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Advancing the experiment to reality: Perspectives on Shanghai pilot carbon emissions trading scheme

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HIGHLIGHTS

- This paper gives a thorough overview on the progress and key elements design of Shanghai ETS.
- This paper conducts an evaluation on the potential uncertainties with Shanghai ETS development.
- This paper highlight the importance of symmetric information disclosure and participation of non-regulated entities.

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ABSTRACT

Shanghai, as the most advanced mega city in China, has launched a pilot carbon emission trading scheme (SH-ETS) that is designed to achieve a compromise between the domestic context in Shanghai, and a need for national policy appeal. This paper gives an overview of the latest progress of the SH-ETS and sheds some light on the features of key design components, such as the threshold for inclusion, sector coverage, cap setting, allowance allocation and the Monitoring, Reporting and Verification (MRV) system. Based on a concern that manipulative principles and economic dynamics may lead to uncertainties and ultimately influence the emission reduction effect of the scheme, this paper conducts an evaluation of potential uncertainties, such as those caused by changes in patterns of economic growth, strategic trading activities related to the bankable allowances, carbon leakage risks and insufficient MRV capabilities. To advance the experiment to reality, this paper suggests some changes are made to the pilot, which include adjusting the allowance allocation principles to facilitate change in the domestic energy structure, improving the disclosure of emission data to guarantee information symmetry, gauging the carbon leakage risks to strengthen compliance, and introducing risk management for non-regulated players and derivatives products.

1. Introduction

As one of the pilot cities and provinces designated by the Chinese central government for a carbon emissions trading scheme (ETS), Shanghai has laid out a regional scheme to facilitate its accomplishment of a 19% carbon intensity reduction target over the period of the 12th Five Year Plan (FYP) (SMPG, 2013). After more than two years of preparation, the Shanghai carbon emissions trading scheme (SH-ETS) was formally launched on 26 November, 2013. The Shanghai experiment is a trial of an ETS in a mega city with high population density, concentrated production and consumption activities, and a relatively mature market environment. In principle, to build a well-functioning cap and trade system, several conditions should be met to ensure the efficient pricing of carbon, achieve emission reduction and avoid leakage. Such conditions include an elastic factor and commodity market, differentiated abatement costs, a sufficient amount of participants, effective governance, an appropriate market and institutional environment and rigorous Monitoring, Reporting and Verification (MRV) systems (Benkovic and Kruger, 2001). The Chinese ETS has drawn great attention within the academic community regarding the performance of these necessary conditions. Han et al. (2012) give an overview of the development of the Chinese ETS and focus specifically on several key issues, such as the choices between intensity targets and absolute targets, the lack of a mature market environment and prospects in the 13th FYP. Lo (2013) argues that the socialist market, but not the liberal political economic system, will cause uncertain viability. Qi and Wang (2013) discusses the allowance allocation, pricing mechanisms and state owned enterprises (SOEs) of the Chinese ETS and provides some solutions to

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the problem of the monopoly of SOEs. Most of the existing literature focusses on national level analysis and little goes into detail with respect to the pilot cities and provinces to look at how their system design can compromise the national policy appeal and local social and economic context.

This paper offers an overview of the progress of the SH-ETS and sheds light on some features of the key design components, such as sector coverage, cap setting and allowance allocation. Compared with the other six pilot cities and provinces, Shanghai has specific advantages but also some limitations in building a well-functioning carbon market. It has a relatively mature financial market, an efficient administrative system, advanced manufacturing technologies for clean energy equipment and a large number of applications for renewable energy: electric vehicles, smart grid, etc. On the other hand, it has a limited number of participants, relatively high abatement costs and rapidly changing economic growth patterns, which bring about a series of challenges for the design of the ETS. In fact, all of China's pilot cities and provinces, including Shanghai, are seeking a way to design the trading system according to their own social, economic and institutional context. Detailed analysis is definitely needed to make a more comprehensive evaluation of China's pilot ETS development from a regional perspective. By taking the endogenous factor design and exogenous socioeconomic context into consideration, this paper makes an evaluation of the potential uncertainties for the development of the SH-ETS and identifies their likely impact on market performance.

2. Progress of the SH-ETS

After more than two years preparation, Shanghai commissioned its pilot ETS on 26 November, 2013. The Shanghai Municipal Government released the *Guidelines of Implementing Pilot Emissions Trading Scheme* in July 2012 (SMPG, 2012), which details the sector coverage, pilot period, fundamental allowance allocation mechanisms, MRV principles, trading platform and key milestones of the development of the SH-ETS. At the end of November 2012, a listing of 197 participants was publicly announced (SMDRC, 2012k).[1] In order to facilitate the allowance allocation and MRV processes, the Shanghai Municipal Development and Reform Commission (SMDRC) released the *Guideline on Measuring, Reporting and Verification of Shanghai ETS* at the end of 2012 (SMDRC, 2012a). In line with these general guidelines, detailed methodologies of carbon accounting for nine key sectors – steel, power and heat generation, chemistry, non-ferrous metals, textile and paper making, manufacture of non-metallic mineral products, aviation and transportation, commercial and public buildings – were also announced (SMDRC, 2012b–j). Just before the official commissioning of the pilot ETS, SMDRC released the *Allocation and Administration Guidelines on Carbon Emission Allowances over the period of 2013 to 2015* (SMDRC, 2013). This document details the principles of allowance allocation, trading and banking, and off-setting. Procedures of allowance issuing, registration, monitoring and verification are also included.

