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# Platform for China Energy & Environmental Policy Analysis: A general design and its application

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## ABSTRACT

This paper introduces the China Energy & Environmental Policy Analysis (CEEPA) system. The core of CEEPA is a recursive dynamic computable general equilibrium model, in which the interactions among different agents in the macroeconomic system of China are described. The specific characteristics of Chinese labor market and energy market are also taken into account. The corresponding software system is also developed. CEEPA and its related software was designed for providing decision makers a uniform platform to simulate, analyze and compare different energy and environmental policies conveniently, flexibly and immediately. The application of CEEPA is illustrated in a case study which compares the energy, environmental and socio-economic impacts of energy tax and carbon tax. Results show that given the same extent of direct disturbance, carbon tax is able to restrict energy consumption and CO<sub>2</sub> emissions to a greater extent, but the general socio-economic cost caused by energy tax is lower.

**Keywords:** Computable general equilibrium; Energy and environmental policy; Decision support system

## 1 Introduction

Energy and environmental policies play important roles in ensuring energy supply security, coordinating energy with economic development and environmental protection, as well as addressing global climate change. If introduced properly, energy and environmental policies could promote energy producers and consumers to change their behavior patterns, thus guide the development of energy demand toward established mid- and long term energy strategic objectives. Improperly introducing energy and environmental policies, however, could seriously hinder economic development and improvement of people's living standards.

The foundation and implementation of any policy would be a highly complex process. There are usually many primary elements to be set for a certain policy. For example, primary elements of a tax scheme

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include taxpayer, tax rate, object of taxation and tax base, tax relief, revenue recycling, tax payment stage and place, tax calendar (assessed in regular periods or on a transaction-by-transaction basis) and penal clause. Besides that, the decision-making environment for a certain policy could be complex. For example, there could be disturbances from international markets. Moreover, the uncertain effects of a policy could also be a major obstacle in its foundation and implementation. Therefore, in order to promote an efficient and reasonable decision making process, it is necessary to develop proper tools for performing policy simulations scientifically and conveniently.

Currently there are many policy modeling tools (Alcántara et al., 2010; Allan et al., 2007; Amann et al., 2011; Cheng and Steemers, 2011; Iniyan et al., 2006; Liu, 2013; Nabel et al., 2011; Zhang et al., 2011). As for energy and environmental policies, related modeling practices show that, Computable General Equilibrium (CGE) model is one of the most popular tools: energy policy issues are related to various aspects of the economy such as price formation, output determination, income generation and distribution, consumption behavior, government operation, therefore a coherent and systematic mechanism is required for such analysis (Bhattacharyya, 1996). On the other hand, given that almost all the production activities and daily life need energy, and interact with environment, any local introduction of energy and environmental policies will eventually ripple throughout the economy, and general equilibrium models are most suitable for analyzing such policy measures with both direct and indirect effects (Wissema and Dellink, 2007). In particular, a lot of issues such as the interaction between energy supply and demand, government revenue, welfare of people, are addressed through pricing policies (Bhattacharyya, 1996). CGE models demonstrate superior advantages in elaborating the adjustment of energy consumption resulting from changing energy prices (Bergman, 1988). Therefore, CGE models have been widely employed in analyzing energy and environmental policies. Among them, studies focusing on China include analyzing energy and environmental financial policies such as sulfur tax (Wu and Xuan, 2002), carbon tax (Lu et al., 2010), fuel tax (Xiao and Lai, 2009), energy tax (Gao and Li, 2009), energy subsidy (Lin and Jiang, 2011), investigating technology policies such as energy efficiency improvement (Liang et al., 2009), coal cleaning technology (Glomsrød and Wei, 2005), quality-enhancing innovation (Fisher-Vanden and Sue Wing, 2008), and examining variations of external macro disturbances such as international oil price fluctuations (Jiao et al., 2010), China's WTO-accession (Vennemo et al., 2008). In particular, given the fact that China is still a developing country which is continuously promoting its market-oriented reforms and infrastructure constructions, issues such as energy price reforms (Hu and Liu, 2009), coal price-electricity price adjustment (He et al., 2010), capital market reforms (Fisher-Vanden and Ho, 2007), Western China energy development (Chen et al., 2010) are also attracting attentions. Therefore, CGE could be a best suited core model for our system.

Besides establishing a proper mathematical model, it is also necessary to develop a related software system. Actually there has been a trend of building energy and environment related computer systems, including not only large-scale energy analysis systems that integrating social, political, economic, environmental and technological factors (Cai et al., 2009; Lin et al., 2010; Warren et al., 2008), but also special systems focusing on issues such as risk hedging (Chen et al., 2012), consumption forecasting (Cárdenas et al., 2012), market analysis (Schuler, 2001; Zimmerman et al., 1999), statistical analysis (Bai et al., 1998), natural resource management (Boschetti et al., 2010). Currently, software system focusing on China's energy and/or environmental policy simulation still lacks. Computer-based tools would be especially necessary and helpful for a large and complex model as CGE. Existing modeling studies usually focus on one particular policy or disturbance, or merely compare several policies. In practical applications, however, before deciding to put strong emphasis on a certain policy, decision makers might want to firstly compare different alternatives. It would be difficult to directly compare results from different studies due to their different model assumptions, parameter settings, baseline scenarios, solving algorithm, policy settings.

Besides that, after the policies to be focused on are identified, the detailed policy settings that decision makers expect to examine, such as tax rate in a tax policy, might also be different from existing studies. Moreover, a CGE model that bases on real data could generate abundant results, not only including macro-level results such as GDP, total investment, household welfare, but also including micro-level results such as sectoral output, sectoral employment, and distributional income of different household groups. Existing studies usually could just demonstrate a portion of these results. The un-demonstrated results, however, might also include indices that decision makers are interested with.

Focusing on the above problems, combining the computable general equilibrium theory with computer technology, this study aims to develop a decision support system which provides decision makers a uniform platform to simulate, analyze and compare different energy and environmental policies conveniently, flexibly and immediately.

## **2 China Energy & Environmental Policy Analysis (CEEPA) model**

The core model of our system is the China Energy & Environmental Policy Analysis (CEEPA) model. CEEPA is a multi-sector recursive dynamic CGE model that describes the interactions among different agents in the macroeconomic system of China. In particular, the characteristics of the labor and energy markets in China are taken into account in CEEPA. CEEPA has now been successfully employed on assessing different energy saving or emission mitigation issues in China, such as carbon tax (Liang et al., 2007; Liang and Wei, 2012), energy end-use efficiency improvement (Liang et al., 2009), renewable power generation (Liu and Wei, 2010), China's marginal abatement cost (Yao et al., 2012a), sectoral emission trading (Yao et al., 2012b).

