ISSN 2004-2965 Energy Proceedings, Vol. 20, 2021

International Conference on Applied Energy 2021
Nov. 29 - Dec. 5, 2021, Thailand/Virtual
Paper ID: 242

# Recycling Carbon Pricing Revenue and the Effects on Income Inequality and Regional Disparity: A CGE-based study of China

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## ABSTRACT

Carbon pricing policy is one of the most efficient tools to mitigate carbon emissions. However, additional carbon cost alters the production behavior and sectoral development, thus leading to income redistribution and regional disparity. Revenue recycling schemes use the carbon pricing revenue to reduce preexisting revenue-motivated taxes. This paper intends to evaluate the effect on income inequality and regional disparity of carbon pricing policy with different revenue recycling schemes. This study adopts the China Hybrid Energy and Economic Research (CHEER) model, a dynamic CGE model, and extends it to the CHEER-Plato model in order to better study the effects of the carbon pricing policy and the revenue recycling schemes. Results show several key findings. First, carbon pricing policy without recycling the revenue will lead to greater income inequality, increasing the national Theil index by 0.87% and 3.61% in 2030 and 2040 respectively. The inter-provincial disparity will raise obviously by 3.97% and 12.72%, while the inner-provincial inequality will change slightly. Second, recycling carbon pricing revenue through individual income tax return reduces income inequality. Compared with policy without recycling schemes, returning the revenue with progressive tax return rates by labor income groups, reduces the Theil index by 2.53% and 7.88% in 2030 and 2040, while the scheme with region-specified return rate by 1.42% and 4.42%, and the scheme with uniform return rate by only 0.43% and 1.23%. Third, carbon pricing policy reduces the inequality in Shanxi and Inner Mongolia by more than 2% and revenue recycling scheme with progressive tax return rates by labor income groups further narrows the income gap in Yunnan, Guizhou, and Xinjiang by over 3% in 2030.

**Keywords:** Carbon Pricing Policy, Tax Revenue Recycling, Income Inequality, Regional Disparity, Dynamic CGE model

## NONMENCLATURE

| | |
|---|---|
| *Abbreviations* | |
| ETS | Emission Trading Scheme |
| BaU | Business as Usual |
| CHEER | China Hybrid Energy and Economic Research |
| CPP | Carbon Pricing Policy |
| RR | Revenue Recycling |
| -U | Uniform |
| -R | Regional-specific |
| -C | Categorized labor group |
| *Symbols* | |
| *T* | Theil Index |

## 1. INTRODUCTION

Carbon pricing policy internalizes the externality of carbon emission, increases the energy costs and thus reduces the carbon emission amount. It has been widely developed in many countries to provide economic incentives to reduce carbon emissions and help governments achieve their mitigation targets. Until May 2021, 64 carbon pricing instruments are in operation and 3 are scheduled for implementation in the world (World Bank, 2021).

National carbon pricing scheme influences energy costs of most sectors and households, thus rebalances the sectoral growth and distribution. Employment and income distribution among labor groups alter accordingly (Huang et al., 2020). At the same time, regional development

 

