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Risk-based assessment of the cost-efficiency and the effectivity of renewable energy support schemes: Certificate markets versus feed-in tariffs

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HIGHLIGHTS

- Paper analyzes the performance of *feed-in tariffs* and certificate markets.
- Model simulates the evolution of a power system considering investors' risk aversion.
- Tariffs could obtain better efficiency but also low effectiveness or over-investment.
- Barriers to entrance could result in higher certificates prices.
- Certificate performances benefit from higher social discount rates.

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ABSTRACT

The introduction of renewable energy sources in the electricity generation mix has the potential to reduce power sector's emissions and countries' dependence on imported oil. Climate change concerns and highly volatile oil prices have attracted governments' interest and support to sustain investments in renewable energy capacity, and different support policies have been implemented in many countries around the world. This paper analyzes the effects of investors' risk aversion on the performance of support schemes. The analysis compares two policy options, a *feed-in tariff* mechanism with a certificate market system. Results show that while a tariff mechanism could obtain better results than a certificate market, its performance is strictly dependent on regulator choices. A certificate market instead, permits to obtain the desired level of renewable energy market share with good cost-efficiency as long as investors' risk aversion is moderate. Moreover, discounting future cash flows with higher social discount rates further benefits a certificate system making it preferable to *feed-in tariffs*.

1. Introduction

The global demand for primary energy increased from 1980 to 2006 by 67% (U.S. Energy Information Administration, 2008) and will rise in the future. Today fossil fuels cover about 80% of the world primary energy demand (International Energy Agency, 2009) being the major source of greenhouse gas (GHG) emissions. CO_2 emissions from fuel combustion account for around 70% of total GHG emissions (International Panel of Climate Change, 2007) which cause the average temperature of the earth's oceans and atmosphere to rise and result in damage to the environment. In order to mitigate the impact of energy consumption on the environment, the global economy must evolve towards sustainability and energy efficiency. For these reasons, energy sustainability remains a key topic for political decision makers at the moment.

Renewable Energy Sources (RES) received increased support from National Governments in the past decade. These technologies can decrease society's dependence on fossil fuels, limiting the environmental impact of conventional electricity generators, thus obtaining a reduction in pollutants emission. Moreover, RES could improve energy independence of industrialized countries decreasing the risks connected to highly volatile fossil fuel prices and geopolitical risks related to import dependency. With its directive 2009/28/EC the European Commission established that by the year 2020, at least 20% of the Community's gross final energy consumption has to be covered using energy from renewable sources. "*Member States shall introduce measures effectively designed to ensure that the share of energy from renewable sources equals or exceeds that shown in the indicative trajectory, and in order to reach their targets they may apply support schemes or*

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measures of cooperation with third countries" (European Commission, 2009).

After the liberalization of the electricity markets in Europe, decisions regarding power plant investments are made by private investors based on economic profitability. Therefore, since the cost of renewable power generation is generally higher than electricity generated from conventional fuels, public policies are required to create incentives for producers to adopt renewable technologies. Currently, support policies for renewable energy are mainly divided in two categories: price-based and quantity-based mechanisms.

Within the category of regulatory price-based strategies, no quantity goals or targets are established. Alternately, the focus is on providing electricity generators with financial support in terms of a payment per kWh of energy produced. For example, under a *feed-in tariffs* system generators receive a fixed amount per kWh of generated electricity, reflecting regulator's estimation of the average generation cost of renewable energy technologies. Instead, under a *feed-in premium* scheme, such that implemented in Spain, a fixed amount is added to the electricity price.

Regulatory quantity-based strategies, alternatively, are based on the government decision with respect to the desired level of electricity production from RES. The price of renewable energy is then set through the creation of a market mechanism. Producers whose electricity is generated from RES receive an amount of certificate corresponding to their production creating supply of certificates. Demand for certificates is created obligating one or more parties involved in the electricity supply chain such as wholesalers, distribution companies, or retailers to acquire certificates covering a certain percentage of electricity they sell or consume. Regulator imposes a penalty fee to be paid by any party having a quota obligation who does not hold the necessary number of certificates corresponding to their obligation. This creates a market mechanism in which the price of certificates is determined by the relationship between supply and demand. In this way, the system encourages the expansion of renewable energy production by giving electricity producers extra revenues from selling their certificates.

