computable general equilibrium (CGE) model is built to quantitatively analyse the effects of different allocation methods on the macro-economy and the industries that are covered by the ETS to analyse the possible emissions reduction outcome of the ETS during China’s 13th Five-Year Plan period, and provide a basis for comparing these methods.

2. Model

This article builds a recursive dynamic general equilibrium model in an open economic environment. The construction of this model refers to approaches regarding model structure, further division of the energy sector, etc., used in the models of Löfgren, Harris, and Robinson (2001), Zhang (2010), Lu, Zhang, and He (2010), Boehringer, Rutherford, and Springmann (2015), Bohringer and Lange (2005a), Fujimori, Masur, and Matsuoka (2012), Wang (2003), Qi (2014) and Zhao and Wang (2008). This model analyses the policy effects of the ETS by setting up a
cap-and-trade module and providing a detailed description of nine common allowance allocation methods. However, due to the limitation of CGE modelling when dealing with a fast-changing economy and heterogeneity of enterprises, the result is not perfect in some respects.

2.1. Model structure and sector division

2.1.1. Model structure
The basic structure of the model is shown in Figure 1, which describes the flow of capital and labour, general goods, energy commodities and allowances in the economic system. This model divides the economic system into a factor market and a commodity market and sets up four accounts: residential, enterprise, governmental and external. The model describes the circulation of factors and commodities through the depiction of economic behaviours, including production, consumption, investment and savings. Enterprises buy capital and labour factors from the factor market and energy and other intermediate inputs from the commodity market. With sufficient carbon emissions allowances, enterprises can use technology to produce goods, which they then sell in domestic and international markets. Goods in the domestic market have two destinations: intermediate inputs and final commodities. Goods in the domestic market consist of goods that are produced both domestically and abroad. These two types of goods satisfy the Armington conditions (Armington, 1969) during consumption and cannot be completely substituted. Domestic-market consumers include both residents and the government. A portion of individual and government income is used for goods consumption, and the rest is saved. In the dynamic model, the current savings of the economic system is the source of the capital supply in the next period, so the savings rate significantly affects both the macro-economy and sectoral development.

2.1.2. Sector division
The model covers 37 production sectors, which are determined by the sector-division standards of the 2012 input–output table of 139 sectors in China and the China Energy Statistical Yearbook 2013. This model divides as many sectors as possible based on the accessibility of the output and energy-consumption data for relevant sectors.

This article aggregates the sectors in the original input–output table. The new input–output table includes one agricultural sector, 32 industrial sectors, one construction sector and three service sectors, all of which are shown in Table S1. In terms of error data processing and the splitting of the petroleum and natural gas exploration industry, this article refers to the approach that was used in the input–output table for China in the Global Trade Analysis Project (GTAP) database of Li and Janus (2008) and Liu and Chen (2015).

2.2. Static model construction
The static model contains seven modules: the production module, the international trade module, the price module, the income module, the savings and investment module, the carbon emissions control module and the macro-closure module. The details of the static model construction are explained in the Section S2.

Figure 1. Basic structure of the model.
2.3. Constructing the dynamic model

The construction of a dynamic model is primarily driven by savings-investment. From the perspective of the entire economic system, all gross social savings in the current period become investment and a component of the capital stock in the next period. From the perspective of sectors, the capital stock $QK_{a,t}$ of sector $a$ in period $t$ consists of the capital stock after depreciation in the prior period $QK_{a,t-1} \cdot (1 - r_{dep,a})$ and the newly added fixed capital formation $QFK_{a,t-1}$, as shown in formula (1). The capital stock $QK_{a,t}$ of all of the sectors cannot flow freely. The fixed capital formation $QFK_{a,t}$ comes from the total fixed capital formation of the entire economy $AGGFK_t$ and can flow freely between different sectors.

$$QK_{a,t} = QK_{a,t-1} \cdot (1 - r_{dep,a}) + QFK_{a,t-1}$$  (1)

In terms of labour force supply, Zeng Yi (2013) showed that China’s working-age population from 18 to 64 generally will remain stable at 940 million from 2010 to 2020. Based on the results of this research, the amount of the labour force supply remains unchanged at the base year level in this dynamic model.

