Macroeconomic Effects of Carbon Dioxide Emission Reduction：Cost and Benefits

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Abstract: Global climate change is hitherto the most serious environmental problem, and China's CO_2 emissions reductions have been one of the hottest problems discussed in the world. This paper quantifies the impacts of different abatement policies on economy based on a modified MACRO model. The empirical results show that CO_2 direct emissions control with the most serious GDP loss is the most effective strategies in term of mitigating CO_2 emissions, and carbon tax on coal with great effects and less economic loss is the most suitable strategy for China.

Keywords: CO_2 emissions, Modified MACRO Model, Energy efficiency, Greenhouse gases

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Ⅰ. Introduction

Emissions of global warming gases continue to rise as the world burns ever more coal, oil and gas for energy. From the data of Institute for Environmental Studies, the effects of emissions of CO_2 and other greenhouse gases on the global climate are becoming visible, causing the changes in temperature, sea level rise, atmospheric circulation patterns, ecosystems and so on(see Table 1).

Table 1. The influence of climate change caused by greenhouse gas

Objects	Phenomenon
Global average surface temperature	Rised 0.6℃ in 20 Century
Global Sea Level	Increased 0.1 to 0.25 meter
The extent and thickness of Arctic ice	Reduced by 10-15% in spring and summer
Precipitation in the high latitudes of the Northern Hemisphere	Increased 0.5%-1.0% annually, and frequency of heavy rain rised 2%-4%
Total global economic losses from natural disasters	Increased by 10 times over the past 40 years

The risk of destabilizing the Earth's climate system is growing every day. There is evidence that economic damage as a result of extreme weather events has greatly increased over past few decades. Such events take a heavy toll on social economies. Few things can be more pressing for the protection of ecosystems and the well-being of society than avoiding the catastrophic effects of global warming. In 1998, drought and widespread wildfires caused by extreme weather conditions resulted in US $276 million worth of damage. In the same year, floods along the Yangtze River in China induced 4,000 deaths and US $30 billion economic losses. Compared losses in 1950s with losses in the 1990s, Munich Re(2000) and Francis(1998) concluded a large part of the increase in losses was resulted from extreme weather events. Taken inflation, insurance penetration and price effects into account, while real global GDP increased by a factor of three since 1950, the total sum of extreme weather-related damage increased by a factor of eight.

Table 2. The costs of natural disasters (Munich Reinsurance Company, 2000)

Year	Times	Insured Losses (million US$)	Economic Losses (million US$)
1983	1	2,200	3,500
1987	1	4,700	5,600
1989	1	6,300	12,700
1990	4	13,200	19,100
1991	2	9,100	15,700
1992	2	22,800	40,300
1993	2	3,200	24,400

1994	1	17,600	50,600
1995	4	7,700	120,600
1996	1	1,800	5,700
1998	4	7,150	45,700
1999	7	13,685	36,500

Based on Kyoto Protocol, China, India, and other developing countries were not included in any numerical limitation of the Kyoto Protocol because they were not the main contributors to the greenhouse gas emissions during the pre-treaty industrialization period. However, even without the commitment to reduce according to the Kyoto target, developing countries do share the common responsibility that all countries have in reducing emissions. China, as the world's second largest emitter of carbon dioxide, its attitude and actions will become the focus of the coming negotiations. For developing countries, to choose which kinds of policies will depend on their economic development, carbon dioxide emissions, energy supply, and the political structure and so on. On the one hand, China's attitude would influence the international negotiations; on the other hand, study the favorable policy will help to do the suitable selection. This proposal will study the cost and benefit of different emission reduction policies, in order to provide the guide and reference.

Ⅱ. Methodology

There are many mature energy-economy-environment models used throughout the world. The research on the influence of Carbon Dioxide Emission Reduction mainly based on these models to analyze the combined effects of Carbon Dioxide Emission Reduction on environment improvement and the national economy. The impact of carbon emission reduction policy is a relatively new research area, thers is not a generally accepted energy-economic-environment model, though a variety of existing models and their improved ones have certain degree of usage. Table 3 shows several typical models.

