Optimal carbon taxes in carbon constrained China: a hybrid energy economy environmental model

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Overview

Climate change has increasing become one of centrals of public attention. The market failure, that is, the full social cost of climate damage cannot be reflected by market price of conventional energy, is the main difficulty in address climate change. Carbon tax is an effective option to internalize climate damage and correct the specific market failure. On one hand, fossil fuel costs will increase by embracing carbon tax, which is in turn benefit to economize fuel use and reduce our dependence on high-carbon energy; On the other hand, the revenues resulting from carbon tax could be used to subsidy the development of new energy technologies and finally promote their technological progress (Schneider & Goulder, 1997).

Carbon tax policy has been successfully implemented in several countries, mainly in Europe, such as France, Denmark, Norway, New Zealand and Switzerland (Anderson & Ekins, 2009). Attempts have also been taken by some Asia & Pacific countries (e.g. India, Australia). Moreover, China has put carbon tax on the table, and plan to carry this policy into effect in the following one or two years (Alibaba news, 2010).

In this paper we establish a hybrid energy-economy-environmental model to explore the optimal carbon tax trajectory of China under various CO_2 emissions constrains. Emphases are also placed on investigating the evolution of carbon-free energy technologies, and the impacts of different emission space constrain on gross domestic product (GDP), consumption. We also try to determine which conditions are needed to fulfill the announced carbon intensity target, that is, to make the carbon intensity in 2020 reduced by 40%-45% than that of 2005.

Method

CE3METL (Chinese Energy-Economy-Environmental Model with Endogenous Technological change by employing Logistic curves) is a optimal economic growth model based on neoclassical economic theory, and is also a infinitely lived agent model (ILA) obeying the Ramsey saving rule. CE3METL includes three sub-modules: macro-economic module, energy technology module and emission model. The policy-logistic sub-model is introduced to the energy module of our model so as to make energy technology sector more detailed than that of conventional macro-growth integrated models, which enables us to capture more bottom-up model features. In addition, we endogenize technological change of CE3METL by employing learning curve in terms of Learning-by-Doing process.

We defined four different carbon constrain scenarios besides reference case based on several popular studies dedicated to investigating the allocation of carbon emission for China, that is, FANG, GARN, UNDP and OECD cases, and the stringency of emission control is increasing from FANG to OECD (UNDP, 2008; Garnaut, 2008; OECD, 2008; Fang, 2009 etc). 2010 is chosen to be the base year, and the projection horizon is from 2010 to 2050, with 5 years per period. The program codes are written by GAMS, and we optimize the CE3METL by employing CONOPT solver.

Results

In reference case, China's GDP will skyrocket from 5.93 trillion US dollars (USD) in 2010 to 16.82 trillion USD, ending up 263.44 trillion USD. The average GDP growth rate between 2010 and 2020 is 8.02%, which to a large degree fits with the mainstream forecasts, and the average growth rate for the whole period horizon is around 4.82%. The energy demand reaches 13.3 billion tce (tons of coal equivalent) in 2050, up 300% over 2010. There is no CO_2 emission peak occurring in the reference case, and carbon emission will grow at an average rate of 3.27%. In 2050, the CO_2 emission is 7.06 GtC (giga tons of carbon) which is three-fold more than in the base year.

Optimal carbon tax trajectory of China is monotonically increasing during the next four decades, and is characterized by classical S shape. The tax level will increase with the stringency of emission control targets. In the weak FANG scenario, the tax level in 2030 is 0.64 USD/tC, it grows to 27.66 in GARN scenario, and the carbon tax in UNDP and OECD cases will further increase to 48.44 and 301.23 USD/tC, respectively.

New energy technologies would be largely promoted by inducing carbon constrains. The share of carbon-free energy in total primary energy demand will increase from 8.67% in 2010 to 23% GARN scenario in 2040, which is 63.1% higher than that in reference case. When moving to a more stringent OECD case, the share will reach 42.43% in 2040. The energy supply market is dominated by new energy from around 2050 under the three scenarios except for FANG. Nuclear energy, biomass and wind power are three of the largest energy technologies among all the considered. In 2050, their shares will increase to 33.71%, 17.37% and 13.8%, respectively. However, the emission control is not so effective in promoting the development of PV solar, geothermal, and tide due to their higher use-costs.

Emission space controls have a negative effect on both GDP and consumption. In FANG case, the maximal GDP loss is 7.88% (compare to reference case), and the ratio grows to 29.3% if OECD scenario is induced. Consumption will at most reduce by 4.64% in FANG case compared to reference case, versus 18% in OECD scenario. Noting that consumption will experience a steep growth process in the early stage of carbon control cases, which to a large extent attributes to the immediate decline of gross investment, especially for energy investment.

Conclusions

The main findings includes: (1) the optimal carbon tax for China is monotonically increasing during the next four decades, and is characterized by classical S shape. The tax level will increase with the stringency of emission control targets. (2) The development of carbon-free technologies will be promoted effectively by controlling CO_2 emissions, and the share of non-carbon technologies starts to soar after 2030. (3) Emission control has a negative impact on both GDP and consumption, the more stringent of emission control, and the more negative effect on GDP. (4) The announced target of 40%-45% in 2020of that in 2005 can be achieved in the reference case, which entails that the 40%-45% carbon intensity target can be realized by extending the present energy saving and mitigation measures. While additional carbon control action may be needed to achieve the carbon intensity target in China's 12th five-year development plan.

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