Impact of Carbon Tax and Reduced CO_2 Discharge on Chinese Economy: A Static CGE Analysis

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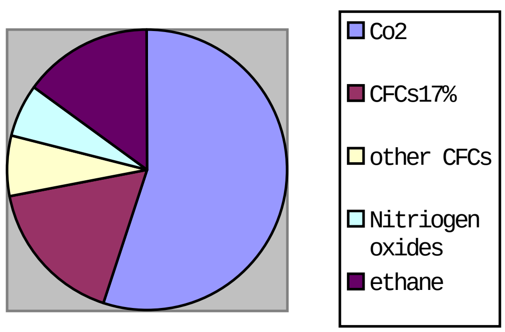
1. Background of the Problem

The global climatic warm-up is the common challenge facing mankind, and also one of the global ecological crises most concerned by mankind. Such concern has been fully reflected in the Framework Convention on Climatic Changes (FCCC) signed by more than 150 countries, and several negotiations afterwards. Meantime, in view of the ambiguity in the statements of the framework convention on key problems, and the intensive quarrels emerged in later negotiations, it could be also seen that genuine cooperation among mankind across national boundaries is very difficult.

How to reduce the discharge of greenhouse gases is the central problem facing the FCCC. Carbon dioxide produced by combustion of fossil fuels is the principal contributor of incremental greenhouse gases (the proportional relation among the main hothouse gases in relation to their cumulative greenhouse effects are shown in Illustration 1.1), so the allocation of its reduction of discharge has become the focus of negotiations about FCCC fulfillment.



`Figure 1

China is one of the signatories of the FCCC. According to the rules of the FCCC, China as a developing country has no obligation of reducing CO_2 discharge. However, it does not mean we could neglect our own efforts of mitigating the world climatic warm-up process. Similar to most developing countries, China has to face global environmental problems, while serious domestic environmental problems remain to be solved. As a responsible member of the world community, China is concerned greatly

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about the global environment. As a result of rapid economic growth, China has become the second large energy consumer after the U. S. A. And fossil fuels dominates the energy structure of China (use of fossil fuels is equivalent to 94% of the total energy usage of China), As the economy grows rapidly, discharge of CO_2 will also grow rapidly in China. Between 1986 and 1996, the net increase of CO_2 discharge in China ranked first in the world. In 1990 the global discharge of CO_2 caused by human activities was 5.7 billion tons of carbon (tc), China discharged 596,000,000 tc, about one tenth of the global total, ranked second in the world. It is anticipated that the discharge of China between 2010 and 2020 will exceed that of the U. S. A. , thus will become the largest emissioner of CO_2 in the world. Hence, though the 1990 CO_2 discharge averaged only 0.6 tc per capita in China, much less than that of the U. S. A., 5.3 tc and that of Japan, 2.3 tc, and will continue to be much less than that of the U.S.A. and Japan in rather distant future, the potential impact on world climatic changes of China should not be neglected.

Now some developed countries try to persuade China to participate in the reduction of CO_2 discharge agreement. The reason is: if only developed countries reduce their discharge of CO_2 , and China continues to increase her discharge, the global CO_2 stock would grow, and the efforts of developed countries will come to nothing. The argument is obviously wrong, it forgets the history, sets obstacles for China to realize her basic natural rights : right to develop. It also confuses the different meaning of discharge reduction of developed and developing countries. The principal part of present world stock of CO_2 has been produced be developed countries in the course of industrialization , because of lavish consumption of fossil fuels. Therefore, the developed countries have a responsibility to compensate for the harm to mankind caused by their past behavior. Moreover, their extremely high per capita discharge postulates that they have to assume more responsibility in the reduction of discharge. And developing countries also manage to reduce CO_2 for the sake of the future of mankind. Hence, the present reduction of CO_2 discharge in developed countries is not connected directly with the problem whether China should limit her CO_2 discharge. China, as a low income country, and a low per capita discharger of CO_2 at the same time, cannot reduce CO_2 discharge through restraining economic development. In addition, economic development itself is a fundamental means to reduce CO_2 discharge. In fact, as a result of more than a decade of rapid economic development, China has been able to introduce a series of advanced energy-saving technology and technique with higher efficiency, industrial structure tends to upgrading. Hence, while while the Chinese economy grows rapidly, energy consumption has grown at a relatively slow pace. It could be seen clearly through comparing the incremental energy inputs of GDP growth by 1% in different years: in 1962, 1.2% growth of energy inputs accompanied 1% growth of GDP, but in 1992 only 0.5% growth of energy inputs was necessitated. According to our estimate, since China began to reform and open her door, the discharge of CO_2 has been reduced cumulatively by 18.3 billion tons. Many people are concerned with the policy of CO_2 discharge reduction in China. The key problem is the comparison of cost and benefits, that is to say, whether benefits accrued to discharge reduction could compensate for the costs incurred. There is no reason for China to refuse those discharge reducing measures which do not affect economic development. Recently, scholars in developed countries used CGE models to analyze the costs of discharge reduction in China, and obtained differential results. This is an important reason for us to conduct the study. We hope to obtain more reliable results through our own research.

