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# Reduction potential and control policy of agricultural nitrous oxide greenhouse gas emissions in China


## Abstract

By using the improved global general equilibrium model of the environment (GTAP-E) and the database of agricultural nitrous oxide greenhouse gas emission established by the authors, the paper simulates the reduction potential and control policy of Chinese agricultural nitrous oxide greenhouse gas emissions. The result shows that levy carbon tax on agricultural nitrous oxide has changed the model of China's export-oriented international trade, Chinese welfare and real GDP has increased, while GDP price index, export price index, consumer price index have raised. Prices of land, unskilled labor drop, prices of capital and the skilled labor assumed the upward trend. The negative influence of carbon tax on the agricultural nitrous oxide to the paddy rice sector and other crop sector is much serious than on animal husbandry. Most of the sectors has lose trade balances, the national welfare of developing countries and some developed countries have reduced, is advantageous to Chinese economy.


**Keywords:** agricultural nitrous oxide greenhouse gas, potential of emission reduction, policy implications.
**JEL Classification:** Q56.

## Introduction

According to the definition of intergovernmental panel on climate change, the agricultural source of the non-$CO_2$ greenhouse gas emissions mainly include the following four aspects: methane emissions caused by feed fermentation in the intestines of ruminant animals, methane emissions resulted from the anaerobic environment for the soil under water for a long time in the rice planting; nitrous oxide emissions caused by excessive amounts of nitrogen fertilizer in farmland soil; methane and oxygen and nitrogen oxide emissions in the process of livestock manure storage.

The fourth assessment report of IPCC shows that agriculture is the main source of greenhouse gas emissions. According to estimates, globally, agricultural emissions of $CH_4$ accounting for 50% of the total $CH_4$ emissions caused by human activities, $N_2O$ accounting for 60%. If not implement additional agricultural policy, it is estimated that by 2030, agricultural source methane and nitrous oxide emissions than 2005 will be up 60% and 35%~60%. The IPCC also points out, the share of agricultural greenhouse gas emissions in global greenhouse gas total emissions, which is about 14%, is more than the whole of proportion of transportation industry in global greenhouse gas total emissions.

According to the data of the Initial National Information Bulletin of the People's Republic of China on Climate Change, $CH_4$ emissions in China mainly come from agricultural activities, energy activities and waste disposal. $CH_4$ emissions in 1994 amounted to 34.29 million tons, among which those from agricultural activities were 17.2 million tons, those from energy activities about 9.37 million tons, and those from waste disposal about 7.72 million tons. Agricultural activities are the largest source of $CH_4$ emissions, accounting for 50.15%, about 10.18 million tons of which are emissions from intestinal fermentation of ruminants, 6.15 million tons emissions from rice plantation and 870 thousand tons emissions from animal manure management systems.

As a major country developing toward industrialization where agriculture still occupies a leading position, China's emission reduction policy has always been one of the hotspots in the international political, economic, environmental and academic circles. The GHG emission reduction problem in China has drawn global concern, mainly for the following reasons. Firstly, the Chinese economy has been developing rapidly since the 1980s, and this tendency is expected to last for quite a long future period, which makes China one of the countries with a rapidly rising GHG emission ratio. Secondly, though China's GHG emission ratio per capita is far lower than that of developed countries such as the USA, as China's population base is extremely large, the total amount of emissions is rising rapidly. Thirdly, as China's population base is large, and its reliance on agricultural production is great, agricultural production accelerates with the growth of population, which imposes challenges for emission reduction of agro-greenhouse gases. With economic development in China, China's GHG emissions will be further increased. So China must clarify the following points on the problem of global GHG emissions reduction: (1) How to evaluate the risk of global climate change to China; (2) How to understand China's national interests in the problem of global GHG emissions reduction; (3) How to participate in


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the reformation and innovation of the global GHG emissions reduction mechanism (firstly by clarifying the advantages, disadvantages, gains and losses of various emission reduction mechanisms); (4) How to prepare policies related to global GHG emissions reduction at the international and national levels (including foreign policy, economic, trade and environment policies etc.); and (5) How to conduct agro-GHG emission reduction. On this basis, a complete and unified Chinese national strategy on the problem of global agro-GHG reduction has been formed, to guide the internal affairs and foreign policy in the GHG reduction problem.

## 1. Research review

In 2008, the U.S. Environmental Protection Agency, Washington, Steven K. Rose and the Japanese National Institute for Environmental Studies Huey-Lin Lee study of non-$CO_2$ greenhouse gases (including agriculture, greenhouse gas) emissions data on the impact characteristics of the greenhouse effect. They believe that non-$CO_2$ (carbon dioxide) emissions of greenhouse gases equivalent to the third radiation, and emissions from land-related activities around the world 2/3, the non-$CO_2$ (carbon dioxide) greenhouse gases, therefore, simulation of non-$CO_2$ (carbon dioxide) greenhouse gas emissions estimates for the study of climate change and climate change strategy, the net environmental impacts is necessary.

Table 1. The global non-$CO_2$ greenhouse gases emissions in 2001

| Sectors | Percentage change |
|---|---|
| Rice | 8.0% |
| Wheat | 2.3% |
| Other crops | 2.7% |
| Fruits and vegetables | 6.0% |
| Oil crops | 2.0% |
| Sugar crops | 0.7% |
| Fiber crops | 1.3% |
| Other agriculture | 2.2% |
| Livestock feed | 24.6% |
| Animal products | 5.5% |
| Milk | 5.4% |
| Forestry | 0.0% |
| Other sectors | 39.4% |

Source: Rose, Steven, Huey-Lin Lee. Non-$CO_2$ Greenhouse Gas Emissions Data for Climate Change Economic Analysis, GTAP Working Paper No. 43, 2008.

Robert C. Hyman (2002) uses a global CGE model to simulate the reduction potential and cost for non-$CO_2$ (including agro-GHG $CH_4$ and $N_2O$, as well as $SF_6$ and PFCS) in emission reduction. The study found that as non-$CO_2$ gases have a very high comprehensive warming tendency, non-$CO_2$ abatement is an important cost-effective policy, which plays an important role in GHG reduction. The study also found that the contribution of non-$CO_2$ to cost-effectiveness is not proportional to their emissions. For the USA, Japan and the EU, the contribution ratio of non-$CO_2$ gases in relation to GHG emissions with GWP as standard is lower than 20%, while its contribution to GHG cost-effectiveness is two times that of the former. For developing countries, non-$CO_2$ emissions account for a larger proportion, but these emissions come from ruminants and rice production for which reduction is difficult. So the contribution of non-$CO_2$ gases to cost-effectiveness is larger, but this portion is greatly related to their portion of emissions.

Bruce A. McCarl (2000) thinks, the impact of greenhouse gas emissions reduction on agricultural economic depends on three aspects, which are emission intensity, emissions market efficiency and the rate of technological progress on agricultural and non-agricultural department.

IFPRI (2008) proposed the non-$CO_2$ greenhouse gas of the agriculture source should be added to the content of the climate talks. On the international climate change negotiations, increasing agricultural investment has been mentioned, such as promote agricultural science and technology, build the agricultural emissions database and increase infrastructure construction of emissions, etc.

By establishing the database for and constructing the GTAP-E model of Reduction Potential and Control Policy for Chinese Agricultural Greenhouse Gas Emissions, and Introduction of “Carbon Tax” to achieve the established emission reduction targets, we simulates control policies and the reduction potential of Chinese Agricultural Nitrous Oxide Greenhouse Gas Emissions.

## 2. China-agro-GHG emission reduction GTAP-E model

**2.1. Basic hypotheses of the model.** Hypothesis of producers: (1) each sector produces one kind of product; (2) no impact on market, price takers; (3) minimizing cost; (4) nested Leontief/CES production function allows substitution between domestic production and import input (hypothesized by Armington), and substitution among labor, capital and land.

