Energy 69 (2014) 345–356

Contents lists available at ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy

Optimal carbon taxes in carbon-constrained China: A logistic-induced energy economic hybrid model

Hong-Bo Duan, Lei Zhu*, Ying Fan

Center for Energy & Environmental Policy Research, Institute of Policy and Management, Chinese Academy of Sciences, Beijing 100190, PR China

ARTICLE INFO

Article history:
Received 17 September 2013
Received in revised form
3 March 2014
Accepted 6 March 2014
Available online 3 April 2014

Keywords:
Aggregated modeling
Revised logistic curves
Learning effect
Carbon space constraints
Optimal carbon tax
Technical diffusion

ABSTRACT

Carbon tax is an effective option for internalizing climate change and correcting market failure, an optimal set of carbon taxes can result in superior carbon mitigation. Then what is the optimal trajectory of carbon tax under various carbon-constrained scenarios, and what are the impacts of carbon controls on the economy and performance of carbon-free technologies are important questions to be addressed. We construct an energy–economy–environment aggregated model of China, combining top–down and bottom–up modeling and introducing revised logistic curves for enriching technical details. We also propose four carbon-constrained scenarios based on representative international carbon allocation plans. Our analysis shows that the optimal carbon tax in China is a monotonically increasing one, following a classical, S-shaped pattern. Carbon space constraints play an important role in promoting development of carbon-free technologies, while the substantial transition from fossil fuels to non-carbon energy would not happen before 2040, making clear that it will take at least 30 years to promote the development of carbon-free technologies. However, present energy-saving and efficiency-improving measures ensure that China is capable of achieving the voluntary goal of reducing carbon intensity in 2020 by 40–45% of what they were in 2005; nevertheless, introducing some carbon controls is necessary to fulfill the task of carbon emissions reduction in the Chinese Twelfth Five-Year Plan.

© 2014 Elsevier Ltd. All rights reserved.

1. Introduction

The issue of climate change has gained considerable attention in both academia and politics in the past few years for its complex causes, widespread and uncertain consequences, and the global cooperation required to control carbon emissions. The difficultly in dealing with the problem lies in how to appropriately address the environmental externalities it brings about. The existence of negative environmental externalities makes market prices of fossil energy unable to reflect the full social cost of climate change, and therefore leads to market failure. Hence, how to internalize climate damage into market prices is the root of curbing CO_2 emission, and even of addressing the problem of global climate change.

Carbon tax (or other equivalent measures) is an effective option for internalizing climate change and correcting market failure. An optimal set of carbon taxes can result in superior carbon mitigation. First, by taking into account climate damage, the prices of carbon-intensive goods, especially energy goods, will rise, which gives individual consumers the incentive to reduce energy use and increase the consumption of less-carbon-intensive goods. Second, the relative prices of new energy technologies will be lower when carbon tax is levied on the conventional ones, and this may enhance the market competitiveness of new technologies. Furthermore, revenues from a carbon tax could be used not only to finance cuts in ordinary income taxes, thereby helping to avert inefficiencies brought about by disincentives to work, but also to subsidize R&D activities for carbon-free technologies and accelerate their substitution to carbon-based energy [1]. Finally, as compared to fuel-efficiency standards, direct caps, or other carbon-management measures, a carbon tax is more flexible and dynamic in response to new information, and it is a potentially cost-effective option for reducing CO_2 emissions [2,3].[1]

[1] Carbon emission trading scheme (ETS) is also a popular and effective option to control emissions. And despite different abatement costs, the optimal carbon tax should be equivalent to the equilibrium carbon price in the emission trading market for achieving the same carbon control target. Hence, in our paper, based on general equilibrium analysis, the carbon tax derived in our model can also be viewed as the equilibrium carbon price in ETS. To simplify, we only discuss the emission control measure in the form of carbon tax.

* Corresponding author. No. 15 Zhong Guan Cun Bei Yi Tiao Alley, Haidian District, Beijing 100190, PR China. Tel.: +86 18601989016.
E-mail address: lions85509050@gmail.com (L. Zhu).

http://dx.doi.org/10.1016/j.energy.2014.03.022
0360-5442/© 2014 Elsevier Ltd. All rights reserved.

Currently, carbon tax policies or equivalent measures have been implemented in several countries, notably European countries, despite EU Emission Trading Scheme which covers most of the EU countries, such as France, Denmark, Norway, and Switzerland have launched carbon tax policies in their domestic market, so as to enhance their measures in control CO_2 emissions [4]. In addition, in recent years, attempts have been made in some Asian countries to introduce carbon taxes for fossil energy use. For example, in order to achieve the domestic voluntary target of cutting CO_2 emissions in 2020 by 25% from what they were in 2005, India has levied a tax on coal from both domestic production and import since July 1, 2010, with a rate of 50 rupees per ton of carbon (11.07 USD (US dollar) per ton of carbon). The Australian government has also taxed fossil energy since July 1, 2012. The initial tax level is 23 AUD per ton of CO_2 (around 6.3 USD per ton of carbon), with a growth rate of 5% per year, and the revenues from the carbon tax will be used to reduce income taxes, increase pensions and welfare payments, and compensate industries that suffer from implementation of carbon tax policy. In addition, China and South Korea have also put carbon taxes on their agendas, and policies might be implemented to reduce CO_2 emissions in the near future [5].