The framework of CEEPA is illustrated in Fig.1. In CEEPA, consumers are divided into households, enterprise and government to reflect their different roles in policy disturbances. Different types of consumers are interacting through taxes, subsidies, and transfer payments. Moreover, considering the current energy- and emission-intensive international trade structure of China, a foreign account was included, making CEEPA an open economy model.

The current version of CEEPA includes 24 sectors, i.e. Agriculture, Iron and Steel, Non-Metal, Chemical, Non-ferrous Metal, Paper, Food, Textile, Clothing, Wood, Metalwork, Equipment Manufacturing, Other Heavy Industry, Construction, Transportation, Service, Water, Coking, Gas Production and Supply, Coal Mining, Crude Oil, Natural Gas, Petroleum Processing, Electricity. 8 types of primary energy (coal, crude oil, natural gas, nuclear, hydro, biomass, wind, solar) are taken into account, as well as 2 types of secondary energy (refined oil and electricity). Households are divided into urban and rural households to reflect their different income level, income composition, saving tendency and consumption pattern. The current time horizon of CEEPA is 2007-2030.

CEEPA is composed of five basic modules, i.e. production, income, expenditure, investment and foreign trade module. Basic assumptions for each sub-module, as well as the principles for macro closure and market clearing, are shown as follows:

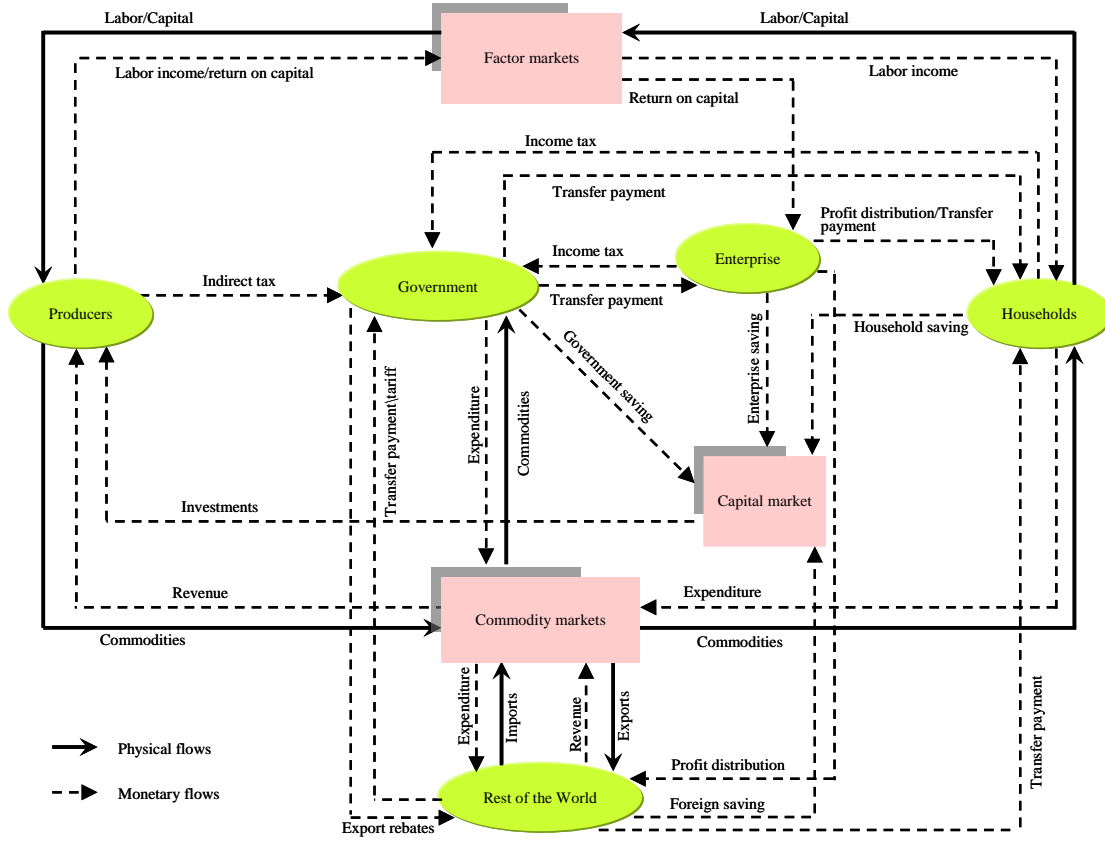


Fig.1 General framework of CEEPA (Liang and Wei, 2012)

## 2.1 Production module

Main assumptions for this module include:

- 1) Each sector produces one, and only one, distinct commodity;
- 2) Inputs in each sector include labor, capital, energy and other intermediate inputs;
- 3) Production in each sector follows a nested constant elasticity of substitute (CES) function, the basic form of which is shown in Eq. (1):

$$Y_i = \text{CES}(X_j; \rho) = A_i \cdot \left( \sum_j \alpha_j \cdot X_j^\rho \right)^{1/\rho} \quad (1)$$

where  $Y_i$  is the  $i$ th output,  $X_j$  is the  $j$ th input,  $A_i$  is the shift parameter,  $\alpha_j$  is the share parameter of  $X_j$ ,  $\rho$  is the substitution parameter among different inputs.

- 4) Considering the production characteristics of different sectors, and referring to existing studies (Paltsev et al., 2005; Wu and Xuan, 2002), the following four production patterns are specified in CEEPA:

### (1) Generic economic sectors

For all sectors other than the ones listed below in (2)-(4), a five-level nested CES function is employed, as shown in Eq. (2)-(6):

$$Z_i = \text{CES}(RM_{j,i}, KEL_i; \rho_{Z,i}) \quad (2)$$

$$KEL_i = \text{CES}(KE_i, L_i; \rho_{KEL,i}) \quad (3)$$

$$KE_i = \text{CES}(K_i, \text{Energy}_i; \rho_{KE,i}) \quad (4)$$

$$\text{Energy}_i = \text{CES}(\text{Fossil}_i, \text{Electricity}_i; \rho_{\text{Energy},i}) \quad (5)$$

$$\text{Fossil}_i = \text{CES}(\text{FoF}_{fe,i}; \rho_{\text{FoF},fe,i}) \quad (6)$$

where  $Z_i$  is the total output of sector  $i$ ,  $RM_{j,i}$  is the intermediate input of commodity  $j$  in sector  $i$ ,  $KEL_i$  is the composite capital–energy–labor input in sector  $i$ ,  $KE_i$  is the composite capital–energy input of sector  $i$ ,  $L_i$  is the labor input of sector  $i$ ,  $K_i$  is the capital input of sector  $i$ ,  $\text{Energy}_i$  is the composite energy input of sector  $i$ ,  $\text{Fossil}_i$  is the composite fossil fuel input of sector  $i$ ,  $\text{Electricity}_i$  is the electricity input of sector  $i$ ,  $\text{FoF}_{fe,i}$  is the input of fossil fuel  $fe$  of sector  $i$ ;  $\rho_{Z,i}$ ,  $\rho_{KEL,i}$ ,  $\rho_{KE,i}$ ,  $\rho_{\text{Energy},i}$  and  $\rho_{\text{FoF},fe,i}$  represent the substitution parameters for different levels respectively.

## (2) Agriculture sector, Primary energy sector

Besides various inputs similar to generic economic sectors, agriculture production still needs an important and necessary input, i.e. land. Therefore, requirement for this factor should be reflected in the production pattern of this sector. Similar to agriculture production, primary energy productions also require necessary resource inputs, therefore the production pattern of this type of sectors is similar to that of the agriculture sector.

The production in these two types of sectors follows a six-level nested CES function, where the functions for the top two levels are shown in Eq. (7) and Eq. (8) respectively.

$$Z_i = \text{CES}(R_{j,i}, \text{KELM}_i; \rho_{Z,i}) \quad (7)$$

$$\text{KELM}_i = \text{CES}(\text{KEL}_i, \text{RM}_{j,i}; \rho_{\text{KELM},i}) \quad (8)$$

where  $R_i$  is the resource input of sector  $i$ ,  $\text{KELM}_i$  is the composite capital–energy–labor–material input in sector  $i$ ,  $\rho_{\text{KELM},i}$  is the substitution parameter of sector  $i$  between the composite capital–energy–labor input and various raw materials.

Production functions for the other levels of these two types of sectors are the same with generic economic sectors.

## (3) Oil refining sector, Gas production and supply, Coking

Since crude oil is the most important raw material in the oil refining process, in the production function of this sector, crude oil is taken out from the fossil fuel composition and placed in the top level.

Similarly, in the production function of gas production and supply sector, natural gas is taken out from the fossil fuel composition and placed in the top level; in the production function of coking sector, coal is taken out from the fossil fuel composition and placed in the top level.

## (4) Electricity sector

Here it is assumed that the output of electricity sector is composed of stable power supplies and intermittent power supplies, as shown in Eq. (9) and Eq. (10), supposing that there are  $n$  types of stable power

supplies and  $m$  types of intermittent power supplies. Stable power supplies include coal-fired, petroleum-fired, natural gas-fired, hydro, nuclear and biomass power. Intermittent power supplies include wind and solar power.

$$Z_{elec} = CES(Zst, Gin_1, \dots, Gin_m; \rho_{Z,elec}) \quad (9)$$

$$Zst = CES(Gst_1, \dots, Gst_n; \rho_{st}) \quad (10)$$

where  $Zst$  refers to the composite output of stable power supplies,  $Gin_i$  is output of the  $i$  th intermittent power supply,  $Gst_i$  is output of the  $i$  th stable power supply,  $\rho_{st}$  is the substitution parameter among different stable power supplies.

The production of different power supplies follow a nested CES function of raw material, labor, capital, fuel (for coal-fired, petroleum-fired, and natural gas-fired power) or resource (for nuclear, hydro, biomass, wind, and solar) input.

It is noted that, though there exist government subsidies in order to induce renewable energy deployment, due to the problem of data availability, currently we are not able to separate the already existing subsidies from the aggregate net product tax. So the current version of CEEPA is not able to analyze the impacts of adjusting existing subsidies, but focusing on the effects of introducing new subsidies.

## 2.2 Income and expenditure module

Main assumptions in this module are shown as follows:

### 2.2.1 Household

- Household income mainly comes from labor income and profit distribution from enterprises.
- After paying household income tax and receiving various transfers from government and overseas, households get disposable income.
- One part of household disposable income is spent on saving, and the other part on consumption of various goods
- Household saving is obtained by multiplying household disposable income with saving rate, and household consumption is described as Eq. (11):

$$CDh_{i,h} = \frac{cles_{i,h} \cdot (1 - mps_h) \cdot YD_h}{PQ_i} \quad (11)$$

where  $CDh_{i,h}$  and  $cles_{i,h}$  respectively represents the consumption volume and consumption share of commodity  $i$  by household  $h$ ;  $PQ_i$  is the composite price of commodity  $i$  (imports and domestic products);  $YD_h$  and  $mps_h$  respectively represents the disposable income and the saving rate of household  $h$ .

### 2.2.2 Enterprise

- The major source of enterprises income is the return on capital
- After paying enterprise income tax, and receiving transfers from the government, enterprises obtain net profit after tax.
- One part of the net profit after tax is transferred to the households as profit distribution, and the other part is kept as enterprise saving.

### 2.2.3 Government



- Government income is constitutive of various tax and transfers from other countries/regions.
- Government expenditure includes government consumption, transfers to households and enterprises, and export rebate.
- In a given period the difference between government income and expenditure, forms government saving.

### 2.3 Foreign trade module

Main assumptions in this module are shown as follows:

- CEEPA adopts Amington (Armington, 1969) assumption, and assumes that there is imperfect substitutability between imports and domestic output sold domestically. The commodity that is supplied domestically is composed of domestic and imported commodities following a CES function.
- One part of domestic output is used to meet domestic demands; another part is used for exports. CEEPA uses a constant elasticity transformation (CET) function to allocate total domestic output between exports and domestic sales, as shown in Eq. (12) and Eq. (13).

$$X_i = A_{Ex,i} \cdot [\alpha_{Ex,i} \cdot E_i^{\rho_{Ex,i}} + (1 - \alpha_{Ex,i}) \cdot D_i^{\rho_{Ex,i}}]^{1/\rho_{Ex,i}} \quad (12)$$

$$\frac{E_{i,t}}{D_{i,t}} = \left[ \frac{1 - \alpha_{Ex,i}}{\alpha_{Ex,i}} \cdot \frac{PE_{i,t}}{PD_{i,t}} \right]^{\sigma_{Ex,i}} \quad (13)$$

where  $E_i$  and  $D_i$  respectively represent exports and domestic sales of domestically produced good  $i$ ;

$PE_i$  and  $PD_i$  respectively represent export price and domestic sale price of domestically produced good

$i$ ;  $A_{Ex,i}$  and  $\alpha_{Ex,i}$  respectively represent the shift parameter and share parameter in transformation

function;  $\rho_{Ex,i}$  and  $\sigma_{Ex,i}$  respectively represent the substitution parameter and substitution elasticity in

CET function between export and domestic sales.