In addition to these policy making and capacity building activities, the SH-ETS is also producing legal umbrellas to make up for the lack of national legislation on carbon emission control and ETS establishment. Like most of the pilot cities and provinces, except Shenzhen city, Shanghai has no legal right to law enactment. As an alternative, the municipal government issued a regional normative document on the ETS in November 2013,[2] the *Administrative Principles of Shanghai Carbon Emissions* (SMPG, 2013). This normative document comprises six sections, including allowance administration, allowance verification and clearance, trading principles, protective and simulative mechanisms, legal responsibilities and monitoring mechanisms. It legalizes a series of penalty standards regarding non-compliance, including a fine amounting to 100,000 RMB, suspension of new production capacities and the cancelation of national subsidies on energy conservation projects.

3. Overview of the key features of the pilot SH-ETS

To develop a cap and trade system, the principles relating to several key elements need to be clarified, these include: sector coverage, cap setting, permit allocation, the MRV system, the compliance mechanism, and the banking, borrowing and off-setting mechanisms. Hereafter, this paper will give an overview of the SH-ETS in regard to the key design elements mentioned above. Table 1 summarizes the key features of the pilot scheme.

3.1. Threshold for inclusion and sector coverage

In general, a two-step filtering mechanism is utilized by the SH-ETS. First, sectoral carbon intensity is used to filter the high intensity sectors, and then a carbon emission scale as the criterion that determines which entity should be regulated. The SH-ETS sets the threshold of CO_2 emission at 20,000 t for industrial sectors and 10,000 t for non-industrial and service sectors.

In terms of the carbon emissions from final energy use, including electricity and heat, in 2010 the industrial sectors covered by the scheme accounted for 51% of total emissions and the transportation and service sectors that are covered accounted for 26.1%.[3] To calculate the exact emission contribution from regulated entities, we need further information about the ratio of regulated to non-regulated entities. Since the Shanghai government has not released the relevant information, this paper makes a rough estimation based on expert interviews.[4] The regulated entities account for almost 61.7% of Shanghai's total emissions (Fig. 1). As for the GDP share, it seems that the regulated entities only account for 37.8% of total GDP (Fig. 1). Obviously, the regulated industrial sectors are characterized by high carbon emission levels but low GDP contribution, while the regulated transportation and service entities make higher contributions to GDP.

3.2. Cap setting and allowance allocation in the SH-ETS

The SH-ETS announced the general principles for cap setting and allowance allocation (SMDRC, 2013). For most of the involved industrial entities and commercial buildings, overall allowances are determined in accordance with their record over the period

[1] Among these 197 participants, eight are ferrous companies, 16 are non-ferrous companies, 56 are petro-chemical, chemistry and fiber companies, 14 are power generation companies, 32 are construction materials companies, 6 are paper making companies, 8 are clothing and textile companies, 15 are aviation, shipping and logistic companies, 42 are public and commercial buildings, for detail, please see: ⟨http://www.shdrc.gov.cn/main?main_colid=326&top_id=312&now_id=380&now_id_top=&main_artid=22036⟩.

[2] According to China's legal and political system, the compulsory force of various legislation is ordered as follows: national law, national and regional statue, government rules and regulations and government normative documents. Normative documents have their legal position in regional governance.

[3] Carbon dioxide emissions are estimated by the authors using the emission coefficient provided by IPCC; energy data is from the Shanghai Energy Statistical Year Book (2011).

[4] The interview was conducted with experts from the Shanghai Municipal Commission of Development and Reform, Shanghai Energy and Future Exchange. It is indicated that the ratio is about 4:1.

Table 1
Overview of the key features of the SH-ETS. *Source*: Summarized by the authors based on SMPG (2012), SMDRC (2012a–j) and SMPG (2013).

