China’s national emissions trading scheme: integrating cap, coverage and allocation

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ABSTRACT

China is expected to launch its national emissions trading scheme (ETS) in 2017. When designing an ETS, the cap, coverage and allocation are three key elements that must be considered. In general, three approaches are used to determine a scheme’s cap, coverage and allocation when considering whether a cap should be set and the method of setting a cap, namely, no-cap, top-down and bottom-up approaches. However, as a multi-tiered ETS established in an emerging economy, China’s national ETS faces special economic, technical and bargaining cost issues. To address these special issues, a unique approach, which is different from general approaches in theory and in major global ETSs, has been used in China’s national ETS to integrate its cap, coverage and allocation. Based on a comparative analysis of general approaches in theory and practice, this article provides a detailed introduction to the method for integrating the cap, coverage and allocation in China’s national ETS. It further reveals three challenges behind this unique approach and puts forward relevant policy suggestions.

Key policy insights

- As a multi-tiered ETS established in an emerging economy, China’s national ETS faces special economic, technical and bargaining cost issues.
- The general approaches (i.e. no-cap, top-down and bottom-up approaches) to determine a scheme’s cap, coverage and allocation cannot completely address the special issues in China’s national ETS.
- China’s national ETS uses a unique approach combining top-down and bottom-up methods to integrate its cap, coverage and allocation.
- Three challenges remain behind this approach: the harmonization of local differences and national unified rules, the independent selection of covered sectors by local governments and the rationality underlying the selected allocation method.

1. Introduction

As the largest CO\textsubscript{2} emitter in the world, China is expected to launch its national emissions trading scheme (ETS) in 2017. This will be the world’s largest ETS and is expected to potentially increase the proportion of global GHG emissions covered by carbon pricing initiatives from 13% to between 20% and 25% (World Bank, Ecofys, & Vivid Economics, 2016). The success of China’s national ETS relates to China’s Nationally Determined Contribution (NDC) under the 2015 Paris Agreement, as well as to confidence in, and the development of, global ETSs.

To date, inadequate ambition in the setting of caps has been the most obvious failing in the major global ETSs (Energy Innovation, 2017). Among the many design elements of ETSs, coverage and allocation are closely related to cap setting. In theory, and in practice, three approaches are used to determine cap, coverage...
and allocation: no-cap, top-down and bottom-up (Dian, Ann, Tana, & Monique, 2006; Perdan & Azapagic, 2011). Major global ETSs choose the most appropriate approach based on their different phases and main objectives.

As many studies have discussed, China faces a special social-economic context compared with the ETSs in developed economies. This includes emissions targets framed in terms of emissions intensity instead of absolute amounts of emissions (Jotzo, 2013; Zhou, Duan, & Liu, 2011), great uncertainty over the growth of the economy and emissions (Pang & Duan, 2016) and official data on emissions that are far from complete (Lo, 2016). However, many other special issues also need to be clarified during the design of China’s national ETS, in which economic, technical and bargaining cost issues are closely linked with the Chinese situation.

Many studies have also discussed the construction of China’s national ETS, usually from two perspectives. The first perspective analyses key design elements of a certain ETS pilot in China (Qi, Wang, & Zhang, 2014; Wu, Qian, & Li, 2014), or the comparison of several pilots (Pang & Duan, 2016; Zhang, 2015), and then presents relevant policy recommendations for China’s national ETS. In these studies, cap, coverage and allocation are always considered to be separate elements. However, because of the special issues confronting China’s national ETS, cap, coverage and allocation should be analysed as a whole. Another perspective identifies key issues for the design of China’s national ETS and provides a certain allocation method or related suggestions (Duan & Pang, 2014; Fan & Mo, 2015; Lo, 2016). These studies focus more on experience summaries or theoretical analyses instead of a comprehensive analysis of the actual design of China’s national ETS.

Thus, using a systemic summary of the special issues confronting China’s national ETS and a review of whether the three traditional approaches can address these issues, this article analyses the unique approach adopted by China’s national ETS to integrate its cap, coverage and allocation, and the potential challenges to this approach. An evaluation of this approach will provide important reference information both for China in improving its national ETS and for other emerging economies in establishing multi-tiered ETSs. Multi-tiered ETSs means that the ETS is managed by multiple tiers of governments, such as the central government and local governments in China’s national ETS, and the European Commission and governments of member states in the EU ETS.

The remainder of the article is organized as follows. Section 2 presents a theoretical and practical review. Section 3 identifies the special issues confronting China’s national ETS in determining its cap, coverage and allocation. Section 4 presents the approach used to integrate the cap, coverage and allocation. Section 5 discusses challenges observed with this approach. Section 6 concludes the article.

2. Theoretical and practical review

2.1. General approaches to determining the cap, coverage and allocation

Three approaches are generally used to determine whether to set a cap, and then to select the appropriate method for setting a cap and determining the coverage and allocation.

