Utilities Policy 55 (2018) 59–68

Contents lists available at ScienceDirect

Utilities Policy

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

Producer incentives in electricity markets with green quotas and tradable certificates

Kevin M. Currier[a,*], Susanne Rassouli-Currier[b]

[a] Department of Economics, Oklahoma State University, Stillwater, OK, 74078, USA
[b] Department of Economics, University of Central Oklahoma, Edmond, OK, 73034, USA

ABSTRACT

We study both intended and unintended consequences of cost reductions by green producers in a competitive electricity market operated under a green quota enforced via a green certificate system. We show that green producers may not have an incentive to exploit the full cost reduction potential of their technology and can in general be expected to engage in strategic cost padding. We propose a method of incentivizing RE producers to exploit the full cost reduction potential of the green technology. The method allows for strategic cost padding, but only at the expense of profit reducing changes in the RE quota.

1. Introduction

The European Union's 2030 Framework for Climate and Energy Policy calls for an increase in the share of renewable energy (RE) to a minimum (a "green quota") of 27% by the year 2030 (European Commission, 2014). Similar RE objectives exist around the world. Two of the most common mechanisms for the promotion of RE in electricity markets are a system of tradable green certificates (a quantity-based scheme), and the feed-in tariff (a price-based scheme).[1] Under a green certificate system, a green quota (i.e., the percentage of total electricity generated that must originate from renewable sources) is stipulated and RE ("green") electricity producers are allowed to issue one green certificate for each unit of electricity generated. A designated party of the electricity supply-chain is then obliged to purchase certificates in a market separate from the electricity market. Penalties are typically imposed for non-compliance. Revenue from green certificate sales effectively subsidizes green producers, and equilibrium in the green certificate market implies satisfaction of the green quota. Green certificate systems are now employed in the United States, India, South Korea, China and Australia. In the EU, green certificate systems are employed in Belgium, Norway, Romania, and Sweden (European Commission. 2018). Under a feed-in tariff system, green producers are guaranteed a price or a premium over the market price of electricity. Subsidies are typically differentiated by technology type (wind, solar, etc.) and may be financed by the government or an end-user tax on electricity consumption. The use of feed-in tariffs is widespread and currently employed by many EU members including France, Germany, The Czech Republic, Greece, and Italy, among others (European Commission. 2018). For a comprehensive discussion of the anticipated advantages and disadvantages of the green certificate and feed-in tariff schemes in Sweden, see Bergek and Jacobsson (2010).

RE and emissions reduction goals should be achieved efficiently. A number of recent papers have demonstrated some important unintended consequences of the simultaneous use of various combinations of emissions control techniques (i.e., emissions trading) and/or RE promotion methods. For example, Böhringer et al. (2008) demonstrated the existence of excess costs from the simultaneous use of emissions taxes and the EU emissions trading system (ETS). In addition, Böhringer and Rosendahl (2010) demonstrated that the strengthening of a green quota in the presence of an ETS will increase the output level of the most emissions intensive producer. Currier (2014) demonstrated that intensification of RE investment cost reduction policies in electricity markets employing green certificate systems will lead to higher carbon emissions by carbon-based producers. Morey and Kirsch (2014) provided a comprehensive discussion of numerous unintended consequences of Germany's RE promotion initiatives (see also Böhringer and Behrens, 2015; Eichner and Pethig, 2010). In this paper, we provide an analysis of potential unintended consequences of simultaneous cost reduction and green certificate trading.

Regardless of the details of the RE support mechanism,

---

* Corresponding author.
E-mail addresses: kevin.currier@okstate.edu (K.M. Currier), scurrier@uco.edu (S. Rassouli-Currier).

[1] In the USA, Tradable Green Certificates are typically called Renewable Energy Credits or Renewable Energy Certificates. Other RE support mechanisms include, loan guarantees, investment grants, tax incentives and tendering schemes.

https://doi.org/10.1016/j.jup.2018.09.004
Received 4 October 2017; Received in revised form 10 September 2018; Accepted 11 September 2018
0957-1787/

policymakers have the presumption that support will be withdrawn as cost efficiencies and technological advances in the RE production chain permit green producers to eventually compete on an equal footing with carbon-based producers (Couture and Gagnon, 2010; Choi et al., 2015).[2] Hence, the study of cost-reduction incentives facing green producers is an important research question.[3] Cost reductions may be attributable to experiential learning by doing or learning by waiting (Thompson, 2010), as well as improvements in RE equipment production and installation.[4] Within the context of electricity markets employing an emissions tax and a green quota, Currier (2016a) showed that green producers have incentives to engage in rent seeking behavior and even collusion. This may include "cost padding" in the form expense exaggeration, deliberate waste, and managerial perquisites, as well as political lobbying designed to increase or prolong subsidization (Sappington, 1980). Currier (2016b) showed that in an electricity market employing an emissions trading system (ETS) and a green quota, there will always be one green producer with an incentive to pad its own costs and attempt to disadvantage its rival green producers. In addition, Currier and Rassouli-Currier (2018) found cost padding incentives for green producers operating under a green quota with an authorized target rate-of-return to ensure investor confidence.

