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Potential and policy implications of reduction of nitrous oxide emission by technology in China

Abstract

By using the improved global general equilibrium model of the environment (GTAP-E) and database of the agricultural nitrous oxide greenhouse gas emission established by author, this paper simulates the reduction potential and control policy of Chinese agricultural nitrous oxide greenhouse gas emissions by technology. The results show that agricultural technology reduction of nitrous oxide has the following positive impact on China's macro economy: the first is the increase of Chinese social welfare and real GDP; the second is the decrease of GDP price index, export price index, consumer prices; the third is the reduction of amount of import and export; the fourth is the increase of factor prices. These positive effects are the desired result of changing the mode of production. However, reduction of agricultural nitrous oxide by technology caused a relatively negative effect on the grain farming sector. This influence also extends to the food-related sectors, such as pigs and poultry sector and other agricultural sector. But the cattle and sheep sector and other crops sector obtain the relative returns. Overall, the reduction of agricultural nitrous oxide by technology has smaller positive effects on the agricultural sectors, but plays a positive role in the China's economic growth.

Keywords: Chinese agricultural greenhouse gas nitrous oxide emissions, reduction potential by technology, control policy.
JEL Classification: Q56.

Introduction

Agricultural sources of greenhouse gas emissions. Agricultural sources of greenhouse gas emissions mainly includes methane emissions of ruminants, methane emissions in the process of rice plantation, nitrous oxide emissions caused by fertilizer, methane and nitrous oxide emissions in the process of animal waste management. China is a populous agricultural country, animal husbandry, rice cultivation and fertilizer used in China account for a sizeable proportion of the world. In 2005, meat, eggs and milk production in China accounted for 29.3%, 41.1% and 4.6% of the world, China's breeding capacity of pigs, cattle, sheep and poultry accounted for 50%, 8.5%, 18% and 28% of the total world volume, respectively. In 1994-2005, China's end of breeding stock of pigs, cattle and sheep increased by 21.4%, 15.7%, 54.9%, respectively. Poultry slaughter increased by 92.4%. In 2005, China's rice cultivation area is 28.85 million hm^2, accounting for 19% of the world's total rice cultivation area. From 1994 to 2005, China's agricultural nitrogen fertilizer increased by l8%. In 2005, the amount of nitrogen in China reached 2229×104t (pure volume), accounting for 30% of the global total amount. It is obvious that China's agricultural production activities is in large quantities and fast-growing, if no corresponding reduction measures, agricultural sources of greenhouse gas emissions will be larger accordingly.

According to the data of the Initial National Information Bulletin of the People's Republic of China on Climate Change in 1994, China's total greenhouse gas emissions is equivalent to 36.50 × 108t carbon dioxide, of which carbon dioxide, methane and nitrous oxide accounted for 73.05%, 19.73% and 7.22%, respectively. Agricultural sources of greenhouse gas emissions account for 17% in China's total greenhouse gas emissions. Methane emissions from agricultural activities is 1719.6 × 104t, accounting for 50.15% of China's total methane emissions, of which the emissions in the process of animal husbandry and rice plantation are 1104.9 × 104t and 614.7 × 104t, respectively. In 1994, nitrous oxide emissions caused by using fertilization is 62.8 × 104t, and the emissions in the process of animal manure and grazing management is 15.5 × 104t. Nitrous oxide emissions from agricultural sources is estimated at 78.6 × 104t, accounting for 92.43% of China's total nitrous oxide emissions (Table 2).

Table 1. China's methane emissions from agricultural activities in 1994

The emission sources	Methane emissions (1000t)	The proportion in agricultural methane emissions (%)	The proportion in national methane emissions (%)
Animal enteric fermentation	10182	59.21%	29.70%
Rice cultivation	6147	35.75%	17.93%
Animal waste management systems	867	5.04%	2.53%
Agricultural methane emissions	17196	100.00%	50.15%
National methane emissions	34287		100.00%

Source: Initial National Information Bulletin of the People's Republic of China on Climate Change.

