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IMPACTS OF HOUSEHOLD PARTICIPATION IN CARBON MARKET: A CGE-BASED CASE STUDY OF CHINA

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ABSTRACT

Policy on household carbon reduction behavior has an important role on climate actions but is neglected in practice. Household participation in carbon market is a valuable solution. Enhancing understanding of impacts facilitates the deployment on ground in those countries with carbon market. A dynamic computable general equilibrium model is used to analysis the socioeconomic impacts of household participation in carbon market. With the case study of China, we find household participation can reduce 45.5% and 28.1% of fossil fuel emissions of rural and urban households, save carbon mitigation cost by 13.60~14.01%, reduce household welfare loss and influence social equity in 2050. The allocation mechanisms would impact the household welfare and social equity. The methodology can be applied in subregions and other countries to explore the magnitude of impacts. This study evidences the benefits of household participation in carbon market, and give policy-makers some insights to design a reasonable household carbon reduction policy around the world.

Keywords: computable general equilibrium (CGE) model, emission trading scheme (ETS), household participation, allocation mechanism

1. INTRODUCTION

Household energy consumption has increased dramatically worldwide and is far from negligible [1]. The residential and transport sectors consumed 21% and 29% of the world's energy in 2018[2]. Excessive residential and private transport energy consumption contributes to climate change. Reductions in household CO_2 emissions would have benefits on climate change mitigation, which implies needs for appropriate climate policies to reshape low-carbon household behaviors. Policymakers and researchers identify emission trading scheme (ETS) as an economically effective policy. However, no ETS restricts household energy-related emissions, which reduce the efficiency of ETS. For the ambitious climate target, the role of households should be underlined for climate change governance, and the responsibility of enterprises and households should be allocated properly.

Personal Carbon Trading (PCT), as the downstream cap-and-trade policy, has many proposals around the world, see Table 1. PCT is economically effective[3], stabilize the fuel retail price [8],change individual energy consumption behavior [9] and have higher social equity and feasibility [3]. The relatively high enforcement cost

	Energy Coverage	Allocation Mechanism	References
PCA	Residential, personal transport	Free & Equal allocation on individuals with reduction rate	[3]
TEQs	Sectoral & personal emissions	100% auctioning for sectors. Free & Equal allocation on individuals with reduction rate	[4]
TTCPs	Private road transport	Free allocation on individuals with reduction rate	[5]
HHCT	Residential	Free & Equal allocation on individuals with reduction rate	[6]
CGSP	Personal low-carbon behavior	Free allocation on individuals without reduction rate	[7]

Table 1 Description on different PCT proposals

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can be declined by digital technology and "downstream trading and upstream monitoring" mechanism[10]. However, the impacts of the integration of two policies, performed as household participation in carbon market, are still not explored in the previous research, which may be uncertain for implementation, and the trade-off of decisionmakers.

In light of these considerations, this study explores the socioeconomic impacts of household participation in carbon market. This study uses the Extended Linear Expenditure System (ELES) to capture the household consumption patterns, and establishes an ETS module for both enterprises and households in CGE model. The model can unveil the long-term impacts on carbon emissions, mitigation cost, household welfare and social equity. The different allocation mechanisms of household carbon allowances can provide more practical policy implications.

2. MATERIAL AND METHOD

2.1 CHEER-H

China Hybrid Energy and Economic Research - Household (CHEER-H) Model is a dynamic computable general equilibrium model, based on CHEER model, see (http://cheer.nsccwx.cn). The basic model contains 42 aggregated production sectors, 2 households, factor markets (labor, capital, energy, carbon emission permit) and international trade. Details on the production block and international trade block can be found in Huang et al. [11]. Details of labor segmentation methodology can be found in Mu et al. [12]. This study adopts the Extended Linear Expenditure System (ELES) to describe household demand of commodities, which reflects the income elasticity of different commodities and captures the change of consumer behavior with respect to income growth. The income elasticities of food, goods, services are estimated from [13], oil from [14], natural gas from [15] and electricity from [16]. And coal is zero.