2.4. Sources of statistics

2.4.1. Social accounting matrix

The main statistical base of the model is the Social Accounting Matrix (SAM). The statistics of the SAM built in this article come from the China Input–Output Table 2012, the Finance Yearbook of China 2013, the China Custom Statistical Yearbook 2013, the Flows-of-funds Tables 2012, etc.

2.4.2. Exogenous parameters of the dynamic module

The model selects 2012 as the base year. Some key parameters must be provided exogenously in the dynamic module, and most of the values of these parameters refer to the actual data and their changing trends in recent years. The formation of these parameters is explained in Section S3, including the structure of household consumer spending, distribution proportion of fixed capital formation, energy mix, the TFP (total factor productivity) growth rate, the residential savings rate and the autonomous energy efficiency improvement factor.

3. Results

3.1. Scenario design

3.1.1. Baseline scenario

The model does not consider the ETS policy in the baseline scenario but instead establishes some constraints based on the major existing energy policies. Major indicators for year 2020 include the following: the share of non-fossil fuels in primary energy consumption reaches 15%, the share of natural gas consumption exceeds 10% and the share of coal consumption dips below 62% (Office of the State Council, 2014). In the baseline scenario, China’s macroeconomic and industrial development have the following characteristics.

(1) GDP and industrial structure. Table S2 lists the macroeconomic variables in the baseline scenario. During the 13th Five-Year Plan period, China’s annual gross domestic product (GDP) growth rate is 6.8%. In terms of industrial structure, the shares of the added value of primary and secondary industries in GDP gradually decrease while the share of tertiary industry continues to increase. Consumption and investment remain the main drivers of China’s economic growth, according to the expenditure-based accounting of GDP. The share of consumer spending in GDP gradually increases and the share of investment remains generally unchanged while the share of net export declines.

(2) Total emissions and carbon intensity. From 2012 to 2020, China’s total CO2 emissions, including the CO2 emissions from the energy consumption of all sectors and the CO2 emissions from cement production, will increase from 8.75 billion tCO2 to 11.36 billion tCO2, a yearly decline in the emission growth rate. China’s CO2...
emissions per unit of GDP will drop from 1.63 tCO₂/ten thousand yuan in 2012 (the price in 2012 remained unchanged, similarly hereinafter) to 1.23 tCO₂/ten thousand yuan in 2020.

(3) Added value, carbon emissions and carbon intensity of sectors to be covered by the ETS. As shown in Figure 2, the growth rates of the added value in industries to be covered by the ETS, including iron and steel, electric power, chemicals, cement, paper and pulp and non-ferrous metals, have been declining to various degrees since 2012, and are apparently lower than the national GDP growth rates.

As shown in Figure 3, although all six major sectors are high-emission and high-energy-consuming industries, significant differences remain in their CO₂ emissions. In 2012, CO₂ emissions from the power generation, iron and steel, cement and chemical industries constituted 50%, 18.8%, 20.9% and 8.5% of the total emissions to be covered by the ETS, respectively, whereas the shares of CO₂ emissions in the papermaking and non-ferrous metal industries were very small. From 2012 to 2020, the growth rates of the CO₂ emissions in these six sectors decline each year. From 2012 to 2020, the carbon emissions per unit output value of six sectors will drop from 2.32 tCO₂/ten thousand yuan to 1.91 tCO₂/ten thousand yuan, and the decline rate during the 13th Five-Year Plan period reaches 9.93%, which is lower than the decline rate of the carbon emissions intensity per unit GDP of all the sectors. There are two reasons for the gap between these decline rates. On the one hand, the model assumes that the proportion of new investment and the rate of technological progress in these sectors are relatively low. On the other hand, the energy-saving potential of the energy-intensive sectors is
gradually decreasing because of the great efforts made in the past to save energy and reduce emissions (Gao, 2013; Wei, Guo, & Duan, 2015).

