Developing China’s National Carbon Market in Coordination with the Electricity Market

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1. Introduction

The operation of seven carbon emissions trading pilots since 2013 has contributed significantly to development of China’s carbon market during the 12th Five Year Plan period and paved the way of building a national emissions trading scheme in the future.

Chinese studies on carbon markets have been focusing on the design of emissions trading policy itself, drawing lessons from the international experience and domestic pilot schemes. What’s not been discussed extensively when designing the top-level climate policies is the market conditions, for example the impact of energy price control on emissions reductions. It is particularly important in China when the reform of the energy market is lagging behind the development of carbon market.

China’s power generation capacity reached 5.4 trillion kwh in 2013, of which thermal power generation capacity was more than 4.2 trillion kWh (78%) and consumed 2.03 billion tons of coal, a direct result of more than 3.6 gigatonnes of carbon dioxide emissions. Power sector is the largest source of carbon emissions.

By 2020, the electricity consumption will reach 8.2 trillion kWh, at least

60% of which will still come from coal. It is estimated that the cumulative electricity consumption from 2014-2020 is expected to be more than 15 billion ton of coal, equivalent to 27 billion tCO_2 (20.7 billion tCO_2 during the 13th Five Year Period). It is an obvious choice to cover as much as emissions from power companies in the future carbon market to effectively reduce emissions.

Unlike developed countries, China's existing electricity price control could disrupt the market ability and eventually cause serious impact on emissions reductions. In particular, the price control directly stops the power companies from passing part of the carbon cost onto the electricity users. This will potentially undermine the effectiveness of a carbon market by: 1) discouraging energy-savings on the demand side, electricity users are likely to consume more due to a relatively lower price; 2) increasing the risk of companies participating in emissions trading since they are facing a distorted carbon price. Although at the beginning of China national ETS, following the experiences in EU-ETS and other, we believe the free allowances will be given to all partners to reduce their worries, the free quota would be “double-edged sword” for the market. Design the rule to allocate the free quota to each sector and define the optimal number of quota should be the best way to reduce the worries of companies and facilitate the reduction of free quota。

In the paper, we study the comprehensive mitigation effect of ETS, and estimate the impact of regulation of electricity price, and finally give out the policy suggestions.

2. A theoretical framework

We study the theoretical analysis by assuming under the case of perfect electricity market. In such electricity market, since the power company is covered by ETS, the incremental carbon cost will be shared by electricity producers and consumers at a certain ratio between 0 and 1. As equations 1-5 show, in a perfect competitive market illustrated by a simple partial equilibrium framework, the change of electricity demand[1] $demand_e$ depends on the change of the electricity consumer price pd_e and the demand price elasticity ε (negative), the change of electricity supply $supply_e$ depends on the change of electricity supply price ps_e and the supply price elasticity φ (positive). And the difference between pd_e and ps_e is the unit incremental carbon cost p_{ets}. Based on equations 1-4, the share of carbon cost pass-through to downstream users S depends on the electricity supply and demand price elasticity (equation 5). In a perfect competitive market, we have $|\varepsilon| = |\phi|$ and therefore the carbon price pass-through S=0.5. Yet in the real world, most countries are in a type of mixed market economy where both regulated policies and competitive markets can be found. It may not be necessary that S=0.5 which is used as a reference of carbon price pass-through in a

[1] $\text{demand}_e = (\Delta\text{DEMAND}_e/\text{DEMAND}_e) \times 100$, where $DEMAND_e$ is the electricity demand quantity. Same form for other change variables.

perfect competitive economy.

$$\mathrm{demand_e} = \varepsilon \times \mathrm{pd_e} \qquad (1)$$

$$\mathrm{supply_e} = \phi \times \mathrm{ps_e} \qquad (2)$$

$$\mathrm{pd_e} = \mathrm{ps_e} + \mathrm{p_{ets}} \qquad (3)$$

$$\mathrm{demand_e} = \mathrm{supply_e} \qquad (4)$$

$$S = |\mathrm{pd_e}/\mathrm{p_{ets}}| = |\phi/(\phi - \varepsilon)| \qquad (5)$$