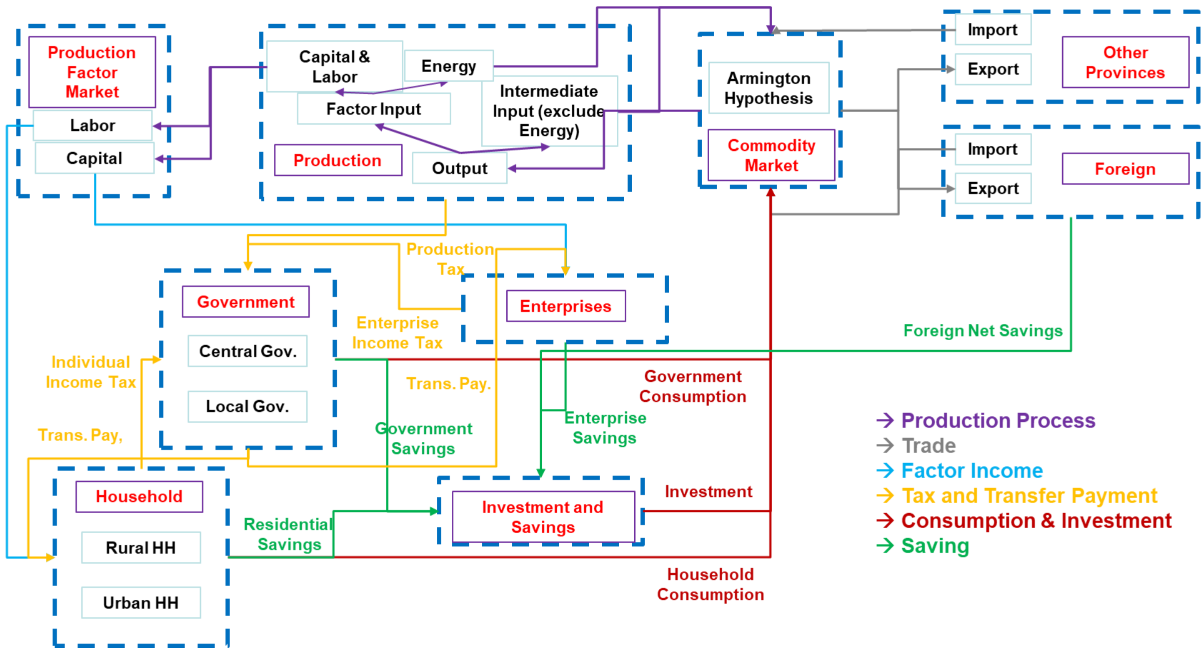


Fig 1 CHEER-Plato Model Structure

alters due to different resource endowments and industrial characteristics(Fan et al., 2016). In pursuit of balanced and harmonious development, the central government in China reinforces the concept of "common prosperity" and aims to reduce inequality.

One way to reduce the distributional effect of carbon pricing is to return the revenue. Policy simulations on carbon ETS in California find that most revenue recycling options contribute to long-term economic growth and job creation(Roland-Holst, 2012). Huang et al. (2019) 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. (2020) simulate carbon tax with revenue recycling schemes in Shanxi province of China and analyze different types of effects.

This study intends to contribute in the following two aspects: one is to evaluate the impacts on income inequality and regional disparity of carbon pricing policy and revenue recycling schemes; the other is to explore the impacts on the regional level. The remainder of this paper is structured as follows. Section 2 describes the materials and methods. Section 3 introduces scenarios including Business as Usual (BaU), carbon pricing policy scenario and three scenarios with different revenue recycling schemes. Section 4 displays the results and discussions. Finally, section 5 concludes with research findings and policy implications.

## 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 (Mu et al., 2018; Wang et al., 2020), 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.

### *2.1 Multi-regional CGE model*

CHEER-Plato model is structured as Fig 1. 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. 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. All commodity markets and production factors markets reach a state of supply and demand equilibrium, i.e., the general equilibrium state.

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 (Armington, 1969). In the production block, the substitution elasticity parameters are same as the CHEER model.

### 2.2 Labor, Government Tax Revenue and Expenditure

In CHEER-Plato, labor factor is labelled 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 and measuring income inequality.

Two types of taxes levied by the government, income tax and production tax, are categorized according to tax categories, 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 the central, and direct expenditure of the central government.

### 2.3 Theil Index and decomposition

Theil (Theil, 1967) proposed that the entropy concept provides a useful device for inequality measurement. The Theil index $T$ can be calculated as:

$$T = \frac{1}{n}\sum_{i=1}^{n}\frac{y_i}{\bar{y}}\log(\frac{y_i}{\bar{y}})$$

where, $n$ is the population, $y_i$ is the income of person $i$ , $\bar{y}$ is the mean income.