### 3.1.2. ETS policy scenario

This article assumes in the ETS scenario that the ETS begins nationally in 2017. In the ETS scenario, the total emissions cap is 2% lower than the emissions of the sectors covered by the ETS in the baseline scenario.

Table 1 shows the formulas and values of the main parameters of different allocation methods. Among these nine methods, HEG and HPB are allocation approaches without ex-post adjustment, whereas HEUG, HPUB, HPI, HPIU, APB and AEM are dynamic allocation approaches that allocate allowances based on the updated or real production or emissions data. In the formula, \( f \) is the distribution coefficient of free allowance and \( \mu_{\text{ex-ante}}, \mu_{t-1} \) and \( \mu_t \) represent the historical emissions intensity, the emissions intensity of the prior year and the emissions intensity of the current year, respectively. \( q_{\text{ex-ante}}, q_{t-1} \) and \( q_t \) refer to the historical output, prior year output and current year output, respectively, and \( BM \) is the emissions benchmark for a specific sector. The value of \( BM \) is set at the level of carbon emission intensity per unit production under certain auction circumstance. For the auction method, the revenue is collected and consumed by the government, not directly recycled to the sectors of enterprise or resident on purpose.

Based on the above-mentioned methods, this article first studies the ‘single allocation method’ scenario, in which the same allocation method will be used in all of the ETS sectors. Considering that different sectors covered by the ETS are facing different economic or social situations, different allocation methods are used for them, in both the EU ETS and China’s seven pilots. Therefore, a scenario of ‘synthetic allocation methods’, in which differentiated allocation methods will be adopted in different industries, is then designed for the purpose of conducting inter-sector comparisons.

### 3.2. Analysis of the ‘single allocation method’ scenario

#### 3.2.1. Macro-economy and emissions

Dynamic allocation methods have output subsidy effects, which can reduce the influence of the ETS on the output of sectors and thus reduce the effect of the ETS on GDP (Bohringer & Lange, 2005b; Burtraw et al., 2001; Fischer, 2001; Sijm, Berk, Elzen, & Wijngaart, 2007; Zetterberg, 2014). However, these approaches will increase the prices of allowances under the ETS and decrease the economic efficiency of the system. At present, the prices of allowances in the seven pilot areas lie between 8.5 and 50 yuan/t.1 At the early stage

