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When renewable portfolio standards meet cap-and-trade regulations in the electricity sector: Market interactions, profits implications, and policy redundancy

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ABSTRACT

Emission trading programs (C&T) and renewable portfolio standards (RPS) are two common tools used by policymakers to control GHG emissions in the energy and other energy-intensive sectors. Little is known, however, as to the policy implications resulting from these concurrent regulations, especially given that their underlying policy goals and regulatory schemes are distinct. This paper applies both an analytical model and a computational model to examine the short-run implications of market interactions and policy redundancy. The analytical model is used to generate contestable hypotheses, while the numerical model is applied to consider more realistic market conditions. We have two central findings. First, lowering the CO_2 C&T cap might penalize renewable units, and increasing the RPS level could sometimes benefit coal and oil and make natural gas units worse off. Second, making one policy more stringent would weaken the market incentive, which the other policy relies upon to attain its intended policy target.

1. Introduction

In order to reduce greenhouse gas (GHG) emissions and promote renewable energy, ongoing efforts at various levels employ a suite of instruments. The purpose of these instruments is to level the playing field of less polluting-intensive facilities (e.g. renewable) by either direct subsidy or tax on polluting resources (e.g. coal). For example, the European Union (EU) launched the Emission Trading Scheme (EU ETS) in 2005. California Assembly Bill 32 (AB 32) or the Global Warming Solution Act stipulates a cap-and-trade (C&T) program as the main policy to control GHG emission from the power sector. Another common tool is the renewable portfolio standard (RPS), which requires a certain percentage of electricity to be generated from renewable sources. In the United States, 34 states and the District of Columbia have established an RPS (Doris et al., 2009). Most states allow producers to use renewable energy certificates (RECs) to meet their obligation. Surplus RECs can be traded for extra revenue in the market. In other words, RECs are essentially the analogue of tradable permits in C&T programs. In Europe, the European Commission (EC) proposed national renewable targets for each member state. The EC allows member states to achieve the targets through feed-in tariffs or transferable tradable green certificates (TGC) (Nielsen and Jeppesen, 2003). TGCs are equivalent to RECs in USA. Several other countries, including Australia, Brazil, China, Japan, South Korea, and Taiwan, also planned or had established similar programs to promote renewable energy (IEA, 2004).

Currently, two proposed energy policies in the USA, i.e. the American Clean Energy and Security Act of 2009 (ACES) and the Clean Energy Jobs and American Power Act, both have language about using C&T and RPS as the main mechanisms to control GHG emissions in the energy and other energy-intensive sectors. One emerging question that remains unanswered, however, is the implication on policy efficiency resulting from the interactions of these potentially overlapping schemes, especially given that their underlying policy goals and regulatory schemes are somehow distinct. Whereas C&T aims to reduce GHG emissions, the RPS mandates a certain level of renewable energy generation but lacks explicitness in emissions abatement.

A number of studies qualitatively discuss the RECs market and its interactions with the C&T program. Mozumder and Marathe (2004) give an overview of RPS and examine the implications of an integrated RECs market. They also address other RPS-related issues, including the fluctuating availability of renewable resources, time lags in capacity development, and the harmonized level on RPS setting in the short and long run. Gillenwater (2008a, 2008b)

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explains the challenges when using voluntary market RECs for offsetting pollution emissions. The study concludes that the offset credits from renewable energy can be identified by fully addressing additionality, ownership of credits on emission reduction, and quantification of emission reduction. Bird et al. (2008) discuss the key issues of how renewable energy markets might intervene with carbon regulation, including the implications for emissions benefits claims, voluntary market demand, and the use of RECs in co-existing markets. They also stress the importance that policymakers need to be aware of the policy interaction with new and emerging policies.