Key features	Fundamental principles	Adjustment conditions
Threshold for inclusion	Above or equal to 20,000 t CO_2 emissions in either 2010 or 2011 for industrial sectors Above or equal to 10,000 t CO_2 emissions in either 2010 or 2011 for non-industrial sectors	
Coverage of regulated entities	Experimental units Experimental units refer to the regulated entities with mandatory targets over the compliance period. They cover 16 industrial sectors, including: power generation, iron/steel, non-ferrous metals, ferrous metals, chemical products, petrochemicals, building material, rubber, chemical fiber, textiles, paper making; and eight non-industrial and services sectors, including: large public buildings, hotels, retail, finance, railway, commercial, aviation and harbor services 197 independent companies are involved in total, which account for just over 50% of all emissions	Reporting units Reporting units refer to the non-regulated entities without mandatory targets but with emission levels above or equal to 10,000 t CO_2 in any year between 2012 to 2015. Reporting units stand by the trading activities and are obliged to report on annual emission Reporting units should be ready to join the trading system as required by the Shanghai government. Participation of intermediate agencies is prohibited in the pilot stage but could be possible in the future
Emission accounting	Direct emissions from energy use and industrial process Indirect emissions from inflow of heat and electricity	
Cap setting	For industrial sectors and commercial buildings, overall quotas are decided based on historic emissions from 2009 to 2011, considering the sectoral development stage, expected growth and previous abatement efforts For power generation, aviation, harbor and airport, the allowance is allocated according to the sector benchmark and activity level	If the changing rate from 2009 to 2011 is larger than 50%, the emission level in 2011 will be taken as a benchmark
Allowance allocation	Entire allowances for the whole pilot stage (2013 to 2015) are allocated to enterprises as one portion Mostly grandfathering (free allocation)	Aiming for timely introduction of auctioning Borrowing quotas in advance is prohibited but banking is allowed
Voluntary trading units coverage	CCER that can be used for final clearance of mandatory quota should be no more than 5%	
MRV	Annual monitoring plan should be put on record Annual report of emission should be submitted Annual verification will be conducted by a third party	
Penalty	Overdue compliance to MRV requirement will result in fined of 10,000 to 100,000 RMB	
Compliance period	2013–2015	

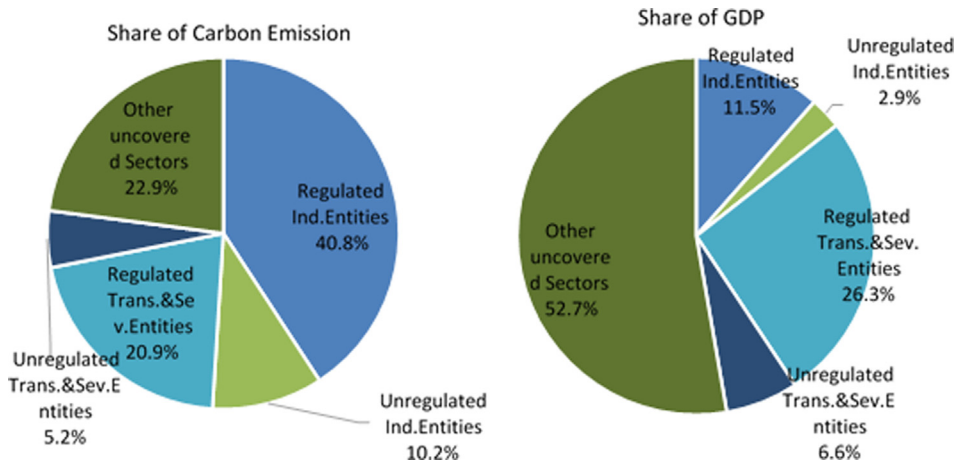

Fig. 1. Share of carbon emissions and GDP of regulated and non-regulated entities in 2010. *Source*: Estimated by authors based on IPCC reference approach; energy data is from SSB (2011).

2009 to 2011. If the growth rate over these three years is higher than 50%, the 2011 emission level will be taken as a benchmark. Power generation, aviation, harbor and airport sectors will take their allowance according to specific sectoral emission benchmarks per unit of production activity, which is further multiplied by their average activity level over the period 2009 to 2011. The electricity generation sector, for example, receives its allowances by multiplying the operating capacities and sectoral benchmark per unit of installed capacity.

The allowances are grandfathered in a lump sum fashion for the period 2013 to 2015; however, borrowing allowances from subsequent years for compliance purposes is prohibited. For sectors such as power generation, aviation, harbor and airport, the benchmarking mechanism allows for ex-post adjustment of the allowance, which can compensate for insufficient allowances, or withdrawal of a surplus amount to balance the difference between the real activity level and the average over the period 2009 to 2011. The emission benchmark of the power generation sector is specified by year and by technology for the whole compliance period of 2013 to 2015. Aviation and airport sectors get their emission benchmark based on their record for the period 2009 to 2011. The harbor sector uses the emission intensity of

2010 as a benchmark. Free allocation based on the benchmark provides weak incentives to the regulated sectors to reduce their production scale because they cannot realize their commitment through production substitution.

The Municipal Development and Reform Commission are entitled to adjust the allowances in light of each entity's development stage, output growth, and previous emission reduction and energy conservation efforts.[5] The government will keep some allowances to adjust the market price and hedge for unexpected risks. The SH-ETS also allows for the possibility of utilizing an auction scheme for emission permit allocation in the future.