Hypothesis of investors: (1) price takers; (2) minimizing cost; (3) constructing capital goods with domestic goods and imported goods.

Hypothesis of consumers: (1) only including one kind of consumers; (2) maximizing effect within budget; (3) price takers; (4) using CDE function to show consumption structure; (5) fixed total consumption or a certain proportion of GDP.

Hypothesis of export: (1) products allowed for export and products for domestic use are not completely substitutes; (2) export demand curve is declining.

Hypothesis of the government: (1) minimizing cost; (2) total expenditure is fixed or is a certain proportion of the total consumption.

Hypothesis of price: (1) price is equal to cost, that is, zero profit condition; (2) model is currency-neutral, which, therefore, needs a price to be currency equivalent. Generally, exchange rate is selected as currency equivalent.

Hypothesis of goods market: goods market is always balanced, that is, market-clearing hypothesis.

Other hypotheses include (1) capital and labor are completely mobile in China; (2) land resources are not completely mobile in China; (3) markets of various products and elements are perfectly competitive markets.

**2.2. Model structure.** *2.2.1. Production model.* CES production function. In production, the producers' aim is to maximize profit, that is to minimize cost. Take two kinds of intermediate input for example.

Objective function:

$$\underset{x_1, x_2}{Min}\ p_1 x_1 + p_2 x_2 . \quad (1)$$

Limiting condition:

$$y = \alpha(\delta_1 x_1^{-\rho} + \delta_2 x_2^{-\rho})^{-1/\rho}, \quad (2)$$

where $x_1$ and $x_2$ refer to the amounts of intermediate input, $p_1$ and $p_2$ refer to their market prices, $y$ refers to production level, $a$ refers to efficiency parameter, and $\delta_1$ and $\delta_2$ refer to distribution parameters. $\sigma = 1/(1+\rho)$ refers to the invariable elasticity of substitution of two intermediate inputs.

Lagrange function is established to minimize total cost:

$$C = p_1 x_1 + p_2 x_2 + \lambda[y - \alpha(\delta_1 x_1^{-\rho} + \delta_2 x_2^{-\rho})^{-1/\rho}]. \quad (3)$$

First-order conditions are:

$$\partial C / \partial x_1 = p_2 - \lambda(\partial f(x) / \partial x_2), \quad (4)$$

$$\partial C / \partial x_2 = p_1 - \lambda\left(\partial f(x) / \partial x_1\right), \quad (5)$$

$$\partial C / \partial \lambda = y - \alpha\left(\partial_1 x_1^{-p} + \partial_2 x_2^{-p}\right)^{-1/p}. \quad (6)$$

The demand function of intermediate inputs may be evaluated through solution:

$$x_1 = y \cdot \left(\frac{s_1 \cdot p}{p_1}\right)^{\partial}, \quad (7)$$

$$x_2 = y \cdot \left(\frac{s_2 \cdot p}{p_2}\right)^{\partial}, \quad (8)$$

where

$$s_2 = x_i / (p_1 x_1 + p_2 x_2), \quad (9)$$

$$p = \left(s_1 \cdot p_1^{1-\partial} + s_2 \cdot p_2^{1-\partial}\right)^{1/(1-\partial)}. \quad (10)$$

The equation of alternation labeled with CES in the production structure diagram of GTAP-E is the application of the result of the above deduction. The equation of each level of CES is the same, and each level differs in that the elements they put in differ and the elasticity of substitution among factors differs.

As for the Leontief structure on the top level, the specific expression is as follows:

Production function: $Q = \text{Min}(ax_1, bx_2)$. (11)

Function of intermediate input demand:

$$x_1 = Q/a, \quad (12)$$

$$x_2 = Q/b, \quad (13)$$

where $Q$ refers to the final output, $a$ and $b$ refer to technical parameters, and $x_1$ and $x_2$ refer to quantity of inputs. The equation in which the profit of the ultimate perfectly competitive market is 0 is expressed as:

$$P \cdot Q = \sum_e PFE_i \cdot QFE_i + \sum_e PF_i \cdot QF_i, \quad (14)$$

where $P$ refers to the market price of final products, $Q$ refers to final output, $PFE_i$ refers to the price of primary element input, $QOF_i$ refers to the quantity of inputs, $PF_i$ refers to the price of intermediate inputs, and $QF_i$ refers to the quantity of intermediate inputs. The market clearing equation of final products is:

$$Q(i,r) = QDS(i,r) + QST(i,r) + \sum_{s \in REG} QXS(i,r,s), \quad (15)$$

where $i$ refers to commodities or services, $r$ and $s$ represent regions; $Q$ ($i$, $r$) refers to output of goods or service $i$ in $r$ region. $QDS$ ($i$, $r$) represent goods or services $i$ for domestic consumption; $QST$ ($i$, $r$) refers to goods or service $i$ used as marginal products; $QXS$ ($i$, $r$, $s$) refers to goods or service $i$ exported from region $r$ to region $s$.

*2.2.2. Goods circulation module.* After production, goods will have a manufacturer value *VOA* (*i*, *r*), and then the manufacturer will be taxed or given a subsidy *PTAX* (*i*, *r*), from which market value *VOM* (*i*, *r*) will be obtained. If the market value of goods export is *VXMD* (*i*, *r*, *s*), an export tax is levied on the goods or they are given export subsidy *XTAXD* (*i*, *r*, *s*), and the export offshore international value *VXWD* (*i*, *r*, *s*) will be obtained. Plus the freightage for transportation to *s* *VTWR* (*i*, *r*, *s*), the *CIF* international value *VIWS* (*i*, *r*, *s*) will be obtained.

The import country levies an import tax on the goods *ITAXD* (*i*, *r*, *s*), and the domestic market value of the import country *VIMS* (*i*, *r*, *s*) will be obtained, and the country importing the goods will distribute and consume the goods in the private sector and government sector, and use it as intermediate inputs of producers. Of course, the surplus *VDM* (*i*, *r*) after goods export of region *r* *VDM* (*i*, *r*) is purchased by the private sector of the home country *VDPM* (*i*, *r*, *s*), government sector *VDGM* (*i*, *r*, *s*) and producer *VDFM* (*i*, *r*, *s*). The above relationship is expressed in an equation as follows:

$$VOM(i, r) = VOA(i, r) + PTAX(i, r) \quad (16)$$

$$VXWD(i, r, s) = VXMD(i, r, s) + XTAXD(i, r, s) \quad (17)$$

$$VIWS(i, r, s) = VXWD(i, r, s) + VTWR(i, r, s) \quad (18)$$

$$VIMS(i, r, s) = VIWS(i, r, s) + ITAXD(i, r, s) \quad (19)$$

$$VIMS(i, r, s) = VIPM(i, r, s) + VIGM(i, r, s) + \sum_{j \in PROD} VIFM(i, r, s), \quad (20)$$

$$VDM(i, r) = VDPM(i, r, s) + VDGM(i, r, s) + VDFM(i, r, s) \quad (21)$$

*2.2.3. Market clearing.* In the following equation, the meanings of the labels after each variable are as follows: *r* refers to region; *s* refers to region (destination); *n* refers to non-depository goods; *d* refers to goods needed; *p* refers to goods produced; *t* refers to negotiable commodities; *e* refers to endowed products; *em* refers to mobile endowed products; *es* refers to immobile endowed products; *ec* refers to endowed capital goods; *c* refers to capital goods.

