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Carbon Pricing Policy, Revenue Recycling Schemes and Income Inequality: A multi-regional CGE assessment for China

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ABSTRACT

Carbon pricing policy is one of the most efficient tools to mitigate carbon emission, while it alters the income distribution. The progressive individual income tax system redistributes income and reduces inequality. With a multi-regional dynamic CGE model, this study intends to explore the distributional effect of carbon pricing policy in China and to evaluate how the carbon revenue recycling scheme influences income inequality as well as the redistributive effect of individual income tax. Results show several key findings. First, in order to achieve the national emission peak by 2030, carbon pricing policy will lead to greater income inequality, increasing the after-tax Gini coefficient by 0.59% and 1.88% in 2030 and 2040 respectively. Second, if the carbon pricing revenue is recycled through the individual income tax return, the redistributive effects vary according to the design of the tax return rate. The proportional recycling scheme, i.e. all income groups have the same tax return rate, will continue widening the inequality, while the progressive recycling scheme, i.e. lower income groups have higher tax return rates, will narrow the income gap since 2030. Third, carbon pricing policy with a progressive recycling scheme influences income inequality by means of both reducing distortions of carbon policies on the economy and enhancing the redistributive effects of individual income tax. The carbon pricing policy increases the income inequality because of the domination of a positive economic distortion effect at first, while the carbon pricing policy turns to decrease the income inequality since 2025 because both distortion effect and redistributive effect are negative.

Keywords: Carbon Pricing Policy, Tax Revenue Recycling, Income Inequality, Distributional Effects, CGE model

NONMENCLATURE

Abbreviations	
CGE	Computable General Equilibrium
BaU	Business as Usual
ETS	Emission Trading Schemes
CPP	Carbon Pricing Policy
RRU	Return Rate is Uniform
RRC	Return Rate is by Labor Category
Symbols	
Gt	Gigaton

1. INTRODUCTION

Carbon pricing policy internalizes the externality of carbon emission, increases the emission costs and thus reduce the emission amount. It has been widely developed in many countries across the world to provide economic incentives to reduce carbon emissions and help governments achieve their mitigation targets. By May 2020, 61 carbon pricing schemes have been implemented or scheduled in the world, including 31 carbon emission trading schemes (ETS) and 30 carbon taxes. [1]

Establishing national carbon pricing scheme not only impacts regional balanced development [2], but also influences sectoral growth. Employment and income distribution among labor groups alter accordingly. [3] One way to reduce the distributional effect of carbon pricing is to return the revenue. Policy simulations [4] find that most revenue recycling options of carbon ETS in California contribute to long-term economic growth and job creation. Huang et al [5] simulate different policy scenarios of recycling carbon ETS revenue to households, with attention on coal labors, and find that impacts on social equality vary a lot under different scenarios. Li et al [6] simulate carbon tax with revenue recycling schemes in Shanxi province of China, and analyzed different types of effects.

Individual income tax has been granted both increasing government revenue and redistribute social wealth, which the latter helps creating a more equal society. MT index proposed by Musgrave & Thin [7] is used to measure the degree of impact on social equality of individual income tax, i.e. the effect of tax revenue redistribution.

This study intends to contribute in the following two aspects. One is to evaluate the economic and environmental impacts of carbon pricing policy and revenue recycling schemes. The other is to explore the redistributive effect of individual income tax under different schemes. The remainder of this paper is structured as follows. Section 2 describes the materials and methods. Section 3 introduces scenarios including BaU, carbon pricing policy scenario and two scenarios with different revenue recycling schemes. Section 4 displays the results and discussions. Finally, section 5 concludes with research findings.

2. MATERIALS AND METHODS

This study adopts the China Hybrid Energy and Economic Research (CHEER) model, a dynamic recursive CGE model of Chinese economy and energy constructed at Tsinghua University in Beijing[8], and extends it to CHEER-Plato (**P**rovincial, **la**bor, **t**ax and g**o**vernment expenditure) model in order to better study the effects of the carbon pricing policy and the revenue recycling schemes. The model is calibrated to the 2017 multi-regional Input-Output Table of China with 30 regions and 12 aggregated production sectors (Table 1).

