Analyzing Carbon Emissions Reductions in China with CGE Model

He Juhuang, Shen Keting, and Xu songling

Centre for Environment and Development Research

Chinese Academy of Social Sciences

Contents

- **Previous Studies on Carbon Emissions Reductions in China**
- **A CGE Model by He et al**
- **Comparison with Previous Studies**

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1 Previous Studies on Carbon Emissions Reductions in China

- **Zhang Zhongxiang (1998b),** ***The Economics of Energy Policy in China: Implications for Global Climate Change***
  - **Using a ten-sector dynamic CGE model to assess the aggregate and/or sectoral effects of carbon taxes designed to reduce the growth of carbon emissions**
  - **Assuming a completely marketized economy**
  - **Using 1987 Input-Output Table for China**

Previous Studies on Carbon Emissions Reductions in China

II Richard F. Garbaccio, Mun S. Ho and Dale W. Jorgenson (1999), *Controlling Carbon Emissions in China*

- Using a dynamic economy-energy-environment CGE model for China to study the effects of carbon taxes on the choice of energy input, given a level of economic activity, and the effects of the policies over time on economic growth (noted as GHJ's Model)
- Emphasizing the dual nature of the Chinese economy--both the plan and market institutions--and the model is somewhat complicated
- Using 1992 Input-Output Table for China

Previous Studies on Carbon Emissions Reductions in China

III Ma Gang, Zheng Yuxin and Fan Mingtai, noted as MZF, (1999), *China CGE Model and Policy Analysis*, ch5

- **Using a 33-sector static CGE model to analyze the aggregate and/or sectoral effects of carbon taxes designed to reduce carbon dioxide emissions**
- **Including short-term and long run comparative static analysis**
- **Using 1992 Input-Output Table for China**

2 A CGE Model by He et al for Analyzing Carbon Emissions Reductions in China

The project is composed of two steps:

- note: the model is preliminarily prepared by professor He Juhuang, the details are included in He's manuscript (2000).
- First step: constructing a static CGE model to assess the effects of carbon taxes (Our discussion will mainly focus on this part in the workshop, noted as He's Model)
- Second step: extending to a dynamic CGE model (in preparation)

Main Structure of the Model (I)

Production(i)

- **Energy**

$$E(t) = A_E[\mathrm{d}_E V_1(t)^{-\mathrm{r}_E} + (1-\mathrm{d}_E)V_2(t)^{-\mathrm{r}_E}]^{-\frac{1}{\mathrm{r}_E}}$$

  - **where E, V_1, and V_2 are the energy, coal, and oil and natural gas utilized in production, respectively**

- **Capital-Energy**

$$KE_i(t) = A_{hi}[\mathrm{d}_{hi}\overline{K}_i(t)^{-\mathrm{r}_h} + (1-\mathrm{d}_{hi})EN_i(t)^{-\mathrm{r}_h}]^{-\frac{1}{\mathrm{r}_h}},$$

$$\sum_i EN_i = E$$

  - **where $\overline{K}_i$ and EN_i are capital stock and energy use by sector *i***

Main Structure of the Model (II)

Production(ii)

- **Labor-Capital-Energy**

$$EV_i(t) = A_{vi}[\mathrm{d}_{vi} KE_i(t)^{-\mathrm{r}_v} + (1-\mathrm{d}_{vi}) L_i(t)^{-\mathrm{r}_v}]^{-\frac{1}{\mathrm{r}_v}}$$

  - **where L_i is the labor utilized in production**

- **Total Output**

$$Q_i(t) = EV_i(t) / (1 - \sum_{j=3}^{n} a_{ji})$$

  - **where a_{ji} is the input-output coefficient**

Main Structure of the Model (III)

Consumption

- **Consumption function in static model**

  $$HC = (1 - s)YD$$

  - **where s is the exogenous save rate of the households**

- **Consumption function in dynamic model**

  $$HC = \mathrm{a}HC_{-1} + \mathrm{b}YD + (1 - \mathrm{a} - \mathrm{b})YD_{-1}$$

- **Consumption on Commodity *i***

  $$C_i(t) = \mathrm{b}_i(t)HC(t) / P_i(t), \qquad \sum_i \mathrm{b}_i(t) = 1$$

  - **in static model, $\mathrm{b}_i(t)$ is an array of constants**
  - **in dynamic model, $\mathrm{b}_i(t)$ is a set of nonlinear function on output *per capita***

Main Structure of the Model (IV)

Carbon Taxes

- Assuming that carbon taxes are imposed directly on carbon and oil (including natural gas in the oil sector)

