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Optimal regulation of renewable energy: A comparison of Feed-in Tariffs and Tradable Green Certificates in the Spanish electricity system

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ABSTRACT

Incentives for renewable energy based on Feed-in-Tariffs have succeeded in achieving high levels of renewable installed capacity. However, these incentives have not been responsive to market conditions or price signals, imposing in some cases a great financial burden on consumers when Renewable Energy Sources reached significant levels. A way out of this problem could be a market mechanism where incentives respond to the level of investment on renewables. We explore this issue comparing a regulatory system based on Tradable Green Certificates, able to react to market changes, to a Feed-in-Tariffs incentive scheme. We model the strategic interaction between participants in the electricity pool and the Tradable Green Certificates market and focus on the optimal regulation for the retailer segment, which generates the desired demand for green certificates as a decreasing function of the certificate price. We then calibrate our theoretical model with data from the Spanish electricity system for the period 2008–2013. Simulations show that a green certificate scheme could both achieve the 2020 targets for renewable electricity and reduce regulatory costs. However, the role of regulators is still important, since setting the right target for renewable electricity affects the cost burden of the system.

1. Introduction

European Union Directive (2009) laid down the guidelines for state aid and incentives for renewable energy in Europe until 2020. The main priority was initially to enhance the deployment of Renewable Energy Sources (RES) and there was less concern over the economic consequences that a large penetration of electricity from RES (RES-E) would have on wholesale markets or the efficiency of incentive schemes. The regulatory design of electricity systems was thus conceived without taking into account the economic impact of RES-E participation. Under this regulatory framework, the deployment of RES-E in the European Union (EU) has been much more successful than estimated in terms of green installed capacity.[1]

This paper evaluates two incentive schemes for renewable electricity sources. In particular, we explore markets for Tradable Green Certificates (TGC) as an alternative to Feed-in-Tariffs (FIT). The main point of the paper is that a TGC-based regulatory system reacts to market changes while a FIT incentive scheme does not. From a theoretical point of view, a FIT system could be equivalent to a TGC market. In principle, and as long as market conditions (demand, costs, …) were observable, the regulator could fix the FIT and the renewable quota in a TGC market at the optimal level. However, we argue that the nonobservability of market conditions makes TGC a preferable incentive scheme.

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[1] According to the previsions of the Member States' Renewable Energy Action Plans and the EU industry roadmap, the share of renewable electricity generation in the EU is expected to be between 34% and 42% by 2020 (European Renewable Energy Council (EREC), 2011; European Wind Energy Association (EWEA), 2011).

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We build a theoretical model that formalizes the interaction between the electricity market and the TGC market. In our TGC model the regulator sets the legal obligations to buy TGC: the renewable target (i.e. the percentage of all electricity traded by retailers that has to be renewable) and the imposed penalty if a retailer does not comply with the objective.

We implement the model using actual data of the Spanish electricity market for the years in which the FIT system[2] was in force. We calibrate the TGC model to replicate the level of support of the actual FIT scheme and simulate it for different renewable targets. The objective is to observe whether a TGC incentive scheme would have outperformed the FIT system. In this comparison we take into account a number of considerations. First, a fixed FIT system resulted in huge costs for consumers, and its phasing out raises doubts regarding the continuity of some RES facilities. Second, there have been considerable breakthrough advances in renewable technologies and, with investment costs dropping significantly in the last few years,[3] some RES technologies may not currently need strong incentive schemes to survive, although a certain level of support may still be required for others. Finally, Spain is almost an electricity island in terms of import/exports (5% of total consumption) and so it is a good example for a model under autarky. Under those conditions, our hypothesis is that a TGC market would have been less expensive than the FIT system to attain the 2020 RES-E objectives in Spain.

The paper is structured as follows. Section 2 compiles a literature review of TGC markets. In Section 3 we build a model that includes the interaction between the spot market and the certificate market. Then, we calibrate our TGC model with data from the Spanish electricity system for the period 2008–2013 in Section 4, so that parameters for the numerical implementation are obtained. In Section 5 we simulate the TGC model using counterfactual scenarios and we discuss some of the policy implications of a system based on TGC compared to FIT. Finally, Section 6 ends with a brief summary of the conclusions of the analysis and provides some directions for further research.