| Abbreviations | Allocation Methods | Formulas | Values of Relevant Parameters |
|---------------|--------------------|----------|-------------------------------|
| AUC           | Auctioning         | \( a_t = 0 \) | –                             |
| HEG           | Grandfathering based on Historical Emissions (not updated) | \( a_t = f \cdot \mu_{\text{ex-ante}}q_{\text{ex-ante}} \) | Historical Emissions Decrease Coefficient: 0.9 |
| HEUG          | Grandfathering based on updated Historical Emissions | \( a_t = f \cdot \mu_{t-1}q_{t-1} \) | Historical Emissions Decrease Coefficient: 0.9 |
| HPB           | Benchmarking based on Historical Production (not updated) | \( a_t = BM \cdot q_{\text{ex-ante}} \) | Value of Benchmarking: the Carbon Emission Intensity per Unit Production Value at a Carbon Price of 30 yuan/tCO2 |
| HPUB          | Benchmarking based on updated Historical Production | \( a_t = BM \cdot q_{t-1} \) | Value of Benchmarking: the Carbon Emission Intensity per Unit Production Value at a Carbon Price of 30 yuan/tCO2 |
| HPI           | Allocation based on actual Production and Historical Emissions Intensity (not updated) | \( a_t = f \cdot \mu_{\text{ex-ante}}q_t \) | Historical Emission Intensity Decrease Coefficient: 0.9 |
| HPIU          | Allocation based on Actual Production and updated Historical Emissions Intensity | \( a_t = f \cdot \mu_{t-1}q_t \) | Historical Emission Intensity Decrease Coefficient: 0.95 |
| APB           | Benchmarking based on Actual Production | \( a_t = BM \cdot q_t \) | Value of Benchmarking: Carbon Emission Intensity per Unit Production Value at a Carbon Price of 30 yuan/tCO2 |
| AEM           | Allocation based on Actual Emissions | \( a_t = f \cdot \mu_tq_t \) | Allowance Adjustment Coefficient: 0.9 |
of the national ETS implementation, the price of allowances that can be accepted by the government and businesses should not be considerably higher. In addition, among the industries to be covered by the ETS, cement, iron and steel and non-ferrous metals sectors are overcapacity industries, and relevant industrial policies do not encourage their production. Therefore, this article sets an upper limit for the use of dynamic allocation methods. When dynamic allocation methods are used, the output of the cement industry will benefit the most from the subsidy effect. Therefore, the model sets a ‘neutral output’ principle for the cement industry in which an upper limit is set on the use of the dynamic allocation methods. When this upper limit is reached, the output level of the cement industry equals the baseline scenario level. The free allowances that exceed the upper limit of using the methods will be allocated according to the shares of the historical emissions of different sectors.

Figure 4 shows the upper limits of the usage of six dynamic allocation methods in each year. Allocation methods (HEUG, HPIU and AEM) with subsidy effects in emissions and output have lower upper limits than allocation methods (HPUB, HPI and APB) with only an output subsidy effect. This result occurs because under the former methods, the carbon abatement cost considered in enterprises’ decision is lower than the market price of allowances, which further decreasing the impacts of ETS on their output. Stricter restraints on usage indicate that the former more easily creates excessive subsidies on production. The upper limit of the usage of dynamic allocation methods decreases each year, indicating that enterprises will gradually adjust and adapt to the ETS policy after the shock from its introduction, and the output will become less affected.

Figure 5 shows the price of allowances when different allocation methods are adopted. Using auctioning and allocation approaches without ex-post adjustment means that the prices of allowances are exactly the same,
approximately 40 Yuan/t. Dynamic allocation methods significantly increase the price of allowances; when they meet the ‘neutral output’ conditions, the price is approximately 70 Yuan/t. From a dynamic perspective, the price of allowances increases yearly, but the increase is not large, so the abatement pressure on industries that are covered by the ETS will slightly increase yearly.

The influence of nine free allocation methods on GDP compared to the baseline scenario, when the use of dynamic allocation methods reaches the upper limit, is shown in Figure 6. In the case in which the ETS cap is 2% lower than the emissions in the baseline scenario, implementation of the ETS policy has limited effect on China’s GDP. Under auctioning and allocation approaches without ex-post adjustment, GDP falls by 0.37–0.44% compared with the baseline scenario. The decline in GDP will slightly increase yearly because of the accumulated effect of the ETS policy. When the use of all dynamic allocation methods reaches the upper limit, their output subsidy levels for all of the covered sectors are similar. Their effects on GDP are also similar: GDP will drop by approximately 0.1% compared with the baseline scenario, which is significantly lower than the decline under auctioning and allocation approaches without ex-post adjustment.

Figure 7 shows the influence of the ETS under different allowance allocation methods on China’s total carbon emissions. There are only small differences among these methods. Through the implementation of the ETS, total carbon emissions will fall by 1.71–1.76% compared with the baseline scenario. With the decline in the share of emissions from sectors that are covered by the ETS in economy-wide emissions, the ETS will gradually contribute less to the reduction in total emissions. In terms of specific allocation methods, adopting dynamic allocation methods slightly lowers the contribution of the ETS to overall emission reductions compared with auctioning and allocation approaches without ex-post adjustment. The increase in the output of industries covered by
the ETS increases the output in other sectors through the input–output relationship, increasing the carbon emissions of the entire economy.