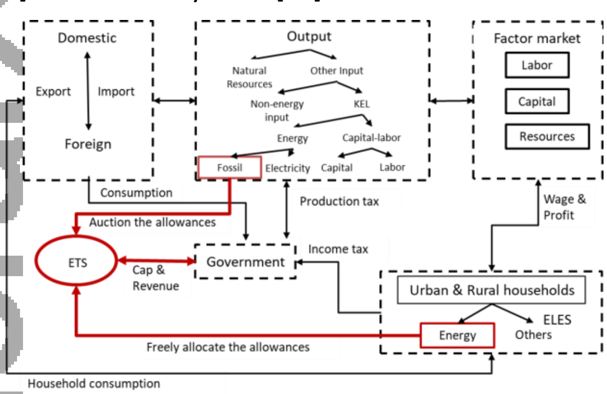

Fig. 1 The structure of CHEER-H with carbon market module

2.2 ETS module with household participation

The ETS module is included in the CGE model, which is referenced from [17]. The ETS module firstly involves the calculation of the covered sectoral CO_2 emissions. And then the ETS module involves households as the demand-side policy shock. The CGE can generate the carbon price under the emission cap, and introduce the carbon price to the production function and household ELES demand function. The emission factors are calibrated by emissions in 2017 [18]. For household incentives, the government provides the carbon revenue to households as different amount of initial carbon allowances.

2.2 Scenarios

To achieve modeling targets, this study considers seven main scenarios. In the BAU scenario, the model simulates China's future carbon emissions without an ETS. This study does not focus on energy transition in China, and the structure of power sectors does not change exogenously. The GDP growth rate is set based on averages for China's projected economy. In NoHHP scenario, ETS only restricts enterprises, and the emission reduction percentage compared with the BAU scenario is set dynamically. This study set an ambitious climate target: carbon-reduction percentage increases from 2% in 2017 to 70% in 2050 gradually.

Scenarios	Description
BAU	The baseline with improving energy efficiency, AEEI=1%
NoHHP	Implementation of ETS only for enterprises based on BAU; national CO_2 emissions are reduced by 70% compared with the BAU in 2050
HHPs	ETS for both enterprises and households; the same carbon cap as NoHHP scenario
HHP-SN	Household-specific allocation to households, household carbon emissions (no reduction rate) in NoHHP scenario
HHP-EN	Equal allocation to households with the total household allowances as HHP-SN (enough)
HHP-SR	Household-specific allocation to households with carbon reduction responsibilities (reduction rate is the same as national target)
HHP-ER	Equal allocation to households with carbon reduction responsibilities (reduction rate is the same as national target)
HHP-AU	Auction to households without initial quota allocation

Table 2 Scenarios and Descriptions

In five HHP (household participation) scenarios, the emission cap is achieved by carbon reduction of both enterprises and households. The HHP scenarios only provide incentives to household fossil fuel emissions but exclude electricity. The five HHP scenarios have different allocation mechanisms, which are based on two principles, i.e. initial carbon reduction responsibility and equality (see Table 2).

3. RESULTS AND DISCUSSIONS

3.1 Household emission reduction

When ETS was established in 2017, annual CO_2 emissions become progressively lower than the BAU scenario. ETS constrains the power sector, and thus household decrease electricity emissions. In 2050, electricity-related emissions only make up 15.2% of total emissions in the BAU scenario. However, the ETS policy cannot effectively reduce household fossil fuel-related CO_2 emissions. The share of household fossil fuel-related CO_2 emissions as a part of national emissions increases from 5.4% to 20.9% after establishing the ETS in 2050, which is economically inefficient (Figure 2).

The trading carbon permits in ETS drive low-carbon behavior of households. As a rational agent, households reduce carbon emissions to maximize their utilities. All HHP scenarios can achieve almost the same household emission reduction. Under the HHP policy, rural and urban household fossil fuel-related emissions reduce by 45.5% and 28.1% in 2050, respectively (Figure 2). The peak time pf household emission is later than it of national emissions, which indicates that household energy consumption is harder to reduce compared with enterprises. Households reduce transport-related emissions prior to reducing residential emissions. Electricity consumption has growth as the substitution of fossil fuels. The ETS with household participation can achieve the peak of household energy consumption, and optimize energy consumption structure.

