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Economic and Environmental Effects of Resource Tax Reform in China: A Computable General Equilibrium

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Abstract. In order to lower carbon emission at a national scale, coal resource tax reform from quantity-based collection to ad valorem collection has been taken by Chinese government in December 2014. To research the economic and environmental impacts from the policy reform, this paper extends a multi-sectoral computable general equilibrium (CGE) model and GAMS are used to solve for the equilibrium. Two scenarios are designed, quantity-based collection and ad valorem collection with different tax rate, within the CGE model. By comparing results from the resource tax reform, some conclusions could be captured. The first conclusion is that there is a negative relationship existing between gross domestic product of China and the higher tax rate due to the decreasing of output and the total output for each industry would decline obviously. The second conclusion is from the environmental aspect. With the higher resource tax burden, the total resource demand would decrease, as a result, the structure of energy would be improved largely. The total carbon emissions, as well as other air pollutants would be decreased. In conclusion, the benefits brought by the tax reform would reach the China's goal for carbon emission reduction.

Keywords: Resource tax reform; CGE model; Economic growth; Environment improvement.

1. Introduction

During recent decades, the rising energy demand and environmental pollution have become the main contributor to the global climate change. From 1979, lots of institutions are founded and devote themselves to resource conservation and emission mitigation. However, problems are presented during the process of resource depletion. Firstly, the extensive mining causes resource overexploitation and waste. Secondly, constrained by the technology, the efficiency for resource usage is low. According to the "Annual Report on Comprehensive Utilization of China Resources", the rate of multipurpose utilization for associated minerals is around 30% which is lower than the average level in developed countries (60%). Thirdly, the ecological destruction and air pollution is the most serious problems caused by resource overexploitation. The irrationality of current resource tax policy is the direct reason for low exploration rate, resource over-depletion and environmental destruction (Lu, 2010) [1].

The main purpose for this paper is to research the economic and environmental effects through using a multi-sectoral CGE model and provide some valuable insights, such as policy design. This paper is constructed as follows. The CGE model is build based on the China's current resource tax system with the social accounting matrix (SAM) and parameters specification. The stimulation results are shown which suggest further improvement related to the policy design.

2. Model and Data Sources

2.1 Data and Parameters

Social accounting matrix (SAM) is an economy accounting table through the formula of matrix. In this paper, SAM is extended using data from the Chinese 2010 input-output data, China's statistical Yearbook in 2011 and the Balance of international payments in 2010. The process of extending SAM employs methods mentioned by Wang and Li (2009) [2] and Feng (2011) [3].

Most parameters are obtained based on the data in the SAM with the exogenous elasticity coefficient which could be gained through GAMS. However, the elasticity coefficient should be calculated using the econometric method or previous research. In this case, other scholars' research is used for reference. Four elasticity coefficients are used in the CGE model which is ρ^A (the elasticity between value added and intermediate input), ρ^v (elasticity between labor and capital), ρ^t (elasticity between products produced and sold domestically compared with export products) and ρ^q (elasticity between products supplied domestically compared with import products). Among those four parameters, substitution elasticity is estimated by Xu (2015) [4] to be 0.3 and other three parameters are estimated by Zhang (2013) [5]. The results after converting to elasticity coefficient are listed in table 1.

Table 1. Substation elasticities of different commodities

Department	Code	ρ^A	ρ^v	ρ^q	ρ^v
Agriculture	AGR	-2.33	-1.34	0.67	0.72
Mining and washing of coal	M_C	-2.33	0.54	0.73	0.78
Extraction of petroleum and natural gas	M_O	-2.33	0.54	0.73	0.78
Other mining industries	OMI	-2.33	0.54	0.73	0.78
Manufacture of food, beverages and textiles	FOD	-2.33	-1.30	0.74	0.78
Processing of petroleum	OIL	-2.33	-1.30	0.74	0.78
Manufacture of raw chemical materials and chemical products	RCM	-2.33	-1.30	0.74	0.78
Mining and processing of ferrous and non-ferrous metal ores and nonmetal ores	MFM	-2.33	- 1.30	0.74	0.78
Manufacture of medicines	MCM	-2.33	–1.30	0.74	0.78
Manufacture of electrical, electronic equipment, water and gas	EEQ	-2.33	0.61	0.77	0.78
Construction	CNS	-2.33	- 2.82	0.47	0.74
Transportation, storage, post telecommunication and other information-transmission services	TRP	-2.33	- 0.38	0.47	0.64
Wholesale, retail and accommodation industry	WRA	-2.33	-0.38	0.47	0.64
Other services	OSR	-2.33	—0. 38	0.47	0.64

