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The Emission Reduction Potential of Non-CO_2 Greenhouse Gases in China and Its Policy Implications

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Abstract Using the improved Energy-Environmental Version of the GTAP Model (GTAP-E) and the sixth version of emission database of non-CO_2 greenhouse gases, we simulate the emission reduction potential of non-CO_2 greenhouse gases in China and its policy implications. The results show that at present, China is a country with the greatest emission of non-CO_2 greenhouse gases in the world, and the emission will account for about 20% of the world's total emission in 2020. The proportion of emission of non-CO_2 greenhouse gases from the agricultural sector reaches 73%. In the next 10 years, the emission of non-CO_2 gases from cattle and sheep, industry and service industry will experience the highest growth rate; the growth rate of emission from service industry will be higher than that of emission from industry, and the emission from service industry will exceed that from industry after 2010. China can implement emission reduction policy of non-CO_2 greenhouse gases to ease the international pressure of CO_2 emission reduction. Although the high carbon tax collected can reduce considerable non-CO_2 emission, there is little difference in policy efficiency between high carbon tax and low carbon tax. So, in the implementation of emission reduction carbon tax policy of non-CO_2 gases, it is necessary to control the carbon tax at a low level.

Key words Non-CO_2 greenhouse gases, Emission reduction potential, Policy implications

There are mainly six kinds of greenhouse gases emmitted by mankind in *Annex A of Kyoto Protocol*: carbon dioxide (CO_2), CH_4 (methane), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and (sulfur hexafluoride) SF_6. The greenhouse gases defined in *The* 2006 *IPCC National Greenhouse Gas Inventory Directory* include CO_2, CH_4, N_2O, hydrofluorocarbons, perfluorocarbons, sulfur hexafluoride(SF_6), nitrogen trifluoride (NF_3), sulfur pentafluoride carbon trifluoride (SF_5CF_3), halogenated ether[1]. Other types of halohydrocarbon not included in *Montreal Protocol* include CF_3I, CH_2Br_2, $CHCl_3$, CH_3Cl, CH_2Cl_2. The emitting sectors defined include energy, industrial processes, product use (IPPU), agriculture, forestry and other land use types (AFOLU), waste and other types (*The* 2006 *IPCC National Greenhouse Gas Inventory Directory*)[2].

The impact of non-CO_2 emission on climate change can not be ignored. The U. S. Environmental Protection Agency pointed out that the non-carbon dioxide greenhouse gases will increase by 44% from 1990 to 2020; CH_4 accounting for two thirds of total emissions in 1990 will increase by 35%; N_2O accounting for less than one third of total emissions in 1990 will increase by 41%; the fluorine gas accounting for 3% of total emissions in 1990 will increase by 300% in 2020, changing to 7% of total emissions. In addition, according to the research of the United Nations Environment Programme, nearly 50% of greenhouse gases responsible for climate warming in the 21st century are non-CO_2 greenhouse gases. As for the emission of non-CO_2 greenhouse gases, the activities of the agricultural sectors are the main sources of emission of non-CO_2 greenhouse gases. In 2000, the agricultural land-related activities were estimated to produce 50% of global methane emission and 75% of global N_2O emission.

This is tantamount to 14% of equivalent of greenhouse gas CO_2 emitted by mankind (USEPA, 2006a)[3]. The cycle of non-CO_2 in the air is short and there are many effective and feasible measures that can achieve emission reduction, so the emission reduction of non-CO_2 can take effect in the short term. The non-CO_2 emission reduction can be used as an alternative for CO_2 emission reduction. On the one hand, it decreases the emission reduction costs of greenhouse gases; on the other hand, it makes the emission reduction targets more flexible. Non-CO_2 emission reduction can bring multiple benefits in health, economy, agricultural production and other aspects. Moreover, the developing countries and developed countries have the ability to reduce non-CO_2 emission[4].

Using GTAP-E model, this study analyzes the emission reduction potential of non-CO_2 greenhouse gases in China and the policy effects based on the idea.