2.1 Multi-regional CGE model

CHEER-Plato model is structured as Fig 1. The system includes two types of economic entities, producers and consumers, and two types of markets, commodity markets and factor markets. Producers use production factors, i.e. capital, energy and labor, and intermediate inputs to produce goods and services. According to the principle of cost minimization and under the constraints of production technology, producers determine the quantity of output of goods or services as well as the optimal combination of inputs. The output of goods and services are used as either intermediate inputs for local producers and those in other provinces and overseas, or consumers' final use. All the households, corporates and governments determine the optimal combination of consumption of goods and services under budget constraints in accordance with the principle of maximum utility. Through price adjustments, all commodity markets and production factors markets reach a state of

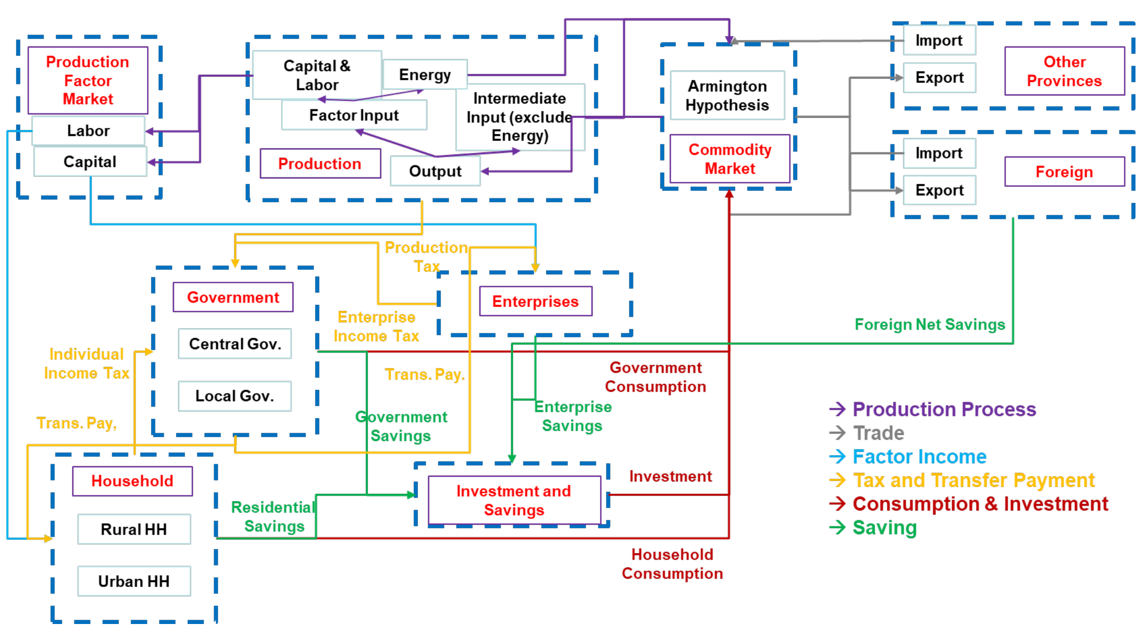

Fig 1 Model Structure

supply and demand equilibrium, i.e. the general equilibrium state of the economic system.

Table 1 Sectors in CHEER-Plato Model

No.	Sector	Abbr.
1	Agriculture	Agri
2	Coal and coking	Coal
3	Crude Oil	OilGas
4	Other mining	Mine
5	Other Manufacturing	OM
6	Refined Petroleum	Roil
7	Non-Metal Manufacturing	NonMet
8	Electricity	Elec
9	Natural Gas	Gas
10	Construction	Con
11	Transportation	Trans
12	Other Services	Serv

In terms of trade, the model simulates the flow of goods and services among provinces and between domestic and foreign market based on the Armington hypothesis. In the production block, the structure is shown as Fig. 2. The substitution elasticity parameters are same as the CHEER model.

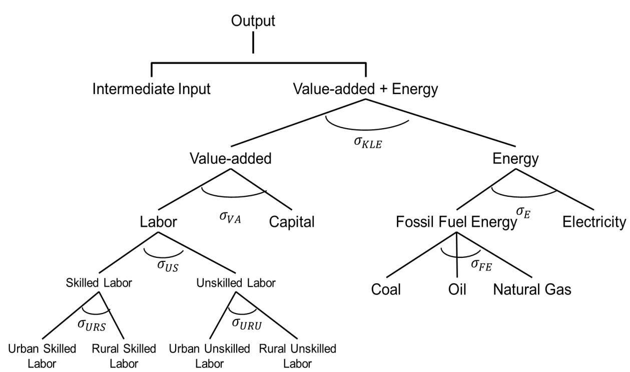

Fig 2 Construction of Production Block

2.2 Labor, Government Tax Revenue and Expenditure

In CHEER-Plato, labor factor is labeled with both locations and working attributes. We classify the labor in each region and its urban or rural living areas. At the same time, labor is also distinguished by sectors and educational level. More details of labor characteristics benefit the analysis on elaborate revenue recycling scheme of individual income tax as well as measuring income inequality.

