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Effects on Carbon Emission and Carbon Policy Choices of the Aging Society - a Case Study of China

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ABSTRACT

As China pledges to achieve carbon neutral by 2060, provincial mitigation routes and plans are carried out in succession. Severe aging in demographic structure will impact future carbon emission and influence the effectiveness of low carbon policies, with shifting consumption pattern induced by age structure changes, age-different respond in low-carbon policies, shrinking labor supply. Current researches on China's new mitigation pledges did not consider the impact of demographic changes. This study used a multi-regional CGE model with detailed household agents and found it necessary to consider the effects of aging in simulation. In extreme scenarios, there are 20% decrease in emission and 17% drop in economic output comparing with traditional scenario without taking aging into account. The implementation speed of delayed retirement faces a trade-off between economic development and emission reduction costs.

Keywords: Carbon emission, Demographic changes, Emission trading scheme, CGE modeling, Economic impacts

1. INTRODUCTION

Climate change is one of the most important global challenges in this century, and directly threatens the sustainable developments of the economy and society. Great efforts have been made globally and nationally. As a country with highest carbon emissions, in September 2020, China pledged to achieve peak of carbon emission by 2030, and strive to realize carbon neutrality by 2060. Recently, in October 2021, China updated its new NDC goals [1]. Other relevant policies have been introduced subsequently such as Opinions on work in Carbon emission peak and neutrality [2], and Carbon Emission Peak Action Plan by 2030 [3]. The economic policy tools supporting the strategic objectives and policies are gradually introduced and improved. In October 2011, the launch of pilot emission trading schemes (ETS) in 7 provinces and cities was approved. The national ETS was established in December 2017 and opened in July 2021. After the declaration of new mitigation target, series of management measures for improving national ETS were carried out [4].

Population aging is a global trend, and is another challenge for China in the long term. The proportion of China's population over 65 years old is 13.5% in 2020, approaching an aged society, according to the World Health Organization's definition. The 2019 UN Population Prospects estimates this proportion will reach 26.1% in 2050 in China [5], which is far exceeding the definition of hyper aged society. Furthermore, the number of working-age population, people aged 15 to 64, has reached its peak in 2015 in China, and dropped by 42.2 million by 2020, which is 4.2% decrease comparing with 2015[6]. The degree of population aging in China varies significantly across provinces, with the highest rate of 17.4% in Liaoning and the lowest of 5.7% in Tibet [7].

Demographers are becoming aware of the important connection between population and climate change [8]. The IPCC Fifth Assessment Report pointed out that economic development and population growth are still the two most important factors of CO2

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emissions [9], and every 1% increasing in population size will increase carbon emissions by 0.31% to 3.32% [10-12]. Although age structure and labor proportion have been identified as an important factor of carbon emissions [12-13], differences still exists in the mechanism and degree of the impacts. Based on iPET model and IPAT model respectively, O'Neill et al. [14] and Kim et al. [15] find out aging will reduce carbon emissions, and estimates to be a 20%-40% reduction [14], while others find that aging will increase emission in Europe [16]. Several researches point out the non-linear relationship between aging and carbon emission, while the openness of economic, degree of population aging and regional heterogeneity affect its significance[17-21].

However, it is unclear to what extent demographic changes will affect carbon emissions, the costs of low carbon policies under the new circumstances. This study aims to solve the above questions with the consideration of heterogeneity among provinces.

2. METHODS

This study based on the extended China Hybrid Energy and Economic Research (CHEER) model, a multi-regional dynamic recursive CGE model of Chinese economy by province [22-23]. The structure of model used in this study is shown in Figure 1. The model was calibrated with the 2017 China's multi-regional input output table (IOT)[24], and with 30 regions and 13 aggregated sectors, including agriculture, coal, oil and gas, refine petrol, apparel, other manufacturing, transportation, electricity transmission, fossil-fueled electricity generation, renewable generation, education, health and other services.

The structure and basic principles of the CHEER model are similar to most of the CGE models in current researches [25]. For production, constant elasticity substitution (CES) functions are used to nest the substitutions of each inputs. The non-energy intermediate demand bundle (ND) and the capital-energy-labor bundle (KEL) generate provincial final output. ND is generated with intermediate demand by fixed proportion input-output relationship. For consumption, the households gain income through factor supply and transfer payments, and maximize their utility through their expenditures on goods and services by the Linear Expenditure System (LES). The provincial government allocates revenue received from taxes net of subsidies and transfer to goods and services. Armington assumption is used to simulate the incomplete substitution between domestic and imported goods [26]. In the dynamic process, the GDP growth rate of the baseline scenario is given exogenously, and the endogenous total productivity rate by years are calculated; while other simulation scenarios take the calculated total productivity rate as the exogenous condition to calculate the economic and environmental impact under different scenarios. .