What concerns us is the costs of CO_2 abatement, and carbon taxation provides a convenient method for us to measure costs of discharge reduction[3]. Before presenting our results, Several early studies on CO_2 discharge in China will be reviewed here.

In 1994 the World Bank conducted a study about discharge of greenhouse gases of China in 2020. It was quite comprehensive, including every important greenhouse gas and its sources, for example, it includes methane generated by rice planting. Its methodology is different from what was used in this paper: we adopted a top-down method, while the World Bank used a combined approach of top-down and bottom-up methods. It used a macro-econometric model to derive final demands for 18 sectors under different growth rates ; then it used these final demands, and input-output coefficient matrix based on international experience, to obtain information about industrial structure of China in 2010 and 2020. Basing on these information, we could compute CO_2 discharge produced by economic activities. With the bottom-up method, alternative possible energy-saving techniques in energy-intensive sectors under different growth rates could be studied in detail. By introducing these techniques, the direct consumption coefficients in the input-output table will decline. Hence, we have no difficulty to grasp one of its important conclusions: a higher economic growth rate does not mean a larger discharge of CO_2, since, as the economy grows, to introduce more effective technologies becomes possible. This study inclined to predict the future CO_2 discharge of China, emphasize the role of technology selection, but without any economic means to control CO_2 discharge, and also without cost analysis of CO_2 discharge reduction.

Similar to our study, Zhang (1996) and Jorgenson.et al. (1997) used their respective dynamic CGE model of Chinese economy to investigate the effects of carbon taxation. The principal reason of using CGE models to analyze carbon taxation is: carbon tax will change the relative prices among commodities, meanwhile, it would exert substantial influences on the economy because of the intrinsic interdependence in economic structure, and the CGE model is an useful instrument in such cases. Since reduced discharge of CO_2 involves also future cases without corresponding policies, for example, CO_2 discharge in 2030 without carbon taxation. Hence both the two models are dynamic, they could derive economic growth and channels of CO_2 discharge endogenously. In respect to model structure, the model of Jorgenson et al. is much more complex. One of its characteristics is that it considered also the rent distribution produced by the dual pricing mechanism and its impact on investment. It considered also the drawbacks in investment allocation caused by imperfect capital market in China. In contrast, Zhang’s model is a typical recursive dynamic CGE model. One contribution of his work is to link the CGE model with the energy technology selection model, MARKEL. While it investigates the effects of discharge reduction, the minimum cost technology of CO_2 discharge reduction is also shown. CGE model alone cannot show choice among different production technologies (different production functions), but MARKEL is a linear programming model, which can choose an optimum technology under the direction of an objective function, subject to several linear technical and economic constraints. The combination of two types of modeling means that people like to synthesize the top-down and bottom-up approaches in evaluation of discharge reduction costs. Such synthesis is

[3] It will be discussed in detail afterwards in this paper.