### 2.4 Investment module

Main assumptions in this module are shown as follows:

- Total investment includes inventory change and fixed capital investment;
- Inventory change in each sector occupies a fixed ratio of the output in that sector;
- Fixed capital investment allocates among sectors according to fixed ratios;
- Fixed capital investment composition in each sector follows exogenous capital composition matrix.

The block of equations for describing investment module is as follows:

$$TotINV = HSav + GSav + ESav + FSav \cdot ER \quad (14)$$

$$FxdINV = TotINV - \sum_i DST_i \cdot P_i \quad (15)$$

$$DST_i = \mathcal{G}_i \cdot Z_i \quad (16)$$

$$Dk_i \cdot PK_i = FxdINV \cdot \mu_i \quad (17)$$

$$PK_i = \sum_j sf_{j,i} \cdot P_j \quad (18)$$

$$ID_i = \sum_j sf_{i,j} \cdot Dk_j \quad (19)$$

where  $TotINV$  represents total investment;  $HSav$ ,  $GSav$ ,  $ESav$  represents household, enterprise and government saving, respectively;  $FSav$  is foreign saving in foreign currency;  $ER$  is exchange rate;  $FxdINV$  represents total fixed capital investment;  $DST_i$  represents inventory change in sector  $i$ ;  $Dk_i$  is the fixed capital investment supplied to sector  $i$ ;  $PK_i$  is the price of fixed capital input in sector  $i$ ;  $P_i$  is the composite price of commodity  $i$  (imports and domestic products);  $ID_i$  is the fixed capital investment supplied by sector  $i$ ;  $\mathcal{Q}_i$  is the share of inventory change to total output in sector  $i$ ;  $\mu_i$  is the share of sector  $i$  obtained in total fixed capital investment, which equals the share of sector  $i$  in base year capital income (depreciation of capital plus earning surplus);  $sf_{i,j}$  is composition matrix coefficient of fixed capital for sector  $j$  from investment good  $i$ .

In particular, here inventory change plays mainly two roles in the model, i.e., to determine how much could be left for fixed capital investment, as shown in Eq. (15), and to balance commodity market as part of final demand, as stated later in section 2.6.

## 2.5 Model closure and price numéraire

Model closure identifies the borderline of the model by differentiating the exogenous and endogenous variables (Wu and Xuan, 2002). Selection for macro closure principles in CGE models is essentially the selection for inherent macro-economic theories (Yan and Fan, 2009), mainly including the following 3 types of closure principles:

- Government budget balance: CEEPA adopts the principle of government consumption set exogenous, while government saving set endogenous.
- Foreign trade balance: CEEPA adopts the principle of foreign saving set exogenous, and the exchange rate set endogenous. Foreign saving is the difference between the income and expenditure of the current account of rest of the world.
- Invest-saving balance: CEEPA adopts the principle of “neoclassical closure”, and assumes that all the saving is transformed into investment and that total investment equals total saving endogenously; thus the model is saving-driving.

In the current version, exchange rate is chosen as the price numéraire.

## 2.6 Market clearing

Market clearing describes the equilibrium conditions in a CGE model. In CEEPA, only commodity and capital markets are cleared.

The clearance of the commodity market requires that the gross supply of a commodity must equal the gross demand for that commodity. The gross supply of a commodity is the Armington (Armington, 1969) composition of domestic and imported goods. The gross demand for a commodity consists of intermediate demand and various final demands (including household consumption, government consumption, inventory change, and fixed capital investment demand).

This model assumes that the capital market could achieve fully sufficient adjustment under external shock. The supply of capital is set exogenously; the allocation of which are adjusted among sectors according to the sectoral return of equity. Market clearing requires that the total capital demand from all the sectors equals the exogenous total supply of capital.

Labor market is not cleared in the current version of CEEPA. According to the forecast of the United Nations (Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, 2012a), though the working-age population (ages 15 to 64) in China will start decline from 2011, there will still be nearly 1 billion in 2030. Considering the expanding labor population of the over-65 age group and the potential policy to delay retirement, and combining the results from related research about the labor force participation rate for different age groups (Ma et. al, 2010), we found that the labor force in China increases continuously from 2007, though slowly declining from 2020, there will still be about 0.77 billion in 2030. As for the demand side, we found that demand for labor force will be smaller than its supply until 2016, following the increasing trends of employment between 2002-2006. However, with the slowing down of economic growth, improvement of labor productivity and technological advance in other aspects, the increasing rate of labor demand tends to slow down. Therefore, we assumed that there will be excess supply in the labor market within the current time horizon of CEEPA, i.e., before 2030. Here we referred to the treatment of Glomsrød and Wei (Glomsrød and Wei, 2005), assuming that the wage rate is rigid, and there exists involuntary unemployment in the labor market.

## 2.7 Dynamic mechanism

CEEPA adopts the recursive dynamic mechanism. The model is pushed forward through capital accumulation, population growth, and improvement of total factor productivity. The process of capital accumulation is shown as Eq. (13).

$$SK_{t+1} = SK_t + INV_t - \delta \cdot SK_t \quad (20)$$

where  $SK_t$  is stock of capital in period  $t$ ;  $INV_t$  is new fixed investment in period  $t$ ;  $\delta$  is the depreciation rate.

## 2.8 Baseline scenario

When applying CEEPA, a baseline scenario was first built where there exist no extra policy disturbances. Results from different policy scenarios are then expressed in percentage deviations from the corresponding baseline values.

When generating the baseline scenario, we first decided the business-as-usual (BAU) development path of real GDP, population, rate of labor force, and urbanization rate, based on the forecasts of existing literatures, as shown in Table 1. Moreover, in the baseline scenario, it is assumed that government consumption increases with a rate of 5 percent per year. Transfers among institutions are assumed to be fixed at their base year level, adjusted with consumer price index or exchange rate. Technological advances are assumed to be neutral.