Theil index has good characteristics such as its decomposability and independence of income scale and population size etc. If all individuals are separated into sub-groups, Theil index can be traced to the source of the inequality within sub-groups and the disparity among all sub-groups. The decomposition formula can be written as:

$$T_{within}^{j} = \frac{1}{n_j}\sum_{j=1}^{n_j}\frac{y_j}{\bar{y}_j}\log(\frac{y_j}{\bar{y}_j})$$

$$T_{between} = \sum_{i=1}^{k} g_i \times \log(\frac{g_i}{f_i})$$

$$T = \sum_{i=1}^{k} g_i \times T_{within}^{i} + T_{between}$$

where $T_{within}^{j}$ is the inequality within sub-group $j$, $T_{between}$ is the divergence among all the sub-groups, $k$ is the number of sub-groups, $g_i$ is the income proportion and $f_i$ is the population proportion of sub-group $i$.

## 3. SCENARIOS

In order to check the impacts of different policies, we develop a reference scenario and 4 policy scenarios with carbon pricing aiming to achieve the carbon emission targets.

China set the carbon emission targets and aimed to peak carbon dioxide emission by 2030 and achieve carbon neutrality by 2060. This study simulates the carbon emission pathway under several policy scenarios. The total carbon emission nationally peaks between 2029 and 2030 at the level of 11.1 Gigaton $CO_2$ equivalent.

The BaU scenario is the baseline scenario with improving energy efficiency under the shared social-economic pathway SSP2 without a carbon pricing policy. The Carbon Pricing Policy (CPP) scenario includes carbon pricing policy to achieve carbon emission targets, based on the social, economic and technological indicators of the BaU scenario. Three scenarios with recycling revenue (RR) schemes are developed to achieve the same carbon emission reduction level as the CPP scenario. RR-Uniform (RR-U) scenario sets a uniform return rate for all the labor groups for all the regions. The RR-Region (RR-R) scenario sets a specific return rate for each region, and regions with higher GDP per capita get higher return rates. The RR-Category (RR-C) scenario sets a specific return rate for each labor category, and the return scheme is progressive, i.e., labor groups with lower income get higher return rates.

## 4. RESULTS

### 4.1 Impacts of carbon pricing policy

Under the BaU scenario, the income inequality gradually decreases and Theil index drops by 2.35% in 2030 and 3.11% in 2040 compared with that in 2017. However, the income gap under the CPP scenario narrows slightly until 2030 and widens from then on.

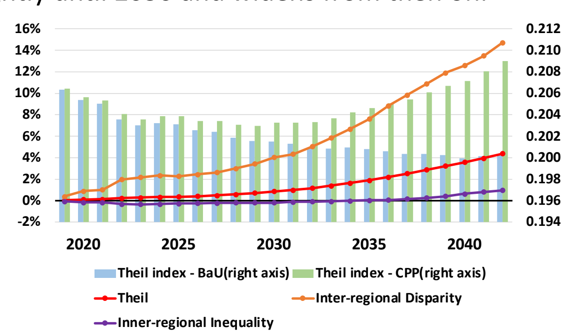


Fig. 2. Change of Inequality under CPP scenario compared with BaU

Compared with the BaU scenario, the national Theil index in the CPP scenario increases by 0.87% and 3.61% in 2030 and 2040 respectively. As shown in Fig 2, the inter-provincial disparity will raise obviously by 3.97% and 12.72%, while the inner-provincial inequality will change slightly.

### 4.2 *Impacts of revenue recycling schemes*

The influence on inequality of different revenue recycling schemes and its mechanism are studied by comparing three RR scenarios to the CPP scenario. As depict in Fig 3, Theil index decreases by 0.43% and 1.23% in 2030 and 2040 under the RR-U scenario, while decreases by 1.42% and 4.42% under RR-R scenario and that decreases by 2.53% and 7.88% under RR-C scenario. The more elaborate the revenue recycling scheme is, the more the inequality decreases by.