Table 3. The several typical models

	Methods	Typical Models	Typical Literature
Top-down models	Econometrics, general equilibrium theory and linear programming theory	3Es-Model MACRO GEM	Arvydas (2000) Toshihiko (2004) Lim (1998) Proost (1992) Robinson (1999)
Bottom-up models	Linear programming and nonlinear programming theory	MARKAL EFOM AIM I/O	Dolf (2001) Hannele (2004) Mikiko (2000) Casler (1998)

Nowadays, Macro Model, CGE model, MARKAL model and 3ES model have become the primary models for academic analysis of the effects on carbon dioxide emission reduction policy.

As a macroeconomic model, MACRO describes the relationship of energy consumption, capital, labor force, and GDP by production function. Its objective function is the total discounted utility of a single representative producer-consumer. The maximization of this utility function determines a sequence of optimal savings, investment and consumption decision. Moreover, we can obtain the carbon dioxide emission from the energy consumption, and the relationship between the GDP and carbon dioxide emission. Therefore, this proposal will use MACRO model to analyze the different emission reduction policies on the impact of macroeconomics, and the data can be obtained from the World Bank and the Bureau of Statistics.

This proposal constructs a modified model to evaluate possible effects for mitigating carbon emission for China. According to the simulation of this study, there are 6 scenarios for modeling strategies: Carbon Tax (including 4 scenarios), CO_2 emissions direct control, Carbon intensity decline. Based on a modified MACRO model, we establish a dynamic relationship. At the national level, the total effect of a country's economic activities can be expressed as follow,

$$GDP_t = aK^{\alpha}L^{\beta}\left(\sum E_{i,t}\right)^{\gamma} \qquad (1)$$

Here, we use Cobb-Douglas production function, rather than the usual of Constant Elasticity Substitution production function in Markal-Macro Model, because the result of the former is more applicable to a dynamic iterative model, and has better statistical predictability. And the constraints as follows,

$$L_{t+1} = (1+r)L_t \qquad (2)$$

$$GDP_t = C_t + I_t + Ec_t \qquad (3)$$

$$K_{t+1} = K_t + I_t - \varepsilon_t K_t \qquad (4)$$

$$K_T \le I_T \qquad (5)$$

$$E_{i,t} = b_0 + b_1 * GDP_t + b_2 * E_{i,t-1} + \sum_{i=1}^{3} b_{3,i} * p_i \qquad (6)$$

$$CO_{2t} = \sum E_{i,t}\mu_i \qquad (7)$$

$$Ec_t = \sum_{i=1}^{3} p_{i,t} * E_{i,t} \qquad (8)$$

During which GDP_t is the gross national product in *t* period, α, β, γ is the output flexibility of capital, labor and energy, a is the coefficient of the CD production function, E_i is the energy inputs of coal, oil, natural gas and others Ec_t is the energy costs in the *t* period, ε_t is the depreciation of assets in the *t* period, C_t is the consumer in the *t* period, I_t is the investment in the *t* period, $p_{i,t}$ is the price of the i kinds of energy, r_t is the annual growth rate of economics, μ_i is the coefficient of carbon dioxide emission of the i kinds of energy, CO_{2t} is the carbon dioxide emission in the *t* period. Fig. 2 shows the dynamic process.

