Comprehensive Analysis of GHG Emission-Energy-Economy Policy in China

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1. Introduction

The interrelation among energy, economy and environment was first explored by Edmonds in 1983[1]. He developed a long-term global energy-economic model which is capable of assessing alternative energy evolutions over periods of up to 100 years. World Bank (WB) was the first research focused on the relations of China's energy, economy and environment (3E) by constructing a so-called China GHG Model for simulation study from 1990 to 2020, which consists of a macroeconomic model, input-output table, energy coefficients and GHG emissions coefficients[2]. However, the equations of the model are not available publicly. Afterwards, more researchers adopt computable general equilibrium (CGE) model to analyze China's 3E issues. Zhang developed a dynamic time-recursive CGE model to assess the impacts of carbon tax in China for 1990-2010[3].Jiang adopted IPAC model which included IPAC-CGE sub-model, IPAC-AIM sub-model and IPAC-Emission sub-model to analyze the relation between energy and GHG emissions in the long-term[4]. Input-output model and CGE model are two popular tools for analysis of energy-economic-environmental implications of climate change policy.

The focus of input-output model in GHG emission is concentrated on accounting analysis of production-based or consumption-based national emission[5-7]. Production-based inventory is referred to the GHG emissions occurring within national territories; consumption-based inventory denotes the emissions from resident institutional units[8]. Many researches focus on the accounting of emissions embodied in trade now, except Yi-Ming Wei. Yi-Ming Wei used I-O model and Multi-regional Input-Output (MRIO) model to analyze the energy requirements and CO2 emissions in China. It is found that the key economic indictor, such as GDP, is exogenous. That is, there is no strong linkage among energy, economy and environment in the model designed.

However, few studies have concentrated on analyzing the impacts of China's climate committee with input-output model. This study attempts to make an systematic and comprehensive analysis on the relation of energy, economy and environment issues in China by establishing a dynamic input-output model and macroeconomic model.

2. Methodology

With a dynamic time-recursive input-output model, we analyze how to achieve China's Copenhagen commitment. There are many mitigation measures to reduce greenhouse gas emissions, such as improving the energy efficiency, non-fossil energy substitution, forestry, carbon capture and storage technology, carbon tax etc. The non-fossil energy alternative is proposed in the model.

2.1 Structure of the model

We use input-output and macroeconomic analysis to construct China 3E model. It operates by simulating the operation of markets for three economic entities, which are government, household and foreign trade separately. In describing the equations, the endogenous variables are denoted by capital letters, whereas the exogenous are expressed in lower-case letters and Greek letters. The indices i and j refer to sectors or goods, t to time period, h to household and g to government. There are 3 sectors in this model (see table 1), including 2 energy sectors. In our model, energy use is disaggregated into fossil energy and non-fossil energy.

Table 2.1 Classification of producing sectors in the I-O model

No.	3-Sector	42-sector
1	Usual industry	001, 004-010, 012-022, 025-030
2	Fossil energy industry	002,003,011,023,024
3	New energy industry	Introduced additionally

2.1.1 Material Balance

$$X_1(t) \geq a_{11} X_1(t) + a_{12} X_2(t) + a_{13} X_3(t) + C_1(t) + G_1(t) + I_1(t) + E_1(t) - M_1(t)$$

In which,

X(t): a column vector of total production of all sectors in term t;

a_{ij}: input coefficient matrix from the i industry to j industry;

C(t): a column vector of the household consumption in term t;

G(t): a column vector of the government expenditure in term t;

I(t): a column vector of the capital formation in term t;

E(t): a column vector of export in term t;

M(t): a column vector of import in term t.

2.1.2 Energy Balance

$$X_e \geq B_1 X_1 + B_2 X_2 + B_3 X_3 + C_e + E_e - M_e - Q \qquad X_e = X_2 + X_3$$

In which,

Xe: the total energy supply by all the energy sectors in term t; (en)

B: the energy consuming factors;(ex)

Ce : the household consumption of energy sectors.

Q: the adjustment item in China's input-output table.

2.1.3 Greenhouse gas emission:

$$\mathrm{GHG}(t) = ef_1 * X_1(t) + ef_2 * X_2(t) + ef_3 * X_3(t) + ef_4 * X_4(t) + ef_5 * X_5(t) + ef * C(t)$$

GHG(t): a scalar of GHG emissions in term t;

ef_i : the greenhouse emission coefficients in different industries.