2.1.1. No cap approach
A cap is needed in a classic ETS to ensure the scarcity of allowances. However, certain ETSs, such as the New Zealand Emissions Trading Scheme (NZ ETS), do not set an explicit cap in the early stage. Thus, New Zealand firms can generate unlimited emissions as long as they purchase a sufficient amount of allowances (Perdan & Azapagic, 2011).

2.1.2. Top-down approach
In this approach, the cap is determined by the distribution of the emissions targets for the whole economy over ETS and non-ETS sectors, and allowances are then distributed to the ETS sectors, as in EU ETS phase 3, Japan’s Tokyo ETS and Saitama ETS (see Table 1). Thus, based on the defined coverage, the cap is determined first and then the allowances are allocated. The distribution of emissions targets is usually based on assumptions regarding economic development trends, emissions reduction potential and costs, as well as political considerations.
2.1.3. Bottom-up approach

This approach takes two forms. Firstly, the cap is based on assumptions regarding the growth of production levels and emissions limitations or reduction efforts based on detailed modelling or expert judgements. Then, the sector (or installation)-level allocations are summed up, to establish the total cap (Dian et al., 2006), as in the Swiss ETS. Secondly, the cap is determined by aggregating the allowances allocated to all market participants, which are determined according to certain allocation rules (Pang & Duan, 2016). This method inverts the top-down approach, and coverage and allocation are determined prior to the cap. This approach was used in the EU ETS phases 1 and 2.

2.2. Comparative analysis of approaches to determining the cap, coverage and allocation

2.2.1. No cap approach

An ETS without an explicit cap does not fit a classic cap-and-trade system, although it may meet specific requirements in the ETS transition period. The NZ ETS does not have a fixed cap, in order to provide a price incentive for planting trees, promote carbon sequestration and ensure that the cost of emissions reductions is similar to that in other countries (Harrison, 2015). However, this scheme is also likely to cause uncertainty in the allowance supply and demand. Therefore, a cap on the supply of New Zealand units (NZUs), which will include those allowances allocated and auctioned, will be established if an auction is introduced. An auctioning mechanism is planned to be developed by 2020 according to the in-principle decisions made by the New Zealand government (Ministry for the Environment, 2016).

2.2.2. Top-down approach

The advantages of the top-down approach are as follows. Firstly, the ETS target is very clear because the responsibility for emissions reduction is explicitly distributed between ETS and non-ETS sectors. Secondly, decisions are concentrated at the top levels of the scheme’s administration, which helps to ensure the realization of emissions reduction targets for the whole economy. Based on macroeconomic modelling data and a macroeconomic modelling framework, this approach fits the ETS in the mature phase, with stable economic and emissions growth and a sophisticated data system. However, this approach also faces great uncertainty, such as the over-estimation of economic and emission growth, which may lead to an allowance surplus, and the difficulty of both setting allocation rules for sectors and firms from the macro level, and considering individual diversity in different regions or member states.

In the EU ETS phase 3, for example, the performance of the ETS is characterized by a large allowance surplus as a joint result of the economic recession, sizeable influx of offset credits and overlapping energy policies (Taschini, Kollenberg, & Duffy, 2014). The Regional Greenhouse Gas Initiative (RGGI) in the United States also

| Table 1. Approaches to determining the cap, coverage and allocation of major global ETSs. |
|---------------------------------|---------------------------------|
| Category                        | ETS                              | Contents                                                                 |
| No cap                          | NZ ETS (Transition phase)        | No explicit cap; entities can emit without limitation as long as they buy enough allowances |
| Bottom-up                       | Swiss ETS (Voluntary phase)      | Each participant receives its own entity-specific reduction target         |
| EU ETS Phase 1 and 2            | EU-wide cap results from the aggregation of the national allocation plan of each member state |
| Top-down                        | EU ETS Phase 3 and 4             | EU-wide cap decreases each year by a linear reduction factor (1.74% in phase 3; 2.2% in phase 4) of the average total quantity of allowances issued annually from 2008 to 2012 |
| Swiss ETS (Mandatory phase)     | Cap is annually reduced by 1.74% based on its 2010 level |
| Japan Saitama ETS               | Saitama-wide cap: sum of the base year emissions of covered facilities × compliance factor × number of years of a compliance period |
| Japan Tokyo ETS                 | Tokyo-wide cap: sum of the base year emissions of covered facilities × compliance factor × number of years of a compliance period |
| Regional Greenhouse Gas Initiative (RGGI) | 2009–2014: cap setting is based on the emissions of covered sources and the projection of emission growth |
| California Cap-and-Trade Program (CAT) | 2015–2018: cap is set to decline by 2.5% per year |
|                                 | 2012: cap equals the total emissions of covered entities under the Business-as-Usual scenario Post 2012: cap declines based on a future emissions reduction target |

Data sources: International Carbon Action Partnership (ICAP).
experienced over-allocation because emissions from the power sector have declined by more than 40% across the RGGI region since 2005 owing to energy efficiency programmes and a shift of generation from coal and oil to renewable power and natural gas (Snyder, 2014). Thus, new mechanisms were used to deal with the problem of over-supply, such as a Market Stability Reserve in the EU ETS (Perino & Willner, 2017) and Cost Containment Reserve in RGGI (Hasegawa & Salant, 2014).