3.2.2. Sector output and emissions

(1) Output of sectors covered by the ETS. Figure 8 shows the effects of different allowance allocation methods on the outputs of industries that are covered by the ETS compared to the outputs in the baseline scenario. After the implementation of the ETS, the outputs of the sectors covered will be lower than those in the baseline scenario regardless of which allocation method is used. Among all the sectors, the output of the power-generation sector will be the most affected by the ETS, suffering a decline of 2.0–2.2% compared with the output in the baseline scenario, whereas declines in the other industries are between 0.5% and 0.7%. One reason is the relatively higher proportional cost of carbon emissions in the production costs of the power-generation industry. Another reason may be the output decline in high-emission industries because of the ETS, which reduces demand for the power-generation industry.

For other sectors covered, compared with auctioning and allocation approaches without ex-post adjustment, dynamic allocation methods will reduce the effect of the ETS on output, and the cement and iron and steel industries will receive the highest output subsidy levels. When the cement industry satisfies the ‘neutral output’ conditions, the output of the iron and steel industry is only approximately 1% lower than that in the baseline scenario; the outputs in the papermaking, chemical and non-ferrous metal industries will also fall to various degrees; and the output decline in the power-generation industry will further increase.

The cement and steel industries are most sensitive to the output subsidy effect under dynamic allocation methods. These two industries are overcapacity industries, so offering them output subsidies contravenes the requirements of ‘excessive capacity reduction’ in industrial policies. Therefore, dynamic allocation methods are inconsistent with industrial policies related to the cement and steel industries.

(2) Consumer price of products from sectors covered by the ETS. Figure 9 shows the effects of different allocation methods on the consumer prices of products from sectors covered by the ETS. Compared with auctioning and allocation approaches without ex-post adjustment, dynamic allocation methods significantly raise the prices of products from all sectors covered by the ETS. The reason for this price increase is that dynamic allocation methods raise the prices of allowances, increasing production costs and thus consumer prices.

(3) Carbon emissions of sectors covered by the ETS. Figure 10 shows the effects of different allocation methods on the CO₂ emissions of sectors covered by the ETS. Overall, carbon emissions will decrease compared with the baseline scenario for all six sectors covered by the ETS, regardless of which allocation method is used. Compared with the baseline scenario, the declines in the carbon emissions of industries covered by the ETS in 2017 can be shown in the following order: power industry (approximately 2.5–2.9%) > paper and pulp industry (approximately 1.8–2.3%) > iron and steel industry (approximately 1.8–2.1%) > non-ferrous metal industry (approximately 1.6–1.7%) > chemical industry (approximately 1.0–1.2%) > cement industry (approximately 0.7–1.3%).

The ETS scenario in the model requires the total CO₂ emissions of the industries covered by the ETS to be lower than those in the baseline scenario by 2%. Assuming that the target can be achieved through command-and-control means, all of the industries must reduce their emissions by 2%. After implementing the ETS, the emission reductions of the power and papermaking industries exceed 2%. Therefore, these two sectors are potential allowance suppliers, and the other four sectors belong to the potential demand side of allowances. This result only applies to the comparison with the assumed scenario. The actual supply-and-demand relationship of allowances requires a comparison between the allocated free allowances and the actual emissions of various industries.