1 Research method

1.1 Model In this study, this study uses the improved Energy - Environmental Version of the GTAP Model (GTAP-E) to analyze the policy efficiency of emission of non-CO_2 greenhouse gases in China. The Energy - Environmental Version of the GTAP Model (GTAP-E) is a comparatively static general equilibrium model. It is widely used to study the impact of climate change on trade and economy. In this study, we add the emissions module non-CO_2 greenhouse gases to the GTAP-E model. This idea comes from the CO_2 emission reduction GTAP-E policy simulation. In the emission reduction policy simulation of CO_2 greenhouse gases, through the capital and alternative energy module, GTAP-E model

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reflects that the industrial production enterprises increase investment, adopt and improve advanced equipment, decrease the use amount of energy per unit of output, and achieve emission reduction and control of greenhouse gases.

In the analysis of non-CO_2 greenhouse gases emission, some places follow the alternative relationship while some alternative relationships are not obvious. Therefore, by modifying and adding the standard GTAP-E model framework, we establish the emission reduction sector model containing all non-CO_2 greenhouse gases, so that the emission reduction of non-CO_2 greenhouse gases follows the analysis paradigm of GTAP-E[5].

Using recursive dynamic method, GTAP-E takes the period 2001 – 2020 as the base, to simulate the four stages (2001 – 2004, 2004 – 2010, 2010 – 2015 and 2015 – 2020), and analyze the changes in population, skilled labor, unskilled labor and natural endowment of various countries during this period. China's GDP growth and demographic changes use the estimates of Huang (2005) and Toth (2004), respectively[6-7]. Other variables are from the estimates of Walmsley (2002)[8].

Benchmark programs assume that the current policies of all countries continue to be performed, and consider that during the period 2004 – 2010, the tariff policy continues to adjusted in accordance with the WTO accession agreement. In January 2005, the Multi-Fibre Agreement (MFA), China – ASEAN Free Trade Area and the European Union's eastward expansion were cancelled. Benchmark programs reflect the changes in emission of non-CO_2 greenhouse gases in China and around the world without the emission reduction limitation of greenhouse gases, along with the development of the domestic economy and changes in international trade.

1.2 Data In this study, we use the sixth edition of the GTAP database, and this database is jointly developed by the U.S. Environmental Protection Agency and GTAP Center of Purdue University, based on the data of highly decomposed emission sources at the national level. The data are based on the social accounting matrix of various countries in 2001, covering 87 countries and 57 kinds of goods. Non-CO_2 types include CH_4, N_2O, and fluorine gases (FGAS, including HFCs, PFCs and SF_6). According to the research needs, we generalize 87 countries and 57 products into 14 countries and regions, 18 product sectors[9].

Based on the model and the database, this study analyzes the emission reduction potential of non-CO_2 greenhouse gases and the policy implication from two aspects: one is baseline emission based on GTAP-E database and model (2001), and simulation emission (2020); the other is the impact on different sectors and economy based on baseline and simulation emission, after the implementation of carbon tax abatement policy in 2020[10-11].

2 The trend of emission of non-CO_2 greenhouse gases

2.1 Baseline simulation conclusion of global non-CO_2 greenhouse gases

2.1.1 Baseline emission in 2001. As can be seen from Fig. 1, the country emitting the greatest non-CO_2 greenhouse gases is China, followed by the United States and India. Fig. 1 shows that the non-CO_2 emission in China and the United States is far greater than in other countries.

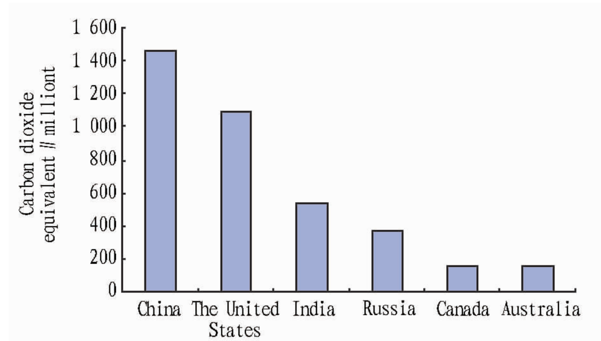

Fig. 1 The top six countries and regions

According to Fig. 2, from a global perspective, 60% of non-CO_2 emission is from the agricultural sector, and only 40% of non-CO_2 emission is from non-agricultural sector.