3.3. Allowance trading, banking, borrowing and off-setting mechanism

While the allowances of different years are allocated to the entities at one time, these allowances are specified by year, and allowances from the subsequent year cannot be used for the preceding years' compliance. This means that banking is allowed within the pilot period but borrowing in advance is prohibited. The annual MRV process will verify whether the available allowance from the corresponding year is sufficient to settle the actual emissions.

A surplus of allowance can be banked for the following year but the insufficient part must be balanced by buying an allowance in the market. Sequential years' allowances can be traded in the market; however, the involved entities should keep at least 50% of the initial allowance in its account. In addition to mandatory allowances, regulated entities are also permitted to use a certain number of verified project-based carbon emission permits – China carbon emission reduction (CCER)[6] – for their compliance. As this principle allows for a potential linkage among emitters in different provinces, in order to avoid arbitrage the share of total CCERs in the final clearance should not exceed 5% or be generated within the pre-verified accounting boundaries[7].

As for the type of trading participants, while the official document states that other qualified participants are allowed to take part in the trading activities in addition to the regulated entities, no further, detailed information is available regarding how participants might qualify for this.

3.4. Emission accounting and the MRV system

The Shanghai government published the "1+9" guidelines on MRV, which outline the following key principles: (1) emission MRV is based on independent legal entities and should strictly obey the technical rules of MRV in the key regulated sectors; (2) regulated entities and reporting units are obliged to submit emission reports annually; (3) emission reports should be verified by third party agencies; (4) the government will authorize the annual emission amount based on the MRV report and use it as reference for allowance clearance and allocation; and (5) the emission reporting system is coupled with a permits certification and tracing system based on an electronic trading platform.

Under the SH-ETS, direct emissions from energy use and industrial processes and indirect emissions from electricity and heat consumption are registered under each entity's account. All indirect emissions are estimated according to the activity level and average emission coefficient of the Shanghai power grid. The input of primary energy in domestic power and heat generation processes and the inflow of secondary energy from other regions and countries to Shanghai territory are all considered when generating the average emission coefficient. Allowances for direct and indirect emissions are not differentiated under the SH-ETS.

Since domestic power and heat generators above the set scale are included, there must be double counting of the emissions from their supply of electricity and heat. Furthermore, since emissions from electricity and heat transferred from other regions and provinces are also counted, there is also double counting at the national level between the outflow and inflow regions. Double counting violates the principle that one ton of CO_2 corresponds to one unit of allowance and hence may distort the price discovery processes. The reason that the SH-ETS includes the indirect emissions is mainly because they want to encourage low carbon transformation on the demand side. Shanghai's dependence on inflow electricity increased from 0.09% in 2000 to 11.43% in 2010 (SSB, 2012a,b) and experienced a historically high record of 13.31% in 2009. Therefore, promoting electricity demand side management is of special significance for carbon emission reduction in China, in the sense of harmonizing efficiency and equity thinking. The SH-ETS is therefore a good trial of the principle of "they who consume, take responsibility" and of the alleviation of pollution transfer. So far, the total emissions estimate based on the MRV principles are only used for domestic allowance allocation in the pilot stage. This means that the national government uses a different statistical system, without double counting, for the final evaluation of the provincial compliance of the carbon intensity reduction target. Inconsistencies between national mandatory targets and regional totals will mean that determining the policy effects of an ETS is not straightforward.

4. Perspectives on the uncertainties of the SH-ETS

Although the main objective of the pilot scheme is to verify the appropriate mechanisms for facilitating a well-functioning carbon market, price discovery capability and the final emission reduction ratio are still the most straightforward indicators for evaluating the performance of this market. The Coase theorem provides a very straightforward way of cap setting, i.e. using the principle that marginal abatement costs equal social marginal benefit; the method of allowance allocation does not matter and hence an ETS can realize the Pareto optimum. The clearance price of the carbon allowance is just equal to the marginal abatement costs, no matter how the allowances are allocated at the initial stage (Sterner, 2002).

However, the practical implementation of emissions trading faces many uncertainties because the avoided global warming damage, the mitigation and adaptation costs, the dynamics of the economic cycle, the technology innovation and the equity perception are still controversial. Experiences from the first stage of the European Union ETS (EU-ETS) revealed the significance of cap setting and allowance allocation, as they were highly related to price fluctuations, emissions reduction and market liquidity. The off-setting mechanisms also proved to be important as they brought about uncertainties regarding market expectations (Ellerman et al., 2010). Since the way of allocating allowances greatly influences the welfare distribution among the entities involved, governments have an incentive to consider some other policy thinking in relation to allowance allocation, such as regional protectionism, GDP champions, regional pollution resolution, an industrial re-distribution strategy and equity thinking. In the long run, the income effects will influence the recipients' final demand and

[5] In the 11th FYP, in order to fulfill the 20% energy intensity reduction target, the Shanghai government had subsidized amounts of energy using entities for their energy conservation and efficiency improvement efforts. For those entities that have made great progress with energy consumption reduction, the government will give them some favorable conditions in allowance allocation.