Tradable goods market clearing equation:

$$QO(t, r) = QDM(t, r) + QST(t, r) + \sum_{s \in REG} QXMD(t, r, s). \quad (22)$$

Market clearing equation of imported goods:

$$QIM(t, r, s) = \sum_{r} QIMS(t, r, s) = \sum_{p} QIFM(t, \mathrm{p}, r) + QIPM(t, r) + QIGM(t, r). \quad (23)$$

Market clearing equation of goods produced at home and consumed at home:

$$QDM(t, r) = QDPM(t, r) + QDGM(t, r) + \sum_{s \in REG} QDM(t, r). \quad (24)$$

Market clearing equation of mobile endowments:

$$QO(em, r) = \sum_{s \in REG} QFM(em, p, r). \quad (25)$$

Market clearing equation of sluggish endowments:

$$QO(es, p, r) = QFE(es, p, r). \quad (26)$$

*2.2.4. Regional income and capital module.* Equation of private family sector total expenditure:

$$PRIVEXP(r) = INCOME(r) - SAVE(r) - \sum VGA(t, r). \quad (27)$$

Regional income equation:

$$\begin{aligned} INCOME(r) = {} & \sum_{e}\left[PS(e, r) \cdot QO(e, r) - (1 - DEP(r)) \cdot KB(r)\right] + \sum_{n}(1 - TO(n, r) \cdot PM(n, r) \cdot QO(n, r)) + \\ & + \sum_{em}\sum_{p}(TF(em, p, r) - 1) \cdot PM(em, p, r) \cdot QFE(em, p, r) + \sum_{es}\sum_{p}(TF(es, p, r) - 1) \cdot PMES(es, p, r) \cdot QFE(es, p, r) + \\ & + \sum_{t}\sum_{p}(TFM(t, p, r) - 1) \cdot PIM(t, p, r) \cdot QFM(t, p, r) + \sum_{t}(TPM(t, r) - 1) \cdot PIM(t, r) \cdot QPM(t, r) + \\ & + \sum_{t}(TPD(t, r) - 1) \cdot PM(t, r) \cdot QPD(t, r) + \sum_{t}(TGM(t, r) - 1) \cdot PIM(t, r) \cdot QGM(t, r) + \\ & + \sum_{t}(TGD(t, r) - 1) \cdot PM(t, r) \cdot QGD(t, r) + \sum_{t}\sum_{s}(2 - TX(t, r) - TXS(t, r, s)) \cdot PFOB(t, r, s) \cdot ZXS(t, r, s) + \\ & + \sum_{t}\sum_{r}(TMS(t, r) + TMS(t, r, s) - 2) \cdot PCIF(t, r, s) \cdot QXS(t, r, s) \end{aligned} \quad (28)$$

Capital change equation:

*Capital at the End of Period = Beginning Capital + Net Investment.*

$$KE(r) = (1 - DEP(r)) + KB(r) + REGIVN(r). \quad (29)$$

$$KSVCES\ (r) = \sum_{ec} QO(ec,r)\,, \quad (30)$$

$$RENTAL\ (r) = \prod_{ec} \left(PS\,(ec,r)\right)^{\frac{VOA(ec,r)}{\sum(ec)VOA(ec,r)}}\,, \quad (31)$$

$$QCGDS\ (r) = \sum_{c} QO\,(c,r), \quad (32)$$

$$PCGDS\ (r) = \prod_{c} \left(PS\,(c,r)\right)^{\frac{VOA\,(c,r)}{REGINV\ (r)}}\,, \quad (33)$$

$$KB(r) = \frac{KB(r)^0}{KSVCES\ (r)^0} \cdot KSVCES\ (r)\,, \quad (34)$$

$$RORC(r) = \frac{RENTAL(r)}{PCGDS(r)} - DEPR(r)\,, \quad (35)$$

$$RORE\ (r) = RORC\ (r) \cdot \left(\frac{KE\,(r)}{KB\,(r)}\right)^{-RORFLEX}. \quad (36)$$

*2.2.5. Market price module.* Prices of different markets are connected by taxes and subsidies. There are altogether six kinds of taxes, i.e. ordinary import tax, special import tax, ordinary export tax (subsidy), special export tax (subsidy), output tax (subsidy), income tax, primary element tax and consumption tax.

Output tax is the ratio of producer price and market price. It is output subsidy when greater than 1 and output tax when smaller than 1. The equation is as follows:

$$PS(n,r) \ = \ PM(n,r) \cdot TO(n,r). \quad (37)$$

Primary element tax is of two kinds, mobile and statical. It is the ratio of the producer price and market price of an element. The equation is as follows.

Mobile primary element consumption tax:

$$PFE(em,\,p,r) \ = \ PM(em,n,r) \cdot TF(em,n,r). \quad (38)$$

Sluggish primary element consumption tax:

$$PFE(es,\,p,r) \ = \ PMES(es,n,r) \cdot TFE(em,n,r). \quad (39)$$

When *TF* and *TFE* are greater than 1, it is tax.

Consumption tax for private sector is equal to the ratio of consumer price and market price of goods. The equation is as follows.

Domestic products:

$$PPD(t,r) = PM\,(t,r) \cdot TPD(t,r)\,, \quad (40)$$

when *TPD* (*t*, *r*) is greater than 1, it is tax.

Imported products:

$$PPM(t,r) = PIM(t,r) \cdot TPM(t,r)\,. \quad (41)$$

Consumption tax for government sector is equal to the ratio of consumer price and market price of goods. The equation is as follows.

Domestic products:

$$PGD(t,r) = PM\,(t,r) \cdot TGD(t,r)\,, \quad (42)$$

If *TGD* (*t*, *r*) is greater than 1, it is tax.

Imported products:

$$PGM\,(t,r) = PIM\,(t,r) \cdot TGM\,(t,r)\,. \quad (43)$$

Consumption tax for producers' intermediate inputs is equal to the ratio of consumer price and market price of goods. The equation is as follows:

Domestic products:

$$PFD(t,\,p,r) = PM\,(t,\,p,r) \cdot TFD(t,\,p,r)\,. \quad (44)$$

Imported products:

$$PFM(t,p,r) = PIM(t,p,r) \cdot TFM(t,p,r)\,. \quad (45)$$

For imported products, two import taxes are levied, one is ordinary import tax, which differs from source of goods, and the other is special import tax, which is targeted at a specific origin. The equation is as follows:

$$PMS(t,r,s) = PCIF(t,p,r) \cdot TM(t,r) \cdot TMS(t,p,r)\,. \quad (46)$$

*2.2.6. Regional family planning sector behavior module (private sector and government).* There are different hypotheses for consumption behaviors of government and private sectors. Assuming that government consumption is CD effectiveness function form and consumption of private sector is CDE effectiveness function form. The specific function equation is as follows:

$$U(r) = UP(r)^{\frac{PRIVEX(r)}{INCOME(r)}} \cdot \left(\frac{UG(r)}{POP(r)}\right)^{\frac{GOVEX(r)}{INCOME(r)}} \cdot \left(\frac{QSAVE(r)}{POP(r)}\right)^{\frac{SAVE(r)}{INCOME(r)}}, \quad (47)$$

$$QSAVE(r) = \frac{QSAVE(r)^0}{INCOME(r)^0} \cdot \frac{INCOME(r)}{PSAVE}, \quad (48)$$

$$UG(r) = UP(r)\frac{GOVEXP(r)^0}{INCOME(r)^0} \cdot \frac{INCOME(r)}{PGOV(r)}, \quad (49)$$

$$PGOV(r) = \prod_t PG(t, r)^{\frac{VGA(t,r)}{GOVEXP(r)}}, \quad (50)$$

$$QG(t,r) = \frac{VGA(t,r)^0}{GOVEXP(r)^0} \cdot \frac{PGOV(r).UG(r)}{PG(t,r)}, \quad (51)$$