Based on these assumptions, a baseline calibration model was run to endogenously generate the wage rate and total factor productivity for matching the BAU settings in Table 1. The solved baseline wage rate and total factor productivity is then fixed in further simulations.

Table 1 Major assumption for baseline scenario (%)

	Period	Assumption	Data Source
Average annual change rate of GDP	2012-2015	7.90	(Li, 2010)
	2016-2020	7.00	
	2021-2025	6.60	
	2026-2030	5.90	
Average annual change rate of Population	2012-2015	0.40	(Population Division of the Department of Economic and Social Affairs of the
	2016-2020	0.25	

	2021-2025	0.09	United Nations Secretariat, 2012a)
	2026-2030	-0.04	
Average annual change rate of labor force	2011-2015	0.44	(Ma et al., 2010; Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, 2012a) and authors' adjustment
	2016-2020	0.53	
	2021-2025	-0.09	
	2026-2030	-0.42	
Urbanization rate	2015	55.60	(Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, 2012b)
	2020	60.99	
	2025	65.35	
	2030	68.74	

## 2.9 Data source and parameter calibration

The database of this model is from the Social Accounting Matrix (SAM). SAM is the detailed description of the economy in a country or a region in a given period (usually a year). In this study we calculated the China SAM 2007 based on input–output table 2007 (Department of National Account of National Bureau of Statistics PR China, 2009) and miscellaneous yearbooks and literatures (China Society for Finance & Banking, 2008; Fu, 2008; General Administration of Customs PR China, 2009; National Bureau of Statistics PR China, 2008, , 2010; State Administration of Taxation, 2011).

The parameters in the model include exogenous and endogenous parameters. The endogenous parameters are decided using the method of calibration: data in the SAM are substituted into each equation as the base year equilibrium data, and the equations are then solved to show the value of the parameters. Exogenous parameters in this model are set through referring to related research and with our own adjustment, including miscellaneous substitute elasticities (Paltsev et al., 2005; Sue Wing, 2006; Wang, 2003; Wu and Xuan, 2002), carbon emission factors (IPCC, 2006), fraction of oxidized carbon (Xue, 1998), composition matrix of fixed capital (Wang, 2003), depreciation rates (Wang, 2003). Appendix Table A1 shows the values of major elasticities in CEEPA.

## 3 CEEPA-DSS: a CEEPA-based decision support system

Based on CEEPA, a decision support system is developed in this study, named as CEEPA-DSS (where DSS is short for Decision Support System). Fig.2 illustrates the general framework of CEEPA-DSS. As shown in Fig.2, CEEPA-DSS has the following important characteristics:

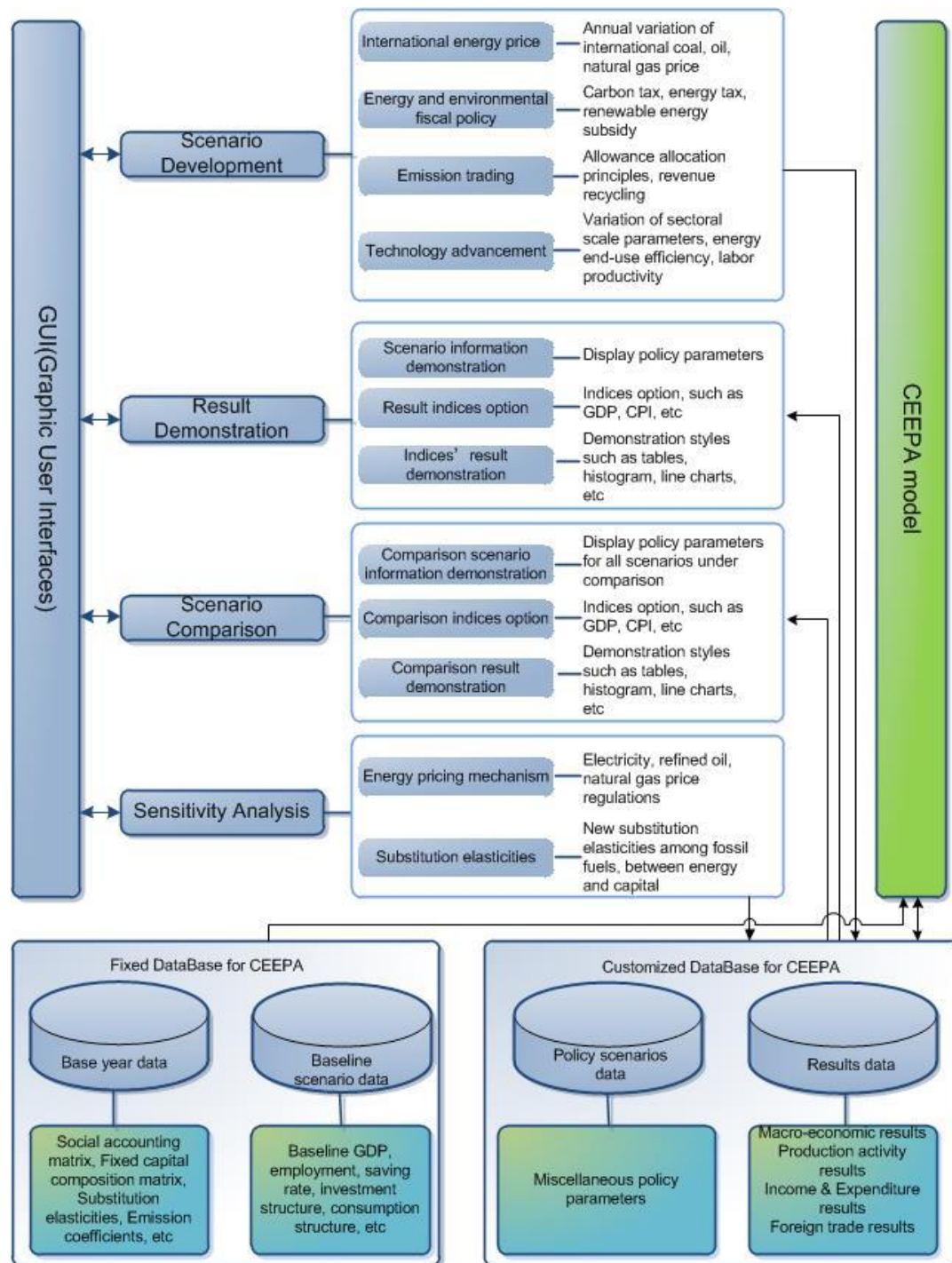


Fig.2. General Framework of CEEPA-DSS

### 3.1 Scenario-oriented design pattern

Potential users of CEEPA-DSS could be government or enterprise decision makers, academic researchers, or students<sup>1</sup>. Considering the diversified demands from users when analyzing energy & environmental policies, as well as the complex inner and outer decision-making environments, CEEPA-DSS employs a scenario-oriented design pattern. Under such a pattern, each policy analysis process is regarded as a