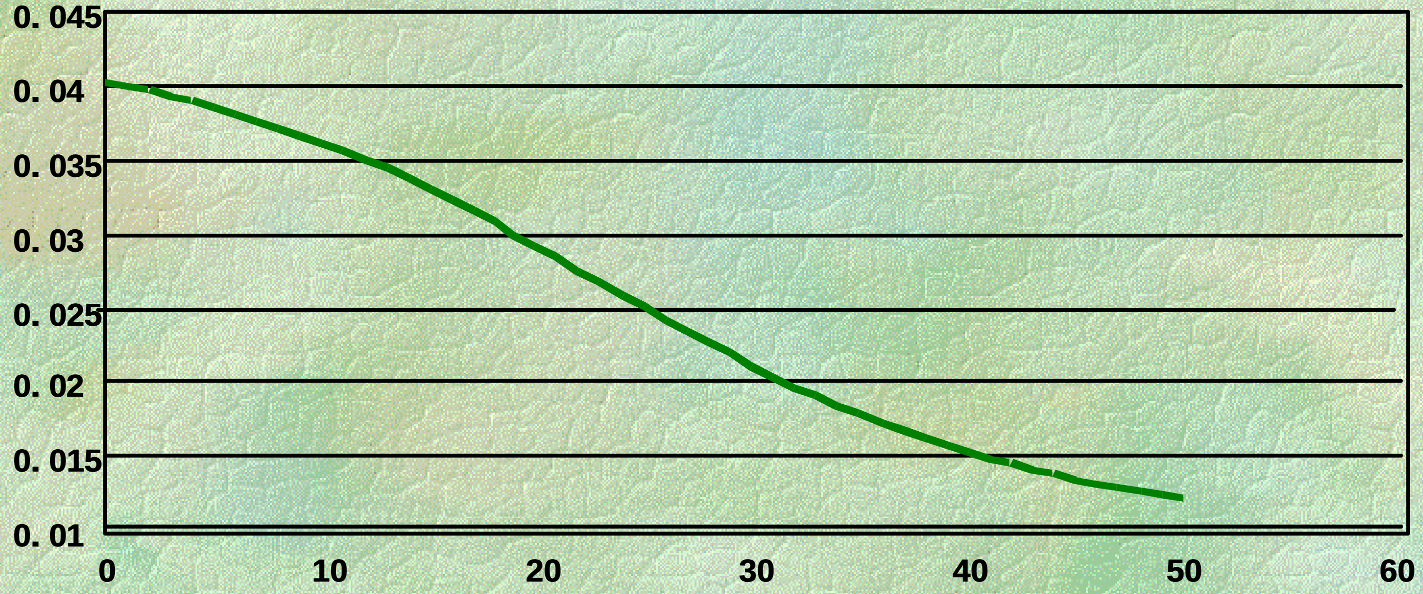
$$P_i(t) = PEV_i(t)EV_i(t)/Q_i(t) + \sum_{j=3}^{n} a_{ji}P_j(t) + tc \cdot e_i$$

  - where P_i, PEV_i, and EV_i are the price of commodity *i*, and quantity and price of Labor-Capital-Energy used in sector *i*, respectively;
  - *tcr* is the rate of carbon taxes;
  - e_1 and e_2 are carbon emitted by unit of coal and oil (including natural gas), respectively; $e_{3,} \cdots_{,} e_9 = 0$

Main Structure of the Model (V)

Technical Progress

- **Assuming that technical progress would lead to changes of the coefficients in the production functions in dynamic model**



Average Rate of Technical Progress in China (1990-2050)

See He (1997), unpublished, for details

Data and Structural Parameters

- Using 1997 Input-Output Table for China (including 40 sectors) to construct a 9-sector SAM for the same year
- Most of parameters are derived from the SAM
- Elasticity of Substitution in the Production Functions
  - Elasticity of Substitution between Coal and Oil

$$s_E = 1.25$$

  - Elasticity of Substitution between Energy and Capital

$$s_h = 0.5$$

  - Elasticity of Substitution between Labor and Energy-Capital

$$s_v = 0.91$$

Result (I)

Table 1. Effects of Carbon Taxes on Sectoral Output

CO_2 Emissions Reductions	5%	10%	15%	20%	25%
Coal	-6.08	-12.16	-18.24	-24.31	-30.38
Oil	0.28	0.55	0.83	1.09	1.34
Agriculture	-0.10	-0.20	-0.32	-0.45	-0.59
Electric	-0.41	-0.85	-1.31	-1.81	-2.35
Industry	-0.07	-0.16	-0.27	-0.39	-0.54
Construction	0.53	1.04	1.56	2.06	2.57
Transp&Telecom	-0.07	-0.14	-0.23	-0.34	-0.46
Business	-0.09	-0.19	-0.31	-0.44	-0.59
Service	-0.14	-0.28	-0.43	-0.59	-0.76