$$PG(t,r) = \left(GMSHR(t,r).(PGM(t,r))^{1-ESUBD(t)} + (1-GMSHR(t,r))(PGD(t,r))^{1-ESUBD(t)}\right)^{\frac{1}{1-ESUBD(t)}},$$

where

$$GMSHR(t,r) = \frac{VIGA(t,r)}{VGA(t,r)}, \quad (52)$$

$$QGM(t,r) = QG(t,r) \cdot GMSHR(t,r) \cdot \left(\frac{PGM(t,r)}{PG(t,r)}\right)^{ESUBD(t)}, \quad (53)$$

$$QGD(t,r) = QG(t,r) \cdot (1 - GMSHR(t,r)) \cdot \left(\frac{PGM(t,r)}{PG(t,r)}\right)^{ESUBD(t)}, \quad (54)$$

$$\sum_t B(t,r)UP(r)^{EP(t,t,r)EY(i,r)}\left(\frac{PP(t,r)}{PRIVEXP(r)/POP(r)}\right)^{EP(t,t,r)} \equiv 1 \quad (55)$$

$$PRIVEX(r) = \frac{PRIVEXP(r)^0}{INCOME(r)^0} \cdot NCOME(r), \quad (56)$$

$$QP(t,r) = \frac{B(t,r) \cdot EPP(t,t,r) \cdot UP(r)^{EP(t,t,r)EY(T,r)}\left(\frac{PP(t,r)}{PRIVEXP(r)/POP(r)}\right)^{EP(t,t,r)-1}}{\sum_t B(t,r) \cdot EP(t,t,r) \cdot UP(r)^{EP(t,t,r)EY(T,r)}\left(\frac{PP(t,r)}{PRIVEXP(r)/POP(r)}\right)^{EP(t,t,r)}}, \quad (57)$$

$$PP(t,r) = \left(PMSHR(t,r) \cdot (PPM(t,r))^{1-ESUBD(t)} + (1-PMSHR(t,r))(PPD(t,r))^{1-ESUBD(t)}\right)^{\frac{1}{1-ESUBD(t)}},$$

where

$$PMSHR(t,r) = \frac{VIPA(t,r)}{VPA(t,r)}, \quad (58)$$

$$QPD(t,r) = QP(t,r) \cdot (1 - PMSHR(t,r)) \cdot \left(\frac{PPD(t,r)}{PP(t,r)}\right)^{ESUBD(t)}, \quad (59)$$

$$QPM(t,r) = QP(t,r) \cdot (1 - PMSHR(t,r)) \cdot \left(\frac{PPM(t,r)}{PP(t,r)}\right)^{ESUBD(t)}. \quad (60)$$

*2.2.7. Amington hypothesis of imported goods.* Amington hypothesis is adopted for import, that is, incomplete substitution of products imported from different regions, and difference between and incomplete substitution between domestically produced products and imported products of the same kind. According to this hypothesis, imported products are integrated into comprehensive, and imported comprehensive goods and domestic products are integrated into comprehensive products.

$$PIM(i,s) = \left(\sum_s MSHRS(i,r,s)\right) \cdot PMS(i,r,s)^{1-}. \quad (61)$$

where $PIM$ ($i$, $s$) refers to the comprehensive price of imported product $i$, and $PMS$ ($i$, $r$, $s$) refers to market price of goods from $r$.

$$P(i,s) = SHRS(i,s) \cdot PM(i,s)^{1-\sigma} + \left(1 - \left(SHRS(i,s) \cdot PM(i,s)^{1-\sigma}\right)^{1/1-\sigma}\right), \quad (62)$$

$$SHRS(i,s) = VDM(i,s)/(VDM(i,s) + \sum_r VIMS(i,r,s)).$$

*2.2.8. $CO_2$ emission module.* In the GTAP-E database, $CO_2$ emission data of various countries are added to the basis of GTAP data. $CO_2$ emission data are derived according to emission source (coal, petroleum and natural gas etc.), type of emission source (domestic or imported) and emission activities (emission of a specific sector).

That is to say, $CO_2$ emission data are four-dimensional data, which can clearly explain which department of a specific country produces $CO_2$ by using what kind of intermediate inputs. That is, it is a four-dimensional variable $ECO_2$ (*i*, *r*, *s*, *t*), where, *i* refers to emission source *i* (coal, petroleum and natural gas etc.), *r* refers to type of emission source *r* (domestic or imported), *s* refers to sector of emission activities, and *t* refers to emission region.

$CO_2$ emission equation of region *r* using energy *i* is:

$$CO_2(r,i) = \sum_{jIPROD-COMM} [CO_2IF(i,j,r) + CO_2DF(i,j,r)] + \\ + CO_2DG(i,r) + CO_2IG(i,r) CO_2DP(i,r) CO_2IP(i,r), \quad (63)$$

wherein $CO_2$ (*i*, *r*) refers to the amount of $CO_2$ emissions of region *r* using energy *i*. From this, it can be deduced that the total amount of $CO_2$ emissions of region *r* is:

$$GCO_2T(r) = \sum_{jIPROD-COMM} CO_2(i,r), \quad (64)$$

Global $CO_2$ emissions are:

$$GCO_2W = \sum_{iIREG} GCO_2(r), \quad (65)$$

In the design of $CO_2$ micro emission amount, the emission amount of $CO_2$ is in direct proportion to the use amount of emission source. The following equation is adopted (taking production emission as an example):

$$GCO_2FD(i,j,r) = GFD(i,j,r), \quad (66)$$

wherein, $GCO_2FD$ (*i*, *j*, *r*) refers to the percentage change of $CO_2$ emitted by sector *j* in region *r* after using *i*. *QFD* (*i*, *j*, *r*) is the percentage change of *i* used by sector *j* in region *r*.

*2.2.9. Design of carbon tax.* In the design of carbon tax, taking producers for example, value purchased by producers minus value excluding carbon tax is equal to the value of carbon tax. The equation is as follows:

$$DFCTAX(i,j,r) = VDFA(i,j,r) - VDFANC(i,j,r), \quad (67)$$

$$IFCTAX(i,j,r) = VIFA(i,j,r) - VIFANC(i,j,r), \quad (68)$$

where, *DFCTAX* (*i*, *j*, *r*) refers to the value of carbon tax levied on domestically produced *i* used by sector *j* in region *r*. *VDFA* (*i*, *j*, *r*) refers to the value paid by producers after excluding carbon tax. *IFCTAX* (*i*, *j*, *r*) refers to the value of carbon tax levied on sector *j* using imported *i* in region *r*. *VIFA* (*i*, *j*, *r*) refers to the value paid by producer *j* in region *r* for purchasing imported *i*, and *VIFANC* (*i*, *j*, *r*) refers to the value paid by the producer after the producer excludes the carbon tax.

Carbon tax rate includes nominal carbon tax and actual carbon tax. Nominal carbon tax means dollars levied on each ton of carbon emissions. Actual carbon tax is the expression of nominal carbon tax, and the specific equation is as follows:

$$RCTAX(r) = [1.0/PIND(r)] \times \\ \times [NCTAXB(REGTOBLOGC(r)) - 0.01 \cdot NCTAXLEV(r) \cdot p(r)]. \quad (69)$$

*PIND*(*r*) refers to the level value of income deflator of region *r*. *NCTAXB*(*REGTOBLOC*(*r*)) refers to the change rate of carbon tax in region *r*, and *NCTAXLEV*(*r*) refers to the level value of carbon tax. *p*(*r*) refers to the change rate of income deflator of region *r*.

## 3. The module of agricultural greenhouse gas emissions

As various production sectors are already set up in GTAP-E, we 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 specific GTAP-E commodity structure diagram is as follows.