Table 2. China's nitrous oxide emissions from agricultural activities in 1994

The emission sources	Methane emissions (1000t)	The proportion in agricultural methane emissions (%)	The proportion in national methane emissions (%)
Farmland	628	93.45%	73.88%
Animal waste management systems	44	6.55%	5.18%
Agricultural nitrous oxide emissions	672	100.00%	79.06%
National nitrous oxide emissions	850		100.00%

Source: Initial National Information Bulletin of the People's Republic of China on Climate Change.
Note: Omit the nitrous oxide emissions from pasture and field burning of straw.

China's agricultural greenhouse gas emissions in 2004 are estimated as given in Table 3.

Table 3. China's agricultural greenhouse gas emissions and composition in 2004

Sources of agricultural greenhouse gases	Emissions (kt)	Carbon dioxide equivalent (kt)
Methane emissions from rice fields	5723.14	120186.00
Nitrous oxide emissions from farmland	770.73	238925.02
Direct emissions from cattle and sheep	7793.49	163663.19
Direct emissions from swine and poultry	525.87	11043.34
Emissions from cattle manure	115.64	2428.39
Emissions from swine and poultry manure	97.07	2038.56
Total	15025.94	538284.51

Source: Initial National Information Bulletin of the People's Republic of China on Climate Change.

China's agricultural greenhouse gas emissions in 2004 are estimated as shown in Figure 1.

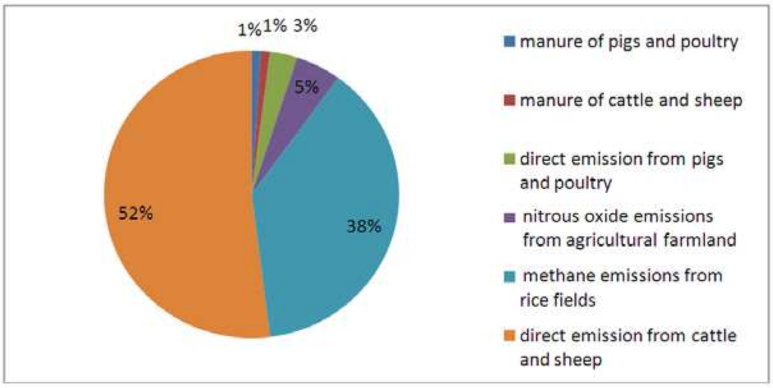

Fig. 1. The share of each source calculated according to the actual amount

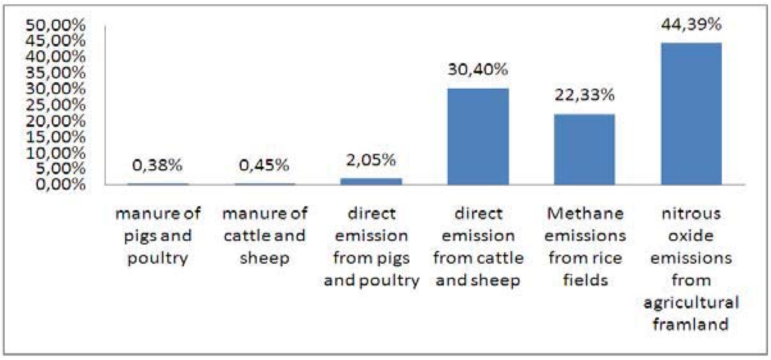

Fig. 2. Carbon dioxide equivalent calculated in accordance with the share of emission sources

Technology to reduce nitrous oxide emissions from farmland. N_2 in soil generated mainly by microorganism with the reaction of nitrification and denitrification. Nitrification will oxide ammonium salt to nitrate, denitrification will reduce nitrate to N_2 or intermediate products of NO and N_2O by soil microbeads. Generally, the reaction of nitrification emit much more N_2O than denitrification does. Factors that affect agricultural N_2O emission are soil type, crop type, fertilization, irrigation and other agricultural practices and climatic factors (temperature, precipitation, light), etc. The supply of nitrogen and the use of nitrogen fertilizer have a significant role in promoting the N_2O emissions from agricultural soils. Excessive fertilization increases the emission rate of N_2O. Denitrification in soil is closely related to the effective carbon content of soil, and has nothing to do with the amount of total carbon. Adding organic matter to soil, such as plant waste or manure, can greatly increase the intensity of denitrification. Intermittent irrigation in dry soil promotes the denitrification process, thus increasing the production and emissions of N_2O. It is the principle way to reduce agricultural N_2O emissions by reducing the quantity of fertilizer usage, improving the efficiency of nitrogen usage, using the slow-release fertilizer and adding nitrification inhibitor.