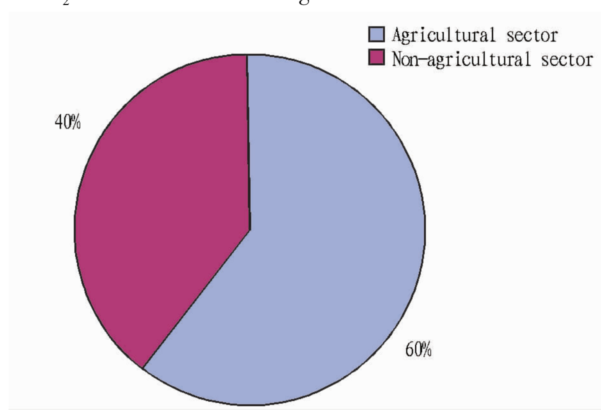

Fig. 2 Sectoral allocation of global non-CO_2 emission

2.1.2 Simulated emission in 2020. From Table 1, we can see the changes in the emission of non-CO_2 in various countries from 2001 to 2020, and the emission of non-CO_2 greenhouse gases in China will account for about 20% of the world's total emission, so controlling China's non-CO_2 emission is essential.

As can be seen from the average annual growth rate in the table, the average annual growth rate of non-CO_2 in the world is 3.71%. The country with the fastest growth rate of non-CO_2 emission is China, reaching 5.98% during a decade. It is followed by sub-Saharan Africa, with the growth rate of 4.32%. The country with the lowest growth rate of non-CO_2 emission is Japan, with the rate of −0.03% over a decade. Non-CO_2 emission in the EU also grows slowly, only reaching 1.79%. The growth rate of other countries is mostly 2% to 4%.

2.2 Baseline simulation conclusion of non-CO_2 greenhouse gases in China

2.2.1 Baseline emission in 2001. China is a country emitting considerable non-CO_2 greenhouse gases. It can be seen from Table 2 that in the top ten sectors in terms of non-CO_2 greenhouse gases emission in China, the first is cattle and sheep, the second is rice, and the third is fruits and vegetables.

The top three are all agricultural sectors. Thus it proves that the agricultural sector in China is the main source of emission of non-CO_2 greenhouse gases. In addition, the top ten also include public services, coal and chemical products.

Table 1 The forecast data of global non-CO_2 emission (CO_2 equivalent, 10^6 t)

Region	2001	2004	2010	2015	2020	Average growth rate
Australia	152.1	159.83	180.23	199.08	220.24	2.24%
Russia	369.37	384.18	443.01	515.32	601.06	3.14%
Other countries	62.16	64.93	73.39	81.04	89.33	2.19%
China	1453.63	1650.23	2111.68	2 599.25	3191.47	5.98%
Korea	62.35	67.49	81.15	96.37	115.56	4.27%
Japan	92.41	93.24	92.95	92.35	91.91	-0.03%
The United States	1094.51	1177.78	1 342.59	1457.48	1586.15	2.25%
India	541.14	594.33	711.43	820.23	952.74	3.80%
Energy - exporting countries	922.43	1 006.2	1217.48	1438.37	1704.75	4.24%
ASEAN	253.76	270.67	313.93	360.15	414.85	3.17%
Canada	153.89	166.58	192.43	212.48	233.16	2.58%
EU	876.97	908.87	993.31	1081.92	1 190.88	1.79%
Sub-Saharan Africa	850.59	925.56	1118.85	1 332.48	1 585.92	4.32%
Other countries	2 093.01	2 272.09	2707.73	3 149.06	3 665.27	3.76%
Total	8978.32	9741.97	11 580.16	13 435.57	15 643.29	
Average growth rate						3.71%

Table 2 The top ten sectors in terms of emission of non-CO_2 greenhouse gases in China (CO_2 equivalent, 10^6 t, 2001)

Sector	N_2O	CH_4	FGAS	Total
Cattle and sheep	60.5	222.57	0	283.07
Rice	38.87	217.43	0	256.3
Fruits and vegetables	240.9	0	0	240.9
Public service	19.43	149.23	0	169.03
Swine and poultry	123.93	26.77	0	150.7
Coal	0	121.37	0	121.37
Chemical products	31.53	0	43.63	75.17
Wheat	35.2	0	0	35.2
Fiber crops	32.27	0	0	32.27
Other crops	21.27	0	0	21.27

According to the results in Table 3 and Fig. 4, we see that non-CO_2 gases in China account for 73% in the agricultural sector, higher than the global average of 60%.

