Computers & Industrial Engineering 113 (2017) 294–304

Contents lists available at ScienceDirect

Computers & Industrial Engineering

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

Coordinating carbon pricing policy and renewable energy policy with a case study in China

Qiang Tu[a,b], Jian-Lei Mo[b,c,*]

[a] College of Management & Economics, Tianjin University, Tianjin 300072, China
[b] Center for Energy & Environmental Policy Research, Institutes of Science and Development, Chinese Academy of Sciences, Beijing 100190, China
[c] Grantham Research Institute for Climate Change and the Environment, London School of Economics and Political Science, Houghton Street, London WC2A 2AE, UK

ARTICLE INFO

Keywords:
Policy mix
Policy interaction
Policy coordination
Renewable energy policy
Carbon pricing

ABSTRACT

In order to reduce greenhouse gas (GHG) emissions, many countries have set various kinds of policy targets and introduced policy instruments accordingly, such as carbon pricing and renewable electricity subsidies. As a consequence, potential interactions and, especially, conflicts between these co-existing instruments have become a significant concern. In this paper, a partial equilibrium model is constructed to explore the interaction between carbon pricing and renewable electricity subsidies. Based on this model, the following issues are explored: the conditions under which a single policy is optimal and the scenarios where a mixed policy is necessary in the realisation of the outlined policy targets, and the means by which to coordinate different policy targets to reduce the negative effects of any potential conflicts, especially possible CO_2 price collapses. The optimal portfolio of the two policy targets is obtained, and the method of coordinating them to stabilise CO_2 prices is delineated. Thereafter, an empirical study of China's case is conducted. The results show that with the policy targets set by the Chinese government for 2020, renewable energy power subsidies may lead to a collapse of CO_2 prices, and a tightening of the carbon emission budget is necessary to stabilise the latter.

1. Introduction

To mitigate the adverse impact of climate change, many countries have introduced a range of policies to reduce greenhouse gas (GHG) emissions, such as energy efficiency policies, subsidies for electricity production from renewable energy sources (RES-E), carbon pricing policies and so on (Zhu, Duan, & Fan, 2014; Zuluaga & Dyner, 2007). For example, the European Union (EU) has agreed on two ambitious objectives for 2030; namely, a 40% reduction of carbon emissions from 1990 levels, and a bolstering of the market share held by renewable energy to 27% (Siitonen & Ahtila, 2010). Accordingly, the EU has implemented a variety of policy instruments, such as the EU Emission Trading Scheme (ETS) and the renewable energy subsidy policy, or the renewable portfolio standard (RPS). As the world's largest producer of CO_2 emissions, China has piloted emission trading scheme in seven provinces and cities, and a nationwide carbon market is planned to be implemented in 2017, with the aim of lowering the carbon emission intensity by 40–45% by 2020 and, further, to realise a carbon emission peak by 2030. Meanwhile, the country has also introduced a feed-in tariff (FIT) policy for renewable energy-based electricity, which will promote renewable energy development and increase the share held by green electricity to 15% by 2020 and 20% by 2030. With this in mind, it can be foreseen that carbon pricing and the FIT policy would coexist for a certain period.

The potential effects of interaction between the coexisting policy instruments are of notable concern for the policymakers (Goulder, 2013; Levinson, 2011). More specifically, the implementation of a carbon emission trading scheme would increase the emission costs of fossil fuel-based power plants and improve the relative competitiveness of renewable energy-derived electricity. As a side effect, the implementation of a carbon emission trading scheme may promote renewable energy development. In addition, the FIT policy for renewable energy could increase the electricity production from RES, promoting the substitution of fossil fuel-based electricity. In sum, the FIT policy for RES may promote carbon abatement. What we have outlined above is only one aspect of the interaction between different policy instruments, that is, the synergy effect; the other one is the possible conflict effect. Some previous studies have pointed out that too stringent a policy for supporting renewable energy may lower carbon prices by reducing the demand for carbon emission permits in the carbon market (Fankhauser, Hepburn, & Park, 2010; Fischer & Preonas, 2010; Greaker & Rosendahl, 2008), which would undermine the effect of the emission trading