far from perfection till now. Results of CGE model could be used as inputs to MARKEL model, however, if the outputs of MARKEL are fed back to the CGE model, it would be impossible in practice to form a consistent model after repeated iteration. As to the CGE models themselves, the two models used different types of functions, chose different parameters, and simulated under different assumptions, hence, obtained different results. The results of Jorgenson et al. are rather optimistic: they showed that with a carbon tax of 9 yuan / tc, and decreased other taxation of enterprises so that revenues of the government kept constant, discharge of CO_2 could be lowered by 5%[4]. Meanwhile, although economic growth might be slowed at an initial period of carbon taxation, but investments might be increased subsequently (because enterprise would have more surplus to invest after reduction of other taxes), economic growth may be more rapid than cases without carbon taxation. Moreover, the long-run economic growth might compensate for short-run economic decline. Therefore, they maintained that the Chinese government faces opportunities of double-dividends, that is to say, both long-run economic growth and environment amelioration (reduced CO_2 discharge) could be realized at the same time through reformulation of taxation basis (introduction of carbon tax to replace other enterprise taxes). Zhang's study showed that a carbon tax of 205 yuan / tc is necessary to reduce CO_2 discharge by 20%. The result is obviously much larger than that of Jorgenson et al. Meanwhile, GDP declined by 1.52% (2010) as compared with the situation without carbon taxation, moreover, it is always less than the situation without carbon tax. He assumed also to reduce other indirect taxes by 5% and 10% for compensating the negative effects of carbon taxation. The results show that effects of such reduction are very limited, for example, decrease of 1.52% of GDP becomes 1.51 and 1.47% respectively. Hence, his study shows a trade-off relation between economic growth and environmental amelioration, you cannot get both simultaneously..

Our study uses the CGE model of Chinese economy, PRCGEM, as developed jointly by the Institute of Quantitative and Technological Economics, Chinese Academy of Social Sciences, and the Center of Policy Studies, the Monash University, Australia. Costs of CO_2 discharge reduction through carbon taxation under different situations are analyzed. It is a comparative static analysis. Since we consider only the effects of carbon taxation, not their paths of realization, or, in other words, we are not interested in the transition process from one equilibrium to another, the differences between a static and a dynamic model is unimportant for us. In addition, we are interested always in the comparison of situations with or without carbon taxation (situations relative to each other), even if we have a (conditional) forecast[5] practically the absolute amount will not be of much significant in comparison. In addition, an advantage of static analysis is that it could deal with the effects in short run, in particular, under rigidity of factor markets; in contrast, if recursive dynamic models are used (such as Zhang's model), we would suppose complete mobility of factors in each period. Of course, it should be admitted that we cannot analyze those interesting problems produced by carbon taxation , which could be studied by dynamic models only.

[4] Relative to cases without carbon taxation. All conclusions hereafter refer to comparison between cases with carbon taxation and without carbon taxation.

[5] Such forecasts are dependent on some assumed exogenous variables, such as population growth, etc. Actually, it is very difficult for us to have accurate forecasts of all exogenous variables, for example, trends of TFP fluctuation in the coming two decades.

2. Modeling and Data

The original PRCGEM is a computable general equilibrium model describing economic activities of China. In order to analyze effects of carbon taxation and CO_2 discharge, we should establish relationships between economic activities and CO_2 discharge, design modes of carbon taxation, and integrate carbon taxation into the model framework. Modeling and data preparation are shown as follows:

2.1 Modeling

a. Basic Assumptions of PRCGEM

PRCGEM is a typical CGE model based on neo-classical general equilibrium theory, its structure is similar to that discussed in Dervis, et al (1982), Horridge, et al (1993).

Assumptions about producers:

·Each sector produces one king of commodity;

·It is a price taker, having no influence on market;

·Cost minimization;

·Nested Leontief/CES production function, with substitution between domestic produced and imported inputs (Arminton assumption), substitution among labor, capital and land;

Assumptions about investors:

·Price taker;

·Cost minimization;

·To construct capital goods with domestic and imported commodities;

Assumptions about consumers:

·One category of consumers only;

·Utility maximization within budget constraints;

·Price acceptor;

·Structure of consumption described by inlaid LES/CES fuction;

·Total consumption kept constant or as a fixed proportion of GDP;

Assumptions about exports:

·Incomplete substitution between products for export and those for domestic consumption;

·Demand curve for exports negatively inclined;

Assumptions about the government:

·Cost minimization;

·Total expenditures fixed or as a certain proportion of total consumption;

Assumptions about prices:

·Price equal to cost, zero profit assumption;

·Model is money-neutral, hence a price is required as a numeriar In general, exchange rate is chosen as the numeriar;

Assumptions about commodity markets:

·Commodity markets always in equilibrium, market clearing assumption;

b. Supplements to PRCGEM

b.1. Revisions of production functions.