It may be important for China to introduce carbon tax (or equivalent measures) to control its greenhouse gas emission. On one hand, China has already announced its carbon intensity reduction target, i.e., 17% reduction in 2015 compared to that of 2010,[2] and 40–45% reduction in 2020 compared to that of 2005.[3] As the economy still grows rapidly in China, the government realizes that it may not be easy to achieve such targets if only traditional command and control measures are used (e.g., the measures for energy-efficiency improvement target during the Eleventh Five-Year Plan). The introducing of market-based emission reduction measures (carbon tax) can help the policy makers to promote the emission reduction to a greater extent. On the other hand, the 2 °C target requires us to control the atmospheric carbon concentration within 450 or 400 ppmv, and this emission-constrained task needs to be decomposed to each country. For China, there is a huge gap between emission space constraints and our current carbon intensity reduction targets. If we take a review of existing allocation plans of CO_2 emission space [6–9], nearly all of these plans are requiring China to cut off its domestic CO_2 emissions substantially before 2050. If China has to face CO_2 emission space constraint, the policy makers may have no choices but to internalize climate damage and introduce market-based emission reduction measures. Also the policy makers need to decide when and how to reduce the CO_2 emissions among different periods. Therefore, carbon tax is more flexible and dynamic in response to new information; it can also be used as an emission regulatory tool for policy makers to achieve the long-term emission control target effectively. In addition, carbon tax takes an important impact on conventional energy system design, and it is also a benefit to advanced systems utilization [10–12].

In this paper, we first try to explore the optimal trajectory of carbon tax to restrain carbon use in China, as well as its level change under different stringency of carbon control targets. Theoretically, the optimal carbon tax should be equal to the marginal climate damage associated with CO_2 emissions; however, climate damage is difficult to measure, and a carbon tax, therefore, is less than optimal [13–15]. Given the specific carbon reduction targets in the future, there is a lot of controversy about the trajectories of the optimal carbon tax along time period (monotonically increasing, steadily decreasing, U-shaped, or hump-shaped) among scholars. Dasgupta and Heal [16] argue that a carbon tax policy with fixed rates plays little role in mitigating the consumption of fossil fuels, and thereby reducing CO_2 emissions, no matter how high the tax rate is. Sinclair [17] concludes that the carbon tax rate of ad valorem will keep monotonically declining in the steady-state. While Ulph and Ulph [18] hold the opposite view, arguing that Sinclair's conclusion is not generally true and the carbon tax may rise and then fall (i.e., the so-called hump-shape) under some circumstances. Hoel and Kverndokk [19] come to a similar conclusion as Ulph and Ulph [18]. In addition, Farzin and Tahvonen [20] believe that the optimal carbon tax may also be monotonically increasing or follow a U-shaped pattern, and van der Zwaan et al. [15] and Bosetti et al. [21] also make this point in their research. It is, therefore, important to determine the optimal carbon tax in the context of constrained carbon emission space.

The second question that we attempt to address is how to evaluate the impacts of various carbon control targets on China's economy, consumption, and energy demand, as well as the performances of carbon-free technologies. Despite a substantial literature studying the influences of carbon tax policy in China, the majority of studies are based on static or dynamic computable equilibrium (CGE) models and econometric approaches [22–26], and carbon taxes in most of these studies are exogenous. However, the social-economic impacts resulted from exogenous carbon taxes in previous studies may be insufficient to support the policy makers to make effective carbon tax policies in the long run.

To address these questions, we first build a regional energy–economy–environment aggregated model with a more detailed energy technical sector and an emissions-control and management sector, as compared to the previous methodology framework of CGE and econometric models. Second, the carbon tax is solving endogenously in our model. The model takes carbon tax as an unknown variable and solved by optimizing the objective function. Meanwhile, it allows us to explore China's optimal carbon tax trajectory in the proposed four carbon-constrained scenarios, which based on representative international carbon space allocation plans. Also the model can investigate the impacts of various carbon control targets on China's economy, consumption, and energy demand, as well as the performances of carbon-free technologies.

Although our model is still type of top-down model, we employ the revised logistic sub-model to enrich the technical detail of the energy module, which brings us more bottom-up features. In general, top-down, endogenous technological models are popular options to assess environmental damage and simulate climate policy. These models are based on neoclassical economic theory and the Ramsey saving principle, and they assume that central planners have perfect foresight and that their lifes are infinite, hence, such types of model are usually referred to as Infinitely Lived Agent (ILA) model [13,27–31]. Conventional constant elasticity substitution (CES) function method is often used in these top-down ILA models to describe the competitive relationships between fossil and non-fossil technologies, while this method may be incapable of considering multiple new carbon-free technologies, and may cause too much uncertainties resulting from sensitive substitution elasticity. The revised logistic model is a suitable option to make up this gap; furthermore, it allows us to introduce policy variables, such as carbon taxes and subsidies, to the energy module, which brings convenience for us to study the impacts of climate policies on economy as well as technological diffusion.

[2] State Council. 2011. National Economic and Social Development Twelfth Five-Year Plan. Available from: http://www.gov.cn/2011lh/content_1825838.htm [in Chinese].

[3] State Council. 2009. The carbon dioxide per unit of GDP will be reduced by 40–45% in 2020. Available from: http://finance.people.com.cn/GB/10461522.html [in Chinese].

دریافت فوری ← متن کامل مقاله

ISIArticles
مرجع مقالات تخصصی ایران

- ✓ امکان دانلود نسخه تمام متن مقالات انگلیسی
- ✓ امکان دانلود نسخه ترجمه شده مقالات
- ✓ پذیرش سفارش ترجمه تخصصی
- ✓ امکان جستجو در آرشیو جامعی از صدها موضوع و هزاران مقاله
- ✓ امکان دانلود رایگان ۲ صفحه اول هر مقاله
- ✓ امکان پرداخت اینترنتی با کلیه کارت های عضو شتاب
- ✓ دانلود فوری مقاله پس از پرداخت آنلاین
- ✓ پشتیبانی کامل خرید با بهره مندی از سیستم هوشمند رهگیری سفارشات