If there is the regulation of electricity price, which means the carbon cost cannot be transmit to down stream, we need give some free quota. Considering the free allocation could be seen as a kind of subsidy to the power companies, we can define the rule allocating free quota is to compensate the over carbon cost left in power companies under the case of regulated electricity prices, and hence, the optimal number of free quota is to offset the over carbon cost, shown as the formula (6)

$$\mathrm{NumFA} = \frac{(\mathrm{Pd_e} - \overline{\mathrm{Pd_e}}) * \mathrm{demand_e} * \mathrm{F_{e-co2}}}{\mathrm{P_{ets}}} \qquad (6)$$

In which the NumFA is the optimal number of free allowance for electricity under the regulated electricity price $\overline{\mathrm{Pd_e}}$.

3. Model description

3. The model

3.1 General features

The SIC-GE model is a dynamic computable general equilibrium model used as an auxiliary tool by the Chinese government for public policy decisions.[2] Some precisions of its key features are given below in order to ensure a better understanding of the research results of this paper.

Detailed database. The current database includes 150 sectors, assembled from China's 2007 Input-Output Table and updated by observed data annually. This ensures the model accuracy when analyzing policies of recent years (for example, the year 2007 which is the reference year of this paper). The 150 sectors are composed of two parts: First, the original 2007 input-output table of China contains 135 sectors where only one agriculture sector is included. Secondly, we further disaggregated the agricultural sector into 16 sectors according to crop products and livestock species as defined in China's agricultural product statistical data. SIC-GE distinguishes five labour types[3] given the segmentation of China's labour markets, thus enabling the analysis to take employment impacts into consideration.

Parameters. SIC-GE includes a large number of parameters designed to describe the technology improvement, changes in consumption preferences and market distortion, etc. For instance, two levels of parameters can be designed to describe the contribution of technology improvement to energy saving in industrial production: parameters on

[2] It was co-developed by the State Information Center (SIC) of China and the Monash University of Australia.

[3] Rural agricultural worker, rural non agricultural worker, rural-urban migration worker, urban skilled worker and urban un-skilled worker.

the aggregating level show the general energy input saving by giving the output, regardless of the changes to the energy mix; and preference parameters on the second level can describe the substitution among different energy products. These two parameter types are calibrated using SIC-GE's historical simulation, which is based on observed historical data, and is considered exogenous in policy simulations, such as for carbon pricing policy. So far, the model is calibrated until 2013.

Modules. The core and dynamic (recursive) modules of SIC-GE are based respectively on the ORANI model (Dixon et al., 1982) and the Monash model (Dixon and Rimmer, 2002). SIC-GE includes six core modules which are the production module, investment module, household and government consumption module, export module, price and tax module, and dynamic module. For the first five modules, the theory basis is similar to most of the CGE models. For instance, in the production module, the multi-level nested production function was applied to describe the production process in each industry. The cost minimization is used to illustrate the demand of primary inputs and intermediate inputs. For the dynamic module, there are two main equations. One describes the capital accumulations (including new investments); the other describes the net foreign liability accumulations (including the foreign liability and foreign assets).

3.2 Carbon trading mechanism in SICGE

Firstly we define a carbon price variable Pcarbon(i) in the model for each industry, which unit is RMB/ton CO2. To introduce the carbon price into cost of energy consumption, we transfer Pc into the part of sales tax rate, shown as formula:

$$\mathrm{Pcarbon(i)} * \mathrm{Q(i)} * \mathrm{I} = (\mathrm{T} - 1) * \mathrm{Pbase} * \mathrm{X(i)} \qquad (6)$$

In which, Q is the quantity of CO2 emission, T is the power of sales tax, X is the value of energy input, which is in accordance with Q, Pbase is the price of X exclude tax. I is the dummy price index to ensure the price homogeneity for Formula (6).

Secondly, we build a carbon market in the model by four steps:

(i)build a set of industries covered by carbon market;(ii)define the variable of quota for each industry, of which, the sum of quota will be equal to the total emission;(iii)define the initial quota variable for each industry, which will be added into the total number quota;(iv)initially each industries have a individual carbon price Pcarbon(i),however the industries covered by carbon market will be given a unified carbon price. Once the module is built, by trading, we will keep each industry's emission be same with the number of quota finally.