[6] China carbon emission reduction units is just a Chinese domestic credit, based on a voluntary emission reduction project and issued by the national department of climate change.

[7] The pre-verified accounting boundary refers to the territory of each participant for executing a mandatory target. All of the MRV processes are conducted within this boundary. The authors add one endnote about the pre-verified accounting boundary.

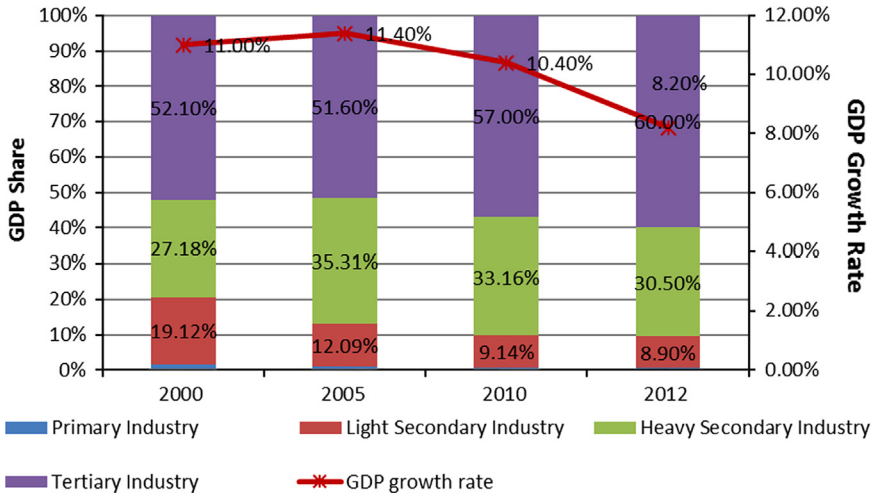

Fig. 2. Economic development and structural transformation in Shanghai. *Data source*: SDRC (2013).

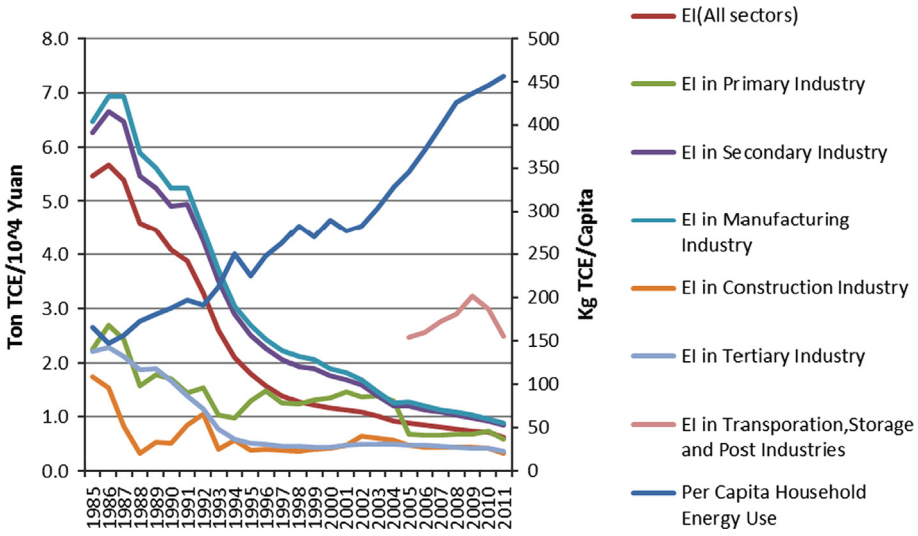

Fig. 3. Historic trends of energy intensity in various sectors in Shanghai. *Data source*: CEIC (2013).

hence total social welfare will also change (Hurwicz, 1995; Tang and Wu, 2013). In addition, even without any rent-seeking or compromises, the government's expectations of sectoral economic growth rates and the state of development may suffer from imbalanced information disclosure and hence influence the compliance effect. Hereafter, this section will touch on the potential.

4.1. Uncertainties caused by changes in economic growth pattern in Shanghai

In the Chinese domestic political context, a commitment to a 40–45% reduction of carbon intensity by 2020 has been taken as a promising policy scenario, which means that all of the pilot regions, including Shanghai, need to make an ex-ante forecast on the growth rate of GDP in advance and then distribute the allowances to each entity. Since the implementation of the practical emission constraint will in turn change the production scale, technology choices and the fuel and product structure – and ultimately the pattern of economic growth – the intensity reduction effect is in some ways uncertain and worthy of investigation to identify the interacting mechanisms.