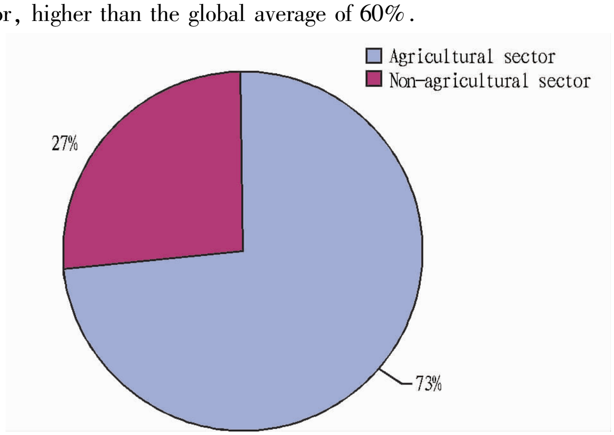

Fig. 3 Sectoral allocation of non-CO_2 emission in China

2.2.2 Simulated emission in 2020. From Fig. 4, we can see that in the agricultural sector, the non-CO_2 emission of cattle, sheep, pigs and poultry will show the growing trend in the future, especially non-CO_2 emission of cattle and sheep grows rapidly. Non-CO_2 emission of rice will decline slightly in the future, while non-CO_2 emission of other crops and other agricultural areas will increase slightly. Fig. 5 shows that non-CO_2 emission of industry and service industry tends to increase in the future, the emission of service industry will grow faster than that of industry, and exceed the industry emission after 2010. Nevertheless, we can see from the data that the sector with the greatest emission is still cattle and sheep in the agricultural sector. Meanwhile, the growth rate of non-CO_2 emission of service industry is also very high in the future, and it is a sector can not be ignored in emission reduction.

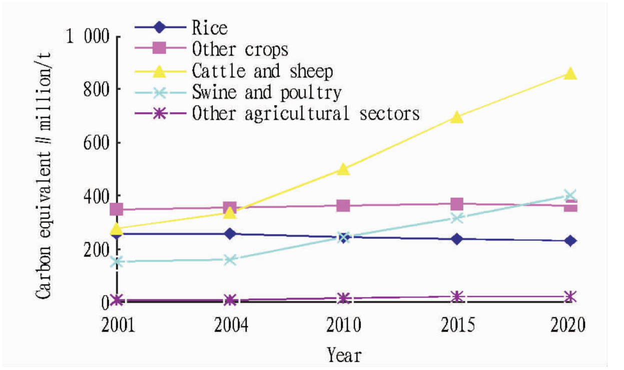

Fig. 4 Changes in the emission of non-CO_2 greenhouse gases in agricultural sector (2001 - 2020, carbon equivalent, 10^6 t)

3 Emission reduction of non-CO_2 greenhouse gases in China and its policy implications

3.1 Simulation scenario Baseline scenario: In this paper, the recursive dynamic method is used to simulate the baseline scenario during the period 2001 - 2020. The baseline scenario reflects the emission reduction potential of non-CO_2 greenhouse gases without

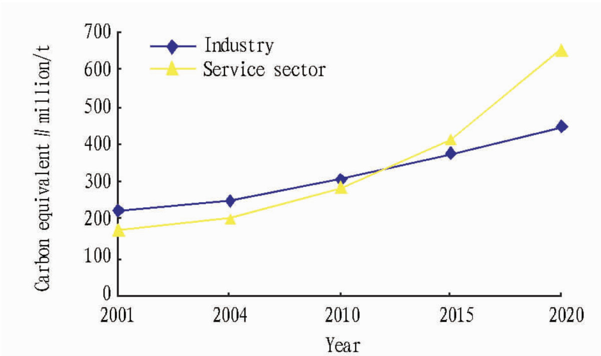

Fig. 5 Changes in the emission of non-CO_2 greenhouse gases in industry and service sector (2001 – 2020, carbon equivalent, 106 t)

the emission reduction policy of non-CO_2 greenhouse gases. On this basis, we select the following policy options to simulate emission reduction potential of non-CO_2 greenhouse gases in China and its policy implications[12 – 13].