2.2 Model

This model divides China's sectors into 16 energy sectors and the coal industry, petroleum & natural gas industry and the other mining industry is the main focus. To clearly depict the relationship between the agents and sectors, nine modules are included in the CGE model which are inputs and outputs module, prices module, demand module, income and expenditure module, environmental module, equilibrium module and closure module.

2.2.1 Inputs and Outputs Module

This module depicts the process of transfer from inputs, such as labor, capital and natural resources, to outputs. Production factors are based on the resource consumption and technology is assumed to be constant returns to scale with CES function. The value of total products output constitutes added value and intermediate inputs which employs Leotief function and no substitution between intermediate inputs and added value. Added value is represented by the Cobb-Douglas function.

The total output function is

$$QA_a = \alpha_a^A[\delta_a^A QVA_a^{\rho_a^A} + (1-\delta_a^A)QINTA_a^{\rho_a^A}]^{\frac{1}{\rho_a^A}} \quad (1)$$

The added valued function is

$$QVA_a = \alpha_a^v[\delta_a^v QLD_a^{\rho_a^v} + (1-\delta_a^v)QKD_a^{\rho_a^v}]^{\frac{1}{\rho_a^v}} \quad (2)$$

2.2.2 Price Module

In this module, the tax reform would bring tax burden and hence influence the resource prices. Price module is connected with different methods for tax collection and obtain the effects from the tax reform. During the process of production, various types of resources can't be substituted perfectly and tax rate is regarded as an exogenous variable. In this case, both quantity-based and ad valorem tax are taken into consideration.

The price equation for quantity-based resource tax is

$$PA_a * QA_a = (PVA_a + tvaq_a) * QVA_a + (PINTA_a + tvaq_a) * QINTA_a \quad (3)$$

The Euler equation for quantity-based resource tax is

$$\frac{PVA_a + tvaq_a}{PINTA_a + tvaq_a} = \frac{\delta_a^A}{1-\delta_a^A}\left(\frac{QINTA_a}{QVA_a}\right)^{1-\rho_a^A} \quad (4)$$

2.2.3 Demand Module

The demand module is separated into four parts which is households, enterprise, government and foreign parts. The demand of the households follows the rule of maximizing the utility constrained by the disposable income. The enterprises' demand includes the investment and intermediate input demand. As the investment demand is exogenous and aggregates to the total social investment, thus investment do not belong to enterprises' account.

The demand equation for households:

$$PH_c * QH_c = shrh_c * mpc * (1 - ti_h) * YH \quad (5)$$

2.2.4 Income and Expenditure Module

This module reflects how tax reform would influence the households', government's, enterprises' and foreign parts' income and expenditure. Households could obtain their income from the wages of labor, return of the capital and transfer income from the other three parts. To capture the different features of rural and urban residents in China, households are divided into two groups which both are price takers. After affording the income tax, the disposable income is used for consumption. Cobb-Douglas utility function is employed to measure the household's utility.

The income equation for households is

$$YH = WL * QLS + shif_{hk} * WK * QKS + tranfr_{hent} + transfr_{hgov} + transfr_{hrow} * EXR \quad (6)$$

Enterprises are profit-driven entities and pre-tax income includes the capital income and transfer income from the government while the expenditure includes corporate income tax and transfer expenditure to households. The savings amount is the difference between the income and the expenditure.

2.2.5 Environmental Module

Environmental effects are equally vital for the economic effects and hence the environmental module is specified in this CGE module. The resource tax policy would bring positive environmental effects through pollution control, which means the benefits brought by tax policy would exceed the cost.