As Shanghai is in a transition stage of economic growth, the development of the growth rate in future years and the extent of the substitutability of the industrial sector by the service sector must be taken into consideration when choosing an emission cap for the pilot period. Fig. 2 clearly indicates that during past decades, the service industry share of total GDP in Shanghai has increased by eight percentage points in and reached 60% in 2012, which reflects a lightening tendency in economic structure. However, within the industrial sector, heavy industry is still in a dominant position. As a result, the share of industrial energy use in total final energy consumption was still as high as 54.9% in 2011. Five energy intensive sectors account for 88.2% of industrial energy use in the enterprises above the set scale[8] (SSB, 2012a,b).

The energy intensity trend of various industrial and household sectors can add more direct references to the above argument (see Fig. 3). In general, the energy intensities of different sectors are converging. Huge gaps in energy intensity have disappeared, and we cannot expect that industrial structural transformation will generate a significant decline in the future. Furthermore, rapidly increasing per capita energy use in the household sector and the relatively high level of energy intensity in the transportation sector are critical factors driving the pattern of energy use and carbon emissions.

[8] Five energy intensive sectors in Shanghai are smelting and processing of ferrous metal, electric power and heat supply, processing of petroleum, coking products, manufacturing of raw chemical materials and chemical products, and smelting and processing of non-ferrous metals.

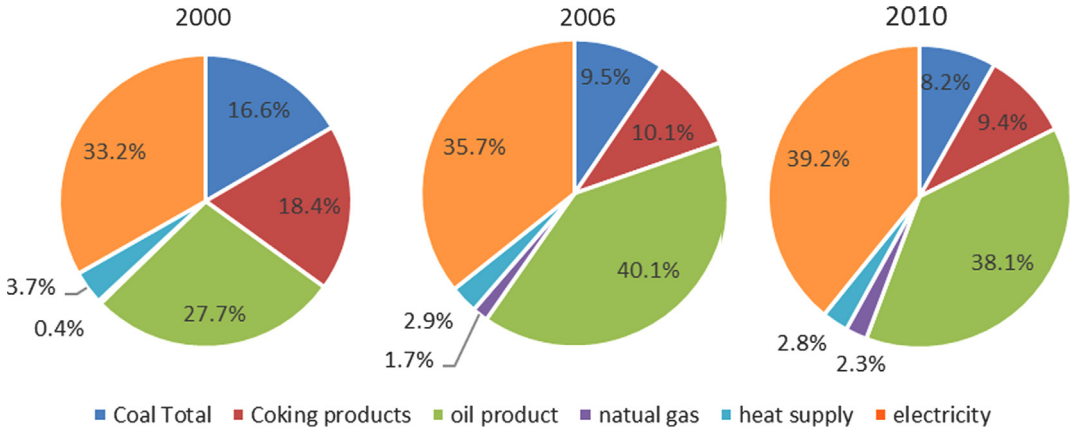

Fig. 4. Fuel structure of energy related carbon emissions in Shanghai. *Source*: Estimated by authors, energy data is from NBS (2012).

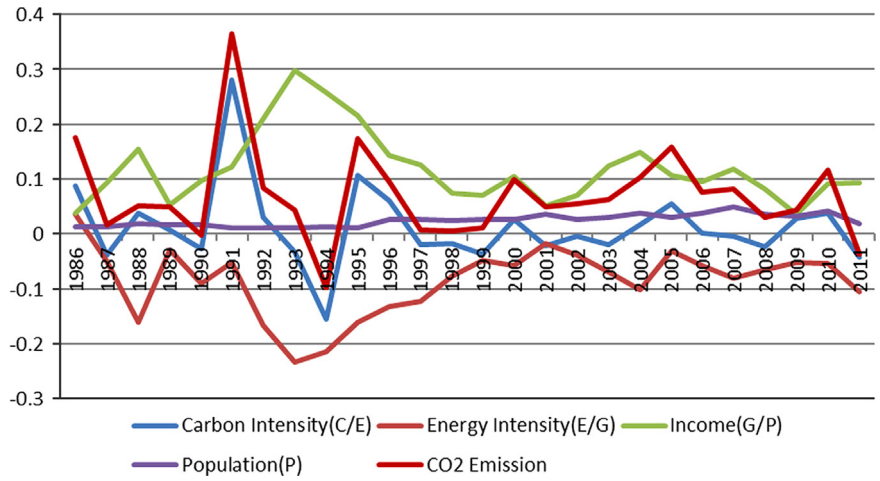

Fig. 5. KAYA decomposition analysis results of Shanghai carbon emission over the period 1986 to 2011. *Source*: Calculated by authors. $C=(C/E)\times(E/G)\times(G/P)\times P, (dC/C)=d(C/E)/(C/E)+(d(E/G)/E/G)+d(G/P)/(G/P)+(dP/P)$, CO_2 emission is estimated based on total final energy consumption by fuel type; energy data is from SSB (2012a); GDP, population data is from SSB (2012b), SDRC (2013).