In PRCGEM, all energy sources, including coal, oil, natural gas and electric power, and factors of production in the sectors are produced according to Leontief's production function. The drawback of its constant coefficient matrix is no substitution among various energy sources. The substitution is possibly important for our problem.

Hence we combine the energy sources and factors of production with CES function, with coal, oil, natural gas and electric power combined into energy according to Cobb-Douglas function. Then elasticities of substitution between energy and factors of production are constant, that among various energy sources is 1. Thus the original inlaid PRCG EM production function is further inlaid in order to allow for substitution between energy and factors, and between energy sources.

b.2. Introduction of carbon taxation and CO_2 discharge equations.

For carbon taxation we require to calculate carbon contents of three types of fossil fuels. In particular, we have:

$$C1(i,j) = A_j X1(i,j) \qquad 2.1$$

In the above formula, 1 means intermediate inputs; i is the sector; j is the kind of fossil fuels; $C1(i,j)$ is the carbon content of fuel j used by sector i,

is the quantity of fuel j used by sector i in tons or kilimeters.

Is the carbon content of one unit of fuel j. The above formula represents carbon consumed in the production process. What follows is that expended in consumption process:

$$C3(j) = A_j X3(j) \qquad 2.2$$

in which, 3 represents consumption of houshold, $X3(j)$ is the fuel j consumed by inhabitants, $C3(j)$ expresses the carbon content of fuel j consumed by inhabitants. Then we add up the above two items to arrive at the total carbon content of fuel j of domestic use (including both production and consumption uses), i.e.,

$$C(j) = \sum_i C1(i,j) + C3(j) \qquad 2.3$$

Based on the total carbon content of fuel j, together with a transformation factor and a combustion efficiency factor, we could calculate roughly the CO_2 discharge caused by fuel j usage, i.e. :

$$Co_2(j) = \alpha \lambda_j C(j) \qquad 2.4$$

in which, the transformation factor, α, is equal to 3.67[6], while λ_j is the combustion efficiency factor. Adding up all the CO_2 produced by fossil fuels, we arrive at the total CO_2 produced by fossil fuels in both production and consumption, that is:

$$Co_2 tot = \sum_j Co_2(j) \qquad 2.5$$

As explained before, we cannot calculate CO_2 discharge of each sector and of consumption.

It is relatively simple to introduce carbon taxation in the model. The purchasers' price of each kind of fossil fuel is equal its producers' price plus carbon tax and other indirect taxes. The carbon tax paid by purchasers are determined by carbon content of fossil fuels consumed and the carbon tax. In particular, the purchasers' price for producers is:

[6] That is, the molecular weight of CO_2, 44, divided by the molecular weight of carbon, 12.

$$P1(i,j) = P0(j) + ITX(j) + A_j TC \qquad 2.6$$

In which, P1(i,j) is the purchaser's price paid by sector I for fuel j , P0(j) is the producer's price of fossil fuel j, ITX(j) is the indirect taxes of fuel j, TC is the carbon tax. And the carbon tax paid by sector i for fuel j is :

$$RTC1(i,j) = TC \times C1(i,j) \qquad 2.7$$

Similarly, the purchasers' prices of fossil fuels for consumers are:

$$P3(j) = P0(j) + ITX(j) + TC \qquad 2.8$$

Carbon tax paid by consumers for use of fossil fuels is:

$$RTC3(j) = TC \times C3(j) \qquad 2.9$$

By adding up (2.7) and (2.9), we arrive at the total carbon tax revenue:

$$RTCTOT = \sum_j \sum_i RTC1(i,j) + \sum_j RTC3(j) \qquad 2.10$$

Finally, we add carbon tax of (2.10) to the fiscal revenue as defined in PRCGEM, and revise the GDP of the original model.