The equation for quantity-based resource tax is

$$YE = tvaq_a(QVA_a + QINTA_a) - PE_{COST} \quad (7)$$

The equation for ad valorem resource tax is

$$YE = \frac{tvaq_a}{1 + tvaq_a} * PA_a * QA_a - PE_{COST} \quad (8)$$

$$PE_{COST} = \sum (SP_{Q1} + EP_{Q2}) PE_{EX} PE_{AC} \quad (9)$$

The quantity of CO_2 and SO_2 emissions are calculated using the resource consumption. The emissions of CO_2 and SO_2 are calculated based on lots of factors, such as conversion rate, emission factors and oxidization fraction factors. These data could be obtained from China Energy Statistical Year Book 2010 and some existing researches. The equations for CO_2 and SO_2 are

$$QC = (R_P * A - B_C) * R_e * 3.67 \quad (10)$$
$$QS = 2S_C FS(1 - NS) \quad (11)$$

2.2.6 Equilibrium Module

Three market clear conditions are exchange equilibrium, commodity market clear and factor market clear. In this case, resource market should be taken into consideration.

The exchange equilibrium employs the fixed exchange rate and the foreign savings are regarded as exogenous variable. Although the current exchange rate system is based on the market supply and demand, it still mainly controlled by the Chinese government and central bank, thus the degree of marketization is low. As a result, it is reasonable to regard exchange rate as fixed system.

The equation for factor (labor, capital) market clear is

$$QLS = \sum_a QLD_a \quad (12)$$
$$QKS = \sum_a QKD_a \quad (13)$$

The equation for products market clear is

$$QQ_c = \sum_a QINT_{ca} + \sum_h QH_{ch} + \overline{QINV_c} + \overline{QG_c} \quad (14)$$

2.2.7 Closure Module

Keynesian macro closure is employed which means the supply of labor, capital and resource is determined by the demand and the price of these factors is fixed.

As prices of factors are exogenous variables, the equation for these prices is

$$WL = \overline{WL} = 1 \quad (15)$$

$$WK = \overline{WK} = 1 \quad (16)$$

According to Keynesian macro-economy theory, investment-saving equation is equal to the supply-demand equation. In order to solve the equation, an error term is added to ensure the solvability.

The investment-saving equation is

$$EINV = (1 - mpc) * (1 - ti_h) * YH + ENTSAV + GSAV + EXR * FSAV + VBIS \quad (17)$$

3. Stimulation Results

3.1 Economic Impact

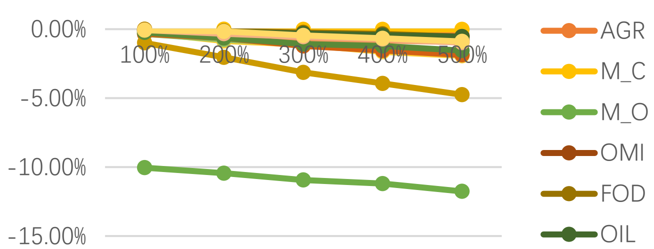

Fig. 1 Percentage change in total output by each industry

From the above figure, the resource tax collection reform influences the resource industry or manufacture industry related with resource evidently, this caters for the common sense about the reality. The tax reform makes a powerful impact on the petroleum and natural gas industry, even increasing the resource tax rate to 6%, the decreasing percentage in coal industry is still less than it in the petroleum and natural gas industry. The reason to explain this phenomenon is that in the long term, the resource tax in the petroleum and natural gas industry does not consider factors causing the increasing price in petroleum and natural gas market, hence, the fixed collection has little impact on the whole market. As the reform in resource tax collection, resource tax connects with the price of petroleum and natural gas and the tax burden would increase. Currently, the tax burden is difficult to be transferred to customers or other entities in the supply chain, thus, the output in those market would diminish dramatically.

Table 2. Impacts of resource tax collection reform on GDP

Index (2010)	Quantity-based resource tax	Ad valorem resource tax (petroleum & natural gas 6%, coal 2%-8%)				
		2%	4%	6%	8%	10%
Real GDP in 2015 (Billion)	425126.100	423396.450	423187.338	422973.348	422754.353	422530.240
Percentage change		-0.407%	-0 .456%	-0.506%	-0. 558%	-0.6 11%
Nominal GDP in 2015(Billion)	438305.009	437368.533	437998.895	438200.389	438396.264	438586.389
Percentage change		-0.214%	-0.070%	-0.024%	0.021%	0.064%

The general index for impacts on the economic growth from the resource tax reform is the nominal and real GDP which includes the total consumption, total investment and total net exports of China. The tax collection reform has negatively effects on the economic growth and this effect would be worse with increasing coal resource tax rate. Due to different coal resource tax rate under ad valorem, GDP dropped off between 0.407% and 0.611%. If the results are applied to choose a certain tax rate, the price level should be taken into consideration.