2.1 Disaggregated household types

We further extent the provincial household agents into six categories in detail by three groups and by urban or rural areas, based on household investigation data from China Social Survey 2017 [27], China General Social Survey 2017 [28] and China Household Finance Survey 2017 [29]. The three agent groups are divided according to age and life status such as studying at school, working or retired. This classification methods, comparing with only grouping by commonly used age levels, such as under 15 years old, 15-65 years old and above, can take the living status into account. For example, the expenditure and income pattern of a 20-year-old college student are quite different from the one who already join in the labor market at the same age. Similarly, the 60-year-olds who have retired and the ones still working also show different income patterns and consumption preferences. With the extension of education periods and the changes of

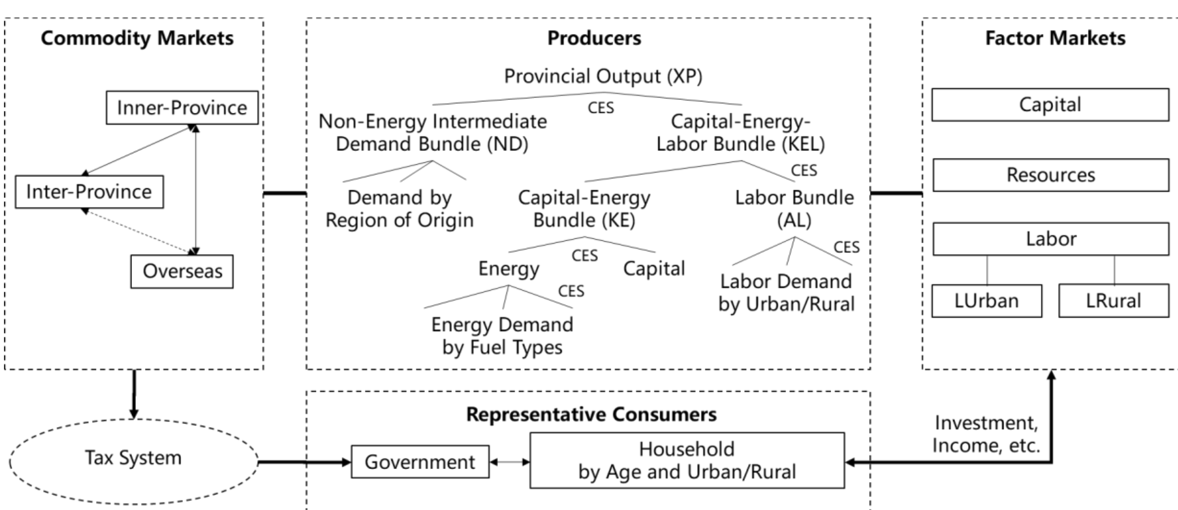

Fig. 1. Model Structure

retirement policy in the future, simple division by age will bias the simulation. The average allocation ratio by household agent types for consumption sectors are shown in Table 1.

Sectors	Household Agent Types					
	HARYng	HARMid	HAROld	HAUYng	HAUMid	HAUOld
Agriculture	0.39	0.34	0.27	0.33	0.37	0.30
Coal	0.35	0.34	0.31	0.31	0.39	0.30
Oil&Gas	0.35	0.34	0.31	0.31	0.39	0.30
Refine Petrol	0.35	0.34	0.31	0.31	0.39	0.30
Apparel	0.15	0.43	0.42	0.12	0.40	0.48
Other Manufacturing	0.35	0.34	0.31	0.31	0.39	0.30
Transportation	0.01	0.36	0.63	0.01	0.39	0.60
Electricity transmission	0.30	0.25	0.45	0.31	0.47	0.22
Education	0.15	0.34	0.51	0.08	0.32	0.60
Health	0.66	0.28	0.06	0.53	0.37	0.10
Other Services	0.30	0.25	0.45	0.31	0.47	0.22

Table 1. Average allocation ratio by household agent types for each sector

2.2 Scenario Settings

This study designed scenario matrices as shown in Table 2. In terms of the age structure assumptions, no aging scenarios do not consider demographic structure changes in the model, where the labor supply and household demand depend on provincial population by years. Meanwhile, labor supply in aging scenario follows the change rate of the workforce from age 15 to 55 expecting for those study full-time at school. The slow, medium and fast retirement postpone assume that the retirement age would reach 65 by 2060, 2050 and 2040 respectively. The future provincial population data used in this study is based on a recursive multidimensional model built by the author's team [30], and is adjusted to fully capture the new trend of the Chinese new census data announced in May 2021.