2. 2 Data

Similarly, the data include those of the original PRCGEM and the additional data about CO_2 discharge of the base period.

a. Data of PRCGEM

The original PRCGEM consisted of a model of 118 sectors and another model of 33 sectors[7], both based on an input-output table of 1992.

In order to calibrate the model, it is necessary to set several important elasticities.. As no appropriate and detailed literature of elasticity evaluation is available, we can only refer to the data of other countries in setting the required parameters. The resulted main elasticities are as follows:

Table 2.1: Value of Main Elasticities

Main Elasticities	Value
Armington Elasticity of Substitution	2.0
Elasticity of Capital-Labor Substitution	See Appendix 2[8]
Elasticity of export demand	-5
CET Transform Elasticity	3-10

b. Data of CO_2 Emission in Base Period

Table 2.2 Consumption of Fossil Fuels, 1992, Quantity and Value

Type of Fossil Fuel	phisical consumption in 1992 [a]	Value of Fossil Fuel[b]	Price of Fossil Fuel
Coal	1.14 billion ton	65 billionYuan	57.02Yuan/ton
Oil	0.13 billion ton	60.9 billionYuan	468.46Yuan/ton
Gas	15.8 billion M^3	1.37 billionYuan	0.09Yuan/ M^3

a: The Chinese Statistical Yearbook, 1994.
b: The 1992 Input-Output Table of China.

[7] The two models have identical structure, with different degree of aggregation.
[8] Estimated by ProfessorsGong Yi and Loyed.

In addition, we must know the carbon content of individual fossil fuel, its combustion ratio, and loss of inefficiency, and other adjustment factors.

Table 2.3 Carbon Content, Combustion Ratio and InefficiencyLoss

Type of Fuel	Carbon Content[a]	Combustion Ratio[b]	Inefficiency Loss[b]
Coal	0.54tC/t	98.3%	1%
Oil	0.84tC/t	98.3%	1%
Natural Gas	0.0006tC/m^3	98.3%	1%

a: IPCC()
b:The World Bank(1990)

Using equation of CO_2 emission, (2.4) and the above data, we could estimate The emission in 1992.

Table 2.4 The World Bank Estimate and Our Estimate

	World Bank's(1990)	Ours(1992)
Total carbon	667.64 Tg	734.32 Tg
Total Co2 emission	2380.84 Tg	2620.28 Tg

1Tg= 1 million tons

There are some difference between the World Bank estimate and ours. They refer to 1990, and we refer to 1992. They consider carbon which became CO_2, while we consider also carbon which did not become CO_2 due to low efficiency of combustion. In practice, some carbon became other products such as plastics. Unfortunately, we cannot derive data for concrete products from input-out tables. So our estimate of CO_2 emission may be too high[9]

3. Simulation Results and the Explanation

We have designed several situations to analyze different emission reducing costs corresponding to them: CO_2 emission reduction by 5%, 10% and 20%. Meantime, we have distinguished between short run and long run costs of emission reduction. Whether other taxes are reduced, when carbon tax is levied. We have done 12 simulations. Tables 3.1 and 3.2 show respectively the short run and long run costs of emission abatement under different situations. The so-called short run and long run do not represent certain length of time, they indicate the reaction process of macro-variables to changes in exogenous variables[10].

[9] If the World Bank estimate is accurate, and if the emission reached what we estimate for 1992, the annual average rate of growth of CO_2 emission will be a incredible 5.?%.

[10] Thus, we don't suppose changes in capital stock caused by investment, increase of labor force and technical progress in the long run.

