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The optimal percentage requirement and welfare comparisons in a two-country electricity market with a common tradable green certificate system☆

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ABSTRACT

The tradable green certificate (TGC) system, with its requirement for a percentage commitment to energy production from renewable sources, has become an important instrument in resolving greenhouse gas (GHG) issues and promoting the generation of sustainable energy. In this paper, based on the model of Aune et al. (2012) and the framework in Currier and Rassouli-Currier (2012), I analyze a competitive electricity market with two countries. I geometrically illustrate that under competitive equilibrium, variations in the renewable quota generate an "equilibrium locus" corresponding to the set of renewable/fossil fuel-based electricity supply and demand levels attainable across the two countries. With this concept, I further derive the pricing rule for TGCs when the percentage requirement is the only policy instrument and the regulator chooses it optimally to maximize welfare along the "equilibrium locus." Using a geometric illustration, I compare the two countries' welfare when the renewable quota is chosen optimally in the common certificate market with three different situations, in particular: (i) before the introduction of a common TGC market when the renewable quota is chosen optimally; (ii) when all firms are fossil fuel energy producers and just produce the competitive equilibrium output; and (iii) when all firms are fossil fuel energy producers regulated by a CO_2 emissions standard. I find that the total welfare with the optimal renewable share in a common certificate market is always greater than situations (i) and (ii), and is also greater than situation (iii) when damages by fossil energy producers are sufficiently bounded. Our policy recommendation is that when the value of the damage parameter is sufficiently small, full integration with a common TGC market is superior in terms of welfare to that of an entirely fossil fuel-based market with an optimal emissions standard. The numerical example demonstrates the welfare comparison results in the theoretical model.

1. Introduction

It is increasingly accepted that renewable energy resources (wind, solar, biomass, hydropower, geothermal energy, etc.) are essential for clean and sustainable energy generation, and thus sustainable development. In the United States (U.S.), fossil fuel combustion accounted for almost 94% of CO_2 emissions in 2013 (EPA, 2015). In the European Union (EU), approximately 95% of CO_2 emissions come from the combustion of fossil fuel to provide energy (Nielsen and Jeppesen, 2003). Several events in the EU have accelerated the need to increase the share of renewable energy resources. First, in late 2008, the European Parliament agreed to the EU's overall environmental target of a 20% reduction in greenhouse gas (GHG) emissions and a 20% share of renewables in the EU's gross final energy consumption by 2020 (EU, 2009a, 2009b). In 2014, the EU's 2030 Framework for Climate and Energy has set these two targets to be at least 40% cuts in GHG emissions (from 1990 levels) and at least a 27% share for renewable energy (EU, 2014). Second, since 1997, EU members have begun to liberalize their energy markets in the direction of replacing monopolistic market structures with competitive markets (EU, 1997). This process requires that cost efficiency, lower consumer prices, and environmental goals are all achieved. In addition to the EU, explicit percentage requirements have been set up in many industrialized countries that require energy producers or consumers undertake a certain percentage of their energy production or consumption from renewable sources. In the U.S., many states have set up regulations with a mandatory renewable quota to promote renewable energy development.[1] As of October 2015, 29 states, Washington, D.C., and two territories have adopted a Renewable

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[1] In most states, the renewable quota is from 10% to 30%, with different time frames and paces.

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Portfolio Standard (RPS), while eight states and two territories have set renewable energy goals (NCSL, 2015).

Against this background, practical instruments have been designed to promote the generation of energy from renewable sources. Three of the most common practices are the feed-in tariff (FIT), the EU Emissions Trading Scheme (ETS), and the system of tradable green certificates (TGCs). The proposition that I discuss in this paper is the introduction of the TGC system. There is supply and demand for green certificates (TGCs) in the TGC market. The demand for certificates is derived by putting the obligation to meet the national percentage requirement for renewable energy on final consumers and distribution companies.[2] All consumers and distributors are required to prove that at least the specified proportion of their energy consumption is renewable. Consumers can fulfill their obligation by purchasing TGCs and handing them over to authorities as proof of compliance. Non-compliers will be sanctioned if the consumer obligation is not met. The supply of certificates is given by issuing a TGC to the green (renewable) energy producer for each unit of renewable energy produced. Thus, energy production from renewable sources is more profitable as renewable energy producers gain the additional certificate revenue when selling TGCs through the TGC market.

I am especially interested in the TGC system for the following reasons. Although the ETS and FIT schemes have already been used in EU countries, and in both the U.S. and Canada, policies aimed directly at GHG emission reductions have been very unpopular for many political reasons, including their questionable effectiveness and ambiguous cost benefit studies. Thus, from the regulator's perspective, it may be better to attack emissions indirectly by promoting renewables, rather than by direct regulations such as cap and trade measures, etc. The implementation of TGCs is a potential way of doing this.