Formula fertilization by soil testing, improving nitrogen utilization, avoiding N_2O emissions caused by excessive fertilization in farmland. Currently formula fertilization by soil testing is the scientific fertilization developing trend in the world today, it is also Chinese scientific fertilization technology. By a reasonable ratio of nutrients, changing the way of superficial fertilization to deep fertilization, mixing organic and chemical fertilizer can improve the nitrogen utilization. If the use efficiency of nitrogen can be improved from 20%-30% to 30%-40%, 10% of N_2O emissions can be reduced. In 2007, China Ministry of Agriculture provided formula fertilization by soil testing services to more than 100 million farmers with free of charge, 4.27 x 108 hm^2 soil was formula fertilization by soil testing. Ratio of fertilizer utilization increased by 3 percentage points. So, 3% of N_2O emissions in the farmland will be reduced by formula fertilization by soil testing.

Using controlled-release feritilizer and slow-release fertilizer can reduce N_2O emissions in farmland. Ammonium bicarbonate and urea is the fertilizer which is largely used by Chinese agriculture, the problem is that those fertilize exit the shorting of short fertilizer, large amount of evaporation loss, low nitrogen utilization. Compared with the application of ordinary urea and ammonium bicarbonate, long-term ammonium bicarbonate and urea can significantly reduce N_2O emissions. The reduction rate is 74% to ammonium bicarbonate, 78% to urea, slow-release urea can reduce 62% of N_2O emissions compared with urea and reduce 54% of N_2O emissions compared with ammonium bicarbonate in corn field according to Huang Guohong (1998) research.

Reduction of soil nitrous oxide emissions by application of nitrification inhibitors. Nitrification inhibitors and nitrogen fertilizer applied together in agriculture can reduce N_2O release in soil. According to Delgado and Mosier reports, DCD and urea applied together in barley filed for 21 days, N_2O emissions reduced by 71%-82%. In the indoor and field soil trials, both nitrification inhibitors, fluorinated methane and dimethyl can inhibit the formation of soil NO, improve the content of NH4+ in soil and significantly reduced the N_2O emissions. Due to different conditions of farmland, nitrification inhibitors have different emission reduction effects on different fields.

1. Agro-GHG emission module

As various production sectors are already set up in GTAP-E, we only choose the sectors in the GTAP-E model that reflect agro-GHG emissions. We select sectors emitting agro-GHG according to sector classification of GTAP-E. Then data of agriculture department greenhouse gas emissions will be combined into the database so as to construct the agricultural greenhouse gas emissions module.

The simulation is realized mainly by the primary factors and energy investment, intermediate input (excluding energy) and output in the model. Specific GTAP-E nested structure chart is as follows.

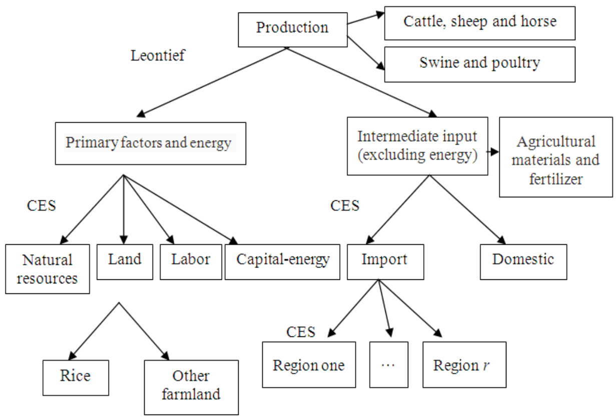

Fig. 3. Agricultural greenhouse gas emissions module

In the design of agricultural greenhouse gas emissions, agricultural greenhouse gas emissions is proportional to the planting area, breeding scale, fertilizer usage, as shown in Figure 3.

In the revised GTAP-E database, agro-GHG emission data of various countries are added on the basis of GTAP-E data. Agricultural greenhouse gas emissions data is set on the base of emissions source, emissions source type (domestic or imported) and emissions activities (what specific emissions department). The agro-GHG emission data are four-dimensional data, which can clearly explain which part of a specific country produces agro-GHG through inputs about region. That is, it is a four-dimensional variable EAGHG (i, r, s, t), wherein, i refers to emission source i, r refers to type of emission source r (domestic and import), s refers to sector of emission activities, and t refers to emission region.