Compared with auctioning or allocation approaches without ex-post adjustment, dynamic allocation methods reduce the decline in emissions from the cement and iron and steel industries; increase the decline in the papermaking, chemical and power-generation industries; and initially increase and then decrease the emission decline in the non-ferrous metal industry. The differences in each sector’s emission reductions are caused by differences in the costs of emission reductions in various sectors with various allowance prices. In
Figure 8. Rates of change (%) of the outputs of six sectors under different allocation methods compared to the baseline scenario.
Figure 9. Rates of change (%) of the consumer prices of products from six industries under different allocation methods compared to the baseline scenario.
Figure 10. Rates of change (%) of the carbon emissions of six sectors under different allocation methods compared to the baseline scenario.
addition, changes in emissions and industry development trends are related from a dynamic perspective. The upper limit of the total ETS emissions is fixed, so industries with faster output or emissions growth will receive relatively more allowances and industries with relatively slower growth will shoulder relatively heavier abatement pressure when dynamic allocation methods are used compared with allocation approaches without ex-post adjustment (Haites, 2003).

(4) Carbon emissions per unit output of sectors that are covered by the ETS. Figure 11 shows how the carbon emissions per unit output of the sectors covered by the ETS change compared to those in the baseline scenario under different allowance allocation methods. Generally, dynamic allocation methods raise the price levels of allowances throughout the ETS, so the carbon intensities of all the industries covered by the ETS are lower than those under auctioning and allocation approaches without ex-post adjustment. Therefore, these industries are experiencing greater abatement pressure. The papermaking industry is the most affected industry in terms of the intensity of output CO₂ emissions. Dynamic allocation methods raise the carbon intensity reduction of the papermaking industry from less than 1.5% to approximately 1.9%. The influences of different allocation methods on carbon intensity changes in other sectors are quite similar.

3.3. Scenario analysis of the ‘synthetic allocation methods’

The ‘single allocation method’ scenario is designed to determine the direction and extent of the effect of various allocation methods based on various types of indicators. However, this scenario is too ideal because it does not consider differences among industries. For instance, under this scenario, allocation methods with an output subsidy effect are still used in overcapacity industries. To solve this problem, this article builds a ‘synthetic allocation method (SYN)’ scenario which uses a benchmarking approach based on historical production (not updated) in industries with relatively severe overcapacity (namely, the cement, iron and steel and non-ferrous metal industries) and a benchmarking approach based on actual production in the chemical and power-generation industries (upper limit of usage: 20%). This article then compares this method’s macro and industrial influence with that of one representative allocation approach without ex-post adjustment, specifically, HEG (grandfathering based on not updated historical emissions) and one representative dynamic allocation method, specifically, APB (benchmarking based on the actual production).

3.3.1. Macroscopic indicators

Figure 12 shows the value changes of the allowance prices, government auction revenues, GDP and total emissions compared to those in the baseline scenario under three scenarios of HEG, APB and SYN. The effects of SYN on these macroscopic indicators lie between those of HEG and APB. In the SYN scenario, the allowance price is 50–60 yuan/t and increases yearly, whereas the GDP decreases by 0.28% compared with the baseline scenario and maintains an annual decline that is almost the same.

3.3.2. Sectoral indicators

Figure 13 shows the changes in several major indicators of the sectors covered by the ETS in the SYN scenario compared to the baseline scenario. The power-generation sector is still the most affected industry in terms of output. The reasons for this include the relatively large share of carbon emission costs in production costs and the decline in electricity demand from the output reduction of other sectors. The power-generation, cement, and iron and steel industries are the most affected industries in terms of consumer prices. However, the increase of the consumer price of electricity drops by 1% compared with the value from the ‘single allocation method’.

Under the SYN scenario, the power and steel industries will become potential allowance suppliers, while the power and papermaking industries are allowance suppliers in the ‘single allocation method’ scenario, further indicating that the adjustment of dynamic allocation methods will affect the distribution of emission reductions between different industries. In terms of carbon intensity, the iron and steel, papermaking and non-ferrous metal industries are the most affected industries, with carbon intensity decreasing by more than 1% compared with the baseline scenario. The rates of decline in the iron and steel and non-ferrous metal industries increase yearly. In terms of import and export intensity, the effect on these sectors in the SYN scenario is generally
Figure 11. Rates of change (%) of the carbon emissions per unit output of six sectors under different allocation methods compared to the baseline scenario.
identical to that under the ‘single allocation method’, and the most affected sectors are still the power, iron and steel and cement industries.