2.2.3. Bottom-up approach
In the bottom-up approach, the cap is determined at the local government/member state, firm or installation level, which decreases the uncertainty of cap setting at the macro level and reduces the costs of data collection and processing. This approach is suitable for quickly starting an ETS based on weak data. However, this approach presents the following issues. Firstly, the aggregated cap may not be consistent with the reduction target of the whole ETS and economy. Secondly, decentralized decision making may cause a ‘prisoner’s dilemma’, whereby local governments/member states or firms try to expand the cap for their own interests, which leads to overall inefficiency. Thirdly, a potential risk of competition distortion may occur.

For example, in phases 1 and 2, the EU ETS did not seek to rapidly achieve its emissions reduction target and instead focused on the introduction of the system and the construction of infrastructure facilities. However, this approach led to inconsistent reduction constraints, which further reflected on the allocation to installations: the same type of installations in different member states were treated differently, thereby leading to the distortion of competitiveness. Although the European Commission’s veto power over national allocation plans can play a role in error correction, it is too ‘clumsy’ and more likely to trigger conflicts between the European Commission and member states, while causing unpredictability and uncertainty in the market (Zhou & Tan, 2013).

All the China ETS pilots except Chongqing and Shenzhen adopt the top-down method to determine the cap and allocation, based on the carbon intensity targets allocated to the provinces or municipalities and economic growth targets during the 12th Five Year Plan and the 13th Five Year Plan period. Various degrees of allowance surplus have arisen in these pilots because of inaccurate economic projections. For example, the carbon price in Hubei declined by around 10% for three consecutive days in the 2016 compliance year because of over-allocation, especially in the cement sector.

The Chongqing pilot uses a purely bottom-up approach. The allowances are allocated through self-declaration by enterprises in which the individual amount of allowances is requested by the enterprise itself (Xiong, Shen, Qi, Price, & Ye, 2017). This approach is based on the fairly liberal view of the local government that enterprises know their own emissions best. The result has been a large allowance surplus, leading to poor market conditions and a low carbon price, to the extent that no transaction occurred for 9 months after June 2014. Although transactions reoccurred in March 2015, the carbon market still performed inactively.

Shenzhen sets an intensity cap rather than an absolute cap because its level of output uncertainty is extremely high owing to its rapid growth and accelerated structural adjustment. However, economic development is still the first priority and the fundamental driving force in improving social welfare (Jiang, Ye, & Ma, 2014). Shenzhen’s method for determining its cap and allowance allocation combines a top-down and bottom-up approach. A set of intensity benchmarks is formulated and combined with projected outputs to calculate the intensity-based cap top-down; then, a multi-round game among participating enterprises is designed to allocate allowances through a bottom-up approach.

3. Specific issues confronting China’s national ETS
As the world’s largest emerging economy, China is confronting special economic, technical and bargaining cost issues pertaining to the establishment of its national ETS.

3.1. Economic and technical issues
3.1.1. Specificity of the emissions reduction target
Unlike developed countries, China’s emissions reduction target is based on emissions intensity, instead of absolute emissions. In its NDC, China indicated that it would
achieve the peaking of CO2 emissions around 2030 and make its best efforts to ensure that peak is earlier and lower by 60% to 65% from the 2005 level in terms of CO2 emission per unit of GDP by 2030.

Thus, although the absolute peak is defined, an intensity target also exists. Because ETSs usually function on the basis of permits for absolute amounts of emissions, China has to convert its emissions intensity target to an absolute emissions target before starting its national ETS.

Because of the strong correlation between the economy and the energy, environment and climate systems, ETSs and other policy targets are not independent, and different policies have an interactive influence on each other. Overlapping policies are often ineffective and inefficient, and can have several adverse consequences (Fankhauser, Hepburn, & Park, 2010). In EU ETS, for example, the coexistence of the EU ETS and policies on renewable energy sources (RES) creates a classic case of interaction effects (Koch, Grosjean, Fuss, & Edenhofer, 2014). The effect of interaction between the EU ETS and RES policies reduces the European Emission Allowances (EUA) demand and price (De Jonghe, Delarue, Belmans, & D’haeseleer, 2009; Flues, Löschel, Lutz, & Schenker, 2014). For energy efficiency measures, such as the EU-wide ban on incandescent light bulbs, the amount of GHG emissions saved might be overestimated once the EU ETS is taken into account (Perino & Pioch, 2017).