Result (II)

Table 2. Effects of Carbon Taxes on Sectoral Prices

CO_2 Emissions Reductions	5%	10%	15%	20%	25%
Coal	9.36	20.22	33.00	48.29	66.80
Oil	3.77	8.03	12.69	17.84	23.79
Agriculture	0.10	0.20	0.30	0.30	0.40
Electric	1.90	4.00	6.41	9.01	11.91
Industry	0.60	1.11	1.71	2.32	3.02
Construction	0.39	0.79	1.18	1.68	2.07
Transp&Telecom	0.10	0.30	0.39	0.49	0.59
Business	0.10	0.20	0.30	0.41	0.51
Service	0.20	0.30	0.50	0.60	0.80

Result (III)

Table 3. Effects of Carbon Taxes on Other Selected Variables

CO_2 Emissions Reductions	5%	10%	15%	20%
Carbon Taxes (*yuan*/ton)	34.50	73.92	119.48	172.82
GDP (%)	**0. 009**	**0. 007**	-0.010	-0.044
Consumption (%)	-0.053	-0.119	-0.200	-0.299
Investment (%)	1.008	2.030	3.071	4.141

Conclusions

- **Emissions Reductions Using Carbon Taxes Leads the Production of Coal to Reduce More Seriously, about 1.2 Times of the Reductions Aims (See Table 1)**
- **Inducing Higher Prices of Primary Energies (See Table 2)**
  - **10% Emissions Reductions----20.2% Coal Price, and 8% Oil Price**
  - **20% Emissions Reductions----48.3% Coal Price, and 17.8% Oil Price**
- **Effect to GDP Seems Small, maybe due to the hypotheses of the market mechanism in the model**
- **Significant Effect to Investment, due to the assumptions of the behavior of the government**

3 Comparison with Previous Studies

Table 4. Percentage Changes of Selected Variables of Different Models

	Zhang's20% (2010)	MZF's10% (Short Term)	GHJ's10% (1st Year)	He's10% (1st Year)	He's20% (1st Year)
GDP	**-1.521**	-0.47	-0.04	0.007	**-0.044**
Consumption	**-1.165**		-0.29	-0.119	**-0.299**
Investment	**-0.686**		0.42	2.03	**4.141**
Output of Coal	**-26.50**	-10.68	-11.91	-12.16	**-24.31**
Output of Oil	**-2.07**		-1.75	0.55	**1.09**
Price of Coal	**64.95**	27*	12.88	20.22	**48.29**
Price of Oil	**15.30**		2.16	8.03	**17.84**

* the price change of coal in MZF's Model isn't given explicitly,

it is inferred by the author.

Comparison with Previous Studies

Conclusion 1

- Effects to the output of coal due to emissions reductions using carbon taxes are similar among models
- Effects to the output of oil are are similar between Zhang's and GHJ's model, He's model has a positive effect, maybe due to the larger elasticity of substitution between coal and oil:
  - He's is 1.25
  - Others' are 1

Comparison with Previous Studies

Conclusion 2

- Effects to prices of coal and oil are significantly different among models, as to prices of coal, the result are:

  Zhang’s>MZF’s>He’s>GHJ’s

  maybe due to the elasticity of substitution between energy and capital/labor, the smaller the values, the more significant the effects are:

  - Zhang’s is 0.3
  - He’s is 0.5
  - GHJ is 1
  - MZF hasn’t given it explicitly

Comparison with Previous Studies

Conclusion 3

- **Effects to GDP are different among models, the result are:**

  Zhang's>MZF's>GHJ's>He's

  maybe due to the hypotheses of the market mechanism of the models, that is, the allocation to labor and capital:

	Zhang's Model	MZF's Model	GHJ's Model	He's Model
Allocation of Capital	Optimal	Short term Nonoptimal Long run Optimal	Optimal	Nonoptimal
Allocation of Labor	Optimal	Optimal	Partly	Nonoptimal

Future Development

- Sectoral economic effects and Cost-Benefit Analysis of the policy
- Estimation of structural parameters
- Analysis for other policy instruments

Thank You!

by He Juhuang[1], Shen Keting[2], and Xu songling[3]

1 E-mail: hejuhuang@sina.com Fax: (8610)65125895(o)

2 E-mail: ktshen@263.net Tel: (8610)65137744-5713

3 E-mail: xusongling@263.net Tel: (8610)65137744-5713