3.3 **Make electricity price change exogenous in SICGE model**

In SICGE model, the changes of electricity price depend on the changes of production cost. The carbon cost is simply introduced into electricity price through the change of purchaser price of coal, natural gas and imported petroleum product (main part is fuel oil) in electricity sector. The nuclear power and hydro power is superior in the present dispatching mode, by which, the power generated will be connected to grid as much as they can. The wind power however is limited to grid because of uncertainty and volatility. In terms of coal-fired power generation, according to the present dispatching mode, the dispatch agency will decide the dispatch plan based on the principle of "fairness" and "economic" and not consider the huge externalities of energy production on the environment and resources, which means the carbon cost will have no impact on dispatching order. So in short term, the carbon price cannot lead to obvious substitution between coal-fired generation and renewable power, and among different coal-fired generations. So, following the year-on-year recursive dynamic mechanism is used in SICGE, based on real case of China's electricity market, we assume the carbon price will lead to weak substitution among the coal-fired power and other power generations, and weak technological improvement in coal-fired power generation annually, but the substitution will continuously happened according to the adjustment of investment towards to the renewable power sector and nuclear power and advanced coal-fired power generation.

3.4 Scenarios design for the analysis

(i) the baseline

The baseline scenario (named S0) is given for the period of 2007 based on Mai (2006). Major macroeconomic variables of 2007 under S0 are given under the growth rate form in table one. The last column of Table 1 also provides real 2006 data of these variables.

Table 1. Major macroeconomic variables under baseline scenario S0 (%)

	2013	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
GDP growth	**50.9 trillion***	**7.4**	**7.0**	**6.8**	**6.6**	**6.5**	**6.3**	**6.2**
TPEC growth	**3.8BTce**	2.5	3.6	4.6	2.9	3.5	3.0	3.1
Coal Growth	**2.5BTce**	-0.7	1.9	3.4	0.8	1.8	0.6	0.6
Oil Growth	**0.7BTce**	3.4	4.5	4.2	2.8	2.2	2.0	1.3
Gas Growth	**0.2Btce**	11.3	14.2	13.4	11.3	10.0	9.8	9.6
Nonfossil Growth	**0.4BTce**	17.3	5.7	6.1	8.7	9.7	10.9	11.6

Source: SIC-GE.

*:2010 price

To answer the key questions in the field, we design much scenarios following the four questions:

Question one: The mitigation effectiveness of ETS compared with command and control policies. To answer the question, we design two scenarios:

S1: we assume there is carbon market covering all secondary industries, and the total emission for all industrial sectors reduce 5% in 2016 and 2% every year from 2017 to 2020. There is no free quota allocated to all sectors, and without regulations in electricity prices.

S2: we assume there is no carbon market, all industry reduce emission by 5% in 2016 and annually 2% from 2017 to 2020 simultaneously.

Question two: How much impact of the regulation of electricity price on carbon price in ETS?

To answer the question, we design six scenarios (S3-S8):

Following S1, we assume there is carbon market covering all secondary industries, but no free quota allocated to all sectors and introducing the regulation of electricity price. We compared three sub-scenarios by setting the cap as total emission for all industrial sectors reduce 2%(5% and 9%) in 2016 and 2% every year from 2017 to 2020. We also design two ways of subsidy to power companies to keep the production meet the demand under the regulation of electricity price, one is borrow money from increase government deficit, and the other is reduce other government expenditure to keep the neutral of government deficit.

Questions Three: what's the optimal number of free quota to power industry under the different level of regulation of electricity price?

Under the regulation of electricity price, we can provide the subsidy to power company through free quota rather than taken money from government finance, and the number of free quota should change following the change of regulated electricity price. To comparing with the number of free quota in the Scenario (total cap is designed follow S1) with fixed regulated electricity price, We design one more scenario (S9) to allow the regulated electricity price changed by half of that in S1.

4. Results

4.1 Carbon Market will be much more effective than command and control policies

According to the quantitative analysis by the State Information Centre Computable General equilibrium (SICGE) model, carbon market can greatly reduce the negative impact on GDP compared with the administrative order. As shown in Table 2, assuming that the industrial sectors need to accomplish the same reduction targets during the 13th Five Year Plan, the GDP loss caused by achieving the target is about 50% less in using carbon market than using administrative measures. The cost advantage will gradually expand over time.

