The timing of China's carbon peaking under an uncertain future

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1 Overview

Followed by the framework of CE3METL model, we extended and developed a stochastic energy-economy-environmental (3E) integrated model, by incorporating a combination of uncertain factors, such as autonomous energy efficiency improvement, energy price as well as technology learning effect; further, we investigated the roles of carbon tax and non-fossil subsidy policies in achieving China's energy and climate targets in 2030, particularly concerning the impacts of these climate policies on the time of emission peak, peaking level and the development of non-fossil energy technologies. With respect to carbon reduction and the deployment of carbon-free technologies, the influences of carbon tax and non-carbon subsidy is significantly different; specifically, the carbon tax plays a major role in curbing and peaking emissions, while the development of non-fossil energy appears to be more sensitive to the subsidy policy. Under the strictest policy case, it's entirely possible to achieve China's non-fossil energy development target in 2030, whereas the goal of peaking CO_2 faces a higher risk to slip out of reach. There exhibits a significant lag between the implementation of climate policies and the transition from conventional fuels to low-carbon energy, and the inertia of energy investment and consumption, as well as the locked-in effect of energy use should be largely responsible for this. It comes at the expense of up to 20% of the output for China to raise the probability of reaching the carbon-peaking goal up to 50 percent (relative to the basic case); fortunately, the economic loss keeps decreasing as the carbon mitigation action goes on.

2 Methodologies

The proposed stochastic 3E-integrated model in this work is essentially based on the prior 3E system model, CE3METL, a Chinese version of the E3METL model. Characterized by the core technology diffusion mechanism, i.e., multi-logistic curves instead of conventional CES method, the E3METL model consists of macro economy, energy technology and climate sub-modules, which is consistent with the typical frameworks of 3E-integrated models (Gerlagh and van der Zwaan, 2004; Nordhaus, 2007; Bosetti et al., 2009; Duan et al., 2013). Research basing on the E3METL and CE3METL models has appeared in several aspects of climate-relevant topics since they were built in 2013. For example, Duan et al. (2013) discussed the optimal paths of carbon taxes under various carbon spaces constrains; Duan et al. (2014) examined the cost-effective policy option for reaching the given concentration-stabilizing targets; then, more other studies, involving technology substitution relationships among multiple energy technologies, integrated assessment of CCS technology and climate benefits evaluation of energy replacement, etc., were carried out in recent two or three years (Duan et al., 2015; Zhu et al., 2015; 2016). By employing the Monte-Carlo simulation and incorporating multiple uncertainties, we extend the framework of CE3METL model and develop a stochastic 3E-integrated model, with the skeleton being depicted in Fig. 1; besides, we gives the corresponding optimum algorithm of this large-scale system model, based on the soft platform of GAMS.

