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

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A B S T R A C T

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_2 emissions to a greater extent, but the general socio-economic cost caused by energy tax is lower.

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 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

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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 undemonstrated 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:

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):

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

where Y_i is the ith output, X_j is the jth input, A_i is the shift parameter, α_j is the share parameter of X_j, ρ 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