Two types of taxes levied by the government, income tax and production tax, are categorized according to tax categories, such as value-added tax, individual and enterprise income taxes, and tax subject (central government and local government on the provincial level). Three types of government expenditure are recognized in the model, which are local government expenditure, special transfer of central government, and direct expenditure of central government.

2.3 Equality Measurement and Redistributive effect

This study uses Gini index to measure inequality and MT index[7], the difference between the Gini coefficient before tax and the Gini coefficient after tax, as an indicator to measure the redistribution effect of individual tax:

$$MT = G_x - G_y$$

where MT is MT index， G_x is before-tax Gini index, G_y is after-tax Gini index.

3. SCENARIOS

3.1 Emission Pathway

According to China's carbon emission targets which aims to peak carbon emission by 2030 and achieve carbon neutrality by 2060, this study simulated the carbon emission pathway under policy scenarios. National carbon emission peaks between 2028 and 2030 at the level of about 11.1 Gt CO_2 equivalent, and then decreases gradually, as depicted in Fig 3.

3.2 Scenarios

In order to check the impacts of different policies, we develop a reference scenario and three policy scenarios.

Table 2 Scenarios and Description

Scenarios	Description
BaU	Business as Usual, the baseline scenario with improving energy efficiency;
CPP	Government implements national carbon pricing policy;
RRU	Government implements carbon pricing policy and return the revenue through Individual Income Tax with uniform return tax rate;
RRC	Government implements carbon pricing policy and return the revenue through individual income tax with the return tax rate by labor categories, where lower income labor groups get higher return rates.

The BaU scenario simulates the social-economic pathway SSP2 without a carbon pricing policy. The CPP scenario includes carbon pricing policy based on the social, economic and technological indicators of the BaU scenario.

RRU and RRC scenarios is developed to achieve the same carbon emission reduction level as the CPP scenario. The RRU scenario returns the carbon pricing revenue proportionally to individual income tax, which the RRC scenario sets a higher return rate for lower income groups and creates a progressive scheme.

4. RESULTS

4.1 Impacts of carbon pricing without recycling the revenue

In the BaU scenario, though the energy efficiency is improving year on year, the national carbon emission continues to increase because of growing economy, as shown in Fig 3. In the CPP scenario, carbon emission targets will be fulfilled and the carbon emission reduction rate compared with the BaU scenario is increasing as well. The reduction rate is 22.60% in 2030 and is raised to 50.29% in 2040.

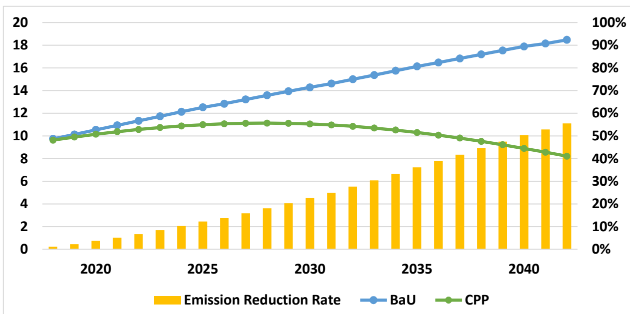

Fig 3 Carbon Emission (Gt CO_2) and Reduction Rate

With the gradually increasing emission reduction rate, the carbon pricing also surges to about 6,000 Yuan per ton CO_2 in 2040. In comparison, we can see a slowdown in the growth of government revenue from carbon pricing, as the base - carbon emission - shrinks.