For China, the interaction between energy conservation and emission reduction has two aspects. First, at the administrative level, energy conservation and emission reduction are managed by different departments involving conflicts of interest and administrative competence. Second, a number of other polices are aimed at emissions reductions, such as energy efficiency policies and renewable energy support policies. Gu, Teng, and Feng (2016) measured the effect of SO2 emission reduction and the synergy effect of CO2 emissions reduction and found that the synergy effects caused by structural and engineering emission reduction achieve different degrees of CO2 emission reduction. Fan and Mo (2015) studied the risk of policy conflicts, and their research shows that when the cap of an ETS is determined, the introduction of other policies could reduce the effective carbon price and even cause the price to collapse. Furthermore, Wu, Fan, and Xia (2017) estimated that the carbon price on China’s national ETS would decrease by 11–64% if the renewable energy subsidy rate increases from 20% to 100%.

Thus, for China, using a purely top-down approach is more difficult with regard to the distribution of emissions targets in ETS and non-ETS sectors, because the conversion from an emissions intensity target to an absolute emissions target is based on future economic growth forecasts, which contain substantial uncertainty. Meanwhile, if the ETS target and other policy targets cannot be well coordinated by the central government, then a purely bottom-up approach will lead to carbon market failure.

### 3.1.2. Uncertainty of the economic situation

Uncertainty surrounds emission trajectories because of rapid structural changes at the macro level. Future emissions projections provide an important basis for ETS cap setting and allowance allocation (Buchner, Carraro, & Ellerman, 2006). China is undergoing a transformational economic process known as the ‘new normal’, which is characterized by an undefined mid to high rate of economic growth, and comprehensive and fundamental changes in the economic structure. Compared with other developed countries, China therefore faces larger uncertainties regarding future emissions trajectories because of its rapid structural changes, which affect energy consumption and carbon emissions (Green & Stern, 2017; Grubb et al., 2015). It is worth noting that in recent years, China’s coal consumption and emissions have declined as the economy has maintained steady growth. China’s coal consumption experienced a decrease of 2.9% in 2014 with another 3.7% decrease in 2015 and 4.7% in 2016. China’s energy related CO2 emissions declined 0.6% in 2015 and 0.35% in 2016 (Qi, 2017), while GDP continued to grow by 7.3%, 6.9% and 6.7%, respectively (NBS, 2017). The above data indicate that China’s coal consumption and emissions are being gradually decoupled from economic growth, which marks an important node of energy substitution and transformation. Thus, emissions trajectories in China are becoming more uncertain.

Uncertainty in production operations occur because of the process of reducing excessive production capacity and inventory at the micro level. In the early stage of an ETS, high-energy-consuming and high-emission sectors with considerable emissions reduction potential, such as iron and steel, cement, glass, pulp and paper, are generally covered. In China, these sectors are undergoing a process of reducing excessive production capacity and
inventory, which will lead to a large-scale structural adjustment. On the one hand, in certain sectors, some small and medium-sized enterprises (SMEs) are being phased out, and production is increasingly concentrated in large-scale enterprises through merging and restructuring. For instance, crude steel production by the top ten enterprises is expected to account for no less than 60% of the total production in China (MIIT, 2015). On the other hand, large-scale enterprises also make positive structural adjustments on products and energy to adapt to the new economic situation.

Under these two types of uncertainty, cap setting and allowance allocation based on macroeconomic modelling using aggregate emission data and the continuation of trends under a purely top-down approach may diverge from reality. However, the aggregated cap using a bottom-up approach based on coverage and allocation methods will not lead to emissions reductions, because the uncertainty in production operations will invalidate benchmarks, carbon intensities and emissions reduction factors based on historic emissions and production data and trends.

### 3.1.3. Weakness of data

Data are the basis of an ETS because cap setting and allowance allocation require complete and reliable emission data. In contrast with ETSs in the EU and other developed economies where emission sources are installations or facilities, China’s national ETS starts at the firm level. The main consideration is that the smallest unit in China’s current energy statistical system is the firm, and CO₂ emissions are largely determined from energy data. Thus, data collection at the firm level is the most convenient method of starting an ETS for China.

In addition, the difference in the calibre of statistics is likely to lead to data corruption. In China, emissions are calculated based on activity data (energy and output) and emission factors because the emissions monitoring system is not widely available (Sun, Liu, Yang, Jiang & Hu, 2016). Under this method, the accuracy of emissions measurements relies heavily on the accuracy of energy data. However, in addition to the Bureau of Statistics, many other government departments, such as the Bureau of Energy, the Development and Reform Commission, and the Commission of Economy and Information Technology also collect energy data. Thus, the inconsistency of data because of the difference in the calibre of statistics increases the uncertainty of emissions data and complicates the process of data collection.

Current data in China are therefore unable to support cap setting and allowance allocation either through a purely top-down approach, which depends heavily on aggregate emissions data and trends, or through a purely bottom-up approach, under which the inaccurate energy data at the sector and firm level may lead to over-allocation.