3.2 Economic impact

ETS constrains sectoral carbon emissions and thus producers need bear the cost of carbon reduction. The marginal mitigation cost increases as the emission reduction target becomes stricter with time. In 2050, the annual mitigation cost is 7.49 trillion Yuan, accounting for 2.83% of GDP. Household participation in ETS can mitigate carbon emissions with higher economic efficiency, and thus save the carbon mitigation cost of ETS (see Figure 3a). The absolute cost saved is more than 1 trillion-yuan, accounting for about 13.60%~14.01% cost saving rate in 2050. Five allocation mechanisms have different economic performance (see Figure 3b). The equal allocation with enough allowances (HHP-EN) performs the best (14.01%), while the auction performs the worst economic benefit (13.60%). The equal allocation is better than household-specific allocation, and enough household allowance allocation is better than the allocation with reduction rate. Such results indicate that equal allocation can redistribute the income from the rich to the poor, and enough allowance allocation can reduce household income loss, which can motivate the consumption of households and thus have a better economic performance.

3.3 Household welfare and equity

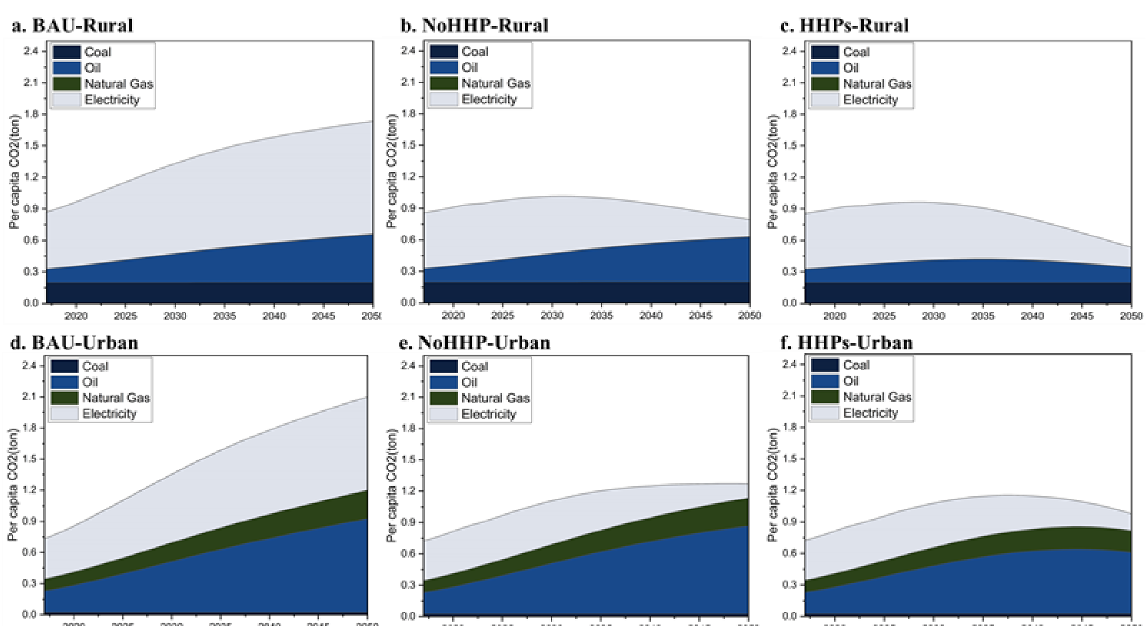

Fig. 2 Per capita rural (a,b,c) and urban (d,e,f) household energy-related CO_2 emissions in BAU (a,d), NoHHP (b,e) and HHPs (c,f) scenarios

Household participation in ETS can mitigate the welfare loss caused by the ETS through two mechanisms (Figure 4). First, household carbon reduction can relieve the pressure of producers and thus reduce the real price of commodities, households can have larger consumption level. Such mechanism can reduce welfare loss. In HHP-AU scenario, although there is no initial allowance for households and the carbon revenue is negative, both the welfare loss of rural and urban households can reduce by 0.32 percentage. Second, the existence of carbon revenue can also change household welfare. The carbon revenue improves welfare of rural households greatly but improves welfare of urban households negligibly. For rural households, carbon revenue is a great share for their disposable income, and thus the equal allocation with enough allowances reduces welfare loss of rural households by 1.12 percentage. While for urban households, carbon revenue is not significant in their income.

With the household participation in ETS, the social inequality can be affected to some degree. Auction of carbon allowances would worsen the urban-rural income ratio of ETS, since rural households are much harder to bear the carbon tax in the level of lower income. The equal allocation with enough allowances has the largest benefits on social equity, because most of low-income households have lower energy consumption, and are more sensitive to reduce energy consumption for carbon revenue. The unused carbon allowances can be sold in ETS to obtain the carbon revenue.