Table 3.1 Short Run Macro-Impacts on CO_2 Discharge under Various Situations

		Reduce $Co_2$5%	Reduce $Co_2$10%	Reduce $Co_2$20%
With carbon tax, no reduction of other taxes.	Real GDP	-0.22%	-0.47%	-1.06%
	Carbon Tax	13.75Yuan/ Tc	29.13Yuan/ Tc	66.11Yuan/ Tc
With carbon tax, reduced enterprise taxes, government revenue neutral	Real GDP	-0.05%	-0.12%	-0.34%
	Carbon Tax	14.68Yuan/ Tc	31.24Yuan/ Tc	71.69Yuan/ Tc

Table 3.2 Long Run Macro-Impacts on CO_2 Discharge under Various Situations

		CO_2 reduced by5%	Co_2reduced by10%	Co_2reduced by20%
With carbon tax no reduction of other taxes	Real GDP	-0.06%	-0.13%	-0.36%
	Carbon tax	13.23yuan/ Tc	28.21yuan/ Tc	64.91yuan/ Tc
With carbon tax reduction of other taxes, keepGovernment revenue unchange	Real GDP	-0.014%	-0.01%	-0.06%
	Carbon tax	13.54yuan/ Tc	28.96yuan/ Tc	67.09yuan/ Tc

3.1 Analysis of Macro-Impacts

a. Some Fundamental Results.

The simulation shows that:

(1) the cost increases with the increase of amount of CO_2 reduced in short term

(2)the cost increases first, then decline with the increase of amount of CO_2 reduced in long term.

(3) Short-term cost of CO_2 reduced is larger than long-term.

(4) If reducing other taxes simutaneously with carbon tax, the decline of GDP become less.

b. Decomposition of Effects of CO_2 Discharge Reduction

Table 3.3 Decomposition of Effects of CO_2 Reduction

		Results of Decomposition		
		Output Effects	Structure Effects	Total
Short Run	No Reduction of Other Taxes	-0.47%	-9.53%	-10%
	Reduction of Other Taxes	-0.12%	-9.88%	-10%
Long Run	No Reduction of Other Taxes	-0.13%	-9.87%	-10%
	Reduction of Other Taxes	-0.015%	-9.985%	-10%

$$Co_2 tot = \frac{Co_2 tot}{GDP} \times GDP \qquad 3.1$$

CO_2tot = s + gdp (3.2)

Structure effects output effects

c. Carbon Tax and Taxes on Fossil Fuels

Carbon tax is based on the carbon content of fossil fuels, so is a tax ad quantum. However, we could convert it into a tax ad valorem. From (2.6) or (2.8), we Have:

$$P(j) = P0(j)(1 + ti(j)) + A_j \times TC$$

That is, the selling prices of fossil fuels are equal to producer's price plus Indirect taxes and carbon tax per unit of fuel. Obviously,

$$P(j) = P0(j)\left(1 + ti(j) + \frac{A_j \times TC}{P0(j)}\right)$$

$\frac{A_j \times TC}{P0(j)}$ is just the tax ad valorem of fuel j required by us, expressed as TCE(j), which is related to the carbon tax, TC, and the producer's price of fossil fuels.

Differentiating the logarithm of (1+TCE(j)), we arrive at the percentage Variation of tax ad quantum corresponding to carbon tax variation

$$d\ln(1 + TCE(j)) \times 100 = \frac{A_j dTC}{P0(j)} \times 100 \qquad 3.3$$

3.2 Analysis of Sectorial Impacts

Table 3.4 Carbon Intensity Measured in Two Ways

MEASURED IN VALUE				MEASURED IN REAL TERMS			
5 Sectors With Max. Intensity		5 Sectors With Min. Inntensity		5 Sectors With Max. Intensity		5 Sectors With Min. Intensity	
Sector	Intensity	Sector	Intensity	Sector	Intensity, TC/yuan	Sector	Intensity, TC/yuan
Oil Refinery	52%	Constructi-on	0.06%	Coke	0.0033	Constr-uction	5.49E-06
Coke	38%	Farming	0.08%	Electric Power	0.0014	Electronic	7.46E-06
Electric Power	18%	Electric	0.11%	Oil Refinery	0.00094	Farming	7.57E-06
Coal	3.5%	Apparel	0.13%	Coal	0.00033	Electric	9.07E-06
Building Materials	3%	Electronic	0.16%	Building Materials	0.00026	Apparel	1.18E-05