<sup>1</sup> At present, CEEPA-DSS is still in the process of internal trials, for debugging and optimizing user experience. The future plan for external trials and deployment is to open for online registration. That is, anyone who visits our website ([www.ceep.net.cn](http://www.ceep.net.cn)) and is interested in this system could apply for an account. Applicants who pass the verifications could obtain a username and password, as well as assigned specific authority (create, read, update, or delete), to access CEEPA-DSS from the outside.

scenario, and could be divided into five phases including scenario development, model calculation, result demonstration, scenario comparison, and sensitivity analysis. Each of these phases is designed as a module in CEEPA-DSS, as shown in Fig.2. Users' policy analysis requirements are fulfilled through information interaction and cooperation among modules.

*Scenario development module:* this module allows users to create desired policy scenarios through setting a series of parameters. Based on the current research progress of CEEPA and the relationship among various policies, policies available for simulation are categorized into different groups in CEEPA-DSS, as shown in Table 2. In general, disturbances to an economic system may come from either outside or inside the system. When it comes to energy and environmental policy analysis, the outside disturbances correspond to the impacts from international energy markets, while the inside disturbances correspond to the impacts from domestic energy saving and emission mitigation measures. As for the impacts from international energy markets, CEEPA-DSS allows users to study not only price shocks but also quantity shocks of various energy types. As for domestic policy measures, CEEPA-DSS allows users to examine three types of policy/disturbance, i.e. fiscal policy, emission trading policy and technology advancement, further details of which is shown in Table 2.

Particularly, when developing scenarios, users can choose to merely simulate a certain item within a category, or select several items in a same category, or even select several items in different categories thereby conducting a combinational simulation.

All the policy settings from users are saved in the database as policy scenarios data, as shown in Fig.2.

Table 2 Categories of policy/disturbance in scenario development module of CEEPA-DSS

Source	Category	Item	Policy parameters to set
Impacts from international energy markets	Energy price	Coal	Annual variation rate of price
		Oil	
		Natural gas	
	Energy supply quantity	Coal	Time and proportion of supply quantity interruption
		Oil	
		Natural gas	
Domestic policy measures	Fiscal policy	Carbon tax	Object of taxation, tax base, tax rate, tax relief, revenue recycling
		Energy tax	
		Sulfur tax	
		Fuel tax	
		Renewable energy subsidy	Subsidy time, subsidy target, subsidy rate
	Emission trading policy	CO <sub>2</sub> emissions	Allowance allocation principals, revenue recycling
		SO <sub>2</sub> emissions	
		NO <sub>x</sub> emissions	
	Technology advancement	Sectoral scale parameters	Percentage variation from baseline
		Sectoral energy end-use efficiency improvement	
		Labor productivity	

*Model calculation module:* scenario parameters are automatically put into CEEPA; an external solver is then invoked to perform calculation work; calculation results are stored in the database, as shown in Fig.2.

In CEEPA-DSS, the General Algebraic Modeling System (GAMS), one of the two most popular tools for solving CGE models nowadays, is chosen as the external solver.

*Result demonstration module:* this module demonstrates simulation results of the current scenario under analysis, including basic scenario information, as well as different demonstration options. As a large-scale CGE model, CEEPA will generate abundant results. In order to provide as many results as possible in a clear way, CEEPA-DSS classifies the analysis results into four categories, which are macro-economic (including 8 indices such as GDP), production activity (including 6 indices such as sectoral output), income & expense (including 5 indices such as disposable income) and foreign trade (including 5 indices such as sectoral import). Users have the options to select one or more items to view the corresponding results. Meanwhile, the system provides various styles for graphical demonstration. For example, users can choose line graphs to clearly reflect trends of different indices over time, or use histograms to express numerical size of different indices, or employ radar maps to clearly compare the good or bad trends of several important indices. Moreover, simulation results could be exported in either Word or Excel format for further analysis.

*Scenario comparison module:* this module allows users to select some or all from the whole simulated scenarios and compare the socio-economic impacts of different policies/disturbances. The demonstration options in this module are similar to those in the result demonstration module.

*Sensitivity analysis module:* this module is used to verify results robustness of policy analysis. As a prominent feature of CEEPA-DSS, this module will be described in detail in section 3.3.

### **3.2 GUI: Graphical User Interfaces**

Although there exists some commercial software for solving CGE models such as GAMS, direct employment of such tools have the following drawbacks: (a) Lack of graphical interfaces will lead to inconvenient interactive operations; (b) Certain CGE modeling knowledge and computer programming technology are required when building and adjusting the model; (c) Tedious coding jobs are also required when outputting and saving model results. In particular, extra plug-in components are necessary when performing graphical outputs; (d) External software such as Excel is usually required for comparing simulation results from different policies. All these problems had hampered CEEPA from becoming a practical, efficient and easily understandable analysis tool for governmental decision makers. Therefore, developing a decision support system with graphical interfaces is particularly important for the modeling and using of CEEPA.

The development of graphical interfaces requires supports from various related software and development framework. CEEPA-DSS adopts the Browser/Server structure, which allows users to access the system anytime and anywhere through browsers, and to simulate, analyze and compare policies via web pages. CEEPA was developed using the ASP.NET MVC architecture, which can separate the parameter setting process from model calculation process so that users can complete model development, calculation, demonstration and comparison through simple clicks on the screen, as shown in Fig.3. In this way, users are freed from tedious data analysis, strenuous modeling, specialized expertise and complicated computations. And the efficiency of scientific research and/or decision-making will be greatly improved.