2.1.4 Gross Domestic Production (GDP)

$$\mathrm{GDP}(t) = X_1(t) * (1 - a_{11} - a_{21} - a_{31}) + X_2(t) * (1 - a_{12} - a_{22} - a_{32}) + X_3(t) * (1 - a_{13} - a_{23} - a_{33})$$

$$\mathrm{GDP}(t+1) >= GDP(t)$$

2.1.5 Household income

$$Yh1(t) = \psi_1 X_1(t) \qquad Yh2(t) = \psi_2 X_2(t)$$

$$Yh3(t) = \psi_3 X_3(t)$$

$$YH(t) = Yh1(t) + Yh2(t) + Yh3(t)$$

$$YH_d(t) = (1 - 0.15) * YH(t)$$

$$S^h(t) = 0.366377 * YH_d(t)$$

In which,

YH(t): the total household income in term t;

YH_d(t): the disposable household income in term t;

ψ: rate of gross income in the industry.

2.1.6 Government revenues

$$YG(t) = \sum_i \mathrm{it}ax_i X_i(t) + 0.15 * YH(t)$$

$$\mathrm{S_g}(t) = 0.1659 * YG(t)$$

In which,

YG(t): Total government revenues in term t;

$itax_i$: the indirect tax rate;

Sg: the saving of government.

2.1.7 Investment and saving Balance

$$\mathrm{I}_1(\mathrm{t}) + \mathrm{I}_2(t) + \mathrm{I}_3(\mathrm{t}) + (E_{\text{1-d}} - M_1(t)) + (\mathrm{E}_{\text{e-d}} - M_e(t)) \leq S^h(t) + S^g(t)$$

2.1.8 Foreign trade

$$M(t)(X_c - E_c + M_c) = M_c(X(t) - E_c + M(t))$$

Where,

M(t): the import in term t;

E(t): the export in term t;

X(t): the total production in term t;

Mc: the import in base year;

Ec: the export in base year;

Xc: the total production in base year.

2.1.9 Production function

$$\mathrm{X}_1(\mathrm{t}) \leq \lambda_1 K_1(t)$$
$$X_2(t) \leq \lambda_2 K_2(t)$$
$$X_3(t) \leq \lambda_3 K_3(t)$$

In which,

K(t): the capital stock in term t; (en)

λ : The factor which is related K with X.

2.1.10 Dynamic Capital accumulation

$$\mathrm{K}_1(t+1) = (1-\delta_1)K_1(t) + \mathrm{I}_1(t+1)$$
$$K_2(t+1) = (1-\delta_2)K_2(t) + \mathrm{I}_2(t+1)$$
$$K_3(t+1) = (1-\delta_3)K_3(t) + \mathrm{I}_3(t+1)$$

2.1.11 Objective function

$$\mathrm{Ma}x\left(\sum_{t=1}^{10} \mathrm{GDP(t)}\right)$$

$$\mathrm{s}ubjected \quad to \quad all\,the \quad constra\mathrm{int}\,s \quad above.$$

2.2 Scenario design

To assess the impacts of non-fossil energy substitution, three scenarios are designed in the study. Scenario1 is business as usual (BAU) scenario. No policy to limit the greenhouse gas (GHG) emission and no new energy industry is introduced; In scenario 2, there is the policy to limit GHG emissions, but no new energy industry is introduced. There is both the GHG emission restriction and new energy industry in scenario 3.

3. Results

3.1 GDP in scenario 1 and scenario 2

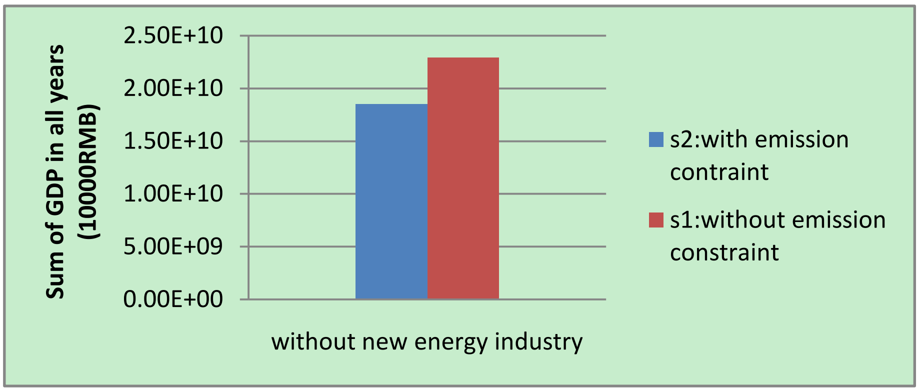

Fig. 3.1 the comparison of scenario 1 and scenario 2

It is seen that GDP of scenario 2 is less than that of scenario 1 by the comparison. That is, without introducing the new energy industry, GDP will be decreased when putting constraints on the GHG emission.