Table 3.5 Short Run Sectorial Impacts

WITH CARBON TAXATION, NO REDUCTION OF OTHER TAXES				WITH CARBON TAXATION, NO REDUCTION OF OTHER TAXES, FISCAL			
5 Sectors with max. Decline of outputs		5 Sectors with miniincreased outputs		5 Sectors With Max. Intensity		5 Sectors With Min. Intensity	
Sector	Intensity	Sector	Intensity	Sector	Intensity, TC/yuan	Sector	Intensity, TC/yuan
Coal	-10.68%	Administr-ation	0	Coal	-10.63%	Food	0.24%
Natural gas	-6.23%	Constructi-on	-0.014%	Natural gas	-6%	Electric power	0.12%
Coke	-2.29%	Restaurants	-0.02%	Coke	-2.1%	Farming	0.02
Textile	-1.37%	Cultural and education	-0.15%	Oil Refinery	-0.86%	Restaurants	0.018%
Apparel	-1.33%	Repair	-0.16%	Minerals	-0.74%	Electronic	0.013%

Table 3.6 Long Run Sectorial Impact

WITH CARBON TAX, NO REDUCTION OF OTHER TAXES, FISCAL REVENUE				WITH CARBON TAX, REDUCTION OF OTHER TAXES, FISCAL REVENUE			
5 Sectors with max. decline of output		5 Sectors with increased output		5 Sectors with max. Decline of output		5 Sectors with increased output	
Sector	Intensity	Sector	Intensity	Sector	Intensity	Sector	Intensity
Coal	-10.68%	Apparel	0.52%	Coal	-10.78%	Electric Power	1.03%
Natural gas	-6.75%	Electric power	0.44%	Natural gas	-6.76%	Apparel	0.45%
Coke	-2.0%	Textile	0.18%	Coke	-1.9%	Foods	0.4%
Oil refinery	-0.85%	Farming	0.15%	Oil refinery	-0.62%	Electroni-cs	0.25%
Metallur-gy	-0.74%	Foods	0.01%	Metal ores	-0.52%	Textile	0.16%

c. Analysis of Regional Impacts

Table 3.7 Short Run Regional Impacts

WITH CARBON TAXATION, AND NO REDUCTION OF OTHER TAXES				WITH CARBON TAXATION, AND REDUCTION OF OTHER TAXES			
5 Regions with max. Decline of Output		5 Regions with least decline of output		5 Regions with max. Decline of output		5 Regions with least decline of output	
Regions	Intensity	Regions	Intensity	Regions	Intensity	Regions	Intensity
Shanxi	-2.5%	Xizang	0	Shanxi	-2.27%	Xizang	0.1%
Ningxia	-1.1%	Hainan	-0.23%	Ningxia	-0.84%	Hainan	0.01%
Heilong Jiang	-0.94%	Qinghai	-0.42%	Heilong Jiang	-0.66%	Gua ngdo ng	-0.1%
Neimeng gu	-0.78%	Guang xi	-0.43%	Neimeng gu	-0.5%	Fujia n	-0.12%
Liaoning	-0.76%	Yunnan	-0.45%	Henan	-0.43%	Zhej iang	-0.123%

Table 3.8 Long Run Regional Impacts

REGIONS WITH CARBON TAXATION, MAX. DECLINE OF OUYPUT				REGIONS WITH CARBON TAXATION, REDUCTION OF OTHER TAXES, FISCAL REVENUE UNCHANGED			
Shanxi	-2.32%	Xizang	0.05%	Shanxi	-2.19%	Xizang	0.16%
Ningxia	-0.87%	Hainaan	0.006%	Ning Xia	-0.72%	Hainan	0.12%
Heilong jiang	-0.68%	Zhe jiang	-0.07%	Hei Long Jing	-0.53%	Guang dong	0.06%
Neimenggu	-0.51%	Fujian	-0.087%	Nei Menggu	-0.37%	Zhe jiang	0.05%
Liao Ning	-0.45%	Guang dong	-0.088%	Henan	-0.31%	Fujian	0.04%

d. Summary

(1).We have conducted cost analysis in connection with carbon taxation and reduction of CO_2 discharge. Is our analysis useful for more general steps in the reduction of CO_2 discharge ? The answer is in the affirmative. According to the basic theory of environmental economics, reduction of CO_2 discharge by carbon taxation will equalize the marginal cost of discharge reduction for all sectors, it will be thus the minimum cost way of reducing a certain amount of CO_2 discharge. Moreover, the use of cleaning techniques produce effects quite Similar to carbon taxation. For example, cost of coal washing is equivalent to levy tax on coal, and make combustion cleaner at the same time.