3.4 Sensitivity analysis

The sensitivity analysis shows that 10% income elasticity change of oil would change the cost saving rate by 7%, welfare loss by less 1%; 10% income elasticity change of gas would change cost saving rate by 1%; when the coal income elasticity is 0.1, the cost saving rate increases by 6%. The sensitivity analysis shows that income elasticity of coal and oil would change the magnitude of socioeconomic impact, but relatively inelastic. Evaluating the long-term income elasticity of

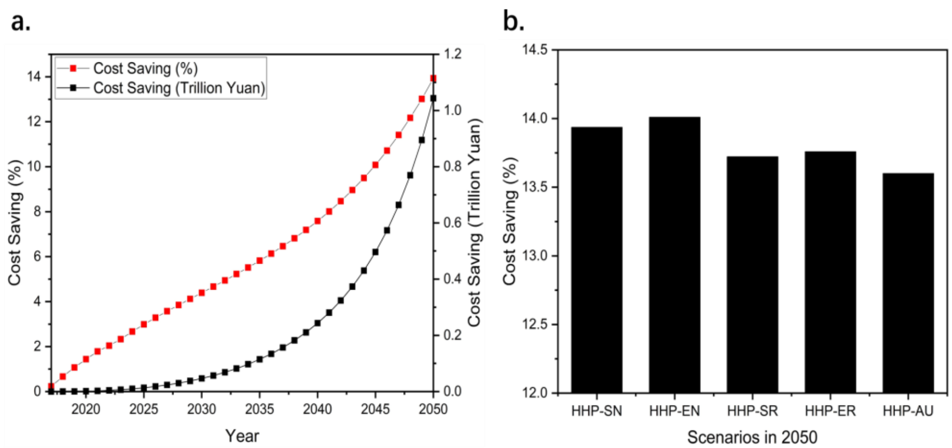

Fig. 3 Mitigation cost saving by household participation(a. trend for HHP-SN scenario, b. different scenarios in 2050)

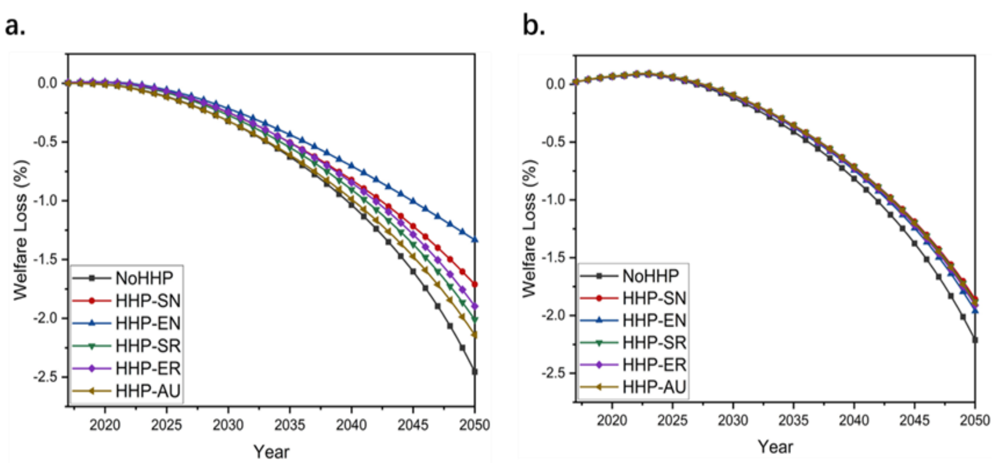

Fig. 4 Welfare change compared with the business-as-usual (BAU) scenario (Welfare is calculated by the equivalent variation method; a. rural households; b. urban households)

household energy consumption is still important for the future demand-side climate policies.

4. CONCLUSIONS

The deep decarbonization requires both households and sectors to take climate actions. This study concludes that establishing the carbon market with household participation can reduce household emissions, welfare loss and carbon mitigation cost, and affect social equity. The carbon tax may be social infeasible since it may cause the direct income loss. This study discussed different allocation mechanisms, and the equal allocation with enough allowances is the best alternative. The equal allocation can redistribute the income and improve social equity. With enough carbon allowances, most households can sell the unused carbon allowances which has the higher social feasibility.

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