### 3.1.4. Asymmetry of information

An important issue concerns information asymmetry between firms and governments. As mentioned above, China’s emissions sources are firms instead of installations or facilities. However, tracing changes in the activity level is more difficult at the firm level, and emissions boundaries will become blurred because of firm separation and mergers as well as the indivisibility of different emission sources, production processes and energy consumption from a variety of products. Thus, firms can easily tamper with emissions data. In practice, the manipulation of emissions data is not uncommon under certain allocation methods (Tao & Mah, 2009). Firms are also much better informed than governments regarding fuel quality, technological level, output and production capacity, all of which influences the emissions and allowance allocation.

Similarly, information asymmetry between local and central governments is also a concern. Local governments tend to allocate excessive allowances to protect local firms, which leads to a ‘race to the bottom’. Because of information asymmetry, the cap and allocation reported by local governments cannot be easily and accurately adjusted by the central government, which influences the impact of emissions reductions and local initiatives.

Based on these two types of information asymmetry, the purely top-down approach would lead to the mis-allocation of allowances due to false emissions data. By contrast, over-allocation may occur in the purely bottom-up approach because of the ‘race to the bottom’ effect.
3.2. Bargaining cost

Unlike most ETSs, China’s national ETS encompasses a multi-tiered market that involves bargaining among central government, local governments and firms influencing ETS efficiency. Local governments generally focus more on local economic development and thus tend to have a looser cap and allocation method. By contrast, the central government is more concerned with the entire economy and achieving environmental targets (Chen, 2013). Firm ownership in China is diversified, especially in the case of key state-owned firms. Key state-owned firms have a significant impact on local economies because of their higher contribution to local GDP and tax revenue, employment and higher emissions (Qi & Wang, 2013). Therefore, an implicit contradiction exists between key state-owned enterprises’ abatement performance and local economic development. This contradiction might lead to dilemmas for local governments.

For the purely top-down approach, the coordination costs for bargaining are relatively high because the emissions reduction target of the ETS and the allowances allocation of firms must be coordinated. For the purely bottom-up approach, local governments and firms are likely to lobby for more allowances, more emissions and less stringent parameters (e.g. benchmark, reduction factor) in order to optimize their own economic benefits. Thus, the ETS cannot realize its reduction target cost-effectively.

To summarize, the above economic, technical and bargaining cost issues cannot be settled through either a purely top-down or bottom-up approach. Therefore, a unique integrated approach has been adopted for China’s national ETS that is top-down, then bottom-up and finally top-down.

4. Integrating cap, coverage and allocation during the policy design of China’s national ETS

In general, the integration approach includes the following three steps.

- The first step is a top-down approach. The general principles of the coverage and allocation method are determined according to the ETS emissions reduction target, which considers the specificity of the emissions reduction target and the weakness of data at the micro level.
- The second step is a bottom-up approach. The foundation for local and national ETS caps is formed by aggregating the allowances allocated to the covered entities. Using this approach, a fair degree of independence on the adjustment of coverage and allocation methods is provided to local governments to stimulate their enthusiasm. In this step, the uncertainty of the economic situation, the weakness of aggregate emissions data at the macro level, the information asymmetry between firms and central governments and the bargaining costs between central and local governments have been considered.
- The third step is another top-down approach. The aggregated cap and allocation plan are reviewed and revised by the central government to ensure the realization of the overall emissions reduction target. Thus, the uncertainty of the economic situation at the micro level and the information asymmetry between local and central governments can be reduced to some extent.

4.1. Top-down: determining the coverage and allocation method

First, coverage and allocation methods are determined using a top-down approach at the central government level.

4.1.1. Emissions reduction targets distributed over ETS and non-ETS systems: determine coverage

The emissions reduction performance of an ETS is closely related to its coverage. Covering different and diverse sectors and emissions sources can provide greater emissions reduction potential and lower abatement costs, which provides greater economic benefits (Li, Li, & Huang, 2011). However, the scale of emissions, carbon leakage, administrative costs, industrial development and regional balance must be fully considered (Wang, Fu, & Zhao, 2012).
In the initial stage, China’s national ETS plans to cover eight sectors: power, petrochemical, chemical, non-metallic minerals, non-ferrous metal, ferrous metal, paper making and aviation (NDRC, 2016). Identifying the coverage of China’s national ETS involves several considerations. The first are international commitments. In the ‘U.S.-China Joint Presidential Statement on Climate Change 2015’, China clearly indicated that it plans to cover key industry sectors in its national ETS. The second consideration is data availability. Most of the sectors covered by China’s national ETS have high energy consumption and high emissions, and these sectors usually have good data. The third consideration is contribution of the ETS to emissions reduction. Based on constant regulatory costs, as many sectors and firms as possible should be covered in order to lower the total abatement costs and ensure the important role of ETSs in emissions reduction. The total emissions of the eight sectors mentioned above are expected to account for 45–50% of China’s total emissions (Zhang, 2016).