Policy scenario I: Carbon tax emission reduction program of levying \$ 30 on per ton of carbon equivalent. On the basis of the baseline scenario, assuming that China will levy carbon tax against the emission of non-CO_2 greenhouse gases in 2020 and the collection standard is to levy \$ 30 on per ton of non-CO_2 carbon equivalent (namely \$ 30/t carbon), the impact of it on macro economy and various sectors (especially the agricultural sector) is analyzed.

Policy scenario II: Carbon tax emission reduction program of levying \$ 50 on per ton of carbon equivalent. On the basis of the baseline scenario, assuming that China will levy carbon tax against the emission of non-CO_2 greenhouse gases in 2020 and the collection standard is to levy \$ 50 on per ton of non-CO_2 carbon equivalent (namely \$ 50/t carbon), the impact of it on macro economy and various sectors (especially the agricultural sector) is analyzed.

Policy scenario III: Carbon tax emission reduction program of levying \$ 70 on per ton of carbon equivalent. On the basis of the baseline scenario, assuming that China will levy carbon tax against the emission of non-CO_2 greenhouse gases in 2020 and the collection standard is to levy \$ 70 on per ton of non-CO_2 carbon equivalent (namely \$ 70 /t carbon), the impact of it on macro economy and various sectors (especially the agricultural sector) is analyzed.

3.2 Simulation results

3.2.1 The impact on the overall economy. As can be seen from the table below, the impact of different carbon tax on the China's welfare is different. With the increase of the carbon tax, the China's welfare will be reduced substantially. In the three simulation scenarios, China's total welfare decreases by \$ 5.495 billion, \$ 9.410 7 billion and \$ 13.379 9 billion, respectively; real GDP decreases by 0.025%, 0.046% and 0.069%, respectively.

Methane emission from rice is directly linked to the use of the land, so after the tax collection, the comprehensive prices of land decline (Table 3). The tax on rice methane emission will lead to substantial reduction of rice's demand for land, and incomplete liquidity of land causes great decline in the prices. Labor and capital are fully mobile, and the prices of these elements are the same among different sectors. After taxation, the part of the labor force in the agricultural sector will be transferred from the agricultural sector. Due to the high proportion of unskilled labor in the agricultural sector and increase in the supply of unskilled labor, wages will decline, and the prices of skilled labor and capital will also decline (Table 3). Relative to the decline in the consumer price index (In GTAP model, the consumer price index is for all goods, and although other commodity prices decline in the simulation, the rising prices of agricultural products such as rice, cattle and sheep are obvious, making CPI increase.), decline in labor wage will lead to decline in the real purchasing power of labor.

Table 3 The macro effects of policy simulation in 2020 (relative to the baseline scenario)

Item	Simulation I	Simulation II	Simulation III
Benefits //10^8 U.S. dollars	–54.950	–94.107	–133.799
Actual GDP//%	–0.025	–0.046	–0.069
Prices of production factors//%			
Land	–1.093	–1.817	–2.538
Non-skilled labor	–0.651	–1.042	–1.419
Skilled labor	–0.800	–1.292	–1.771
Capital	–0.831	–1.300	–1.745
Consumer Price Index	0.007	0.012	0.016

Data source: Simulation results of GTAP-E model.

Table 4 The impact of collecting different amounts of carbon tax due to non-CO_2 emission in China on the agricultural sector (relative to the baseline scenario)