Since 1999, politicians from nine EU countries have worked to establish a scheme called the Renewable Energy Certificate System (RECS), under which harmonized national markets for renewable energy certificates are to be stimulated. Recently, a potential EU-wide TGC system has been under discussion. According to Aune et al. (2012), the EU's "statistical transfers" system can be seen as a first step towards a full TGC system in the EU.[3] However, only five EU countries have agreed to comply with nondomestic instruments to achieve their own national targets, and less than 1% of the renewable energy production can be traded between EU countries or between EU countries and a third country (EU, 2010).

Many studies have investigated the integration of domestic TGC markets within a joint TGC market, and how the system affects renewable energy and fossil fuel-based energy production (Amundsen and Nese, 2009; Aune et al., 2012; Bye, 2003; Nielsen and Jeppesen, 2003; Widerberg, 2011). Aune et al. (2012) compared two scenarios: i) competitive full trade in TGCs, underpinned by a common renewable target for all EU countries, and ii) countries with differentiated national targets having trade or no trade in TGCs. Their theoretical model shows that a common renewable target for all EU member states and full trade in TGCs can ensure the cost effectiveness of the policy, whereas attaining the renewable target through differentiated national targets is not a cost-effective policy. However, their model takes the renewable quota as a given parameter and does not consider the environmental damage from fossil fuel energy production when studying the TGC system. Thus, it does not address the question of the socially optimal percentage requirement within the context of a common TGC framework.

Currier and Rassouli-Currier (2012) studied a duopolistic model for electricity consisting of one green (renewable) energy producer and one black (fossil fuel) energy producer in one country, with producers being obliged to hold TGCs. They investigated the socially optimal choice of the percentage requirement within duopolistic equilibrium, and discussed the "equilibrium locus" generated by variations in the percentage requirement. They demonstrated that with the optimal renewable quota, equilibrium in the TGCs market can ensure socially optimal renewable/fossil fuel-based energy production under the duopolistic market structure.

Because of the complexity of policies, the results of several qualitative models are to a large extent imprecisely determined, especially when the model is extended to an international trade setting for the TGC market and the energy market. Therefore, to make the results clearer, it seems necessary to have stronger but reasonable assumptions concerning TGCs and energy markets.

My study differs in several ways from Aune et al. (2012) and Currier and Rassouli-Currier (2012). First, unlike the model of Aune et al. (2012), where the renewable percentage requirement was treated as a given parameter or a target to achieve, I treat the renewable percentage requirement as a policy variable in my model and as the only instrument that the regulator has to promote renewables and reduce GHG emissions.

Second, Aune et al. (2012) have shown that allowing for full trade in TGCs and implementing a common renewable target for countries has the cost-saving potential in achieving the renewable target. Clearly, cost-effectiveness is one important aspect in evaluating policy's implementation. However, the quota obligation scheme—represented by the TGCs and Renewable Portfolio Standard (RPS), has been found not as cost-effective as a cap-and-trade policy at reducing carbon emissions (Palmer and Burtraw, 2005). Thus, the welfare impact of the TGC system is more interesting and may need to be given more attention from a policy perspective. In this paper, welfare broadly considers consumers' utilities, production costs, environmental damages from fossil-fuel energy productions, etc. I focus on comparing the welfare impact of a fully integrated TGC system with three other situations under or not under a cap and trade regulation.

Third, Currier and Rassouli-Currier (2012) considered a simplified duopolistic model with one renewable energy producer and one fossil fuel based energy producer in one country. I further extend their model into a competitive two-country market setting, given the goal of liberalization of energy markets in many countries around the world.

In this paper, I first discuss the situation when two countries share the common percentage requirement and a common TGC market. Based on this, I examine some competitive equilibrium implications based on variations in the renewable quota committed to and characterize the welfare optimal value. Using a geometric illustration, I then compare these two countries' welfare under the optimal renewable quota and a common TGC market with three other different situations under or not under an optimal emissions standard.

My policy recommendation is that when the value of the damage parameter is sufficiently small, full integration with a TGC market is superior in terms of welfare to the full integration of an all fossil fuel-based market with an optimal emissions standard. Indeed, our model in this study is complementary to those of Aune et al. (2012) and Currier and Rassouli-Currier (2012), showing the potential for achieving greater social welfare through a common well-functioning TGC market.

The rest of the paper is organized as follows. Section 2 presents my theoretical model and assumptions. Section 3 analyzes the regulatory problem and compares social welfare in different situations. In Section 4, I demonstrate the analysis in Section 3 through a numerical example. Section 5 concludes the paper, providing a discussion.

[2] In fact, this obligation could also be imposed on the energy producers. For example, each producer in Italy, except green energy producers or importers, is required to ensure 2% of energy production is green energy. In Sweden, the obligation to hold green certificates is assigned to both suppliers and consumers (see Currier and Rassouli-Currier, 2012; Nielsen and Jeppesen, 2003; Tamas et al., 2010; Widerberg, 2011). In this paper, I assume that certificate obligation is imposed on consumers.

[3] The Renewables Directive in the EU states that member countries can meet their national renewable targets by financing renewable energy production in other countries, and this is called statistical transfer.