Other studies have analyzed the market interaction under different energy regulations quantitatively. Amundsen and Mortensen (2001) apply a static equilibrium model to investigate both long and short-term interactions between the RECs market and C&T for the Danish power sector. The model considers price ceilings and floors of RECs, CO_2 prices, and electricity imports. Their results show that under the condition of autarchy, tightening the CO_2 emission together with a fixed RPS requirement may lead to a reduction in green producers profit and the RECs price. On the other hand, an increasing RPS with a fixed CO_2 emission cap suggests that the effects on the capacity expansion of renewables are ambiguous, depending on the price elasticity of demand. Jensen and Skytte (2002) model a regional electricity market under RPS. They also find that the effect of RPS on the electricity price is ambiguous. This is because raising RPS might induce a greater electricity output, thereby pushing down the price of electricity; on the other hand, it might also increase the RECs demand simultaneously, effectively raising the electricity price. Another study examines the long run implications of the co-existence of the C&T and RECs markets in the Baltic Sea region (Hindsberger et al., 2003). It shows that two policies can effectively increase renewable deployment. However, they did not consider the mechanism under which the permit price interacts with the RECs markets. Linares et al. (2008) examine the interactions of C&T and RPS in the context of the Spanish electricity market using conceptually graphic and simulation approaches. They conclude that the co-existing policies could lower consumer costs if policies are well coordinated because the RPS somehow attenuates the effect of the CO_2 emission cap. Bohringer and Rosendahl (2010), based on a theoretical analysis, examine the consequence of overlapping regulations (i.e. C&T and RPS with feed-in tariff). They conclude that overlapping regulations might promote dirty fossil technology because it will reduce the permit price, thereby benefiting emission-intensive technologies. Fischer (2010) also finds that the RPS program might increase or lower the electricity price, depending on two factors: the elasticity of renewable/non-renewable electricity supply and the stringency of the RPS target. Two European studies which examine the implication of co-existence of C&T and RPS in the energy market using numerical models also reach a similar conclusion (De Jonghe et al., 2009; Unger and Ahgren, 2005). In summary, these studies find that tightening the CO_2 emission cap while subject to a fixed RPS would hurt renewable producers yet the effect of RPS with a fixed CO_2 cap is ambiguous.

Some of these studies examine the market by applying theoretical models that allow market equilibria to be solved analytically. However, these models lack market details that might misrepresent supply and demand. For example, supply curves in these models are usually assumed as smooth functions that require an interior solution assumption when deriving first-order optimality conditions. In reality, the marginal cost function likely is a stepwise or piecewise function. The marginal emission rate, which differs by each unit/technology, is likely non-monotonic and non-differentiable if ordered in commensurate with production costs, can be appropriately represented by this approach. Therefore, they cannot be properly represented in theoretical models. Although some other studies examine market interactions using numerical approaches, intermittence of renewable output (e.g. wind) is generally overlooked, and the results tend to overstate the benefit of renewables. Moreover, the effect of policies on profitability by fuel types and emission intensity is not addressed thoroughly. These are crucial pieces of information in steering firms for their long run investment decision and evaluating efficiency of policies for promoting renewables and CO_2 emissions reduction.

This paper applies both an analytical model and a computational model to study the interaction of RPS and C&T policies. Practically, obtaining permits for new facilities could be a lengthy process, in which RPS or CO_2 requirement might change without any progress being made to bring new capacity to the market. We thus focus on short-run analysis because we are interested in the effects of overlapping policies on generators profits as well as the RECs and C&T permit prices in general. The analytical model is used to generate contestable hypotheses. The numerical model with California data is applied to consider more realistic market conditions. In particular, uncertain wind output is modeled by its empirical cumulative density function. A spinning reserve market is incorporated in order to compensate unavailable wind. Otherwise, its cost is grossly underestimated, and its output is then overstated. We then apply a Monte Carlo simulation in order to examine the distribution of the potential market outcomes. We have three central findings in this paper. First, making one policy more stringent would weaken the market signal created by the other policy. Second, the C&T and RPS policies affect fuel-specific profit differently. More specifically, while lowering the CO_2 cap benefits natural gas units, it also penalizes renewables (in additions to coal and oil) by reducing subsidies received through REC sales. On the other hand, increasing the RPS requirement could sometimes benefit coal and oil units and make natural gas units worse off. These are consistent with other studies (Amundsen and Mortensen, 2001; Bohringer and Rosendahl, 2010; Linares et al., 2008). Third, the CO_2 emission intensity could increase when the authority increases the RPS requirement.

The remainder of this paper is organized such that the theoretical analysis on the co-existence of RPS and C&T is given in Section 2. In Section 3, we introduce the method of numerical simulation including the model formulations, parameter inputs, and assumptions. Then in Section 4, we report our results of simulation and discuss the intuitions behind the market interaction. They include the effects of co-existing policies on the sale-weighed electricity price, the CO_2 emission permit and RECs prices, per MWh profits by fuel types, and emission intensity and policy redundancy.

2. Theoretical analysis

A theoretical economic model is built in this section to overview the interaction of markets in the co-existence of the C&T and RPS policies. We consider three types of power producer, i.e. coal, natural gas, and renewable producers, who face price-responsive electricity demands. Three producers are assumed to be price-takers in the electricity, the spinning reserve, the RECs, and the CO_2 permit markets.

The overall market model is expressed in Eqs. (1)–(6).[1] The indices (either superscript or subscript) c, n, and r denote the coal,

[1] The equivalence of Eqs. (1)–(6) is by formulating the model as a social welfare maximization problem—a nonlinear program (NLP). Their resulting first-order conditions will be the same. In this paper, we use the NLP formulation in Section 3 for numeric simulations. Yet, the formulation here allows us to understand the optimization problem faced by each producer.