Some recent research has focused on green producer incentives for strategic behavior. Gawel et al. (2016) provided a comprehensive overview of the interests of the various stakeholders in RE in Germany and the EU, noting in particular RE producers desire for rents stemming from generous subsidies. Delmas et al. (2016) found strong empirical evidence that across production sectors, producers at the extremes of the environmental performance spectrum (i.e., greenhouse gas emissions) have the highest lobbying expenditures. Bergek and Jacobsson (2010) assessed the performance of the Swedish green certificate system between 2003 and 2008. They found evidence of very large rents accruing to green producers and only minimal technical change (cost efficiencies). Kwon (2015) studies South Korean RE markets and found evidence of rent seeking and rent generation under both green certificate systems and feed-in tariffs, attributable primarily to information asymmetries between policymakers and RE producers. Schmitz et al. (2013) assert that rent management is a key ingredient in RE industrial policy and discussed the factors that are necessary for it to succeed. Stokes (2013) noted that the feed-in tariff for solar PV in Ontario Canada doubled between 2006 and 2009 in spite of significant experiential learning. This finding illustrates the tension between ensuring investor confidence (with generous subsidies) and adaptively managing the RE policy as new information (e.g., learning induced cost reductions) becomes available.

In this paper, we model some consequences (both intended and unintended) of cost reductions by green producers in a competitive electricity market with a green quota implemented by a tradable certificate system. Using a stylized model of a generic competitive electricity market, we first establish that the green certificate system is an efficient policy instrument for implementing a green quota. We then demonstrate *inter alia* that cost reductions by green producers decrease the equilibrium green certificate price over time but increase emissions from carbon-based production, thus supporting the argument that a green certificate system may not be an efficient policy instrument for emissions reduction (Vogstad et al., 2003). In addition, we show that RE producers may not have an incentive to exploit the full cost-reduction potential of green technology, implying that green producers can be expected to seek rents through cost padding. We also demonstrate, however, that side payments between the carbon-based and green producers can mitigate against this behavior, but only to a limited extent. Finally, we propose a method of incentivizing RE producers to exploit the full cost-reduction potential of green technology. This mechanism works by linking the level of the green quota to the realized value of a cost parameter in a manner to ensure that RE producers maximize profits if and only if they fully exploit all potential cost efficiencies.

2. The model

We consider a closed competitive electricity market where q denotes total consumption of electricity. There are n identical "green" (renewable) producers producing output x and m identical carbon-based (fossil fuel) producers producing output y. Thus, $q = nx + my$.

Green producers' parameterized cost functions are $C_x(c,\ x)$ where reductions in the parameter c reflect experiential learning in RE generation as well as reduced manufacturing and installation costs of RE equipment. These costs are increasing and strictly convex in output: $\frac{\partial C_x}{\partial x} > 0$ and $\frac{\partial^2 C_x}{\partial x^2} > 0$.[5]

Furthermore, we assume that $\frac{\partial C_x(c,\ x)}{\partial c} > 0$ and $\frac{\partial^2 C_x}{\partial c \partial x} > 0$. Thus, reductions in the cost parameter c imply reduced total and marginal cost. For notational ease, we shall henceforth denote $\frac{\partial C_x(c,\ x)}{\partial x}$ by $MC_x(c,\ x)$. Thus, $\frac{\partial MC_x}{\partial x} > 0$ and $\frac{\partial MC_x}{\partial c} > 0$. In view of the intermittent (i.e., non-dispatchable) nature of many RE sources, any meaningful notion of green producer cost must also account for the need for back-up generation, such as battery storage in solar PV. We assume that green producers internalize power-balancing costs stemming from intermittency.[6] Thus, in the present setting the cost function $C_x(c,\ x)$ indicates the minimum cost of generating x units of green electricity with certainty when the cost parameter is c. See also footnote 17.

Carbon-based producers' cost functions are denoted by $C_y(y)$ with $C'_y,\ C''_y > 0$. Furthermore, firm-level emissions are proportional to carbon-based output: $e = \lambda y,\ \lambda > 0$. Aggregate emissions are then $E = m\lambda y$. Green producers generate zero emissions.[7]

Consumer demand is formed by the maximization of consumer surplus $V = U(q) - pq$ where $U' > 0,\ U'' < 0$, and p denotes the market price of electricity. The inverse demand function is $p(q) \equiv U'(q)$ where $p'(q) < 0$.

In our setting, the renewables target is implemented through the use of a green certificate system. Specifically, the policy mandate is that the proportion of green output to total output be $\alpha \in (0,\ 1)$, i.e., $nx = \alpha[nx + my]$. Green producers can issue one certificate at price ρ for each unit of x produced. Thus, green producer profits are $\pi_x = (p + \rho)x - C_x(c, x)$. Furthermore, carbon-based producers are obliged to purchase (at price ρ) β certificates for each unit of y produced.[8] Therefore, carbon-based producers profits are $\pi_y = (p - \beta\rho)y - C_y(y)$. Assuming all producers maximize profit, a renewables target of α is met in equilibrium when $\beta \equiv \frac{\alpha}{1 - \alpha}$.[9]

---

[2] The RE maturity threshold is often referred to as "grid parity". For a discussion of the difficulties associated with the determination of grid parity, see Olsen and Jones (2012) and Choi et al. (2015). In most jurisdictions, RE support contracts typically last 15–20 years.

[3] The RE technologies with the greatest cost reduction potential are Solar PV, Concentrating Solar Power and Wind (IRENA, 2015).

[4] Learning by waiting refers to RE spillover effects from other industries, technologies or countries.

[5] See Requate (2015) for a rigorous justification of the assumption of convex costs in RE production.

[6] Alternatively, these costs could be borne by the system itself.

[7] While green electricity production does not generate GHG emissions, external effects may be present. For example, wind power generation may include effects on landscapes and bird life. See Stokes (2013) for concerned citizens' reaction to wind turbines in Ontario.

[8] In general, purchase obligations may be imposed on generators, wholesalers, retailers or consumers. Following Tamas et al. (2010) and Requate (2015) we assume fossil-fuel producer obligations. It should be noted however that in our model producer obligations are formally equivalent to consumer obligations. See also footnote 9.

[9] As noted earlier, in a "compliance market", penalties are assessed for non-