Population Related Scenarios	**Climate Policy Scenarios**	
	No policy	**ETS**
No aging [a]	NAM-NETS (BAU)	NAM-ETS
Aging	AM-NETS	AM-ETS
Aging & slow DR	AMPS-NETS	AMPS-ETS
Aging & medium DR	AMPM-NETS	AMPM-ETS
Aging & fast DR	AMPF-NETS	AMPF-ETS

Table 2. Scenario Settings

3. RESULTS AND DISCUSSION

3.1 Aging impacts on carbon emissions

In the absence of climate policy intervention, whether population structure is considered in the simulation will have a huge impact, as Fig. 2 shows. In 2050, the total carbon emission in AM_NETS scenario which considers aging with medium future population projection, is 22.4% below the NAM_NETS scenario (BAU scenario). The result is consistent with the result from O'Neill et al. that aging would decrease future carbon emissions by 20% to 40% globally [14]. What needs to be pointed out is that here we depicts the most extreme scenario of aging impacts. In the scenario of considering aging, labor supply only considers the rate of change of the working population aged 15 to 55 years old expecting for full-time students in the future. On the one hand, the increase in the level of education in the future will lead to an increase in the number of years of education. Under the same circumstances, the age of the people first enrolled in labor market will be delayed. On the other hand, setting the upper limit of the working-age population to 55 years old, which is the current average retirement age in China, will underestimate the labor supply in the long-term situation, especially when China's average life expectancy will exceed 80 years in 2050.

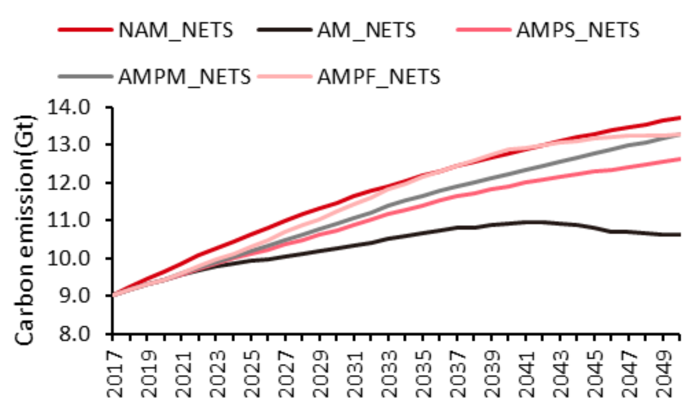

Fig. 2. Future carbon emission with and without the consideration of aging

Scenarios considering aging and delayed retirement policy also show lower carbon emission than the baseline scenario. In 2050, total emission of AMPM_NETS scenario reaches 13.3GtCO_2, which is 3.0% lower than the BAU scenario (NAM_NETS). A more aggressive delayed retirement policy (AMPF_NETS) may generate a higher carbon emission than BAU in several years, from 2037 to 2041, due to higher labor supply increases which boosts the economy, while a slow transition (AMPS_NETS) gains a lower carbon emission by -7.8% in 2050.

3.2 Economic impacts

The real GDP in AM_NETS scenario decreases 7.9% in 2030 and drops 17.5% in 2050 comparing with BAU scenario, as shown in Table 3. In order to further analyze the impact mechanism of aging on the economics, a "half scenario" AM_NETS* is added here, which stands for a new scenario that only considered aging impact from the changes in labor supply, while household consumption are not differentiated by age types. The decline in labor supply is the main reason of negative economic impact in an aging society, contributing 18.8% decrease in real GDP in 2050. It leads to a shortage of human capital and an increase in the cost of commodity production, which in turn has a comprehensive negative impact on consumption, exports and investment.