4. Conclusions

In this article, a CGE model has been developed to analyse the influence of different allowance allocation methods on the macro-economy and related industries under China’s national ETS. Our primary conclusions are as follows.

First, ETS policy has only a limited effect on China’s GDP. Compared with the baseline scenario, GDP will decrease by 0.37–0.44% per year when the emissions of sectors covered by the ETS drop by 2% per year. In the ‘single allocation method’ scenario, auctioning and allocation approaches without ex-post adjustment have the same effects on GDP. Dynamic allocation methods have subsidy effects on output or on both output and emissions, and thus can significantly reduce the effect of the ETS on GDP.

Second, dynamic allocation methods, which are preferred by many, will significantly raise the price of allowances and negatively affect the effectiveness of China’s ETS, and thus the scope and proportion of dynamic allocation should be limited. When auctioning and allocation approaches without ex-post adjustment have the same effects on GDP.

Figure 12. Rates of change of macroscopic indicators in the SYN, HEG and APB scenarios compared to the baseline scenario.
adjustment are adopted by the ETS, the allowance price is 40–45 Yuan/t and increases yearly. When dynamic allocation methods are used and the allocation ratio satisfies the ‘neutral output’ conditions, the allowance price will increase to 70–75 Yuan/t. In addition, dynamic allocation methods will reduce the rate of decline of economy-wide carbon emissions by approximately 0.3%, thus reducing the efficiency of China’s national ETS.

Third, allocation methods have different effects on different industries in the ‘single allocation method’ scenario. (1) In terms of output, the power industry is most affected by the ETS, and dynamic allocation methods have the most significant output subsidy effect on the cement and iron and steel industries. (2) Compared with command-and-control measures, in which all sectors should reduce emissions by 2% equally, the power and papermaking industries become potential allowance suppliers in the ETS, whereas the others are potential allowance buyers. Compared with auctioning and allocation approaches without ex-post adjustment, dynamic allocation methods will increase the emissions of the cement, iron and steel and non-ferrous metal industries and decrease the emissions of the other industries. (3) The carbon emissions per unit output in industries covered by the ETS will decrease to a greater degree and experience greater abatement pressure because of the increase in allowance prices from the dynamic allocation methods.
Fourth, the effect of the ETS on the macro-economy and emission indicators in the ‘synthetic allocation method’ scenario lies between the effects of allocation approaches without ex-post adjustment and those of dynamic allocation approaches. Overcapacity industries no longer enjoy the subsidy effect from dynamic allocation methods, so the effects of the ETS on different industries will change. Although the power sector remains the most affected under the ETS in terms of output, prices and emissions, the degree of this effect significantly decreases. Compared with the command-and-control scenario, the change in potential allowance suppliers further reflects the effect of allocation methods on the distribution of emission reductions among various industries.

Under China’s national ETS, it is recommended to limit the use and scope of ex-post adjustment, in order to maintain the scheme’s incentive to reduce emissions. Particularly for industries with excess capacity such as cement, iron and steel, the ETS must avoid providing them with excessive output subsidies. With the rate of economic and industrial development in China now becoming more stable, and the basic data becoming more reliable, it is possible for China to use allocation methods without ex-post adjustment, and thereby give full play to the advantage of ETS.

Notes
1. Source: China Carbon Transaction Website, http://www.tanjiaoyi.com/ (date of access: 20-03-2016).
2. According to Figure 4, the usage of dynamic allocation methods should be limited to a certain percentage, to avoid too much distorting subsidies. For the cement sector, the upper limit of using APB method is 21.5% in 2016. While for other sectors, this limit could be relaxed to some extent, so 20% is applied in the model.

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