The agro-GHG emission equation of region r using agricultural product i is:

$$AGHG(r,i) = \sum_{j \in PROD-COMM} \left[AGHGIF(i,j,r) + AGHGDF(i,j,r)\right] + AGHGDG(i,r) +$$

$$+AGHGIG(i,r) + AGHGDP(i,r) + AGHGIP(i,r),$$

where *AGHG* (*r*, *i*) refers to the amount of agro-GHG emissions in region *r* using energy *i*. According to this deduction, the total amount of agro-GHG emissions in region *r* is:

$$GAGHG(r) = \sum_{j \in PROD-COMM} AGHG(r,i)$$

Then, the global agro-GHG emissions are:

$$GAGHGW = \sum_{r \in REG} GAGHG(r)$$

In the design of agro-GHG micro emission amount, the amount of agro-GHG emissions is in direct proportion to the amount of emission sources used. The following equation is adopted (taking production emissions as an example):

$GAGHG\ (i, j, r) = qfd\ (i, j, r)$

where *GAGHG* (*i*, *j*, *r*) refers to the percentage change of agro-GHG emitted by sector *j* in region *r* after using *i*. *qfd*(*i*, *j*, *r*) refers to the percentage change of *i* used by sector *j* in region *r*.

3. Module of agricultural nitrous oxide emissions reduction by technology

The formula used to calculate the quantity of agricultural nitrous oxide emissions is:

$E_2 = (1 + A_2{*}F{*}S)$,

where E_2 refers to agricultural nitrous oxide emission, A_1 refers to the emission coefficient of unit area of farmland. *F* refers to the amount of nitrogen for the unit area use of nitrogen fertilizer. Numerical 1 represents background emissions, i.e. the annual emissions quantity of nitrous oxide with per unit area farmland without using nitrogen fertilizer. *S* refers to farmland area.

$$F = A_2' f(Q),$$

where A_2' refer to the inputs efficiency of nitrogen fertilizer. *Q* refers to the yield of per unit area.

So, two technology variables which effect nitrous oxide emissions in agriculture soil can be found in above formula, one is A_1, which is effected by the change of nitrogen fertilizer itself. The other is A_2', which is effected by controlling the quantity of nitrogenous fertilizer usage in per unit area of farmland.

To realize the reduction of agricultural nitrous oxide emissions by technology in GTAP-E model, technology coefficient of emissions is connected with capital, quantity of fertilizer used in farmland is connected with intermediate input of fertilizer. The mechanism is that capital which is invested to improve technology is increased, under the stable condition of yield, reduced the usage quantity of nitrogenous fertilizer in soil (see Figure 4).

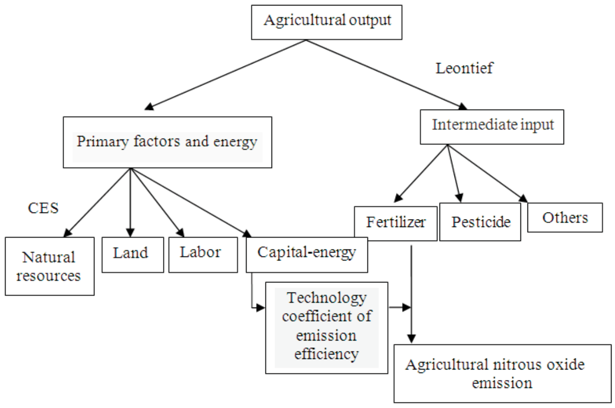

Fig. 4. Structure of agricultural nitrous oxide emission reduction by technology in GTAP-E

3. Data sources

3.1. Input-output data. The input-output data of the GTAP-E model of China's agro-GHG emissions is established on the basis of the input-output table of various countries and regions, and the base period is 2004. We total up the 57 sectors in the model into 13 broad sectors, i.e. rice, wheat, cattle, sheep and horses, pigs and poultry, coal, petroleum, natural gas, petroleum products, electricity, energy-intensive industry, other industries, other agricultural branches, and service industry. The model database includes data of connected mutual inputs among 13 sectors. In this way, each sector establishes relationships through inputs. Besides the input data among sectors, the model also includes initial endowment inputs, including capital, land and labor. The endowment demands of each sector are reflected through this input. The output of a sector is the total of intermediate inputs and initial endowment inputs.