Fig.3. GUI examples of CEEPA-DSS

### 3.3 Sensitivity Analysis

Aware of the limitation of CGE models in setting different elasticity parameters, as well as the uncertainties in China's energy market reforms, it is necessary to perform sensitivity analysis for the main parameters in the model. CEEPA-DSS allows users to adjust and test major coefficients of elasticity, as well as different energy pricing mechanisms. In particular, the "energy pricing mechanism" function allows users to examine how the effects of a policy will change when there exist obstacles in price transmission mechanisms, given that nowadays pricing for refined oil, natural gas and electricity in China is still regulated to different extents by the government. On the other hand, the way how government is performing energy price control is not transparent, which is determined much more by political concerns than by economic factors. Therefore, the current CEEPA is not able to simulate the real-world pricing mechanism, but rather assuming the corresponding price be completely fixed at its initial level when it is regulated. That is why this feature is put in the sensitivity analysis module instead of in the basic model.

The sensitivity analysis function of CEEPA-DSS is mainly used in scenario comparison to examine whether the ranking of different scenarios on a certain index will change if a certain elasticity coefficient or the energy pricing mechanism changes. Such a process is realized as follows:

Step 1: Users can select a coefficient which is needed to be examined and set the upper and lower bound, as well as the step size of these coefficients;

Step 2: CEEPA-DSS will put the range and step size of the parameters into the model, alter the corresponding parameters, and then rerun the model;

Step 3: There is an initial ranking for different scenarios on any certain index (e.g. Scenario 1> Scenario 2>Scenario 3); adjusting parameters in the model may change this initial ranking (e.g. becomes: Scenario 2> Scenario 1>Scenario 3). The system will display the indices for which the ranking among scenarios has changed, and generate a report for users.

### 4 An application: Comparing energy tax and carbon tax

This section demonstrates an application of CEEPA by comparing energy tax and carbon tax.

Ensuring the security of energy supply and addressing global climate change are two of the most concerns currently in China. Tax policies have always been emphasized in discussions around how to realize these energy and environmental objectives, with the focus specifically put on energy tax and carbon tax.

Energy tax or carbon tax has been implemented in many developed countries. Discussions and debates about these two types of tax have never stopped. Thus far there exist a number of studies about energy tax and carbon tax respectively, with specific issues including social-economic impacts (Creedy and Sleeman, 2006; Wissema and Dellink, 2007), international competitiveness effects (Zhao, 2011), income distributional effects (Liang and Wei, 2012; Sterner, 2012), environmental effects (Hofer et al., 2010). However, up to now, quantitative comparisons about these two types of tax policy are relatively limited. Moreover, results from the few quantitative analyses are not unanimous: by comparing the impacts of



carbon taxes and energy taxes on the US economy, Jorgenson and Wilcoxon (1993) found that given a same mitigation target, carbon taxes have the least overall effect on the economy, but have a large effect on coal mining; energy taxes are fairly similar to carbon taxes but have slightly less impact on coal mining and slightly greater overall cost (Jorgenson and Wilcoxon, 1993). Results from Scrimgeour et al. (2005), however, are different. They compared the impacts of carbon tax and energy tax on the New Zealand economy, using equal revenue as a constraint to make the policies comparable. They found that although energy tax performs worse than carbon tax in mitigating CO<sub>2</sub> emissions, its negative impacts on GDP, household consumption, exports and investment are smaller (Scrimgeour et al., 2005).

Given that no consensus conclusions exist from either international practices or from theoretical studies yet, and that related quantitative comparisons about China are still lacking, it is necessary to further perform related quantitative studies based on the fundamental realities of China. Therefore, in this application CEEPA is employed to compare the economic efficiency of energy tax and carbon tax on limiting energy consumption and CO<sub>2</sub> emissions, as well as their global social-economic impacts.

#### **4.1 Policy scenarios**

Two policy scenarios are simulated in this application, corresponding to energy tax (Etax) and carbon tax (Ctax) respectively.

For both policy scenarios, the tax is assumed to be levied from year 2013; the object of taxation is assumed to be coal, crude oil and natural gas; all the tax revenue is assumed to be used to reduce indirect tax by a uniform rate. In both scenarios the tax rate is assumed to be set endogenously so that the total tax revenue in 2030 occupies 1% of the baseline GDP of that year: such an assumption aims to ensure that these two types of tax bring the same direct disturbance to the economic system, thereby provides a uniform basis for this comparative analysis<sup>2</sup>.

The difference between these two scenarios is that the tax base of carbon tax is the carbon-content of fossil fuels; while the tax base of energy tax is the calorific value of fossil fuels.

#### **4.2 Simulation results**

##### **4.2.1 Comparing the energy and environmental impacts of energy tax and carbon tax**

Fig.4 shows the impacts on energy consumption and CO<sub>2</sub> emissions under energy tax and carbon tax scenario respectively. Results show that both energy tax and carbon tax is able to effectively reduce energy consumption and CO<sub>2</sub> emissions. Results also show that both these taxes induce greater decrease in CO<sub>2</sub> emissions than in energy consumption, implying both of them leading to a decrease in CO<sub>2</sub> emissions per unit of energy consumption which reflecting an improved, less carbon-intensive energy structure. However, carbon tax performs better in reducing both energy consumption and CO<sub>2</sub> emissions in the whole period analyzed. This is mainly because that, energy tax and carbon tax influence various economic agents mainly through the usage cost of fossil fuels, and carbon tax will lead to a greater increase in the usage cost of coal thereby a greater decrease in coal consumption. Therefore, the coal-dominant energy supply structure in China leads to greater decrease in total energy consumption and CO<sub>2</sub> emissions under carbon tax scenario.

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<sup>2</sup> It is noted that, beside this assumption of a constant tax revenue share of GDP, there could be other possible scenarios, depending on the political target. The main reason for choosing the current scenario is that, both energy saving and carbon emission mitigation are highly emphasized in China, so it is hard to tell which one receives more priority from decision makers. Therefore, instead of setting an equal emissions or equal energy consumption scenario, here an equal tax revenue scenario is chosen. CEEPA-DSS offers flexibility for users, especially government decision makers who know better their political priorities, to set and test alternative scenarios.

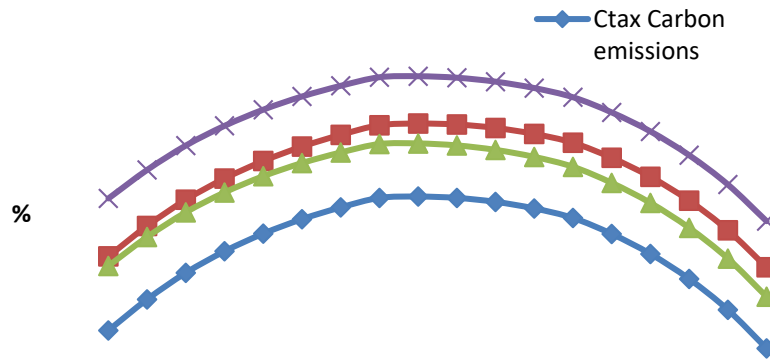


Fig.4. Variations of energy consumption and CO<sub>2</sub> emissions from baseline values under different scenarios

#### 4.2.2 Comparing the social -economic impacts of energy tax and carbon tax

Table 3 shows the impacts on different social-economic indices under energy tax and carbon tax scenario respectively. As shown in Table 3, in both 2020 and 2030, both types of taxes show negative impacts on all the examined indices, with the extents of impacts obviously greater in 2030.