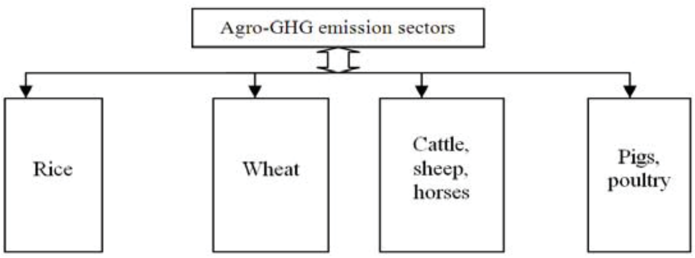


**Fig. 1. Structure of agricultural greenhouse gas emissions**

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.

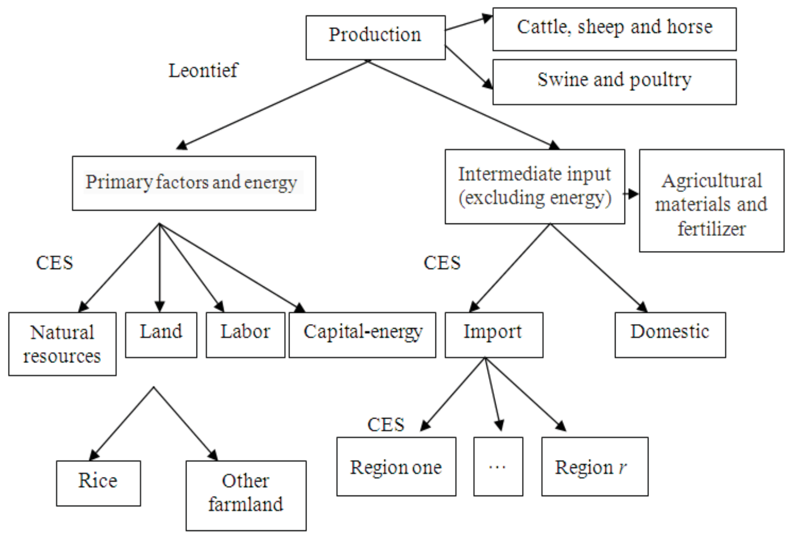


**Fig. 2. GTAP-E production composition structure of agricultural greenhouse gas emissions**

In terms of model treatment of $CO_2$ emissions, generally the method of $CO_2$ emissions and intermediate inputs of $CO_2$ emission sources being in direct proportion is adopted, and the intermediate inputs are then combined into energy integration after layers of nesting, and then combined with capital for mutual substitution. Then, energy input is reduced by raising capital to reduce $CO_2$ emissions. To simplify the problem so as to facilitate analysis, in agro-GHG emissions, we adopt the same setup as for $CO_2$ emissions, that is, GHG emissions are in direct proportion to their quality of inputs. But for inputs in agricultural products, there are no layers of substitution relationship, or substitution relationship with capital.

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:

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

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*.

## 4. The model database

In this study, we adopt the latest GTAP database, the seventh edition, which is based on the social accounting matrix of various countries in 2004, including 113 countries and 57 kinds of goods.

**4.1. 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 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.

**4.2. 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 at 2004. We total up 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.

**4.3. Data of agro-GHG emissions.** The agro-GHG emission data in the GTAP-E model of China's agro-GHG emission reduction is constructed in this study according to the following steps:

1. Determining the kinds of agro-GHG.
2. Positioning the emission source activities of agro-GHG.
3. Combining emission activities with GTAP production sectors.
4. Finding out the emission parameters of agro-GHG emission activities.
5. Researching the scale of agro-GHG emission activities.
6. Calculating detailed amount of agro-GHG emissions of each activity.
7. Converting the amount of agro-GHG emissions into $CO_2$ emissions according to comprehensive warming tendency.
8. Mapping the agro-GHG emission data to the GTAP-E database according to the sector of emission activities, that is, requiring emission sector to correspond to existing GTAP-E sector.
9. Adding corresponding variables to GTAP-E database.

Agro-GHG emission data in the model is three-dimensional data, determined by products used, products produced and region. Limited by the sector classification in GTAP-E, the study can be carried out only in the existing sector of GTAP-E. Detailed data sources and corresponding GTAP-E sectors are as follows.

Table 2. Sources of agro-GHG emissions and GTAP-E sectors

| Agro-GHG | Sources | GTAP-E sector |
|---|---|---|
| $CH_4$ | Ruminants | Cattle and sheep<br>Rice<br>Rice and wheat<br>Cattle, sheep and horses, pigs and poultry |
| | Rice fields | |
| $N_2O$ | Fertilizing farmland<br>Animal manure | |

Source: Collected by the author (2011).

**4.4. Estimation of farmland nitrous oxide greenhouse gas data.** *4.4.1. Estimation of amount of farmland nitrous oxide greenhouse gas emissions.* Farmland is a major source of $N_2O$ emissions. The emissions list of farmland greenhouse gas mainly includes $N_2O$ direct and indirect emissions of farmland soil and $N_2O$ emissions from the burning of straw and animal waste. $N_2O$ direct emissions of soil is mainly because of the use of nitrogen fertilizer and organic fertilizer, biological nitrogen fixation of legume crops, the returning of crops straw and organic soil farming (China can be ignored). However, $N_2O$ indirect emission of soil is due to the settlement of atmospheric nitrogen (including nitrogen fertilizer and animal waste to the atmosphere in the volatile *N*) to the farmland and leaching of nitrogen or runoff loss.

*4.4.2. Estimation of amount of agro-$N_2O$ emissions.* Bouwman has analyzed 174 groups of farmland $N_2O$ emission data, thereby establishing a regression relationship between the amount of $N_2O$ emissions and the amount of fertilizing:

$$E = 1 + 0.0125*F,$$

where $E$ refers to the annual amount of $N_2O$-N emissions per unit area (kg*hm-2*yr-1), and $F$ refers to the amount of nitrogen in nitrogenous fertilizers used (kg*hm-2*yr-1). Numerical value 1 refers to background emissions, that is, the annual amount of $N_2O$-N emissions without applying nitrogen fertilizer (kg*hm-2*yr-1), 0.0125 is $N_2O$-N emission coefficient, and its basic meaning is the proportion of $N_2O$-N emissions in fertilizer *N*, the default value used by the IPCC in compiling country emission lists. This method has been extensively applied in the estimation of farmland $N_2O$ emissions. Therefore, this study adopts this method in the estimation of farmland $N_2O$ emissions.

*4.4.3. Determination of emission factors.* Based on reference to related literature, if the emission coefficient suitable for the country can be found, it shall be selected. If it cannot be found, then the default value 0.0125 recommended by the IPCC is applied, adjustments are made according to actual conditions. See the following table for details.

Table 3. Scope of farmland $N_2O$ emission coefficient

| Units | Latest analysis |
|---|---|
| Low value | 0.0025 |
| Medium value | 0.0125 |
| High value | 0.0225 |

Source: IPCC/OECD (1995).

*4.4.4. Determination of activity level data.* The activity level data are composed of farmland area and the amount of nitrogen fertilizers used[1].

*4.4.5. Summary*. In summarizing above statements, when calculating $N_2O$ emissions of farmland, at first, determine the amount of nitrogen used in total fertilizers of farmland, obtain the average amount of nitrogen used from the farmland area, then calculate the annual amount of $N_2O$-N emissions of unit area according to the Bouwman method, and then calculate the total annual amount of $N_2O$-N emissions. The amount of farmland Nitrous oxide greenhouse gas emissions of Annex-1 countries in 2004 and non-Annex-1 countries in 1994 can be found in the IPCC website database.