4.1.2. Emissions reduction targets of the ETS distributed over different sectors: allocation method selection

The selection of the allocation method focuses on the distribution of emissions reduction targets for the ETSs over different sectors. Based on the quality of data, the different stringency of allocation methods and related parameters, such as benchmarks and adjusted factors, reflects the different emissions reduction obligations among sectors. According to the data used to calculate the allowances, the methods for free allocation can be divided into three types: emissions-based, output-based and input-based (Harrison & Radov, 2002). In practice, the most common methods are emissions-based grandfathering and output-based benchmarking.

Allocation in China’s national ETS follows the benchmarking method. Under this method, the allocation of allowances is dependent on products or industrial benchmarks and output. Research shows that for economic efficiency, the emissions-based allocation rule is costlier than the output-based rule in terms of maintaining output and employment in energy-intensive industries (Böhringer & Lange, 2005). Output-based benchmarking can avoid the problem of purposely increasing emissions to obtain extra allowances (Howe, 1994). The benchmarking method can also result in more equitable allowance allocations for local economic development and mitigate the shocks in provincial output volatility by focusing on the equality of China’s national carbon allowance allocations for local economic development while also considering uncertainties in provincial economic output and business-as-usual carbon emissions (Ye, Jiang, Miao, & Xie, 2017). Thus, the benchmarking method is adopted preferentially in China’s national ETS (see formula 1).

\[
\text{Allocated allowances} = \text{industrial benchmark} \times \text{output}. \tag{1}
\]

The historical carbon intensity method is used when benchmarking is not available because of a lack of data. The historical carbon intensity method can be considered a combination of the emission-based and output-based methods. In this method, the allocated allowances are dependent on a firm’s historical average carbon intensity and its actual production. This method is used in sectors that are incomparable in emission intensity within the industry category because of the complexity and diversity of production, as in the case of the copper smelting sector, which has different production technologies, and the pulp and paper making sector, which generates multiple products. This method is designed to encourage firms to at least keep or reduce their carbon intensity to avoid additional emission costs (Xiong et al., 2017). Similar to the benchmarking method, this method also encourages covered entities to reduce emissions through improvements in energy efficiency instead of reductions in production (Zhou et al., 2011), which prevents the firms from gaining windfall profits because of unexpected economic volatility. The historical carbon intensity method in China’s national ETS is presented in formula 2. The decline coefficient is adopted to reflect the firm’s carbon intensity decline rate.

\[
\text{Allocated allowances} = \text{firm’s historical average carbon intensity} \times \text{output} \times \text{decline coefficient}. \tag{2}
\]

It is worth noting that in China’s ETS pilots and other ETSs in developed countries, a grandfathering method is generally used when the benchmark method is not available instead of using the historical carbon intensity method. However, because of the considerable uncertainty regarding China’s emissions trajectories, emissions-based grandfathering would lead to ‘windfall profits’, and the covered entities could reach compliance...
without any effort. The historical carbon intensity method considers carbon intensity and compensates for the shortages of over-allocation in the grandfathering method under the condition that firms’ emissions decline sharply because of a decline of production, although firms’ emissions intensity actually rises. This condition is quite common in China, taking the background of defusing overcapacity in steel, coal, construction materials and petrifaction industry.

Without applying a decline coefficient, the total emissions of a firm in year \( t \) is assumed to be \( E_t \), the production in year \( t \) is \( Q_t \), and the emission intensity in year \( t \) is \( I_t \), where \( I_t = E_t / Q_t \), \( t = 1, 2, 3 \) and 4. For detailed data, see Table 2.

(1) Grandfathering method

The allowances allocated to firm \( A \) in the compliance year (year 4) are given by formula 2 and equal 34,000 tCO\(_2\)e. As a result, in year 4, the firm would have a surplus allowance of 4000 tCO\(_2\)e.

\[
A = \sum_{t=1}^{3} \frac{E_t}{3}.
\]

(2) Historical carbon intensity method

The allowances allocated to firm \( A \) in year 4 are given by formula 3 and equal 29,274 tCO\(_2\)e. As a result, in year 4, the firm would have to buy allowances of 726 tCO\(_2\)e.

\[
A = \sum_{t=1}^{3} I_t \times Q_4.
\]

Based on these results, the firm gains ‘windfall profits’ under the grandfathering method even if it does not implement any efforts to reduce its carbon intensity. However, under the historical carbon intensity method, the firm has to buy additional allowances because of its increasing intensity in the compliance year, which generates additional incentives for the firm to engage in technology innovation and energy efficiency improvements. Thus, the historical intensity method is preferred in China’s national ETS.

It should be noted that the opposite result is also likely to occur, as the historical intensity method leads to over-allocation, which occurs when the emissions increase while emissions intensity declines. However, the former scenario is more common in China because of its economic situation.

Thus, under this top-down process, the interaction of different policy targets is considered by determining the coverage based on the distribution of emissions reduction targets. The weakness of the data is addressed by covering only sectors of high energy consumption and high emissions in the initial phase and by using different allocation methods for sectors with different data quality.