Table 2: Comparison of GDP loss of carbon market and administrative measures (%)

	2016	2017	2018	2019	2020	Total
With Carbon Market*	-0.02	-0.03	-0.06	-0.08	-0.11	-0.30
Without Carbon Market but Reduction Targets by Sector **	-0.03	-0.05	-0.10	-0.16	-0.23	-0.57

* Results of S1 compared with S0;

** Results of S2 compared with S0;

4.2 The Regulation of electricity price will heavily reduce the effectiveness of carbon market if without other countermeasures

With the comparisons among Scenario S3-S8,further calculations showed that the effectiveness of the carbon market will be significantly weakened if there is a price control over electricity. Based on economics theory, carbon price reflects the marginal abatement cost of achieving certain emission reduction targets (i.e. the cost paid to complete the last unit of reductions). Assuming the cap and coverage of the carbon market is the same, the higher the carbon price, the higher the total abatement cost, the less effective such system is. As shown in Table 3, carbon prices will be higher in systems with price control than without price control. The increase of carbon price varies from 18% to 32% depending on different emission reduction targets.

Table 3: The impact of electricity price control over carbon price

Reduction of total Allowance against baseline	Carbon price without price control (CNY/tCO2)	Carbon Price With Electricity Price Fixed			
		subsidies to power companies by increasing deficit		Subsidies by reducing other government expenditures	
		Carbon Price (CNY/tCO2)	Price increase	Carbon Price (CNY/tCO2)	Price increase
2%*	10.8	13.0	20%	14.1	31%
5%**	30.8	36.3	19%	40	30%
9%***	59	70.4	19%	78	32%

* Total allowances reduce by 2% in 2016 and 2% every year in the following years

** Total allowances reduce by 5% in 2016 and 2% every year in the following years

*** Total allowances reduce by 9% in 2016 and 2% every year in the following years

In addition to undermining the economic efficiency of the carbon market, price control over electricity also affect fiscal spending, and thus indirectly affect the economy. As the carbon price increases, power generation companies are facing a high cost and unwilling to produce electricity. This could lead to a “power shortage” as the demand for electricity will continue to grow. To resolve this problem, the government will have to subsidies the companies to avoid shortage. Usually there are two ways to subsidize power companies: first, to borrow public expenditure (e.g. increase deficit); second, crowd out other expenditures (e.g. reduce production subsidies to other sectors). These two approaches in turn will affect the economy and efficiency of the carbon market. According to the modeling results (Table 2), the increase of carbon price is generally greater in the second approach where the overall government expenditure remains the same but the expenditure structure will be changed.

Since the electricity price has been controlled and kept artificially low, it is relatively cheaper than other energy products. Therefore, the demand for electricity is stimulated by the low price, as shown in Table 4. The emissions from power sector will continue to grow, forcing other departments to bare more obligations of reducing emissions, thereby raising the marginal abatement cost of the entire carbon market, as well as the carbon price.

Table 4: Comparison of electricity demand (100million Kwh)

	2016	2017	2018	2019	2020
Baseline Scenario	65277	69323	73467	77620	81924

Introduce Carbon Market, and allowances reduce every year*	No electricity control	64515	68275	72104	75801	79566
	Subsidies by reducing other government expenditures	65694	69901	74225	78576	83100
	subsidies by increasing deficit	65781	70029	74394	78789	83361

** Total allowances reduce by 5% in 2016 and 2% every year in the following years

The above analysis clearly shows that the market based mechanism is better than administrative measures in reducing emissions and will create less negative impact on economy. However, control over electricity price will seriously affect the validity of the market mechanism. Policy measures need to be taken to limit the negative impact by offsetting the additional carbon cost occurred to the power generation companies and by discovering energy-savings on the demand side.

4.3 Recommendations to carbon market design in response to electricity price control

Replace subsidies with free allowances to offset part of the carbon cost to electricity companies based on optimization principles; less free allowances will be needed if electricity price is allowed to increase.