*4.4.6. Result of estimation.* Calculate according to the above method of summary to get the estimated value of agricultural nitrous oxide greenhouse gas emissions of countries in 2004. See Table 3 for details.

Table 4. The estimated value of agricultural greenhouse gas emissions of countries around the world in 2004 (*t*)

| Countries and regions | Farmland nitrous oxide emissions | Countries and regions | Farmland nitrous oxide emissions | Countries and regions | Farmland nitrous oxide emissions |
|---|---|---|---|---|---|
| Australia | 96912.65 | Other South American countries | 1297.14 | Croatia | 4228.30 |
| New Zealand | 7354.62 | Costarica | 1534.93 | Romania | 19315.43 |
| Other Oceania countries | 1213.73 | Guatemala | 5271.16 | Russian Federation | 208409.73 |
| China | 770725.86 | Nigaragua | 3727.68 | Ukraine | 57825.43 |
| Hong Kong | 0.00 | Panama | 1160.36 | Other East Europe countries | 3318.44 |
| Japan | 17906.82 | Other Central American countries | 4546.20 | Other European countries | 8839.88 |
| South Korea | 10178.40 | Caribbean Sea | 0.00 | Kazakhstan | 36921.38 |
| Taiwan | 942.86 | Austria | 4065.50 | Kirghizia | 2631.20 |
| Other East Asia countries | 5769.36 | Belgium | 1320.00 | Other former USSR countries | 11591.01 |
| Cambodia | 5960.98 | Cyprus | 361.29 | Armenia | 934.74 |
| Indonesia | 87788.31 | Czech Republic | 10634.68 | Azerbaijan | 2892.53 |
| Laos | 1571.43 | Demark | 7143.93 | Georgia | 1018.68 |
| Burma | 16923.24 | Estonia | 1301.79 | Iran | 46313.16 |
| Malaysia | 19114.52 | Finland | 6899.38 | Turkey | 72294.30 |
| The Philippines | 20228.37 | France | 74660.14 | Other Western Asian countries | 52246.35 |
| Singapore | 184.05 | Germany | 54599.42 | Egypt | 37194.65 |
| Thailand | 46401.22 | Greece | 8340.89 | Morocco | 17448.83 |
| Vietnam | 40940.90 | Hungary | 14327.15 | Tunis | 5560.52 |
| Other Southeast Asian countries | 272.27 | Ireland | 8223.52 | Other North African countries | 46363.55 |
| Bangladesh | 31240.77 | Italy | 29030.65 | Nigeria | 5515.71 |
| India | 480635.75 | Latvia | 2357.54 | Senegal | 5157.74 |
| Pakistan | 83950.23 | LTU | 3530.37 | Other Western African countries | 62539.66 |
| Sri Lanka | 4620.67 | Luxemburg | 418.69 | Middle Africa | 3032.86 |
| Other Southeastern countries | 5072.77 | Malta | 26.77 | South Africa and Middle Africa | 28096.71 |
| Canada | 101613.48 | Holland | 24359.42 | Ethiopia | 19905.42 |
| US | 574677.16 | Pol0.and | 46373.88 | Madagascar | 4689.06 |
| Mexico | 57956.80 | Portugal | 4745.79 | Malawi | 6121.30 |

[1] These data should be available from the national statistical institution. If these data are not available in the country, they can be downloaded from the FAO website (http://faostat.fao.org/DesktopDefault.aspx?PageID=291&lang=zh-CN).

Table 4 (cont.). The estimated value of agricultural greenhouse gas emissions of countries around the world in 2004 (*t*)

| Countries and regions | Farmland nitrous oxide emissions | Countries and regions | Farmland nitrous oxide emissions | Countries and regions | Farmland nitrous oxide emissions |
|---|---|---|---|---|---|
| Other North American countries | 10039.78 | Slovakia | 3656.40 | Mauritius | 352.37 |
| Argentina | 63572.59 | Slovenia | 865.35 | Mozambique | 7295.63 |
| Bolivia | 5747.11 | Spain | 41879.06 | Tanzania | 15553.86 |
| Brazil | 137997.87 | Sweden | 7552.46 | Uganda | 8406.18 |
| Chile | 8106.21 | UK | 31502.04 | Zambia | 9447.76 |
| Columbia | 10395.02 | Switzerland | 1543.61 | Zimbabwe | 6089.17 |
| Ecuador | 4670.91 | Norway | 3034.57 | Other Eastern African countries | 16592.77 |
| Paraguay | 7124.92 | Other European free trade union members | 0.00 | Botswana | 355.14 |
| Peru | 9794.71 | Albania | 1519.57 | South Africa | 31202.09 |
| Uruguay | 3701.50 | Bulgaria | 9932.49 | Other SACU countries | 7537.32 |
| Venezuela | 9334.66 | Belorussia | 15520.61 | Summary | 4071145.85 |

Source: Estimated by the author (2010).

## 5. The simulation

**5.1. The benchmark scenario.** *5.1.1. Agricultural greenhouse gas emission in the world (2004-2020).* In 2020, cattle, sheep and horse department produce the most agricultural greenhouse gas. 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 5. The baseline forecast data of global agricultural greenhouse gas emission (classified by sectors, 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% |

Source: Estimated by the author (2010).
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.

*5.1.2. Agricultural greenhouse gas 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, this sector is the fastest, followed by pig and poultry sector and other agriculture sector.

Table 6. The baseline forecast data of Chinese agricultural greenhouse gas emission (classified by sectors, 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 the author (2010).

**5.2. Policy simulation scenario to Carbon tax on agriculture nitrous oxide emissions.** Policy simulation scenario one: Per ton of carbon dioxide equivalent emissions agriculture nitrous oxide levy 100 dollar of carbon tax.

In the baseline scenario, assumed that in 2020 China levy a carbon tax to agriculture greenhouse gas emission, the criterion is that per ton of carbon dioxide equivalent emissions agriculture nitrous oxide levy 100 dollar of carbon tax. Under this condition, analyze the impact of agriculture nitrous oxide emissions reduction on macro economic and each department (especially the agriculture department).

Policy simulation scenario two: Per ton of carbon dioxide equivalent emissions agriculture nitrous oxide levy 200 dollar of carbon tax.

In the baseline scenario, assumed that in 2020 China levy a carbon tax to agriculture greenhouse gas emission, the criterion is that per ton of carbon dioxide equivalent emissions agriculture nitrous oxide levy 200 dollar of carbon tax. Under this condition, analyze the impact of agriculture nitrous oxide emissions reduction on macro economic and each department (especially the agriculture department).

Policy simulation scenario three: Per ton of carbon dioxide equivalent emissions agriculture nitrous oxide levy 300 dollar of carbon tax.

In the baseline scenario, assumed that in 2020 China levy a carbon tax to agriculture greenhouse gas emission, the criterion is that per ton of carbon dioxide equivalent emissions agriculture nitrous oxide levy 300 dollar of carbon tax. Under this condition, analyze the impact of agriculture nitrous oxide emissions reduction on macro economic and each department (especially the agriculture department).

**5.3. Results of policy simulation.** *5.3.1. Impact on macroeconomic. A* carbon tax on agricultural nitrous oxide emission led to Chinese trade conditions becomes worse (-$5.2849 billion, -$10.65726 billion and -$15.82853 billion). Chinese social welfare is growing ($12.36278 billion, $24.82826 billion and $36.72375 billion) (Table 6), the GDP price index rising (0.1944%, 0.3964%, 0.5950%), export price index rising (0.0757%, 0.1513%, 0.2226%), the consumer price index rising (0.3057%, 0.6275%, 0.9485%) and real GDP rising (0.0034%, 0.0036%, 0.0007%).