Even though many researchers have conducted microeconomics analysis on support schemes to evaluate which achieve better performance (Menanteau et al., 2003), still a controversial discussion remains on whether price-based or quantity-based systems lead to preferable results for society (IPCC, 2011). The lesson learned so far in Europe illustrates that many countries have successfully promoted renewable energy in an effective and economically efficient way implementing *feed-in tariffs* (Haas et al., 2010). In fact, where implemented, this policy has resulted in higher levels of new renewable energy investment than Tradable Green Certificate (TGC) systems, probably due to the lower risk involved for investors (Mitchell et al., 2006).

The problem with a certificate system is the volatility of certificate prices which theoretically could drop to zero in case of over-investments, leaving investors with high capital losses. Hence, investors demand higher return on capital to accept what they perceive as riskier investments, consequently making renewable energy project less desirable, slowing their market introduction. Sweden was one of the first countries in Europe to adopt a certificate system to support renewable energy development in 2003. An analysis of its performance demonstrated that even if the certificate market was proved to be effective, consumers cost could have been substantially high (Bergek and Jacobsson, 2010).

Another argument in favor of *feed-in tariffs* is the possibility to give each technology a specific subsidy, which permits investments in more expensive technologies such as photovoltaic or off-shore wind. On the contrary, under a certificate market, competition encourages investments in less expensive technologies. The use of least-cost resources, theoretically, permits to develop the required amount of renewable energy theoretically at a minimum cost, but leaves no room for less mature technologies which in the long-term could obtain better economic performance. Moreover, a certificate market fixes a uniform price decided by the most expensive technology sold in the market, creating an excess surplus for low cost technologies. A technologic specific tariffs system instead, limits the burden on consumers giving to each technology the right price to cover its costs (Haas et al., 2010).

The higher investment risk of certificate markets alongside the creation of windfall profits for low cost technologies could appear to provide an argument for *feed-in tariffs*, which guarantee a fixed price level for investors. Such instruments, however, might be costly because subsides levels are set by the regulator in an arbitrary way without perfectly knowing the real cost faced by generators (Lesser and Su, 2008; Menanteau et al., 2003). Therefore, the dilemma is that market risk provides an incentive to make efficient use of resources, limiting the cost to society, but deterring investors, thus potentially resulting in less renewable energy and higher prices as they include a higher risk premium.

2. Research objective

This paper analyzes how different policy options affect the evolution of the electricity system where energy companies are risk-averse agents driven by profit maximization. Analysis is based on a model which simulates the behavior of generating companies in a liberalized market using a system-dynamic approach (Sterman, 2000). As suggested in a previous paper (Wustenhagen and Menichetti, 2012), the model supposes that generating companies are more risk-averse with respect to renewable energy than conventional technologies, because of previous choices which create a path dependency causing incumbents producers to be locked-in to their technology preference. The model estimates the performance of *feed-in tariffs* and certificate markets changing the risk-aversion factor that investors apply to renewable energy projects, using the Conditional Value at Risk (CVaR) as a measure of project risk (Rockafellar and Uryasev, 2000).

The research question analyzed is: *Are the gains from an efficient use of resources higher than the additional cost due to a higher risk premium*? *When is a certificate market more cost-efficient than a feed-in mechanism*?

This paper aims to clarify when a certificate market is preferable to a *feed-in tariff* system trying to help policy makers in their decision process. The point of view taken in the analysis is that of the policy maker or regulator, whose target is the development of renewable energy technologies while limiting the burden on consumers who eventually pay for it.

The paper is organized as follows. In order to better understand the impact of support policies on the electricity market, Section 3 explains how investment decisions are driven by expected profits and project risk, and how firms' choices are strongly affected by support schemes. Then, Section 4 describes the model used in the analysis and its assumptions with further modeling details given in Appendix B. The results of the analysis are presented in Section 5 and discussed in Section 6. Finally, Section 7 presents the conclusions and some suggestions to policy makers.

3. Risk, cost of capital and financing of renewable energy projects

Before the liberalization of the electricity market, investment choices were based on integrated planning and cost-minimization. Levelized costs were the key parameter for technology choice. The system evolution was centrally planned by a regulated power