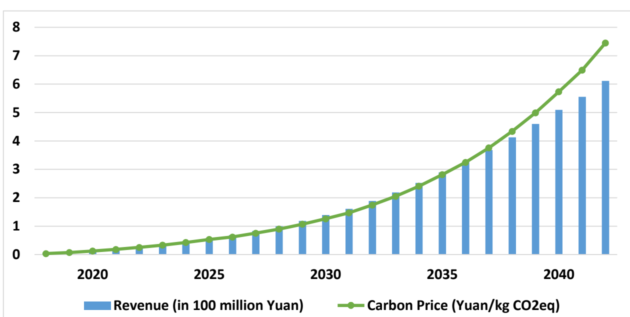

Fig 4 Carbon Price and Revenue

Implementing carbon pricing policy increases costs of energy use, and causes economic loss. Compared with the BaU scenario, GDP in the CPP scenario is 0.2% lower in 2030, and 1.13% in 2040. Carbon pricing policy not only brings to economic loss, but also widens the income inequality. As shown in Fig 5, the Gini index in the CPP scenario is increasingly higher than that in the BaU scenario, with 0.59% in 2030 and 1.88% in 2040.

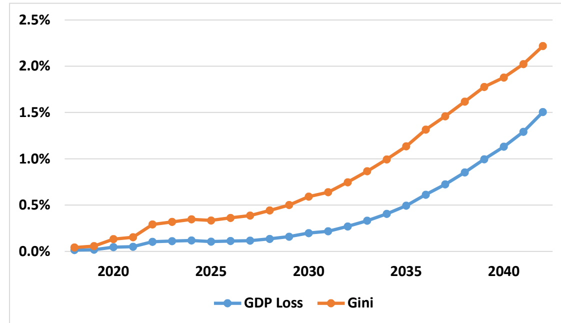

Fig 5 Economic and Equality Effects

4.2 Economic and environment impacts with revenue recycling schemes

Compared with the CPP scenario, RRU and RRC scenarios recycle the carbon pricing revenue and make differences in economy, carbon price and social equality. As shown in Fig 6, GDP will increase 0.09% and 0.19% under the RRU scenario in 2030 and 2040 respectively, and 0.14% and 0.27% under the RRC scenario. At the same time, carbon price will increase when the carbon emission pathway is set as the same as the CPP scenario. For the RRU scenario, the increment is 1.43% and 2.45%, while the number is 1.11% and 2.59% for the RRC scenario.

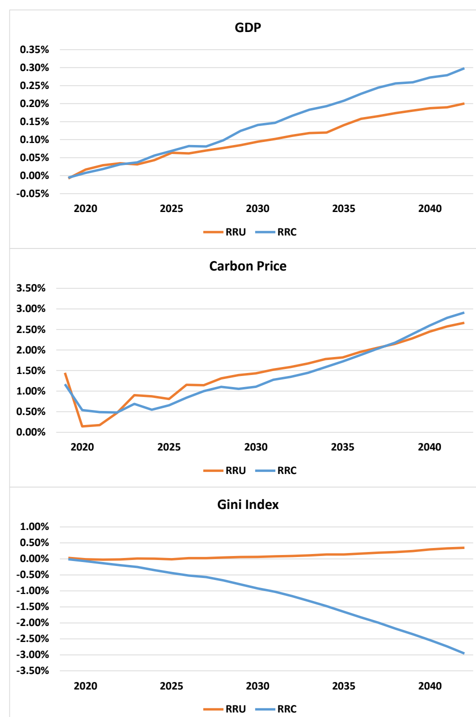

Fig 6 Changes from CPP to RRU and RRC scenarios

Although the performances on GDP and carbon emission have similar trends for both RRU and RRC scenarios, the performance on social equality is quite different. As shown in Fig 6, returning the carbon pricing revenue proportionally is not able to narrow the income inequality, but further widens it slightly. On the contrary, the progressive return rate decreases the Gini index by 0.92% and 2.54% in 2030 and 2040 respectively.

4.3 Social equality impacts with revenue recycling schemes

In order to better understand the impacts of carbon pricing policy on social equality, we reference the concept of MT index. By definition, a positive MT index means the decrease of social inequality. We define a total effect as the increase of inequality, that is, the opposite number of the MT index. The total effect is divided into two parts: the economic distortion effect and the redistributive effect of individual income tax. The economic distortion effect means that the policy distorts the economy and create distributive impacts before the income tax, and can be observed from the before-tax Gini index. The redistributive effect is the nature of individual income tax, and can be observed from the difference between the after-tax and before-tax Gini index.