A carbon tax on agricultural nitrous oxide emission results that prices of land (-2.4362%, -4.9074%, -7.2808%) and the non-skilled labor (-0.0448%, -0.0949%, -0.1476%) are on the decline trend, whereas, the prices of capital (0.1043%, 0.2067%, 0.3017%) and skilled labor (0.1686%, 0.3368%, 0.4953%) are on the rise trend.

Table 7. Compared to the baseline scenario, the macro effect of the simulation scenario

| Index | The first simulation | The second simulation | The third simulation |
|---|---|---|---|
| Welfare ($1 million) | 12362.78 | 24828.26 | 36723.75 |
| Trade conditions ($1 million) | -5284.90 | -10657.26 | -15828.53 |
| Actual GDP (%) | 0.0034 | 0.0036 | 0.0007 |
| GDP price index (%) | 0.19 | 0.40 | 0.60 |
| Export price index (%) | 0.08 | 0.15 | 0.22 |
| Exports (%) | -0.20 | -0.39 | -0.57 |
| Imports (%) | 0.28 | 0.57 | 0.86 |
| Factor prices (%) | | | |
| (1) land | -2.44 | -4.91 | -7.28 |
| (2) non-skilled labor | -0.04 | -0.09 | -0.15 |
| (3) skilled labor | 0.17 | 0.34 | 0.50 |
| (4) capital | 0.10 | 0.21 | 0.30 |
| Consumer price index | 0.31 | 0.63 | 0.95 |

Source: Simulation results in 2011.

*5.3.2. Impact on agricultural sector*. Tax on the agriculture nitrous oxide emissions will bring the flowing impact on agricultural sector in the three simulation scenario.

In the rice sector, product price drop (-1.64%, -3.31%, -4.93%), output decrease (-4.93%, -0.07%, -0.23%), exports increase (20.93%, 47.24%, 78.62%), imports decrease (-8.47%, -16.49%, -23.68%), land rent rise (0.07%, 0.13%, 0.20%) and labor cost decline (-0.47%, -0.95%, -1.43%).

In other agriculture sector, product price rise (2.10%, 4.32%, 6.53%), output decrease (-0.64%, -1.29%, -1.94%), exports reduce (-7.87%,-15.36%, -22.10%), imports increase (2.90%, 5.95%, 9.00%), land rent decline (-0.41%, -0.83%, -1.25%) and labor cost decline (-1.14%, -2.31%, -3.46%).

In the cattle and sheep sector, pigs and poultry sector, product price drop (-1.31%, -2.65%, -3.93%, -0.90%, -1.82%, -2.71%), output increase (0.26%, 0.53%, 0.79%, 0.26%, 0.53%, 0.79%), exports increase (5.52%, 11.54%, 17.76, 2.58%, 5.30%, 8.02%), imports decrease (-2.49%, -5.01%, -7.42%, -1.15%, -2.32%, -3.44%), land rent rise (0.%, 36%, 0.74%, 1.11%, 0.49%, 1.00%, 1.49%). The labor cost in the cattle and sheep sector drop (-0.11%, -0.22%, -0.33%), but in pigs and poultry sector rise (0.05%, 0.10%, 0.14%).

In other crops sector, product price rise (0.14%, 0.28%, 0.41%), output increase (0.03%, 0.06%, 0.09%), exports decrease (-0.31%, -0.59%, -0.82%), imports increase (0.07%, 0.12%, 0.15%), land rent and labor cost rise (0.06%, 0.12%, 0.18%).

Table 8. The impact on agriculture by reducing agricultural nitrous oxide greenhouse gas emissions, as compared with the benchmark

| Sectors | Price changes (%) | | | Output changes (%) | | |
|---|---|---|---|---|---|---|
| | The first simulation | The second simulation | The third simulation | The first simulation | The second simulation | The third simulation |
| Rice | -1.64 | -3.31 | -4.93 | -0.07 | -0.15 | -0.23 |
| Other crops | 2.10 | 4.32 | 6.53 | -0.64 | -1.29 | -1.94 |
| Cattle and sheep | -1.31 | -2.65 | -3.93 | 0.26 | 0.53 | 0.79 |
| Pigs and poultry | -0.90 | -1.82 | -2.71 | 0.40 | 0.80 | 1.18 |
| Other agriculture | 0.14 | 0.28 | 0.41 | 0.03 | 0.06 | 0.09 |
| Rice | 20.93 | 47.24 | 78.62 | -8.47 | -16.49 | -23.68 |
| Other crops | -7.87 | -15.36 | -22.10 | 2.90 | 5.95 | 9.00 |
| Cattle and sheep | 5.52 | 11.54 | 17.76 | -2.49 | -5.01 | -7.42 |
| Pigs and poultry | 2.58 | 5.30 | 8.02 | -1.15 | -2.32 | -3.44 |
| Other agriculture | -0.31 | -0.59 | -0.82 | 0.07 | 0.12 | 0.15 |
| Rice | 0.07 | 0.13 | 0.20 | -0.47 | -0.95 | -1.43 |
| Other crops | -0.41 | -0.83 | -1.25 | -1.14 | -2.31 | -3.46 |
| Cattle and sheep | 0.36 | 0.74 | 1.11 | -0.11 | -0.22 | -0.33 |
| Pigs and poultry | 0.49 | 1.00 | 1.49 | 0.05 | 0.10 | 0.14 |
| Other agriculture | 0.47 | 0.96 | 1.44 | 0.06 | 0.12 | 0.18 |

Source: GTAP-E model simulation results.

*5.3.3. Impact on other sectors.* Tax on the agriculture nitrous oxide emissions will bring the flowing impact on other sectors.

In terms of the product price change, all industrial and service sectors are on the rising trend except the light industry. Output of sectors of electricity, processed food, cotton and textile, heavy industry, public utilities and building industry are on the downward trend. Overall, these sectors have certain relation with agricultural production sectors. On the export side, beside the coal and light industry department show a growing trend, the rest sectors are on a declining trend. On the import side, sectors of coal, light industry, electricity and petroleum are on a declining trend. Tax on the agriculture nitrous oxide emissions makes the product price of industry sectors and service sectors increase, thus, inhibit the export and expand the import. In most of the sectors, the capital and labor prices are on the downward trend.

Table 9. The impact on non-agricultural sectors by reducing agricultural nitrous oxide greenhouse gas emissions, as compared with the benchmark

| | 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 | 0.07 | 0.14 | 0.2 | -0.08 | -0.16 | -0.23 |
| Natural gas | 0.03 | 0.05 | 0.07 | 0.06 | 0.13 | 0.19 |
| Coal | 0 | 0 | 0 | 0 | 0 | 0 |
| Petroleum | 0.04 | 0.08 | 0.11 | 0 | 0 | 0 |
| Electricity | 0.03 | 0.06 | 0.09 | -0.03 | -0.06 | -0.1 |
| Oil products | 0.03 | 0.06 | 0.08 | 0.03 | 0.06 | 0.09 |
| Processed products | 0.84 | 1.72 | 2.59 | -0.12 | -0.24 | -0.37 |
| Cotton and textile products | 0.3 | 0.61 | 0.91 | -0.68 | -1.37 | -2.04 |
| Light industry | -0.05 | -0.1 | -0.15 | 0.21 | 0.44 | 0.65 |
| Heavy industry | 0.04 | 0.08 | 0.12 | -0.07 | -0.14 | -0.2 |
| Public utilities and building industry | 0.24 | 0.49 | 0.73 | -0.06 | -0.14 | -0.21 |
| Transportation and communication | 0.09 | 0.18 | 0.27 | 0.09 | 0.17 | 0.25 |
| Other services | 0.09 | 0.17 | 0.25 | 0.3 | 0.59 | 0.88 |
| Chemical products | -0.23 | -0.45 | -0.66 | 0.01 | 0.01 | 0.01 |
| Natural gas | -0.13 | -0.23 | -0.29 | 0.03 | 0.04 | 0.05 |
| Coal | 0.06 | 0.13 | 0.21 | -0.05 | -0.10 | -0.16 |
| Petroleum | -0.11 | -0.21 | -0.31 | 0.05 | 0.11 | 0.15 |
| Electricity | -0.07 | -0.12 | -0.17 | -0.06 | -0.12 | -0.18 |