Table 3 also shows that, the negative impacts of carbon tax on macro economy are generally greater than those of energy tax: GDP loss induced by carbon tax is about 6.7% higher than that induced by energy tax in both analyzed years; decrease in total investment incurred by carbon tax is about 6.8% higher than that incurred by energy tax in both analyzed years; decrease in total employment induced by carbon tax is about 7.5% and 7.2% higher than that induced by energy tax in year 2020 and 2030 respectively; the negative shocks on both urban and rural welfare are also greater in the carbon tax scenario. This is mainly because that, carbon tax leads to a greater increase in the usage cost of coal thereby incurs a greater increase in the usage cost of electricity, given the current coal-dominant power generation structure in China. This brings stronger negative shocks on production activities in general. The more seriously hurt production thus results in a greater decrease in employment. These will also incur greater negative impacts on enterprise, household and government income, thereby greater negative impacts on their savings and hence on total investment given the saving-driving assumption. Greater negative impact on investment leads to greater negative impact on GDP, given the current investment-driven economic growth pattern in China.

Table 3 Variations of main social -economic indices from baseline values under different scenarios (%)

	2020		2030	
	carbon tax	energy tax	carbon tax	energy tax
GDP	-1.73	-1.62	-3.22	-3.02
Total consumption	-1.43	-1.34	-2.96	-2.78
Total investment	-2.34	-2.19	-4.01	-3.75
Total exports	-2.11	-2.01	-3.70	-3.51
Employment	-1.63	-1.51	-3.05	-2.85
Consumer Price Index	-0.26	-0.24	-0.31	-0.30
Rural household welfare	-1.51	-1.41	-2.91	-2.72
Urban household welfare	-1.27	-1.19	-2.69	-2.51

### 4.2.3 Comparing the impacts of energy tax and carbon tax on sectoral output

Fig.5 shows the impacts of energy tax and carbon tax on sectoral output in 2030. Both energy tax and carbon tax will reduce the output of all sectors in 2030, with much greater negative impacts on Coal Mining and Electricity than on other sectors. Fig.5 also shows that, energy tax has smaller impacts on the production activities in all sectors than carbon tax except those in gas and oil production sectors. This is mainly because that oil and natural gas is less carbon-intensive but with a higher calorific value than coal. Compared with carbon tax, energy tax leads to a greater increase in the usage cost of natural gas and oil, therefore leads to a greater decrease in their consumption thereby production.



Fig.5. Variations of sectoral output from baseline values under different scenarios in 2030

### 4.3 Conclusions

Based on the above results and discussions, some conclusions are drawn as follows:

**(1) Carbon tax has higher economic efficiency in limiting both energy consumption and CO<sub>2</sub> emissions.**

Carbon tax and energy tax are both able to effectively reduce energy consumption and CO<sub>2</sub> emissions, no matter in the long run or in the short term. However, given the same extent of direct disturbance on the economic system, carbon tax performs much better than energy tax both in reducing energy consumption and in limiting CO<sub>2</sub> emissions.

**(2) Energy tax is able to realize energy saving and emission mitigation with lower global social-economic cost.**

Results show that energy tax has smaller negative impacts than carbon tax on GDP, total consumption, total investment, total exports, employment, rural and urban welfare, especially in the long term. In 2030, with about 6.7% higher GDP loss than energy tax, carbon tax can only lead to about 3.7% and 3.9% higher decrease in energy consumption and CO<sub>2</sub> emissions respectively. Also, the negative impacts of energy tax on sectoral production are smaller than carbon tax in general. It is worth noting, however, that energy tax will bring much greater impediment to natural gas development than carbon tax.

### 5 Discussion and perspectives

In order to provide decision makers a convenient, instant, scientific and uniform platform to analyze and compare the energy, environmental and socio-economic impacts of different energy and environmental policies, this study established the China Energy & Environmental Policy Analysis (CEEPA) system, developed a corresponding software, and illustrated the application of CEEPA by comparing the effects of levying energy tax and carbon tax in China.

Further work is needed to improve our system:

As for the core model, critical issues include refining and enhancing database and module descriptions. For example, due to the problem of data availability, in the current model household expenditure shares of different commodities are all assumed to remain constant. However, with the change of income level, households' preferences to different commodities also tend to change. Therefore, one important improvement in future is to introduce income elasticity into the descriptions for household consumption behavior, based on more available data.

As for the software system, critical improvements intended in future include (1) based on the improved core model, enriching the policy/disturbance options in the scenario development module; (2) increasing the extent of usability, e.g. when performing the above application in the current version system, users have to control total tax revenue through a trial-and-error process including inputting tax rate, comparing results and adjusting tax rate. The next version intends to allow users set the control objectives exogenously thereby generating the endogenous tax rates through the software in the true sense; (3) linking CEEPA-DSS with our two other systems, i.e. OPFor (Oil Price Forecast system) and EAGER (Emission Allowance Generator for Emission Reduction), thus facilitate quantitatively assessing issues such as the social-economic impacts on China of different emission allocation regimes, as well as the required capital and technology transfers.

## Appendix

Table A1 Substitute elasticities in CEEPA

Elasticities	Current value in CEEPA	
among fossil fuels	1	
between electricity input and fossil fuel composition	0.5	
between capital and energy composition	0.9	
between labor and capital-energy composition	0.6	
between resource and non-resource input composition (applied to agriculture and primary energy sectors)	0.6	
among different stable power supplies (applied to electricity sector)	10	
between stable and intermittent power supplies, as well as among different intermittent power supplies (applied to electricity sector)	3	
between intermediate inputs and capital-energy-labor aggregate	0	
between import and domestic production (Armington elasticities)	Agriculture	3.0
	Energy products	4.0
	Other products	2.0
between export and domestic sales (CET)	Agriculture	4.0
	Energy products	5.0
	Other products	3.0

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