As depicted in Fig 7, CPP and RRU scenarios have shown an obvious economic distortion effect compared with the BaU scenario, and the RRC scenario almost offsets this effect. The individual income tax benefits social equality via redistributive effect. The after-tax Gini index is smaller than before-tax Gini index in all scenarios. However, this effect shows different intensity in different scenarios, and the RRC scenario witnesses a stronger effect since 2030.

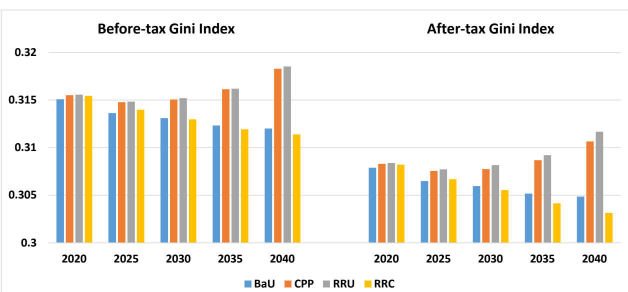

Fig 7 Before-tax and After-tax Gini Index

We further explore the mechanism of the effects under the RRC scenario. As shown in Fig 8, a positive economic distortion effect dominates at first and leads to a positive total effect on increasing social inequality. Since 2025, the economic distortion effect turns negative, and along with the negative redistributive effect, the total effect becomes negative. The redistributive effect accounts for 30.13% and 50.72% in 2030 and 2040 respectively, while the economic distortion effect accounts for 69.87% and 49.28%.

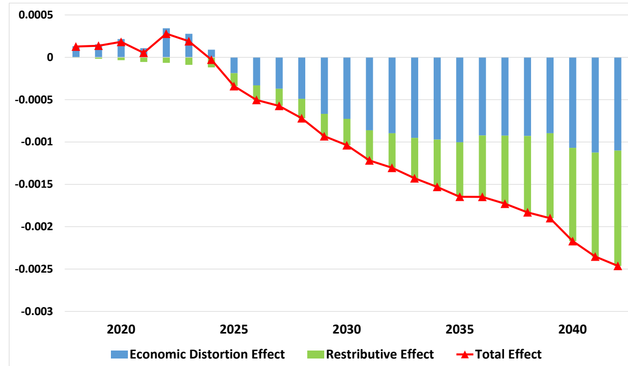

Fig 8 Contribution of effects that the RRC scenario lowers after-tax Gini index compared to the BaU scenario

5. DISCUSSIONS AND CONCLUSIONS

Carbon pricing policy is one of the most efficient tools to mitigate carbon emission, while it alters the income distribution. The progressive individual income tax system redistributes income and reduces inequality. With CHEER-Plato model, a multi-regional dynamic CGE model with detail description on labor and tax, this study intends to explore the distributional effect of carbon pricing policy in China and to evaluate how the carbon revenue recycling scheme influences income inequality as well as the redistributive effect of individual income tax.

Results show several key findings. First, in order to achieve the national emission peak by 2030, carbon pricing policy will lead to lower GDP and greater income inequality, increasing the after-tax Gini coefficient by 0.59% and 1.88% in 2030 and 2040 respectively.

Second, if the carbon pricing revenue is recycled through the individual income tax return, the redistributive effects vary according to the design of the tax return rate. The proportional recycling scheme, i.e. all income groups have a same tax return rate, will continue widening the inequality with a 0.71% and 2.24% increase of Gini coefficient compared with Business as Usual scenario, while the progressive recycling scheme, i.e. lower income groups have higher tax return rate, will narrow the income gap with a 0.14% and 0.56% decrease of Gini coefficient.

Third, carbon pricing policy with a progressive recycling scheme influences income inequality by means of both reducing distortions of carbon policies on the economy and enhancing the redistributive effects of individual income tax. The carbon pricing policy increases the income inequality because of the domination of a positive economic distortion effect at first, while the carbon pricing policy turns to decrease the income inequality since 2025, because both distortion effect and redistributive effect are negative. The contributions of economic distortion effect and distributive effect are 69.87% and 30.13% in 2030, 49.28% and 50.72% in 2040 respectively.

This paper draws the policy implication that if carbon pricing policy is carried out in order to reduce carbon emission, a related revenue recycling scheme with a progressive and detailed return rate is vital to reduce income inequality and regional disparity.

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