Table 9 (cont.). The impact on non-agricultural sectors by reducing agricultural nitrous oxide greenhouse gas emissions, as compared with the benchmark

| | Price changes (%) | | | Output changes (%) | | |
|---|---|---|---|---|---|---|
| Sectors | The first simulation | The second simulation | The third simulation | The first simulation | The second simulation | The third simulation |
| Oil products | -0.01 | -0.03 | -0.04 | -0.02 | -0.04 | -0.06 |
| Processed products | -2.93 | -5.88 | -8.71 | 1.36 | 2.79 | 4.21 |
| Cotton and textile products | -0.92 | -1.86 | -2.77 | 0.37 | 0.75 | 1.12 |
| Light industry | 0.41 | 0.83 | 1.25 | -0.16 | -0.32 | -0.48 |
| Heavy industry | -0.13 | -0.26 | -0.37 | 0.01 | 0.02 | 0.03 |
| Public utilities and building industry | -0.86 | -1.74 | -2.59 | 0.57 | 1.17 | 1.75 |
| Transportation and communication | -0.19 | -0.37 | -0.55 | 0.28 | 0.57 | 0.85 |
| Other services | -0.24 | -0.47 | -0.69 | 0.31 | 0.61 | 0.90 |
| Chemical products | -0.13 | -0.26 | -0.38 | -0.24 | -0.49 | -0.38 |
| Natural gas | 0.06 | 0.13 | 0.19 | -0.03 | -0.06 | 0.19 |
| Coal | -0.01 | -0.02 | -0.03 | -0.04 | -0.07 | -0.03 |
| Petroleum | -0.01 | -0.02 | -0.02 | -0.03 | -0.06 | -0.02 |
| Electricity | -0.07 | -0.14 | -0.21 | -0.21 | -0.42 | -0.21 |
| Oil products | 0.03 | 0.06 | 0.09 | -0.15 | -0.29 | 0.09 |
| Processed products | -0.17 | -0.35 | -0.53 | -0.25 | -0.51 | -0.53 |
| Cotton and textile products | -0.74 | -1.51 | -2.25 | -0.84 | -1.7 | -2.25 |
| Light industry | 0.15 | 0.31 | 0.46 | 0.06 | 0.12 | 0.46 |
| Heavy industry | -0.13 | -0.26 | -0.37 | -0.23 | -0.46 | -0.37 |
| Public utilities and building industry | -0.15 | -0.31 | -0.47 | -0.25 | -0.5 | -0.47 |
| Transportation and communication | 0.02 | 0.05 | 0.07 | -0.11 | -0.22 | 0.07 |
| Other services | 0.27 | 0.54 | 0.8 | 0.18 | 0.36 | 0.8 |

Source: GTAP-E model simulation results.

*5.3.4. Influence on trade balance.* Most of the sectors lose trade balances, including other crops, chemical products, natural gas, processed food, cotton and textile products, heavy industry, public utilities and building industry, transportation and communication, other services, other agriculture, petroleum and oil products.

Table 10. The impact on trade balance by reducing agricultural nitrous oxide greenhouse gas emissions, as compared with the benchmark

| Trade balance change (1 million dollars) | The first simulation | The second simulation | The third simulation |
|---|---|---|---|
| Rice | 5.4 | 10.64 | 15.5 |
| Other crops | -2526.63 | -5193.64 | -7859.89 |
| Cattle and sheep | 40.62 | 81.63 | 120.83 |
| Pigs and poultry | 105.52 | 213.37 | 317.72 |
| Other agriculture | -92.44 | -175.61 | -244.76 |
| Chemical products | -164.22 | -322.41 | -466.37 |
| Natural gas | -0.01 | -0.01 | -0.02 |
| Coal | 4.51 | 9.41 | 14.45 |
| Petroleum | -67.94 | -134.92 | -197.27 |
| Electricity | 0.18 | 0.4 | 0.66 |
| Oil products | -0.97 | -1.23 | -0.73 |
| Processed products | -487.29 | -992.51 | -1488.53 |
| Cotton and textile products | -1697.69 | -3446.39 | -5151.78 |
| Light industry | 1010.45 | 2064.49 | 3105.39 |
| Heavy industry | -1007.96 | -1955.65 | -2790.64 |
| Public utilities and building industry | -29.82 | -60.5 | -90.39 |
| Transportation and communication | -233.15 | -467.92 | -691.59 |
| Other services | -143.46 | -286.42 | -421.1 |

Source: GTAP-E model simulation results.

*5.3.5. The influence on the welfare of the other countries.* Social welfare of sub-Saharan Africa, the European Union, Middle East and North Africa, energy exporter, East Asia, Southeast Asia, Japan and the United States, will decrease. However, social welfare of The Pacific region, India, North America, Latin America and other countries will increase.

Table 11. The welfare change of various countries as compared with the benchmark scheme

| Welfare change (1 million dollars) | The first simulation | The second simulation | The third simulation |
|---|---|---|---|
| The Pacific region | 36.32 | 75.15 | 114.43 |
| Japan | -243.69 | -489.95 | -725.57 |
| The United States | -25.93 | -29.07 | -8.65 |
| India | -40.67 | -82.29 | -122.63 |
| Energy exporter | -110.94 | -224.81 | -335.54 |
| East Asia | -58.06 | -115.7 | -169.87 |
| Southeast Asia | -25.48 | -50.54 | -73.84 |
| South Asia | -17.21 | -35.28 | -53.29 |
| North America | 25.74 | 54.56 | 84.98 |
| Latin America | 129.75 | 269.3 | 411.36 |
| The European Union | -525.15 | -1049.55 | -1544.88 |
| The Middle East and North Africa | -36.57 | -74.45 | -111.62 |
| Sub-Saharan Africa | -5.12 | -9.23 | -12.08 |
| Other countries | 8.59 | 17.34 | 25.74 |

Source: GTAP-E model simulation results.

## Conclusions and suggestions

The results showed that levy on agricultural nitrous oxide emission has changed China's export-oriented international trade model and increased the Chinese social welfare. The specific performance is real GDP increase, GDP price index, export price index and consumer price index rise. The price of land and unskilled labor declined, whereas the price of capital and skilled labor are on the rise trend.

Levy on agricultural nitrous oxide emission, rice production department and other planting sectors suffered the bigger negative influence, and the animal husbandry department suffered less.

Levy on agricultural nitrous oxide emission makes product price of the industrial sector and service sector increase, thus inhibiting exports and expand imports. Capital and labor price in most industrial and service sector decline, which led most of domestic sectoral trade to be in unbalanced, including other crops, chemical products, natural gas, processed food, cotton products, heavy industry, utilities and construction, transportation and communication, other services and other agriculture, oil and oil products.

Welfare of most of the countries around the world reduced, which include Sub-Saharan Africa, the European Union, the Middle East and North Africa, energy exporter, East Asia, Southeast Asia, Japan and the United States.

So it seems that levy on agricultural nitrous oxide emission will increase China's welfare, change the international trade situation, making most of the production department lose international trade balances and the welfare of the developing countries and some developed countries intend to decline, overall is on China's economic benefit.

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