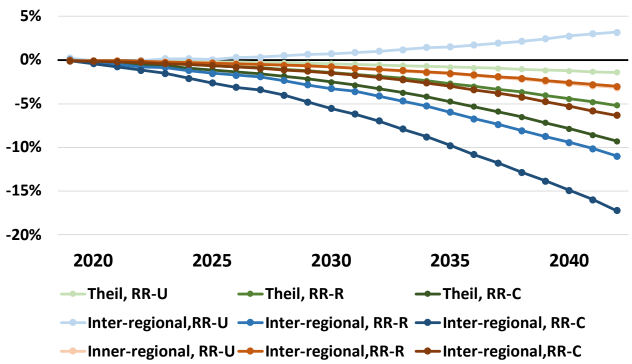


Fig 3. Change of Theil index, Inter-regional Disparity and Inner-regional Inequality, compared with CPP

By dividing the inequality into inter-regional disparity and inner-regional inequality, the influence mechanism is further investigated. Three recycling schemes impact on inter-regional disparity with obvious differences. Compared with the CPP scenario, the inter-regional disparity increases by 0.72% and 2.77% in 2030 and 2040 under the RR-U scenario. By comparison, it decreases by 3.26% and 9.43% under the RR-R scenario, while further decreases by 5.53% and 14.90% under the RR-C scenario.

All three RR scenarios reduces inner-regional inequality. The inner-regional inequality under RR-U and RR-R scenarios shows similar trends, while it nearly doubles under the RR-C scenario, with a 1.47% and 5.28% decrease in 2030 and 2040 respectively.

### 4.3 *Regional impacts*

Inner-regional inequality within the regions, expressed as Theil index inside the region, under CPP and RR-C scenarios is shown in Fig 4 and Fig 5 respectively. The inner-regional income gap varies a lot in different provinces. In general, western areas have relatively higher inner-regional inequality than the eastern areas. For example, inner-regional Theil index for Shanxi province is nearly 0.4 while it is less than 0.1 for Zhejiang and Hainan.

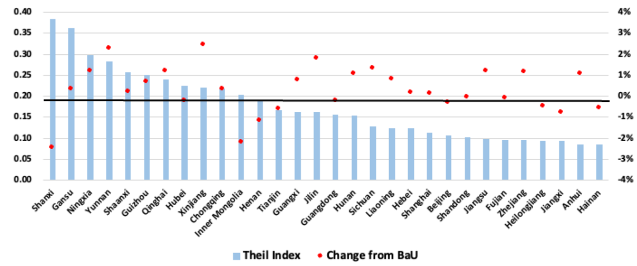


Fig 4. Regional Theil index and the Change in 2030 under CPP scenarios compared with BaU

Both carbon pricing policy and recycling schemes exert impacts on inequality inside of the regions. Carbon pricing policy reduces the inequality in Shanxi and Inner Mongolia by more than 2% compared with the BaU scenario in 2030, while it also increases the inequality in some other regions such as Yunnan and Xinjiang. By contrast, revenue recycling scheme (especially by labor category) narrows the income gaps in almost all the regions compared with the CPP scenario, and it decreases the inequality by more than 3% in Yunnan, Guizhou and Xinjiang in 2030.

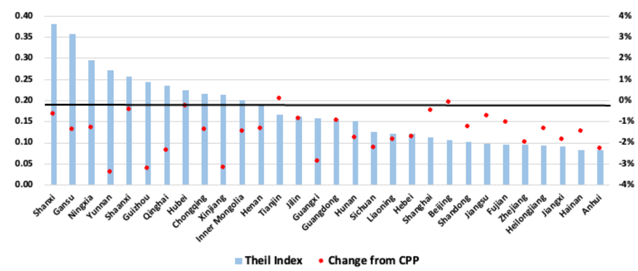


Fig 5. Regional Theil index and the Change in 2030 under RR-C scenarios compared with CPP

## 5. CONCLUSIONS AND POLICY IMPLICATIONS

This study concludes that carbon pricing policy widens the income gap and enlarges the regional disparity, while revenue recycling schemes help reduce income gap. The precise and elaborate design of recycling scheme reduces income inequality and regional disparity markedly.