3.2. Trade data. The trade data of the GTAP-E model of China's agro-GHG emission reduction are the bilateral trade data of countries and regions, tariff data and trade transportation data, with the base period in 2004. We total up the 117 countries and regions in the model into 9 countries and regions, i.e. the USA, the EU, Eastern European countries and former USSR countries, Japan and other Annex I countries, China, energy net export countries, India, and other countries in the world.

In the model database, bilateral trade data is three-dimensional data, determined by export products, export country and import country. Tariff data is also three-dimensional data, determined by export products, export country and import country; and trade transportation data is four-dimensional data, determined by marginal products, export products, export country and import country.

3.3. Data of agricultural greenhouse gas emissions. Agricultural greenhouse gas emissions data is same as agricultural greenhouse gas emissions data.

4. The benchmark scenario (the baseline forecast)

4.1. Agricultural greenhouse gas emission in the world (2004-2020). In 2020, cattle, sheep and horse department produce the most agricultural greenhouse gas in global. From the average annual growth rate of the agricultural greenhouse gas emissions, pig and poultry department has the fastest growth rate, followed by other agricultural sector. The emission of rice department declined slightly.

Table 4. The baseline forecast data of global agricultural greenhouse gas emission (classified by departments, carbon dioxide equivalent, millions *t*)

Sectors	2004	2010	2015	2020	The growth rate
Rice	749.44	756.48	751.41	735.76	-0.61%
Other crops[1]	1333.02	1473.83	1568.98	1647.56	7.32%
Cattle, sheep and horse	2572.52	3111.26	3653.49	4261.25	18.32%
Pig and poultry	517.55	660.37	809.65	980.84	23.75%
Other agriculture[2]	572.95	693.89	825.11	982.67	19.70%

Notes: [1]Wheat, cereals, vegetables, fruits, nuts, oilseeds, sugar cane, sugar beet, fiber; other crops, the processing of rice. [2]Milk, wool, silk, cocoons, forestry, and fisheries
Source: Estimated by the author (2010).

4.2. Agricultural GHG emissions in China (2004-2020). In 2020, cattle, sheep and horse sector produce the most agricultural greenhouse gases in China, followed by services sector. From the growth point of view, cattle sheep and horse is the fastest, followed by pig and poultry sector and other agriculture sector.

Table 5. The baseline forecast data of Chinese agricultural greenhouse gas emission (classified by departments, carbon dioxide equivalent, millions *t*)

Sectors	2004	2010	2015	2020	The growth rate
Rice	260.24	261.96	256.75	245.82	-1.88%
Other crops	375.83	412.31	423.81	423.24	4.04%
Cattle, sheep and horse	344.88	511.19	686.01	877.21	36.50%
Pig and poultry	184.75	267.12	354.13	450.99	34.65%
Other agriculture	14.17	19.41	24.37	29.99	28.39%

Source: Estimated by author (2010).

5. The policy simulation scenario to reduction of farmland nitrous oxide emission by technology

Policy simulation scenario one: 20% reduction of agricultural nitrous oxide emissions in per unit area of farmland by technology.

In the baseline scenario we assumed 20% reduction of agricultural nitrous oxide emissions in per unit area of farmland by technology. Under this condition, we analyze the impact of agriculture nitrous oxide emissions reduction by technology on macro economic and each department (especially the agriculture department).

Policy simulation scenario two: 30% reduction of agricultural nitrous oxide emissions in per unit area of farmland by technology.

In the baseline scenario we assumed 30% reduction of agricultural nitrous oxide emissions in per unit area of farmland by technology. Under this condition, we analyze the impact of agriculture nitrous oxide emissions reduction by technology on macro economic and each department (especially the agriculture department).

Policy simulation scenario three: 50% reduction of agricultural nitrous oxide emissions in per unit area of farmland by technology.