### 4.2. Bottom-up: forming the foundation of local and national ETS caps

Based on the coverage and allocation methods determined through the top-down approach, a bottom-up approach is then used to form the foundation of local and national ETS caps. First, at the firm level, covered firms report their own production and energy consumption data, and the results are delivered to a third-party for verification. Second, at the local government level, the local ETS caps are calculated by adding together all the allowances allocated to the covered entities. In this process, local governments enjoy a fair degree of
independence regarding the adjustment of coverage and allocation methods. Thus, local governments can extend their scope of coverage and adopt more stringent methods, such as setting more rigorous benchmarks or carbon intensities. Finally, the national ETS cap is calculated by adding together all the local aggregates.

This bottom-up approach is able to avoid the information asymmetry caused by the micro data gathering process at the macro level. The cap of the individual sector is determined by its own allocation methods, benchmarks, carbon intensities, adjustment factors and other related parameters. Therefore, if the allocation method or related parameters in one sector were designed improperly, only that specific sector would be affected. Thus, the systematic risk to the whole ETS can be avoided to a certain extent.

Second, the bottom-up approach is also a process of discovering problems and the dynamic optimum. Problems can be revealed when local governments report their allocation results to the central government based on the unified rule. For example, a certain allocation method may be inapplicable because of poor data quality, and related parameters may be impractical. Thus, the central government can then settle these problems through a top-down approach.

Third, implementing a fair degree of independence regarding the adjustment of coverage and allocation methods for local governments can avoid the ‘waterbed effect’ to some extent. The ‘waterbed effect’ means that applying pressure in one place causes a rise over the rest of the surface, because the total volume is constant (Netherlands Environmental Assessment Agency, 2008). In the EU ETS, for example, Article 193 of the ‘Treaty on the Functioning of the European Union (TFEU)’ indicates that member states can introduce more stringent environment protective measures, and emissions that are reduced by an additional policy instrument by member states may lead to additional emissions elsewhere in the European economy because of the existing cap (Begemann, Lam, & Neelis, 2016). For China’s national ETS, the ‘waterbed effect’ leads to issues in encouraging local governments to introduce stricter measures to reduce emissions under the precondition that the uniformity of emissions reduction targets is ensured (Chen, 2013). In China’s national ETS, the leftover allowances from free allocation can be auctioned by local governments, and the revenue can be used to support their own capacity in emissions reductions (NDRC, 2014), thereby giving local governments incentives to adopt more stringent measures. Additionally, policy continuity can be achieved for ETS pilots, which means that the covered entities in ETS pilots that are not included in the coverage of the national ETS can be still included in the ETS according to the extended scope determined by local governments.

Thus, through the bottom-up process, the problem of an allowance surplus results from the uncertainty of emission trajectories at the macro level. Additionally, the information asymmetry between firms and governments can be mitigated to some extent by using the micro data provided by firms, but the problem of the manipulation of emissions data still exits. The bargaining cost between the central and local governments has also been taken into consideration by giving some degree of freedom and flexibility to local governments.

4.3. Top-down: forming the final local and national ETS cap

The top-down adjustment in China’s national ETS involves the following steps. According to the targets for controlling greenhouse gas emissions and considering factors such as the economic growth, industrial structure, energy structure and regional ecological balance, the central government revises the local reported cap and allocation plans to determine the final local ETS caps (NDRC, 2014). Then, taking into account factors such as coverage, the development of major national industries and economic growth forecasts, the central government revises the aggregated national cap to form the final national ETS cap.

Several considerations are behind this process. First, the aggregated cap determined through the bottom-up approach may not be consistent with the reductions target determined through the top-down approach. In addition, the allocation plans of local governments must be reviewed and revised to ensure that they are consistent with the national allocation rules. Thus, under this top-down approach, the adjustment, the risk of over-allocation because of the uncertainty of production operations at the micro level may be partly reduced and the ‘race to the bottom’ effect caused by the information asymmetry between local and central governments is eliminated to a certain degree, although a completely accurate adjustment is very difficult.

In summary, Figure 1 shows the integration process of the cap, coverage and allocation in China’s national ETS.
5. Challenges to the integration of cap, coverage and allocation

5.1. Harmonization of local differences and national unified rules

Setting the general allocation rules top-down at the central government level is favourable to ensuring the unification of a national ETS. However, because of differences in basic capacity and awareness, the cap setting, coverage and allocation of local governments is likely to diverge from national unified rules in the bottom-up process. In EU ETS phase 1, unequal treatment of otherwise equal installations has led to competition distortions because EU Member States differed in their implementation of the IPPC Directive and thus Annex I of the EU ETS Directive (Betz, Eichhammer, & Schleich, 2004).

Figure 1. Process of integrating the cap, coverage and allocation in China’s national ETS.
Thus, how to harmonize different interpretations of national unified rules is an issue that should be considered in the construction of China’s national ETS. On the one hand, during the process of policy design and implementation, the central government should solicit opinions, collect information from local governments, and conduct regular training seminars about key design elements of the ETS, such as allocation and measurement, reporting and verification (MRV). On the other hand, local governments should be actively involved in the policy design and should submit reasonable proposals on the basis of individual uniqueness.