Firstly, carbon pricing policy without recycling the revenue will lead to greater income inequality, increasing the national Theil index by 0.87% and 3.61% in 2030 and 2040 respectively. The inter-provincial disparity will raise obviously by 3.97% and 12.72%, while the inner-provincial inequality will change slightly by -0.16% and 0.62%.

Secondly, recycling carbon pricing revenue through individual income tax return reduces income inequality. Compared with policy without recycling schemes, returning the revenue with progressive tax return rates by labor income groups, reduces the Theil index by 2.53% and 7.88% in 2030 and 2040, while the scheme with region-specified return rate by 1.42% and 4.42%, and the scheme with uniform return rate by only 0.43% and 1.23%. The scheme with progressive return rates by labor income groups reduces both inter-provincial disparity and inner-provincial inequality. By contrast, the scheme with a simple uniform return rate will continue widening the provincial gap.

Thirdly, inner-regional inequality varies a lot in different regions. Carbon pricing policy reduces the inequality in Shanxi and Inner Mongolia by more than 2% and revenue recycling scheme with progressive tax return rates by labor income groups further narrows the income gap in Yunnan, Guizhou and Xinjiang by over 3% in 2030.

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

## ACKNOWLEDGEMENT

This research was supported by China's National Natural Science Foundation (No. 71773062) and China's National Social Science Foundation (No. 17ZDA077).

## REFERENCE

[1] Armington, P. S. (1969). A Theory of Demand for Products Distinguished by Place of Production. Staff Papers (International Monetary Fund), 16(1), 159–178. https://doi.org/10.2307/3866403

[2] Fan, Y., Wu, J., Xia, Y., & Liu, J.-Y. (2016). How will a nationwide carbon market affect regional economies and efficiency of CO2 emission reduction in China? China Economic Review, 38, 151–166.

[3] Huang, H., Roland-Holst, D., Springer, C., Lin, J., Cai, W., & Wang, C. (2019). Emissions trading systems and social equity: A CGE assessment for China. Applied Energy, 235, 1254–1265.

[4] Huang, H., Roland-Holst, D., Wang, C., & Cai, W. (2020). China's income gap and inequality under clean energy transformation: A CGE model assessment. Journal of Cleaner Production, 251, 119626. https://doi.org/10.1016/j.jclepro.2019.119626

[5] Li, X., Yao, X., Guo, Z., & Li, J. (2020). Employing the CGE model to analyze the impact of carbon tax revenue recycling schemes on employment in coal resource-based areas: Evidence from Shanxi. Science of The Total Environment, 720, 137192. https://doi.org/10.1016/j.scitotenv.2020.137192

[6] Mu, Y., Evans, S., Wang, C., & Cai, W. (2018). How will sectoral coverage affect the efficiency of an emissions trading system? A CGE-based case study of China. Applied Energy, 227, 403–414.

[7] Roland-Holst, D. (2012). Options for cap and trade auction revenue allocation: An economic assessment for California. Paper.

[8] Theil, H. (1967). Economic and information theory North Holland publish. Co., Amsterdam.

[9] Wang, C., Huang, H., Cai, W., Zhao, M., Li, J., Zhang, S., & Liu, Y. (2020). Economic impacts of climate change and air pollution in china through health and labor supply perspective: An integrated assessment model analysis. Climate Change Economics, 11(03), 2041001. https://doi.org/10.1142/S2010007820410018

[10] World Bank. (2021). State and Trends of Carbon Pricing 2021 [Serial]. World Bank. https://doi.org/10.1596/978-1-4648-1728-1