In the baseline scenario we assumed 50% reduction of agricultural nitrous oxide emissions in per unit area of farmland by technology. Under this condition, we analyze the impact of agriculture nitrous oxide emissions reduction by technology on macro economic and each department (especially the agriculture department).

6. The simulation results

6.1. Impact on macroeconomic. Reduction of farmland nitrous oxide emissions by technology will increase Chinese social benefits and real GDP, but GDP price index, export price index, consumer price index and exports will decrease.

Reduction of farmland nitrous oxide emissions by technology will increase the price of production elements, in which the land price rise faster, followed by skilled labor, non-skilled labor and capital. Reduction of farmland nitrous oxide emissions by technology led the following positive effect on China's macroeconomy. The first is Chinese social welfare and real GDP increase, the second is GDP price index, export price index and the consumer price index decrease, the third is exports reduce, and the fourth is the production elements prices rise. It could be expressed that these positive impacts represent the desired transfer result of production mode.

Table 6. Compared to the baseline scenario, the macro effect of the three simulation scenario

Index	The first simulation	The second simulation	The third simulation
Welfare ($1 million)	2007.91	5103.46	7378.49
Trade conditions ($1 million)	604.48	1544.77	2242.30
Actual GDP (%)	0.09	0.22	0.32
GDP price index (%)	-0.02	-0.05	-0.07
Export price index (%)	0.00	-0.01	-0.02
Exports (%)	-0.02	-0.06	-0.09
Imports (%)	-0.11	-0.27	-0.39
Factor prices (%)			
Land	0.99	2.53	3.67
Non-skilled labor	0.04	0.10	0.15
Skilled labor	0.03	0.07	0.10
Capital	0.01	0.03	0.04
Consumer price index	-0.05	-0.12	-0.17

Source: GTAPAGRI model simulation results.

6.2. Impact on the agricultural sector. In terms of the product price change, all agricultural sectors are on the rising trend except the other crops sector. Outputs of department of cattle and sheep, other agriculture are on the downward trend. Refer to export change, only the sector of other crops show a growing trend, the rest agricultural sectors are on a declining trend. However, on the import side, the sector of other crops is on a declining trend, the rest agricultural sectors show a growing trend. In terms of land rental price change, only other crops show a growing trend. In terms of labor cost, all agricultural sectors are on the rising trend except the sector of other agriculture.

Table 7. The impact on the agricultural sector of simulation scenario, compared to the baseline scenario

	Price changes (%)			Output changes (%)		
Sectors	The first simulation	The second simulation	The third simulation	The first simulation	The second simulation	The third simulation
Rice	0.39	1.00	1.45	0.08	0.21	0.30
Other crops	-0.46	-1.16	-1.67	0.21	0.53	0.76
Cattle and sheep	0.30	0.76	1.11	-0.05	-0.13	-0.19
Pigs and poultry	0.20	0.52	0.76	0.01	0.03	0.04
Other agriculture	0.01	0.01	0.02	-0.01	-0.03	-0.05
	Exports changes (%)			Imports changes (%)		
Sectors	The first simulation	The second simulation	The third simulation	The first simulation	The second simulation	The third simulation
Rice	-3.89	-9.61	-13.61	2.24	5.79	8.49
Other crops	1.81	4.66	6.78	-0.76	-1.92	-2.76
Cattle and sheep	-1.11	-2.81	-4.05	0.58	1.48	2.15
Pigs and poultry	-0.50	-1.28	-1.85	0.26	0.66	0.95
Other agriculture	-0.06	-0.14	-0.20	0.03	0.08	0.11
	Land rental price changes (%)			Labor cost changes (%)		
Sectors	The first simulation	The second simulation	The third simulation	The first simulation	The second simulation	The third simulation
Rice	-0.03	-0.07	-0.10	0.18	0.46	0.66
Other crops	0.06	0.15	0.21	0.32	0.82	1.18
Cattle and sheep	-0.14	-0.36	-0.52	0.04	0.10	0.14
Pigs and poultry	-0.09	-0.22	-0.32	0.11	0.27	0.39
Other agriculture	-0.17	-0.44	-0.64	-0.01	-0.04	-0.05

Source: GTAP-E model simulation results.