The historic change in carbon emissions from total final energy consumption illustrates a trend in fuel structure transformation, i.e. the contribution from coal and coking products has declined greatly over the period 2000 to 2010; however, the share of oil products has increased tremendously in Shanghai (see Fig. 4). The direct and indirect emissions from electricity has maintained its largest share and increased gradually. Since there is very limited space for further substitution of coal and coking products, technology choices for low carbonization in Shanghai are highly dependent on energy efficiency improvement and penetration of natural gas, renewable energy and new energy vehicles. A number of demonstration projects of renewable energy and electric vehicles have been carried out in Shanghai; however, most of them have not been profitable and are still highly dependent on government subsidies, soft loans and tax preferences. Limited land and roof resource endowments, poor profit gains, contradictions or overlapping of various industrial, energy efficiency, and renewable energy and emission reduction policies are potential factors deterring the further expansion of cleaner energy utilization.

The KAYA Index decomposition analysis on the change of total carbon emissions in Shanghai indicates that income growth and population expansion were the main positive driving forces of carbon emission increases; while contradictorily, the decline of energy intensity acted as the dominant negative driving force (see Fig. 5). As a complex economic center, the slowdown and restructuring of energy intensive sectors could be foreseen in the short and long term, although the upgrading pattern and pace might differ greatly from a service-driven city like Beijing. Therefore, a further contribution from energy intensity decline is still predictable but the scale of such a contribution is uncertain. Carbon intensity has declined slightly since the mid-1990s but has also experienced fluctuations in some years. Since carbon intensity depends on a change in fuel mix, the result of the decomposition analysis regarding carbon intensity change is consistent with Fig. 4. We cannot expect a significant change of the carbon intensity trends during the pilot period because even in the Shanghai 12th FYP, the share of domestic renewable energy and natural gas can only account for 12% of the total primary energy supply in 2015.

How should we understand the uncertainties of pattern of change in economic growth with respect to its impact on the pilot SH-ETS performance? First, the identical allowance allocation mechanisms for industrial and commercial buildings are somehow contradictory to the above mentioned difference in the development stages of various sectors: acceleration of service industries must face tighter emission constraint than most of the industrial sectors. Second, since in the 11th FYP, most of the commercial buildings were not involved in energy conservation activities but most of the energy intensive sectors were: they will face different compliance difficulties, given that energy intensive sectors are offered a historic reward allowance.

4.2. Uncertainties caused by bankable allowance trading and risk management

According to the latest allowance allocation and MRV document released by the Shanghai government, trading activity is strictly limited within the geographical boundary, and trading participants must have a registered account with pre-allocated allowances. While CCER can be used for the purpose of annual compliance, it must be generated by non-regulated voluntary entities but cannot be used by the regulated ones. All of these measures are made to prevent the market from speculating among pilot provinces and different traders.

Does the SH-ETS provide any possibility of price discovery and risk management? It seems that the banking and borrowing mechanisms of carbon emission allowance across years may leave some space for these purposes. While the subsequent years' allowances cannot be borrowed for the current year's clearance, they are still tradable in the market. Such products can be taken as a proxy future derivative of the subsequent year's allowance. Entities with long expectations of future allowances may buy more allowances for the current year or subsequent years and bank them to get higher revenues in the future. Entities with short expectations may sell out additional allowances to avoid price risks. In fact, as argued by Fell et al. (2012), quantity-based regulation with banking allows regulated firms to shift obligations across time in response to periods of unexpected high or low marginal costs. Such banking mechanisms make the SH-ETS more amiable to regulated entities by providing them with the possibility for optimizing their dynamic revenue over the whole pilot period. On the other hand, it certainly brings about additional challenges for the Shanghai government if it would like to maintain a stable carbon price or optimize its own carbon deposit based on social welfare optimization preferences. The merits of such mechanism design are to leave great space to the invisible hand of the market and reduce the possibility of government failure.

4.3. Uncertainties caused by carbon leakage

Carbon leakage is another issue worthy of special attention. Zhang (2012) reviews the literature on international carbon leakage and finds little evidence that the implementation of a carbon tax or an ETS can cause carbon leakage, whereas some other factors, such as physical and human capital, labor supply, transportation costs and business environment are more important for business strategy. However, there are indications that the practical implementation of carbon markets still raises serious concerns about leakage risks. California's ETS developed a set of methodologies gauging the risks of leakage according to a sector's dependence on international trade (CARB, 2008). A sector with high potential for carbon leakage can receive allowances for free but others should join the auctioning process. Shanghai's economic structural transformation is being driven by the increasing costs of land, labor and living expenses. On the other hand, Shanghai also has very strong advantages, such as modern transportation and logistics systems, high-quality financial services and a mature market environment. Since most of the industrial entities involved in the SH-ETS are energy intensive industries, they may have some incentives to move to less developed regions, such as low energy and carbon abatement costs, the increasing demand for capital goods in inland China and their low dependence on modern service sectors. As discussed in the previous section, ex-post adjustment of allowance is available for the power generation, aviation, and harbor and airport sectors but is prohibited for the industrial and commercial sectors. Since commercial sectors are more reliant on Shanghai's location advantage, the leakage risks would not be as high as for energy intensive sectors. Anyway, the implicit policy context of the 13th FYP regarding the development of the ETS put enterprises in a hard position and the leakage effect is quite difficult to predict.