Sector	Item	Simulation I	Simulation II	Simulation III
Rice	Price change//%	2.10	3.52	4.95
	Yield change//%	–0.20	–0.32	–0.44
	Export//%	–17.61	–27.65	–36.43
	Import//%	10.23	17.64	25.51
Other crops	Price change//%	0.04	0.09	0.14
	Yield change//%	–0.10	–0.17	–0.24
	Export//%	0.16	0.17	0.15
	Import//%	–0.15	–0.21	–0.24
Cattle and sheep	Price change//%	9.73	14.87	19.60
	Yield change//%	–0.52	–0.77	–1.00
	Export//%	–29.05	–40.12	–48.45
	Import//%	19.47	30.40	40.84
Swine and poultry	Price change//%	–0.09	–0.16	–0.23
	Yield change//%	–0.27	–0.43	–0.58
	Export//%	0.45	0.75	1.07
	Import//%	–0.44	–0.71	–0.98
Other agricultural sectors	Price change//%	–0.59	–0.96	–1.31
	Yield change//%	–0.01	–0.02	–0.03
	Export//%	2.65	4.32	5.97
	Import//%	–0.91	–1.46	–1.98

Data source: Simulation results of GTAP-E model.

Table 5 The impact of collecting different amounts of carbon tax due to non-CO_2 emission in China on non-agricultural sector (relative to the baseline scenario)

Sector	Item	Simulation I	Simulation II	Simulation III
Product of chemical industry	Price change//%	0.40	0.68	0.97
	Yield change//%	-0.35	-0.61	-0.88
	Export//%	-1.92	-3.25	-4.59
	Import//%	1.11	1.85	2.57
Natural gas	Price change//%	-0.12	-0.20	-0.28
	Yield change//%	-0.44	-0.73	-1.03
	Export//%	5.73	9.68	13.70
	Import//%	-2.47	-4.06	-5.60
Coal	Price change//%	-0.09	-0.20	-0.31
	Yield change//%	-0.13	-0.23	-0.34
	Export//%	0.56	1.17	1.83
	Import//%	-1.16	-2.05	-2.96
Petroleum	Price change//%	-0.06	-0.10	-0.15
	Yield change//%	0.03	0.05	0.06
	Export//%	0.81	1.41	2.03
	Import//%	-0.42	-0.73	-1.05
Electricity	Price change//%	-0.25	-0.40	-0.53
	Yield change//%	0.10	0.13	0.14
	Export//%	1.63	2.58	3.49
	Import//%	-0.76	-1.23	-1.69
Petroleum products	Price change//%	-0.01	-0.02	-0.04
	Yield change//%	-0.15	-0.27	-0.40
	Export//%	0.17	0.28	0.38
	Import//%	-0.29	-0.50	-0.70
Processed foods	Price change//%	0.03	0.05	0.08
	Yield change//%	-0.15	-0.25	-0.35
	Export//%	0.10	0.15	0.20
	Import//%	-0.18	-0.30	-0.41
Cotton spinning products	Price change//%	-0.01	-0.03	-0.05
	Yield change//%	0.15	0.26	0.38
	Export//%	0.32	0.56	0.79
	Import//%	-0.21	-0.35	-0.49
Light industry	Price change//%	0.21	0.31	0.40
	Yield change//%	-0.31	-0.45	-0.56
	Export//%	-0.79	-1.10	-1.34
	Import//%	0.23	0.29	0.32
Heavy industry	Price change//%	-0.20	-0.31	-0.41
	Yield change//%	0.69	1.08	1.46
	Export//%	1.36	2.14	2.87
	Import//%	-0.54	-0.85	-1.14
Utilities and construction	Price change//%	-0.30	-0.47	-0.64
	Yield change//%	-0.82	-1.28	-1.72
	Export//%	1.51	2.40	3.27
	Import//%	-1.52	-2.39	-3.21
Transport and communications	Price change//%	-0.18	-0.28	-0.39
	Yield change//%	0.08	0.11	0.15
	Export//%	0.82	1.32	1.81
	Import//%	-0.53	-0.88	-1.22
Other services	Price change//%	0.37	0.64	0.93
	Yield change//%	-0.41	-0.71	-1.02
	Export//%	-1.11	-1.97	-2.85
	Import//%	0.32	0.58	0.86

Data source: Simulation results of GTAP-E model.

3.2.2 The impact on the agricultural sector. The non-CO_2 greenhouse gases are the major sources of agricultural greenhouse gases, so levying carbon tax against the non-CO_2 emission is vital to the agricultural economy. After taxation, the input costs of the agricultural sector emitting agricultural greenhouse gases will be increased, thereby leading to increase in the prices of agricultural products. Table 4 shows that after the collection of carbon tax, compared with the price of the baseline scenario, the prices of rice, other crops, sheep and cattle increase; the prices of pigs, poultry and other agricultural prices decline. In comparison with the baseline scenario, the quality of the Chinese agricultural products declines, and the production of cattle and sheep experiences the greatest decline. Meanwhile, according to the relationship between prices of commodities and substitution, the exports of agricultural products with rising prices will decline, while the imports will rise (Table 4).