6.3. Impact on other sectors. In terms of the product price change, most of the industrial sectors are on the declining trend except the light industrial, heavy industrial, transportation and communication department and other services. Output of departments of processed food, cotton and textile, public utilities and building industry, transportation and communication and other service are on the rise trend. On the export side, beside the chemical products sector, light industrial, heavy industrial, transportation and communication department and other service, the rest departments show a growing trend. On the import side, departments of light industrial, heavy industrial, public utilities and building industry, transportation and communication department and other service are on a rise trend. In most of the departments, the capital and labor prices are on the downward trend.

Table 8. The impact on other sectors of simulation scenario, compared to the baseline scenario

	Price changes (%)			Output changes (%)		
Sectors	The first simulation	The second simulation	The third simulation	The first simulation	The second simulation	The third simulation
Chemical products	0	0	0	-0.65	-1.66	-2.4
Natural gas	-0.03	-0.07	-0.1	-0.15	-0.39	-0.57
Coal	-0.06	-0.16	-0.23	-0.01	-0.03	-0.05
Petroleum	-0.03	-0.07	-0.1	-0.01	-0.02	-0.03
Electricity	-0.02	-0.04	-0.06	-0.06	-0.15	-0.22
Oil products	-0.02	-0.05	-0.08	-0.04	-0.09	-0.13
Processed products	-0.14	-0.36	-0.52	0.11	0.29	0.41
Cotton and textile products	-0.03	-0.08	-0.12	0.09	0.22	0.32
Light industry	0.02	0.05	0.07	-0.05	-0.12	-0.17
Heavy industry	0.01	0.02	0.02	-0.04	-0.11	-0.16
Public utilities and building industry	-0.02	-0.04	-0.06	0.02	0.05	0.07
Transportation and communication	0.01	0.01	0.02	0	0.01	0.01
Other services	0.01	0.03	0.05	0.05	0.14	0.2
	Exports changes (%)			Imports changes (%)		
Sectors	The first simulation	The second simulation	The third simulation	The first simulation	The second simulation	The third simulation
Chemical products	-0.05	-0.12	-0.18	-0.58	-1.48	-2.14
Natural gas	0.72	1.84	2.69	-0.46	-1.17	-1.69
Coal	0.2	0.51	0.75	-0.16	-0.41	-0.59
Petroleum	0.1	0.26	0.37	-0.07	-0.18	-0.27
Electricity	0.06	0.16	0.24	-0.12	-0.3	-0.43
Oil products	0.02	0.06	0.09	-0.08	-0.2	-0.29
Processed products	0.49	1.25	1.81	-0.18	-0.45	-0.65
Cotton and textile products	0.1	0.24	0.35	-0.01	-0.03	-0.05
Light industry	-0.13	-0.33	-0.48	0.05	0.13	0.19
Heavy industry	-0.07	-0.17	-0.25	0.01	0.02	0.03
Public utilities and building industry	0.05	0.14	0.2	0	0	0.01
Transportation and communication	-0.04	-0.1	-0.14	0.04	0.11	0.16
Other services	-0.06	-0.16	-0.23	0.05	0.13	0.19
	Capital price changes (%)			Labor cost changes (%)		
Sectors	The first simulation	The second simulation	The third simulation	The first simulation	The second simulation	The third simulation
Chemical products	-0.64	-1.64	-2.37	-0.68	-1.72	-2.37
Natural gas	-0.16	-0.4	-0.57	-0.19	-0.49	-0.57
Coal	-0.03	-0.07	-0.1	-0.04	-0.09	-0.1
Petroleum	-0.02	-0.04	-0.06	-0.02	-0.05	-0.06
Electricity	-0.07	-0.18	-0.26	-0.12	-0.31	-0.26
Oil products	-0.03	-0.09	-0.13	-0.1	-0.25	-0.13
Processed products	0.12	0.32	0.46	0.1	0.26	0.46

Table 8 (cont.). The impact on other sectors of simulation scenario, compared to the baseline scenario

	Capital price changes (%)			Labor cost changes (%)		
Sectors	The first simulation	The second simulation	The third simulation	The first simulation	The second simulation	The third simulation
Cotton and textile products	0.11	0.27	0.39	0.08	0.2	0.39
Light industry	-0.03	-0.08	-0.11	-0.05	-0.14	-0.11
Heavy industry	-0.03	-0.08	-0.11	-0.06	-0.15	-0.11
Public utilities and building industry	0.04	0.11	0.15	0.02	0.04	0.15
Transportation and communication	0.02	0.05	0.07	-0.01	-0.04	0.07
Other services	0.07	0.18	0.25	0.05	0.12	0.25

Source: GTAP-E model simulation results.