(2) Our another important observation in the analysis is: to reduce CO_2 discharge by carbon taxation causes no serious problem for the economy. Is the conclusion reasonable ? Let us to look at the problem from two points of view:

In the first, because of the substitution relationship in the economy, it is unnecessary for GDP to decline to the same extent as decrease of energy production in response to the carbon taxation, as evidenced clearly by our CGE model. From this point of view, it is probably not a calamity to levy the carbon tax. On the second hand, substitution in the economy means changes in the structure of production and consumption. We assume no adjustment costs in the model, which is unrealistic in practice. For example, workers in coal fields cannot simply moved to other occupations without re-training. People must first buy electric equipment to replace coal with electricity. Because of the adjustment costs, carbon tax will be more burdensome than the revenue, it will be necessary to reduce other taxes at the same time[11]

4. Conclusions and Prospects.

We have used a computable general equilibrium model to analyse the possible costs for controlling CO_2 discharge with carbon taxation. The costs depend on several factors: the required extent of discharge reduction, short run or long run reaction to carbon tax, and whether other taxes are reduced.

Impacts on the whole economy will be much more moderate than impacts on Individual sectors. Simulation has shown that under the worst conditions (20% reduction of discharge in the short run, without reduction of other taxes), the real GDP will decrease by only 0.96%. Under the best conditions (5% reduction of discharge in the long run, with reduction of other taxes), the real GDP will decline by only 0.016%. We have decomposed the effects of discharge reduction into output effects and structural effects. We have also discussed impacts on outputs of individual sectors under a 10% reduction of discharge. Outputs of coal fields, oil refinery and coke industry have declined the most, while sectors using few energy sources, such as apparels, foods, increase their outputs slightly. It is noteworthy that output of electric power will increase because of substituting electricity for fossil energy. In regional analysis, Shanxi, Ningxia, Heilongjiang, and Neimenggu are regions where outputs decrease the most, while Heinan, Guangdong, Zhejiang and Fujian will gain in output mostly.

Finally we suggest some topics for future research:

- Preparation of data with more and better quality;
- Analysis of a larger set of policies, selection of optimum policies;
- Developing dynamic models, introducing costs of structural adjustments.

Refeeerences

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[11] Our analysis of short run costs could be seen as increasing certain adjustment costs, for example, capital cannot move freely among sectors. Obviously short run costs are much larger than long run costs.

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Appendix 1

Classification of Sectors in the Model

Code	Sector	Code			Sector
1	Farming	13	Oil Refinery	25	Other Indutries
2	Coal Mines	14	Coke	26	Construction
3	Oil Wella	15	Chemicals	27	Traffic
4	Natural Gas	16	Building Mat.	28	Trade
5	Mineral Mines	17	Metallurgy	29	Restaurants
6	Other Metallic Minerals	18	Metallic Products	30	Passenger Traffic
7	Foods	19	Machinery	31	Public Utillity
8	Textile	20	Transportation Equipment	32	Culture and Education
9	Sewing	21	Electric Machine	33	Finance
10	Furnitures	22	Electronic	34	Administrat-ion
11	Papermaking	23	Weights and Measures		
12	Electric Power	24	Repair		

Appendix 2: Capital-Labor Substitution Coefficients of Individual Sectors

1	0.5	10	1	19	1	28	0.5
2	0.77	11	1	20	0.5	29	0.5
3	1.79	12	0.8	21	0.5	30	0.5
4	1.79	13	1.59	22	0.9	31	0.5
5	0.62	14	1.59	23	0.9	32	0.5
6	0.8	15	0.9	24	0.8	33	0.5
7	0.8	16	1	25	0.8	34	0.5
8	1.07	17	0.8	26	0.5		
9	0.8	18	1	27	0.5		