Scenario	Compared Scenarios	real GDP	Consumption	Investment
AM_NETS	NAM_NETS	-17.5%	-43.2%	5.8%
AM_NETS*	NAM_NETS	-18.8%	-32.9%	-7.8%
AMPS_NETS	NAM_NETS	-5.9%	-18.2%	4.7%
AMPM_NETS	NAM_NETS	-2.2%	-9.4%	3.6%
AMPF_NETS	NAM_NETS	-2.2%	-9.3%	3.5%
NAM_ETS	NAM_NETS	-1.35%	-1.50%	-1.43%
AM_ETS	AM_NETS	-0.96%	-1.26%	-0.97%
AMPS_ETS	AMPS_NETS	-1.24%	-1.60%	-1.23%
AMPM_ETS	AMPM_NETS	-1.31%	-1.54%	-1.33%
AMPF_ETS	AMPF_NETS	-1.31%	-1.54%	-1.33%

Table 3. Economic impacts

Considering aging in demand side have a positive effect of 1.3% increase in real GDP in 2050. Even though the young and old people have lower purchasing power than the middle-aged resulting in further decrease in consumption, the higher saving rate of the old has eased the economic impact of labor shortage with capital to a certain extent. The delayed retirement scenarios increase supplementary labor supply by carrying out policies, which largely alleviates the negative impact of aging on the economy. The rapid delayed retirement policy experience less short-term negative impact on the economy.

Since considering aging reduces social carbon emissions, the GDP loss, characterized as the percentage change, from mitigation through ETS in AM_ETS is 0.96% by 2050, which is lower than the 1.35% in the NAM_ETS scenario. The impacts of the delayed retirement policy on the mitigation costs are between the above two scenarios.

3.3 Provincial heterogeneity

Effects of whether considering aging at the province level is not uniform. Under the extreme AM_NETS scenario, the province with the most negative impact of aging on the economics is Jilin province. Compared with the NAM_NETS scenario, its real GDP drops by 25.8%, far exceeding the national average of 17.5%. Meanwhile, Hainan province has a positive economic impact with 38% increase in export due to less labor intensified production. The economic impact of the three delayed retirement scenario is lower than that of the AM_NETS, but it still shows large provincial differences (Fig. 3).

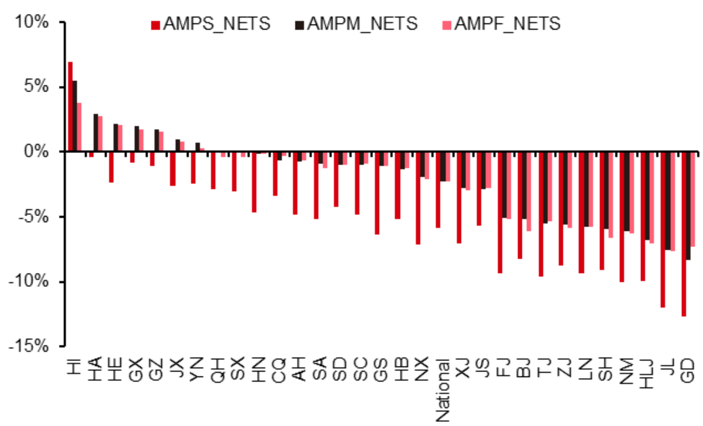

Fig. 3. Percentage changes in real GDP comparing with NAM_NETS scenario in 2050

Provincial heterogeneity also exists comparing the economic impacts of whether implementing mitigation polices under the same population assumptions. Fig. 4 shows the difference between the mitigation cost of each aging scenario, which is characterized by the rate of GDP change, and the abatement costs of NAM_ETS scenario. For majority of provinces, the proportion of the economic impact of emission reduction after considering aging is smaller than those without. This means that traditional research may overestimate the cost of achieving China's mid-term and long-term emission reduction targets. On the other hand, delaying the implementation of the retirement policy may possibly face to a trade-off between economic development and the cost of abatement.

4. CONCLUSION

This study used a multi-regional CGE model with detailed household agents to explore to what extent demographic changes will affect carbon emissions and the costs of low carbon policies. We found that in extreme scenarios, there are 20% decrease in emission and 17% drop in economic output comparing with traditional scenario without taking aging into account. Results support it necessary to consider the effects of aging in simulation.

The implementation speed of delayed retirement faces a trade-off between economic development and emission reduction costs. Promoting delayed retirement faster, which is reaching retirement age of 65 by 2040 in the AMPF assumption, will promote economic growth in the short term, even gain economic growth higher than the baseline, but accordingly increase the emission reduction costs towards net-zero in 2060.

Effects of whether considering aging at the province level show large heterogeneity. For majority of provinces, the proportion of the economic impact of emission reduction after considering aging is smaller than those without. The traditional research may overestimate the cost of achieving China's mid-term and long-term emission reduction targets.

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