2. Literature review

There is a wide range of literature published on green certificates. First, focusing on European countries, some authors pose numerical models on the implementation of TGC markets in Nordic countries (Bergman and Radetzki, 2003; Bye, 2003; Nese, 2003). Second, another line of research includes the interaction between TGC and Emission Trading Schemes (Aune et al., 2012; Finon and Menanteau, 2003; Jensen and Skytte, 2003; Morthorst, 2001; Unger and Ahlgren, 2005). Third, and closely related to our paper, other authors analyze the interaction between TGC and the electricity market. Some solve partial equilibrium models under autarky (Jensen and Skytte, 2002), others focus on multi-country models (Amundsen and Mortensen, 2001; Buttler and Neuhoff, 2008; Morthorst, 2003) and yet others address the market power problem in the TGC market (Amundsen and Bergman, 2012; del Rio, 2007; Madlener et al., 2008).

An important element in the design of a TGC market is how to induce the demand for certificates. Usually, this demand is generated by regulation by setting the legal obligation to buy certificates. Non-compliance with that legal obligation implies a penalty. Regarding this penalty, some authors consider the hypothesis of a variable fine as a percentage of the certificate price, for instance 200% of the market price of certificates (Jensen and Skytte, 2002); whereas others pose a fixed fine depending on the number of certificates missed (Madlener et al., 2008). In the former case, the information on the value of the penalty is not known in advance, since it depends on the certificate price. On the contrary, in the latter case retailers are given this information in advance, so that they will take their demand decisions depending on the value of the fine. Both fix and variable penalty functions are used to establish the demand for certificates, which generally is modeled as inelastic. However, it seems reasonable to model the demand for certificates as price-sensitive (Ciarreta et al., 2014b) and in this paper price-elasticity comes from regulatory decisions affecting the renewable share target and a fine that increases according to a loss function.

Finally, concerning the Spanish market, Linares et al. (2008) study the interactions between the electricity market, the TGC market and the emissions allowance market. Similarly, Fagiani et al. (2014) use Spanish data to calibrate their model and analyze the impact of carbon reduction and renewable support policies in the electricity sector. Both papers conclude that a single policy is not a cost-efficient way of achieving both a reduction of CO_2 emissions and an increase in renewable electricity generation, which are two important goals of the European energy policy.

3. The model

In this section, we develop a model for the interaction between the certificate market and the electricity market. When consumers cannot distinguish the energy source, electricity has to be considered a homogeneous good. However, as long as there is some mechanism to certify the origin of the electricity consumed, the green attributes of electricity become relevant. In our model we consider that electricity is sold as a commodity in the spot market and the green attributes of electricity are sold on a separate market, a TGC market.

We consider only one renewable energy source and one non-renewable. Even though the environmental impact of different renewable or non-renewable energy sources may be different, as well as the cost they impose on the management of the electricity system, for simplicity we will ignore any differences between technologies and assume that the ecological value of different renewable energy sources is a homogeneous good. The introduction of different energy sources would be straightforward.

We need a sequential model to take into account the fact that when the incentives to RES are provided through the market, green electricity is produced first and then their ecological attributes can be sold in the certificate market. We consider that each generator has renewable and non-renewable production plants.

The timing of the game is as follows. At stage 1 electricity generators' decisions determine the supply function, retailers' decisions the demand function, and the spot market clears every subperiod h (on an hourly basis). Producers are awarded certificates depending on their production using renewable sources. This endowment of certificates will constitute the supply in the TGC market. At stage 2 retailers demand certificates to meet their legal obligations regarding renewable sources, set by the regulator. The TGC supply is fixed from stage 1. The TGC market clears every period H, with $H > h$ (on an annual basis).[4]

[2] For the sake of simplicity we call it the FIT incentive system from now onwards, but we are actually considering the combined system of tariffs and premiums (FIP). Under a FIT scheme renewable generators receive a minimum guaranteed price per kWh sold in the electricity market, including different fees by technology. Under a FIP scheme, renewable generators receive a premium paid on top of the market price for the electricity they sell in the market. See Ciarreta et al. (2014a) for a more detailed explanation on the regulation of renewable energy in Spain.

[3] For a detailed analysis of the economics of photovoltaics and the change in their costs see Bazilian et al. (2013).

[4] The notation used in the model is compiled in Table A.1 in Appendix A.