Operational Strategies And Optimal Policies For The Diffusion Of Renewable Energy Systems

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Motivation and Introduction

Improving energy efficiency, fostering green transportation, developing and deploying new low-carbon and zero-carbon technologies, renewable energy, and ensuring sustainable development all can be solutions for global warming and can help reducing greenhouse gas emissions into the atmosphere. Renewable energies (RE) in particular are considered one of the most effective and least risky solutions to curb greenhouse gas emissions. They offer opportunities for diversifying energy supply and hedge against the risk of oil price fluctuations. Recently, they have been also regarded with renewed interest as a powerful instrument to stimulate economic growth, and accelerate the recovery from the global economic downturn.

Yet, notwithstanding these advantages and the fact that they have experienced a substantial growth over the last decade, RE technologies only account for a small fraction of the world's primary energy supply. Their market penetration keeps remaining below the levels required to effectively curb CO2 emissions.

Several technical, economical and behavioral reasons hinder the market diffusion of these technologies including the intermittency of energy supply, their high investment cost, the lack of adequate information as well as the lack or the inadequacy of sustainable energy policies. Increasing RE penetration requires therefore that concerned actors such as RE companies and policy makers develop a more thorough understanding of the factors that affect the RE diffusion process.

Some of these factors have been studied in depth. Others remain under investigated and deserve further attention from the research community. To that end, in this study we adopt a new technology diffusion perspective to shed further light on the factors that may hamper or accelerate the diffusion of a specific type of renewable energy: Photovoltaic systems (PV).

First Chapter

The first chapter of the study focuses on the demand side of the PV value chain. We especially discuss and examine the time related value of following factors on the PV adoption: i) the type of PV-related information about PV systems acquired by individuals before adoption which is either customized (face to face contact, talking, etc.) or non customized information (article readings, ads, etc.); ii) information channel, either commercialized (information from PV suppliers) or non

commercialized channels (information from non-supplier sources) iii) the total amount of PV-related information acquired by individuals before adoption iv) economic value of PV system and v) the perceived degree of competition in the PV supply market.

We put forth a conceptual model of PV diffusion and we test it using primary data obtained through a survey of three groups of individuals: 1) Actual clients: those who already installed the PV systems, 2) Prospects: individuals who showed their interest in PV by asking quote but they have not bought the system yet, and 3) Potentials: individuals who only have knowledge about PV systems. We consider being Potential, Prospect or Actual client as the first, second and third steps of adoption. We used a set of logit models to compare clients with prospects and prospect with potentials to study how the effects of these factors vary in the different steps of adoption.

The analysis provides interesting insights, particularly with respect to the time value of different information dimensions (Information type, channel and quantity). The results indicate that the value of information varies over the adoption time. Our results show non-customized and commercialized information, information quantity, perceived degree of PV supplier market competition and economic value of the PV system have positive effect on moving from first step to second step of adoption. Results also show that Clients received more customized and non-commercialized information compare to Prospects and knew lower number of PV suppliers in the market.

Altogether, our results indicate that in addition to focusing on improving technological effectiveness and reducing system cost, RE providers should pay a lot of attention to the way they provide information about their product, and to how organize their distribution channels and design their marketing campaigns.

Second Chapter

In a context of growing need for renewable energy sources (RES), tariff design has become a critical component of energy system regulation. Accordingly, the second part of this study aims to identify optimal policies to foster the adoption of photovoltaic systems and to examine the impact of competition among PV manufacturers on both subsidies and the diffusion of renewable energy.

We model a three-player environment, which includes a grid operator responsible for meeting electricity demand, a PV manufacturer and some customers who are potentially interested in installing PV panels. The grid operator seeks to meet all the exogenous electricity demand, while minimizing its own cost. Thus it buys back all the excess electricity produced by the PV systems. The PV manufacturer and the customers seek to maximize their own profits. Customers decide whether or not to adopt the PV system. This, in turn, would affect the profit of two other parties by

determining the PV demand as well as the amount of the electricity fed into the grid. The decision variable for the PV manufacturer is the price to charge for each PV unit, while the grid operator decides on the incentive schemes to support adoption, including feed-in tariffs. It is clear how the decision of these three parties is intertwined, by affecting the profit and welfare of other parties. Then we study the role of competition in influencing the effectiveness of feed in tariff, the number of PV adopters as well as the cost involved in satisfying electricity demand. The results show that a higher number of PV manufacturers in the market always results in higher number of PV adoptions. The grid operator is always better off when competition among PV manufacturer is intense whereas PV manufacturer's profit decreases with an increase in the level of competition.

Further Research and Schedule

The first two parts of this research are well advanced. We expect to finalize both chapters by the end of spring 2015. The results obtained so far have important implications for PV distributors. Accordingly, further research efforts in this dissertation will aim to examine these implications. Since PV manufacturing is becoming increasingly concentrated (Chinese and American PV manufacturers have the highest market share in the world), distributors play a very important role in the PV supply chain. They must provide customers in different markets with sufficient knowledge and information about PV systems and help them discriminate among products from different suppliers. In order to appreciate the implications of our results for distributors, in the next part of this study we aim to conduct some interviews with experts and managers from REXEL and study how our results could be useful to distributors to promote renewable energy systems. The interviews will take place during the spring of 2015.