From the real GDP, if fixing the resource tax rate for petroleum and natural gas as 6%, the real GDP shows shrinkage trend with the rising coal resource tax rate. Decreased from 423396.450 billion yuan to 422530.240 billion yuan, the overall decline is from 0.407% to 0.611%. The negative effects on GDP would diminish as time goes. For example, with the 8% coal resource tax rate, the real GDP would decline by almost 0.2% in 2015 while only 0.15% in 2020. When the tax rate changes from 2% to 8%, the total consumption, the total investment and the total net exports would be cut down and the total consumption suffers the most when the coal resource rate is set to 2%. The reason is that when the tax burden is higher, the labor-intensive industry would be encouraged and the capital-intensive industry would be dampened. For this reason, labor-intensive industry would create more employment opportunities while the capital-intensive industry would reduce the investment. As a result, the investment would be cut down most.

From the nominal GDP, opposite tendency could be observed in the ad valorem tax collection which increase slightly.

The root cause for the difference between the real GDP and the nominal GDP is the price. The tax collection reform has aggravated the total tax burden for enterprises, thus these tax burden has been transferred to customers and then raise the price level of products. Meanwhile, with the increasing tax rate, the price level would increase obviously, therefore the opposite trend could be illustrated for the nominal GDP and the real GDP. In this paper, real GDP is of more importance because it is a better measurement to reflect the economic growth.

3.2 Environmental Impact

Compared with the basis condition, the resource tax reform stimulated the decrease in total intermediate inputs among all three industries. When 6% tax rate is executed, the petroleum and natural gas industry is cut down most with decreasing between 10.044% and 12.938%. Coal industry's demand for intermediate inputs declines between 1.377% and 5.612% with increasing tax rate. Other mining industries are influenced lightly, only decreased between 0.924% and 2.042%. The above results illustrate the resource tax reform reduce the intermediate inputs for energy industry, as a result, the energy structure would be improved. As table 11 shows, China's CO_2 and SO_2 emissions would be significantly mitigated effected by the policy reform.

Table 3. The impacts of resource tax reform with ad valorem tax rate and quantity-based tax rate

Indexes (2010)	SO_2 emissions (%)	CO_2 emissions (%)
Ad valorem tax (6%)	-2.31%	-3.81%
Quantity-based tax (6%)	-2.23%	-3.76%

4. Conclusion

In order to build a low-carbon economy, tax policy reform has been taken by Chinese government in December 2014 which change the resource tax collection from quantity-based to ad valorem and this reform is regarded as efficient tool for carbon emission mitigation and environment improvement. This paper estimates both the economic and environmental effects brought by the tax reform. Firstly, a computable general equilibrium (CGE) model related to resource tax has been built to analysis the different collection methods in terms of effects in China. Secondly, a social accounting matrix (SAM) for the year 2010 with 16 energy sectors has been formulated, to capture the detailed effects for different industries where coal, petroleum & natural gas and other mining industries are the main focus.

From the stimulation results, some conclusions could be captured. As for the economic effect, firstly, China's both real and nominal GDP are negatively affected. When the coal resource tax rate is fixed at 2%, the consumption would suffer the most compared with investment and net export, while if the coal resource tax rate is set at higher rate, the investment would rank first. Secondly, from the perspective of each department, due to the negatively income effect and the substitution effect, the total output would decrease in different degree. As for the environmental influence, the tax reform would improve the total environment by energy conversation and the emissions would be reduced.

The empirical results demonstrate that the tax reform is an efficient tool for emission mitigation due to the substitution effects. Nevertheless, the negative income effects could not be ignored by the Chinese government. As a result, when to choose appropriate tax rate, government should balance the negative economic effects and the positive emission reduction and resource conservation. Moreover, other policies could be taken into consideration, such as feed-in tariff policy and carbon emissions trading scheme.

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