* Corresponding author at: Center for Energy & Environmental Policy Research, Institutes of Science and Development, Chinese Academy of Sciences, Beijing 100190, China.
E-mail addresses: mo_jianlei@126.com, mojianlei@casipm.ac.cn (J.-L. Mo).

http://dx.doi.org/10.1016/j.cie.2017.09.026
Received 4 December 2016; Received in revised form 14 September 2017; Accepted 16 September 2017
Available online 20 September 2017
0360-8352/

scheme on emission abatement and, especially, on low carbon energy investment (Abadie & Chamorro, 2008; Blanco & Rodrigues, 2008; Grubb & Neuhoff, 2006; Mo, Zhu, & Fan, 2012; Nordhaus, 2011; Löfgren, Wråke, Hagberg, & Roth, 2014; Mo, Agnolucci, Jiang, & Fan, 2016). For example, the carbon prices set out by the EU ETS are low for several reasons, including the generous allocation of allowances, the lavish use of credits from offsetting projects, the outbreak of the financial crisis and so on. Besides these factors, faster-than-expected growth in renewable energy as a result of the related supporting policy is also a critical reason (Mo & Zhu, 2014). Consequently, the FIT policy for RES may negatively affect the performance of the emission trading scheme. At that point, how to coordinate the different policy instruments to avoid the effects of possible conflict would become a challenging issue.

There have been a handful of relevant qualitative studies on the interaction and coordination between the coexisting policy instruments. The coevality of ETS and RES deployment targets creates a classic case of interaction effects. Amundsen and Mortensen (2001) applied a static equilibrium model to investigate both long- and short-term interactions between the renewable energy certificates (RECs) market and ETS in the context of the Danish power sector. The model considered price ceilings and floors of RECs, CO_2 prices and electricity imports. The results showed that under the condition of autarchy, tightening CO_2 emissions, together with a fixed share of renewable energy-based electricity, may lead to a reduction in green producers' profits and the RECs' price. However, an increasing share of renewable energy-derived electricity with a fixed carbon emission cap would lead to CO_2 price reductions. Abrell and Weigt (2008) simulated the interaction between the 20% CO_2 reduction target and the 20% renewable energy (RE) share target using a computable general equilibrium model of the German economy based on 2004 data, and found that achievement of the 20% RE share target made the CO_2 reduction target superfluous and thereby reduced the CO_2 price to zero. In addition to this theory, several simulation-based studies have also predicted that RES deployment may impose a strong downward pressure on CO_2 prices. For example, simulations by Van den Bergh, Delarue, and D'Haeseleer (2013) suggested that RES deployment reduced CO_2 prices by €46 in 2008 and more than €100 in 2010. Meanwhile, in the simulation by Jonghe, Delarue, Belmans, and D'Haeseleer (2009), the allowance price could even drop to zero, depending on the stringency of the targets (see also Unger & Ahlgren, 2005; Weigt, Ellerman, & Delarue, 2013). As mentioned above, many researchers argue that the interaction between the ETS and RES policies has a negative effect on CO_2 prices by reducing the demand for carbon permits in the electricity sector.

To address the possible effects of conflict between the coexisting policy instruments, especially the possible low CO_2 price, some researchers have considered the attainment of coordination between them. These authors believe that the long-term carbon emission cap target needs to be reconsidered to avoid a weakening of CO_2 prices (Gawel, Strunz, & Lehmann, 2013; Freitas & Silva, 2015; Fais, Blesl, & Voß, 2015). In fact, many countries have pondered reducing CO_2 emission allowances to stablize said prices. For example, the EU will establish a Market Stability Reserve (MSR) in 2018, while the placing of allowances within the reserve will come into operation from 1 January 2019. When CO_2 prices are too low in the eyes of the ETS, the MSR will absorb excess carbon emission allowances to avoid a possible collapse of such prices. Additionally, within the EU's framework for climate and energy targets by 2030, the CO_2 emissions cap will need to be lowered by 2.2% per year from 2021, compared with the current 1.74%.