3.2 GDP in scenario 2 and scenario 3

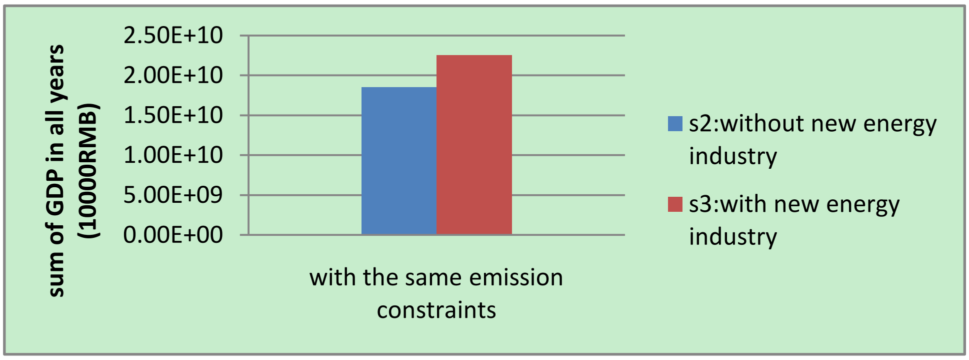

Fig. 3.2 the comparison of scenario 1 and scenario 2

It is seen that GDP of scenario 3 is more than that of scenario 2. Considering the same constraints on GHG emission, GDP will be increased when introducing the new energy industry.

3.3 Development trend of each sector

We analyze the development trend of each sector in scenario 3. The production of usual industry will be increased to the constant. And the production of fossil energy industry will be decreased greatly from the year 2005 to 2011, and it will keep stable from 2012 to 2014. The production of new energy industry will be increased greatly from the year 2005 to 2009, and it will keep stable in the later.

It represents the development trend of three sectors in the future. With the mitigation pressure, the new energy industry will be developed in priority and the development of new energy industry will be limited by the resource reserves in China.

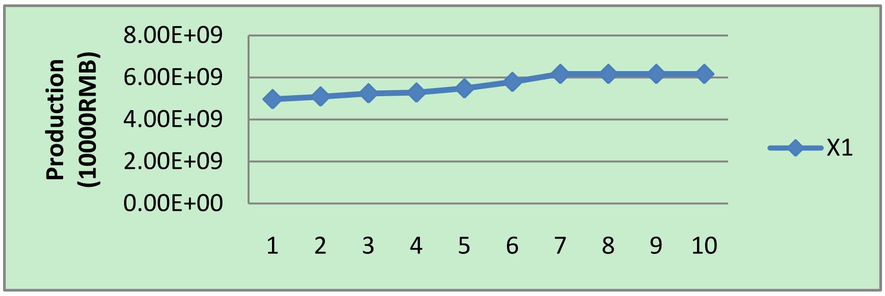

Fig. 3.3 the development trend of usual industry

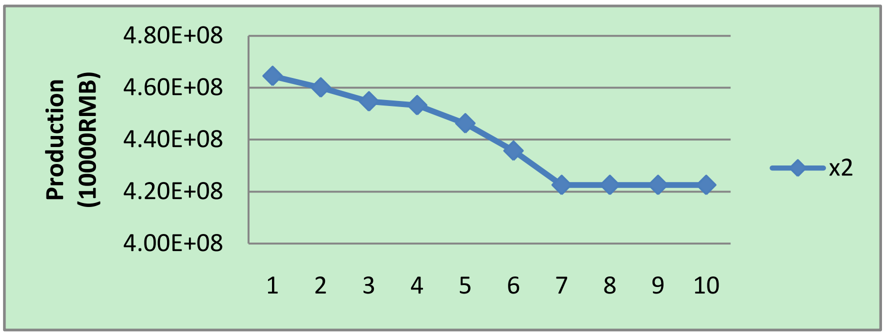

Fig. 3.4 the development trend of fossil energy industry

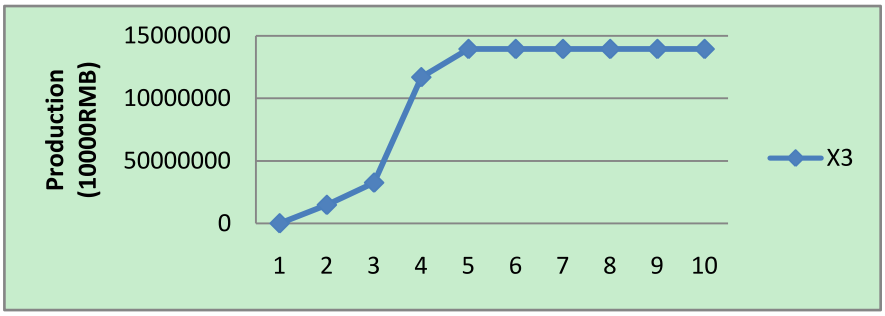

Fig. 3.5 the development trend of new energy industry

4. Conclusions

With a dynamic time-recursive input-output model, the study analyzes how to achieve China's Copenhagen commitment. The non-fossil energy alternative is proposed and the mitigation impacts are assessed through model simulation. It is found that GDP will be decreased while the GHG emission restriction becomes severe. And the production of fossil energy will be decreased to its lower limit while the production of new energy industry will be increased to its upper limit.

Reference:

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