In theory, if the electricity price can be flexibly adjusted conducting carbon costs, power companies should not be given free allowance. But in China's current system, the retail electricity price is capped and the government anyway needs to give subsidies to power generation companies to meet electricity demand. Therefore, the government can replace the subsidies with free allowances to the power sector and encourage them to participate in carbon market. Meanwhile, clear rules of free allocation must be set to avoid over allocation.

Table 5 presents the modelling results on how many free allowances needed in different scenarios. In the case of price control, assuming the retail electricity price is kept at 2016 level from 2016-2020, the cumulative subsidies to power sector will be CNY648.9 billion, equivalent to about 3.7 billion tCO2 allowances every year, or 18.4 billion tCO2 in total. This accounts for 89% of the total carbon emissions of the entire power sector in baseline year.

Free allocation is affected not only by the cap, coverage of market players, but also by the variance of the regulated electricity price. If the electricity price can be as low as half of the price without control, total free allowance will drop to 9.76 billion tCO2.

Table 5: Calculation of free allowances to power sector

		2016	2017	2018	2019	2020	Total
Electricity price is stable	Subsidies to power sector (billion CNY)	64.3	92.7	124.5	161.5	206	648.9
	Allowances to power sector (100MtCO2)	35.8	36.4	36.8	37.2	37.7	184.0
Allowances, when the electricity		19.2	19.4	19.5	19.7	19.9	97.6

price increase to 50% of the price **without control (100MtCO2)**

Note: Total allowances reduce by 5% in 2016 and 2% every year in the following years from 2016 to 2020

Given the power sector is the biggest emitter, with free allowances, power companies can easily hold a large number of allowances and has the ability of manipulate the price in carbon market. At an early stage of EU ETS, many power companies got “windfall” profits because they can pass the cost to consumers even though they receive allowances for free. For this reason, as the electricity price is gradually liberalized, the government needs to make a smooth transition to phase out free allocation to power companies.

In any case, if the carbon cost cannot be passed to downstream users, the emission reduction potential of the electricity sector would be seriously undermined. It is necessary to explore a linking mechanism between the carbon price and the electricity price. However, China’s electricity market reform requires long term effort, and the existing electricity pricing system won’t be changed any time soon. The impact could be dramatic if the adjustment of the retail electricity tariff affects all downstream users. It will be difficult to implement. For this reason, we recommend to allow the electricity price in selected industries to increases as the carbon price increases, as the first step to explore the linking mechanism.

The level of the surcharge will depend on the coverage of the sectors. In order to pursue operational efficiency of the carbon market, the smaller the group of sectors are chosen, the higher the level of the surcharge should be. The government should allow the surcharge to fluctuate within certain range and review it periodically based on the level of carbon price.

It can work as a better approach than regulating the indirect emissions and allocating allowances to electricity users, an approach which is currently being taken by the ETS pilots. It is a temporary measure to cover both direct and indirect emissions. When design the national ETS, we recommend to remove because it will inflate China's overall cap making one ton of CO_2 in China less valuable. In addition, calculating and monitoring indirect emissions will increase the management costs.

The above two measures are recommended respectively to deal with electricity price control on the supply side and the demand side. According to the above analysis, flexing the electricity price will affect the electricity demand of some industries, and changes in electricity demand directly determine the number of free allocation needed.

Therefore, in order to ensure the effectiveness of the carbon market, we should consider both measures to avoid interference between rules. For example, when promote the electricity surcharge from pilot sectors to wider economy, the free allocation should be adjusted accordingly.

5. Short Conclusions

The study results show that in the absence of the necessary response measures, price control in general will lead to 18%-32% decline of operating efficiency of the carbon market, because the carbon costs are not well reflected in the electricity price. In order to reduce the negative impacts, policy makers need to improve the design of carbon market in the following three areas:

1. The power companies need to receive free allowances to offset the negative influence by electricity price control, but the free allowance need to be phased out over time;
2. It is recommended that electricity price is allowed to increase in certain industrial sectors and gradually expand to other sectors to discover the potential of saving on the demand side;
3. Ensure the consistency of the above two measures, and jointly develop the carbon market and electricity market.