4.4. Uncertainties of the MRV systems and institutional settings

A successful ETS requires not only creditable carbon emission measurement and statistics but also reliable monitoring and verification. Many aspects of an ETS have the potential for misuse and rent-seeking, thus corrupting the scheme as a whole and rendering it ineffective (Han et al., 2012). Regarding the Shanghai MRV, the most important concern is data quality. Different to many other provinces, the Shanghai government does not provide detailed sectoral energy consumption data to the public, which makes it very difficult to check historic consistency and structural change at the industrial level. A direct reporting system and third party verification at the firm level is the most important institutional setting in the ETS regarding MRV; however, a tentative comparison between official statistics and the summation of firm data has shown a great difference either in Shanghai or in other pilot provinces. Such inconsistency will invalidate the cap setting and permit allocation and hamper the smooth functioning of the SH-ETS. The moral hazard of data distortion should be of particular concern in the development of the ETS system. Capability development to improve the reliability of the statistical system is also a critical task for the SH-ETS.

5. Conclusions and policy implications

To move from experiment to reality, the SH-ETS still faces uncertainties arising from matters such as economic fundamentals, allowance allocations, trading principles, leakage risks and technology development. All of these uncertainties will directly influence the carbon emission reduction ratio, abatement costs and burden sharing among producers, consumers and the government. To reduce these uncertainties and build an efficient market, several policy recommendations should be considered.

5.1. Adjust the allowance allocation principles to facilitate energy structure change and deal with the uncertainties of changes in economic pattern

Free allocation based on sectoral emission intensity for the power generation, aviation, harbor and airport sectors can hardly provide incentives for the transportation and electricity sectors to cut their activity level. Given the ever-rising expansion of transportation and household energy use in Shanghai, the ETS needs responses to this trend. However, the authors acknowledge that it is not easy to deal with this issue in the current context of the SH-ETS, and suggest two points: first, the emission benchmark of the aviation, harbor and airport sectors should be specified by taking both the historic record and international standards into consideration. With the development of the MRV system, more specific benchmarks based on fuel emission intensity for aircraft, ships and vehicles can also be established; second, credits associated with renewable energy utilization and energy saving from un-regulated entities should be included to encourage both the supply and demand side of low carbon transformation.

On the other hand, it should also allow a compromise for increases in the commercial sector, as this is the growth engine of Shanghai's economic development and its substitution to industrial sectors can also contribute to emission reduction: the SH-ETS

should provide some favorable conditions to commercial sector. Benchmark allowance allocation is a better choice for the commercial sector then a cap and trade system.

5.2. Improve the openness of the MRV data base

Information disclosure is always the key element of an efficient market. Based on concern for the critical role of carbon emission data, the Shanghai government should publish and validate the firm level carbon emission data in an open information platform. The trading activities of big dealers should also be registered and reported to avoid speculation.

5.3. Gauge the risks of carbon leakage in certain sectors and design corresponding mechanisms

Carbon leakage is a market failure, as it leads to a shift of emissions to other places without improving compliance to a committed target. As a developed region facing rising factor costs, Shanghai needs to learn more from international experiences to reduce leakage risks. Anti-leakage measures will not only benefit the carbon market by stabilizing the supply and demand but will also prevent a race to the pollution bottom line, as well as stimulating improvements in the development of energy efficiency and low carbon technology.

5.4. Open the market to non-regulated players, introduce derivative products and loosen the CCER restriction

What is the ultimate objective of the ETS? It should be to optimize the social abatement costs for achieving a specific emission reduction task. Non-regulated players can provide various kinds of intermediary services to reduce transaction costs, fight against the monopoly power of large emitters and increase liquidity. As the financial center of China, the Shanghai government should take responsibility for gaining some experience of non-commercial trading activities. Accompanied by the participation of non-commercial dealers, derivative products of a specific year's carbon allowance are also potential choices to strengthen price discovery capability and to hedge market risks.

Numerical simulation also illustrates that to achieve an identical carbon intensity reduction target of 20% by 2015, the marginal abatement cost to Shanghai will be approximately 240 CNY/ton CO_2, and the national average is just 200 CNY/ton CO_2 (Tang and Wu, 2013). Therefore, the participation of CCER in Shanghai can reduce total abatement costs and improve compliance efficiency. Furthermore, CCER can offset the price fluctuation of mandatory allowance and diversify the investment portfolio for market players.

The last but not least point regarding the development of the SH-ETS is about future linkage to other regional or even national markets. In order to prepare for this, policy makers should check the compatibility of the ETS design elements between Shanghai and other pilot regions, evaluate the abatement costs and measure the social benefits of pilot projects.

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