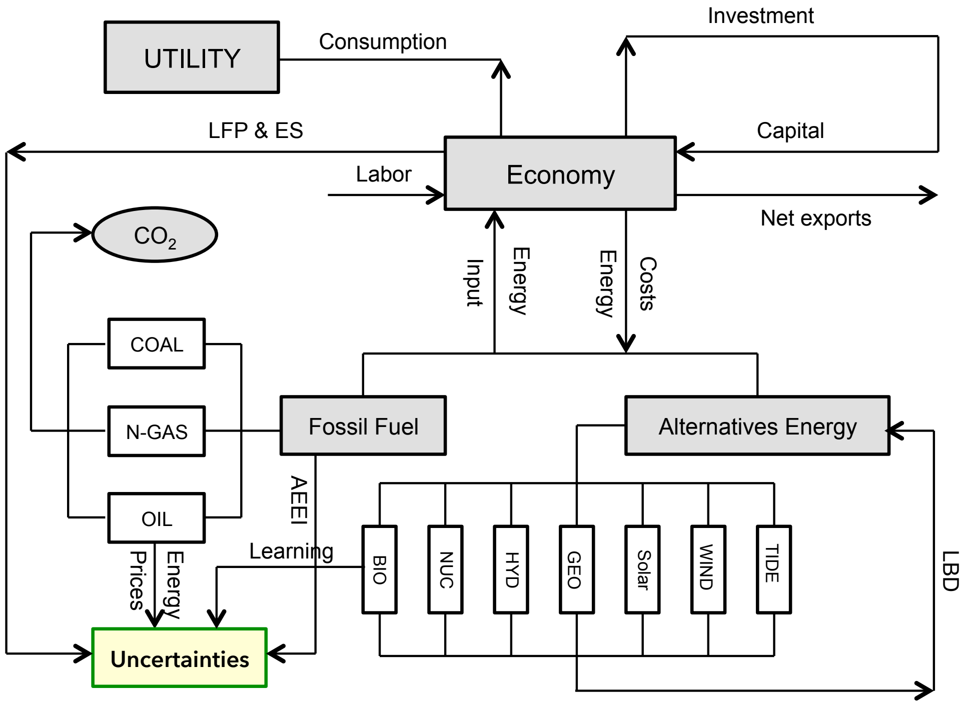

Fig.1 Framework of stochastic version of CE3METL model

3. Results and discussion

It is impossible for China to realize the target of carbon emission peaking in 2030 without taking any policy measures, and the probability for the carbon emission to peak does not reach 50% until 2040. The effect of the single subsidy policy for the renewable energy on the carbon emission is limited, and the probability for the carbon emission to peak before 2030 is only 21.3% with 40% subsidy being introduced (Fig. 1).

Apart from the time for the carbon emission to peak, the peak value is another great concern. In the baseline scenario, the median value of the carbon emission in 2030 is 3.98 GtC. Carbon tax policy has a significant effect on the carbon emission peak value, and the median values of the carbon emission peak are 3.05 GtC, 2.38 GtC, 1.90 GtC, and 1.57 GtC respectively in the carbon tax scenarios of 200 USD/tCO_2 400 USD/tCO_2 600 USD/tCO_2 and 800 USD/tCO_2 (Fig. 1). In addition, the uncertainty of the carbon emission peak value would also decrease with carbon tax increasing.

Besides the carbon emission peaking target, Chinese government also committed to increase the share of the non-fossil energy to 20%. The simulation results show that the carbon tax policy and the renewable subsidy have more significant effect on the energy mix. More specific, with the carbon tax of 800 USD/tC being introduced, the probability to realize the non-fossil energy target is 82.5% which is much higher than the probability to realize the target of carbon emission peaking, i.e. 51.1%. It follows that it is easier to realize the non-fossil energy target, and some addition efforts and measures are needed to realize the carbon emission peaking target.

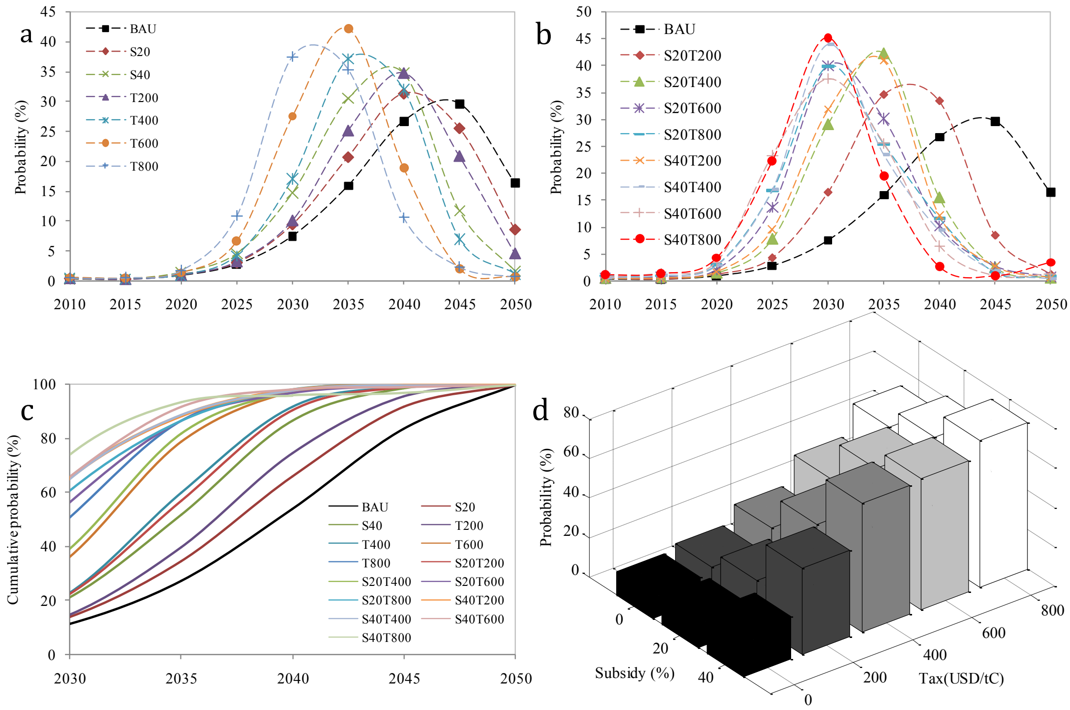

Fig. 1. Probability and cumulative probability distribution of optimal time for CO_2 emissions to peak. Results under single policy scenarios (**a**), under policy mix scenarios (**b**), cumulative probability distribution of CO_2 emission peaking time (**c**), probability of CO_2 emissions peaking before 2030 (**d**).

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