5.2. Independent choice of covered sectors by local governments

In the bottom-up aggregation process, local governments can extend the scope of coverage. This is helpful for the realization of emissions reduction targets and market liquidity. However, this ability of local governments also leads to some problems. Suppose that region A chooses to extend its ETS coverage by covering a new sector X, which is not covered in region B but is covered in region C. First, different levels of competitiveness arise among firms in the same sector X located in different region A and B, which causes carbon leakage. Second, determining an appropriate allocation method in sectors that are covered in different regions but not in the national ETS must be resolved. The allocation method of sectors covered by the national ETS is determined uniformly by central governments. Sector X covered by local governments but not covered in the national ETS, also needs a reasonable allocation method. However, because of the differences in the availability and quality of data, the applicable methods in the same sector X may differ in region A and region C. Thus, issues related to selecting a proper allocation method and avoiding the inhomogeneity of allowances must be resolved. Third, ETS pilots face the issue of whether to continue to include the sectors that are already in the pilots but not covered by the national ETS. Excluding these sectors can help the ETS pilots maintain consistency with the national ETS. However, other problems remain. These include a negative impact on the realization of emissions reduction targets because of the narrower scope compared with that of the pilot period, along with a negative impact on market liquidity and price stability, and issues related to managing the left-over allowances in these sectors.

In view of the above problems, first, the coverage of China’s national ETS should be expanded gradually, and related guidelines (such as allocation, MRV, transaction and compliance) for the sectors that are not covered by national ETS should be issued. Second, central government should carefully consider extending the scope of coverage or adopt more stringent methods based on costs and benefit, such as policy design and administration costs. Third, for the additional sectors that must be included, market-oriented principles should be followed.

5.3. Rationality of the allocation method

Although benchmarking and historic intensity methods have been adopted preferentially in China’s national ETS, these two methods are heavily dependent on the accuracy and rationality of benchmarks, emission intensities, adjusted factors and production data.

The benchmarks and adjusted factors are determined by the central government via a top-down approach, and the uncertainty of macro data and the asymmetry of information may lead to the wrong settings for the above parameters. Additionally, the setting of benchmarks should follow the principle of ‘one product, one benchmark’ to ensure that the benchmarks will not vary because of differences in the techniques, fuel mixes, sizes, ages, climatic environment and raw material quality in installations (Neelis et al., 2009). The benchmarks in China’s national ETS are based on sectors instead of products; thus, product diversity may be ignored.

The historical intensities and production data are reported in a bottom-up manner by firms according to the MRV standards. Because firms are most familiar with their own data, even with the MRV process, firms can still falsify statistics. If one of the above parameters or data points are exaggerated, then a surplus in the allowances allocated to the sector will occur; if all of the parameters and data are overstated, then the surplus of allowances will be magnified.

Thus, first, MRV should be more accurate at the product and installation level in order to follow the principle of ‘one product, one benchmark’. Second, under the benchmark and historical intensity methods, production in current year can be used to calculate emissions instead of historical data in order to avoid over-allocation.
because of the fluctuation of production. Third, for individual sectors, the benchmark can be determined by production and emissions in the current year, given the inaccuracy of historical intensities and production data and the uncertainty of the economic situation.

6. Conclusions

There are three approaches to determining the cap, coverage and allocation for an ETS: the no-cap approach, the top-down approach and the bottom-up approach. These three approaches suit different stages and types of ETSs. ETSs worldwide should choose an appropriate approach according to their own targets and social-economic backgrounds.

The no-cap approach meets the particular needs of the early or transition stage of ETSs and can guide firms in participating in the market and make the best use of international carbon credits. However, this approach lacks the ability to promote emissions reductions. The bottom-up approach is effective at rapidly initiating a carbon market under a background of weak data but may not be consistent with the whole ETS and economy, and in a multi-tiered market, the Prisoner’s Dilemma will arise because of decentralized decision making. As the market matures, the top-down approach can be introduced, which helps to ensure the realization of emissions reductions targets for the whole economy. However, the risk of allowance surplus still occurs because of the uncertainty of the macroeconomic situation.

The multi-tiered ETSs established in emerging economies, such as China, face special economic, technical and bargaining cost issues that differ from ETSs in developed economies. Thus, different approaches must be integrated by fully exploiting their advantages and avoiding their shortcomings. The general principles of the coverage and allocation method can be determined through the top-down approach to avoid competition distortions resulting from decentralized decision making among member states or local-level governments. The bottom-up approach can provide a foundation for local and national ETS caps by compensating for weaknesses in the data. Using this approach, a fair degree of independence regarding the adjustment of coverage and allocation methods can be provided to the member states or local governments to stimulate their enthusiasm. Finally, the aggregated cap and allocation plan should be reviewed and revised to ensure the realization of the overall emissions reduction target.

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