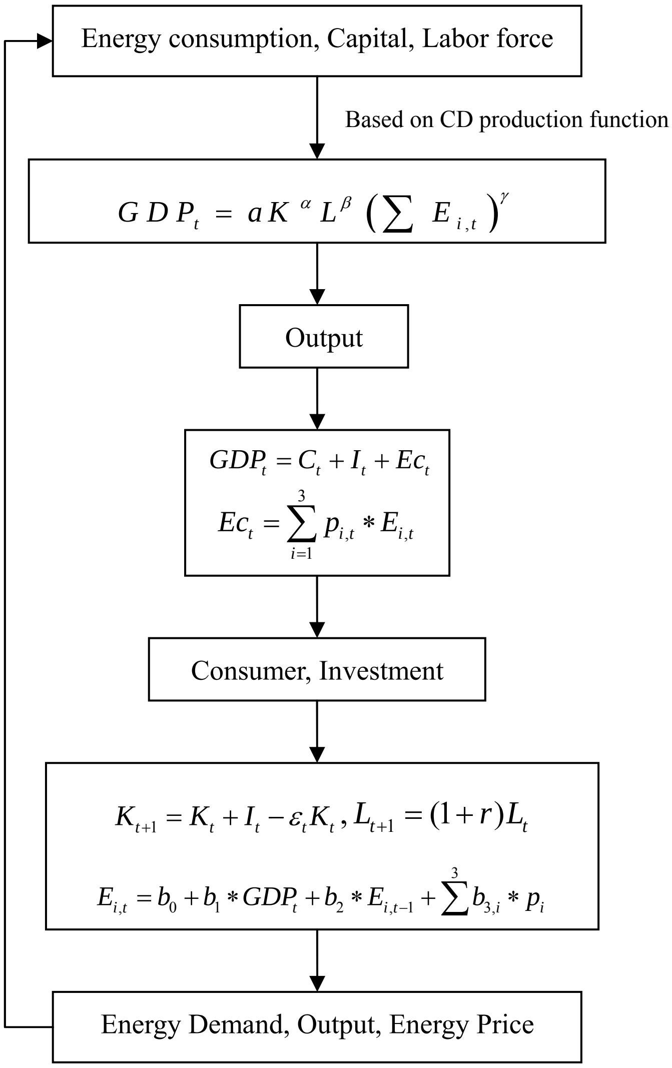

Figure. 1 The dynamic process of a modified MACRO model

In the modified model, (2) represents the labor force growth; (3) is the balance equation, assuming that all the current output used for current consumption, investment and energy costs; (4) is the dynamics of accumulation equation of the fixed capital stock, assuming that the capital stock combined the beginning of the current capital stock with investment minus depreciation; (5) is the limited conditions, considering that the final investment is bigger than a capital stock; (6) is the energy demand function, determined by GDP as well as former energy consumption and energy prices which is given by equation (8); (7) is the carbon dioxide emissions function. The overall model includes 13 variables and eight dynamic equations, and its dynamic relationship is completed by capital accumulation and energy demand. In the study of macroeconomic model, the data covers over 20 years. Also in 2012, China will join the carbon emission reduction program. So we assume that 2000 is the initial period, and 2022 is the end period to study social cost and benefit if China will implement carbon emission reduction in 2022.

Ⅲ. Results

Based on regression analysis over the year 1990-2005, we obtain the Cobb-Douglas production function as below:

$$GDP(t) = \exp(-10.29) K(t)^{0.57} L(t)^{0.71} * \left(\sum_i E_i(t) \right)^{0.64} \quad (9)$$

From the above results, nearly 15 years China's growth trend shows increasing returns to scale, $0.57 + 0.71 + 0.64 > 1$. In the subsequent calculations, we will use the price in 1990 to obtain the value of GDP in order to remove the inflation effect. At the same time, we mainly consider energy consumption of coal, petroleum and natural gas. Using the consumption and price indices of these three kinds of energy as dependent variable, the demand functions in 1980-2001 are obtained respectively based on price indices of industrial products in 1990 under the method of time serie.

$$Coal = -1.32 * Oil(-1) - 0.006865 * Pc + 10135.812 + 0.002244 * Po + 1.22 * Coal(-1) \quad (10)$$

$$Oil = 0.001117 * Pg + 0.28 * GDP - 0.000258 * Po + 0.60 * Oil(-1) \quad (11)$$

$$Gas = 563.25 - 0.0000279 * Pc + 0.036 * GDP + 0.54 * Gas(-1) \quad (12)$$

Where Coal, Oil and Gas are the demand in the *t* period, *Pc*, *Po* and *Pg* are the price of there three different kinds of energy, *Coa*l(-1), *Oil*(-1) and *Gas*(-1) are the demand in the last period.

Table 4. Energy demand function

Variables		Coefficient	Variance
Coal Dmand function	Oil(-1)	-1.3154980	0.634571
	Pc	-0.0068654	6.215876
	Constant	10135.812	67.54982
	Po	0.0022436	2.563271
	Coal(-1)	1.2239084	0.287736
Petroleum Dmand function	Pg	0.0011167	2.175302
	GDP	0.2838123	0.263829
	Po	-0.0002582	1.117563
	Oil(-1)	0.5985618	0.385547
Natural gas demand function	Constant	563.25463	17.23554
	Pc	-0.0002794	1.142753
	GDP	0.0362279	0.102194
	Gas(-1)	0.5394788	0.472312

Without taking any measures to reduce carbon dioxide emissions, GDP, energy demand and other economic indicators during 2000-2020 is shown in Table 5 under the assumption that the potential economic growth rate is 6.5%. Using these results as the benchmark, the influence of different emission reduction polices on economic indicators is obtained as Table 6 shown.