6.4. Influence on the trade balance. To the sectors which lose trade balance we can include the following ones: rice, cows and sheep, pigs and poultry, other agriculture, light industry, heavy industry, transportation and communication, and other services.

Table 9. The impact on trade balance of simulation scenario, compared to the baseline scenario (1 million dollars)

Sector	The first simulation	The second simulation	The third simulation
Rice	-0.82	-2.05	-2.92
Other crops	280.61	709.56	1021.99
Cattle and sheep	-2.04	-5.23	-7.60
Pigs and poultry	-11.91	-30.47	-44.27
Other agriculture	-2.94	-7.21	-10.13
Chemical products	611.76	1559.20	2258.82
Natural gas	0.19	0.49	0.71
Coal	7.34	18.73	27.15
Petroleum	41.50	105.91	153.60
Electricity	0.52	1.33	1.94
Oil products	16.83	42.97	62.33
Processed products	70.36	178.11	256.74
Cotton and textile products	143.17	362.64	522.96
Light industry	-221.13	-561.78	-811.91
Heavy industry	-275.31	-691.74	-991.56
Public utilities and building industry	0.70	1.78	2.56
Transportation and communication	-32.59	-82.54	-119.03
Other services	-21.76	-54.95	-79.08

Source: GTAP-E model simulation results.

6.5. The influence on the welfare of the other countries. Social welfare has decreased in the countries such as sub-Saharan Africa, the Pacific region, energy exporter, East Asia, Southeast Asia, Latin America, the Middle East and North Africa, and other countries. However, social welfare of the United States, the European Union, Japan, India, South Asia and North America will increase.

Table 10. Countries welfare change in the three simulations, compared to the baseline scenario

Sectors	The first simulation	The second simulation	The third simulation
The Pacific region	-3.95	-9.99	-14.39
Japan	38.42	97.82	141.61
The United States	29.35	75.48	110.06
India	6.96	17.78	25.81
Energy Exporter	-5.28	-13.44	-19.45
East Asia	-18.42	-46.82	-67.71
Southeast Asia	-16.92	-42.98	-62.10
South Asia	0.93	2.41	3.53
North America	0.06	0.21	0.37
Latin America	-2.81	-6.90	-9.74

Table 10 (cont.). Countries welfare change in the three simulations, compared to the baseline scenario

Sectors	The first simulation	The second simulation	The third simulation
The European Union	114.32	291.64	422.79
The Middle East and North Africa	-24.30	-61.98	-89.84
Sub-Saharan Africa	-5.95	-15.12	-21.87
Other countries	-17.12	-43.68	-63.33

Source: GTAP-E model simulation results.

Conclusions and suggestions

Reduction of farmland nitrous oxide emissions by technology has the following positive effect on China's macro economy. The first is Chinese social welfare and real GDP increase, the second is GDP price index, export price index and the consumer price index decrease, the third is exports reduce, and the fourth is the production elements prices rise. It could be expressed that these positive impacts represent the desired transfer result of production mode.

Reduction of farmland nitrous oxide emissions by technology relatively has negative effects on grain sector and also extends the negative effects to other sector which are connected with grain sector, such as pig and poultry industrial and other agriculture industrial, however, it makes cattle and sheep sector, crop sector gets the relative benefits. It has led to exports increase and imports decrease in such sectors as natural gas, coal, petroleum, electricity and oil products sectors, processed food, cotton and textile products sector. But in the light industry and heavy industry, exports decrease and imports increase.

Sectors which lose trade balance include rice, cows and sheep, pigs and poultry, other agriculture, light industry, heavy industry, transportation and communication, and other services.

Social welfare has decreased in the countries including sub-Saharan Africa, the Pacific region, energy exporter, East Asia, Southeast Asia, Latin America, the Middle East and North Africa, and other countries.

Overall, reduction of farmland nitrous oxide emissions by technology has relatively positive effects on agricultural sector, but plays a positive role in China’s economic growth.

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