3.2.3 The impact on other sectors. After the taxation and reduction of emission of non-CO_2 greenhouse gases, the product prices in the agricultural sectors emitting many non-CO_2 greenhouse gases will rise, while the product prices in the downstream sector with agricultural products as inputs (such as food processing, light industry) will rise. The price of the chemical products sector will also rise. Due to decline in the price of land, labor and capital, other sectors benefit from it, and the prices of products will decline correspondingly. The decline in product prices promotes the exports of the sector (Table 5).

3.2.4 The impact on the welfare of other countries. Relative to the baseline scenario, the welfare in many countries of the world will decrease (Table 6), but there is a slight increase in the welfare of some countries. The EU experiences the greatest increase in the welfare, followed by Japan; the energy-exporting countries experience the greatest decrease in the welfare. If we do not consider the welfare losses of China, the total welfare of the other countries of the world is increasing. Due to the decrease in the welfare of China, it leads to the decline in global welfare.

Table 6 Changes in the welfare of other countries (relative to the baseline scenario, 10^8 U.S. dollars)

Countries and regions	Simulation I	Simulation II	Simulation III
Australia	-77.83	-125.87	-172.1
Russia	-96.35	-155.36	-212.6
Other countries	-53.21	-85.75	-117.13
Korea	22.83	35.89	48.05
Japan	501.89	807.1	1103.35
The United States	290.96	480.84	670
India	-18.65	-28.74	-38.42
Energy-exporting countries	-152.96	-245.33	-334.82
ASEAN	-3.76	-4.47	-4.72
Canada	25.85	38.91	50.79
EU	514.4	833.74	1146.53
Sub-Saharan Africa	-7.82	-13.28	-18.75
Other countries	-33.03	-63.2	-95.6
Summarizing	912.32	1474.48	2024.58

Data source: Simulation results of GTAP-E model

4 Discussions and policy recommendations

In the studies at home and abroad about the greenhouse gases emission reduction, GTAP-E is widely used in the research of CO_2 emission reduction. CO_2 is related to industry and energy industries, so carbon tax becomes a major policy instrument. Levying carbon tax against CO_2 emission can promote enterprises to reduce fossil fuel or develop energy-saving technology. In this study, the main policy instrument is to collect carbon tax to achieve emission reduction. An important role of applying GTAP-E model is the impact of analyzing the implementation of this policy on the agricultural sector. As we all know, at this stage, the main mode of production of the agricultural sector is the household responsibility system. In order to improve the income of the farmers and inspire the enthusiasm of the farmers to grow food crops, government has abated the agricultural tax, and given subsidies in food and farm machinery. From a long-term perspective, with the deepening of China's modern agriculture construction, scale land management, and burgeoning of agricultural enterprises, the feasibility of the implementation of the carbon tax can not be excluded. Therefore, this study can be used as a prospective study of greenhouse gas emission reduction.

Finally corresponding recommendations are put forward as follows:

(1) China has emitted the most emission of CO_2 greenhouse gases, and this trend is more pronounced in the future. Therefore, in the face of global climate change, China can reduce non-CO_2 emission, to reduce the international pressure of CO_2 emission reduction in China, and provide more flexible space and policy options for China's low-carbon economy.

(2) High carbon tax could result in high emission reduction of non-CO_2, but there is little difference in the policy efficiency between the high carbon tax and low carbon tax. Therefore, in the implementation of carbon tax policy of non-CO_2 emission reduction, the carbon tax should be controlled at a lower level. This study derives that 30 U. S. dollars / t carbon is reasonable, so that the emission reduction policy can achieve the best emission reduction target, and have the minimum negative impact on the economy.

(3) It is necessary to take full advantage of international clean energy carbon trading mechanism, actively adjust the non-CO_2 emission target, and fight for dominance in the international non-CO_2 emission trading.

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