Table 5. Economic indicators forecast without CO2 emission reduction

	2000	2005	2010	2015	2020
Final comsuption(billion)	3125.14	4260.79	6103.80	6641.33	5611.91
Investment(billion)	1497.80	1621.27	1790.01	1976.32	2182.01
GDP(billion)	5261.11	6908.91	9858.37	13826.88	19392.91
Coal（Million tons of standard coal）	880.99	1017.97.34	120903.3	143595.2	170546.05
Petroleum (Million tons of standard coal)	327.84	412.19	558.98	679.73	808.38
Natural gas(Million tons of standard coal)	36.43	46.88	65.41	60.28	36.43
Energy(Million tons of standard coal)	1245.26	1477.04	1833.42	2175.96	2550.26
CO_2(Million tons of standard carbon)	766.26	905.46	1117.03	1328.25	1563.92

Table 6. The social costs and emission reduction effect of different emission reduction policies

Policies	Loss rate of GDP growth	The proportion of CO_2 reduction in 2020	The social cost of emission reduction(Yuan/ton)
Direct emissions control	-19.28%	42%	10084
Emissions intensity control	-1.27%	6.67%	4185
Holland carbon tax	-2.32%	7.12%	7679
Sweden carbon tax	-11.22%	25.69%	9744
Progressive carbon tax	-2.93%	23.0%	4025
Carbon tax on coal only	-1.87%	22.52%	2719

In the post-Kyoto, China's CO_2 emissions reductions will be remarkable and will always be the one of the hottest problems. If China will commit to cut its greenhouse gases emissions in the future, then what effects will occur? In order to achieve this object, a modified MACRO model is constructed to evaluate possible effects for mitigating carbon emissions for China. According to the simulation of this study, the following conclusions are obtained:

1) Energy has a great contribution on production output by a weight of 0.63. This means that China's economic growth depends on energy consumption. Therefore, the constraint of carbon dioxide emissions induced by fossil fuels has a negative impact on the economy.

2) All emissions reduction policies have adverse effects on the economy. China is in the period of rapid economic growth. So to control energy consumption and carbon dioxide emissions, the economic development will face a big loss.

3) Different emissions reduction policies have marginal different social cost. There are 6 scenarios for modeling strategies: carbon tax(including 4 scenarios), CO_2 emission intensity control and CO_2 direct emissions control. The empirical results show that GDP will suffer a loss in all these scenarios. The above results in Table 6 shows the emission direct control is the most effective strategies in terms of mitigating CO_2 emissions but will induce the greatest GDP loss, follow by Sweden carbon tax and progressive carbon tax. And the emissions intensity control and carbon tax on coal cause the small GDP loss, but effects on emission reduction are not as good as the others. From an economic point of view, it is not quite suitable to stabilize the China's carbon dioxide emissions at current levels. China is a developing country. Although it has responsibility to reduce carbon emission, the economic development is equally important.

Based on the overall conclusions above, we suggest that China should not commit to directly cutting CO_2 emissions on the current emissions level. Also, the economic loss caused by carbon tax on coal in all scenarios is very small, and the effect on emission reduction is great effect. Considering the balance on less GDP loss and more CO_2 emissions reduction, we suggest that China should select carbon tax on coal which has small GDP loss but great CO_2 reduction.

Ⅳ. Conclusion

G1obal climate change is hitherto the most serious environmental problem，and is also one of the most complicated challenges in the 21st century. As the largest developing country and the second largest CO_2 emissions source next to the US, China's CO_2 emissions reductions have been one of the hottest problems discussed by academe, environmental administers and all governments in the world. It is of great importance to analyze China's CO_2 emissions, which is beneficial to China's sustainable development, but also can contribute to mitigate the global climate warming. Therefore, this paper quantifies what impacts possible different abatement policies will have on economy in the future based on a modified MACRO model. In our research, although CO_2 direct emissions control has the great effect on reducing the CO_2 emission, it causes a great loss on GDP. Combined the GDP loss and effect on CO_2 emissions reduction, the empirical results show the carbon tax on coal will be the best strategy for China.

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