Although there have been a few qualitative discussions on how one of the coexisting policy instruments affects the performance of the others, quantitative studies are scarce, and techniques for coordinating different policy targets and their corresponding instruments are little discussed.

In this work, therefore, we explore the potential interaction and coordination between carbon pricing and renewable subsidies within the context of a renewable energy power policy. To conduct a quantative analysis and highlight the interaction effect explicitly, a partial equilibrium model of the electricity market was built, incorporating the decision optimisation behaviour of fossil fuel power producers, renewable energy power producers and power grid firms. Based on this model, the portfolios of the carbon emission cap and renewable energy targets, under which one single policy is optimal and a policy mix is necessary, were obtained. In addition, we were able to determine the manner of coordinating different policy targets in order to reduce potential conflict between the varying instruments and, especially, to avoid possible CO_2 price collapses. These two points are the main contribution of our work. In addition, an empirical study of China's case was conducted. The results show that with the policy targets set by the Chinese government for 2020, a renewable energy power subsidy may lead to a collapse of CO_2 prices, and adjusting the carbon emission cap target is therefore necessary for stabilisation.

The remainder of this paper is organised as follows. Section 2 describes the model; analytical results are presented in Section 3; Section 4 undertakes an empirical study in China and Section 5 offers discussions and a conclusion.

2. Model

Based on the characteristics of the Chinese electricity market, three representative participants were incorporated into our model: a power grid firm, a fossil fuel electricity producer and a renewable energy electricity producer. Their relationship was that the power grid firm purchased electricity from both types of producers at corresponding on-grid prices, and sold all of it to consumers at a consumer price. During this process, all participants pursued profit maximisation. The decision making of the three participants were as follows:

(1) The representative fossil fuel electricity producer has the flexibility to comply with CO_2 emission regulations by reducing his own carbon emissions, cutting his own production or purchasing emission permits from the markets, with the objective of maximising his profit π_F,

$$\max_{Q_F,A_F} \pi_F = R_f(Q_F,P_f) - C_f(Q_F) - C_e(A_F) - C_c(\theta,Q_F,A_F) \\ = P_f Q_F - C_f(Q_F) - C_e(A_F) - P_c(\theta Q_F - A_F) \quad (1)$$

where $R_f(\cdot)$ is the revenue from fossil fuel electricity sales, in other words, the fossil fuel power generation, Q_F multiplied by the on-grid price P_f for fossil fuel power. $C_f(\cdot)$ is the electricity production cost function, which is strictly monotonic, increasing in Q_F and convex; more specifically, $C_f'(\cdot) > 0$, $C_f''(\cdot) > 0$. $C_e(\cdot)$ is the carbon abatement cost function, and is similarly monotonic, increasing in abatement mount A_F and convex, $C_e'(\cdot) > 0$, $C_e''(\cdot) > 0$ (Lecuyer & Quirion, 2012). $C_c(\cdot)$ is the cost of purchasing carbon emission permits through auction or from the carbon market, which is the CO_2 price, P_c multiplied by the gap between the carbon emission amounts θQ_F and the abatement amount A_F, in which θ is the intensity of CO_2 emissions by the fossil fuel power producer. It should be noted that the carbon emission permits are allocated by auction method in this situation.

(2) There are N kinds of renewable energy sources, and for each kind, the producer maximises its profit π_{iR},

$$\max_{Q_{iR}} \pi_{iR} = R_{ir}(Q_{iR},P_r) - C_{ir}(Q_{iR}) \\ = P_r Q_{iR} - C_{ir}(Q_{iR}), \quad i = 1,2,3...,N \quad (2)$$

where $R_{ir}(\cdot)$ is the revenue from electricity sales, which equals to the amount of electricity produced, Q_{iR}, multiplied by the on-grid price P_r for renewable energy power. The cost function $C_{ir}(\cdot)$ is assumed to be monotonic, increasing in the amount of electricity produced, and