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Incentive mechanisms to promote energy efficiency programs in power distribution companies

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ABSTRACT

Power distribution companies (DISCOs) play an important role in promoting energy efficiency (hereafter EE), mainly due to the fact that they have detailed information regarding their clients' consumption patterns. However, under the traditional regulatory framework, DISCOs have disincentives to promote EE, due to the fact that a reduction in sales also means a reduction in their revenues and profits. Most regulatory policies encouraging EE have some embedded payment schemes that allow financing EE programs. In this paper, we focus on these EE-programs' payment schemes that are embedded into the regulatory policies. Specifically, this paper studies two models of the Principal–Agent bi-level type in order to analyze the economic effects of implementing different payment schemes to foster EE in DISCOs. The main difference between each model is that uncertainty in energy savings is considered by the electricity regulatory institution in only one of the models. In terms of the results, it is observed that, in general terms, it is more convenient for the regulator to adopt a performance-based incentive mechanism than a payment scheme financing only the fixed costs of implementing EE programs. However, if the electricity regulatory institution seeks a higher level of minimum expected utility, it is optimal to adopt a mixed system of compensation, which takes into account the fixed cost compensation and performance-based incentive payments.

1. Introduction

Energy efficiency (EE),[1] within the international context, is becoming more relevant as an energy source. Power distribution companies (DISCOs) play an important role in such, mainly due to the fact that they have detailed information regarding their clients' consumption patterns. In addition, they are in a privileged position, given their condition as energy suppliers, to balance supply and demand (Blumstein et al., 2003; Joskow, 1999). However, under the traditional regulatory framework, DISCOs have disincentives to promote EE, since a reduction in energy sales reduces their revenue and profits. In addition, there are other financial concerns related to recovering EE programs' direct costs and to having the opportunity of sharing earnings that motivate the optimal implementation of EE programs (Kushler et al., 2006).

Different regulatory policies have been developed towards providing incentives and eliminating disincentives so that DISCOs foster EE. One of them is the so-called decoupling mechanism. This mechanism breaks the link between utilities' revenues and the amount of energy that DISCOs sell by setting the utilities' revenues for a specified term in accordance with expected costs and reasonable returns to investors. As such, if utility's sales are reduced for any reason, including energy efficiency, its revenue requirement would be ensured, no less no more, by tuning the retail electricity tariff (Sullivan et al., 2011). This mechanism has been implemented in California, where the Californian power distribution companies consider EE their first alternative to satisfying long-term demand, before increasing their capacity (Weber et al., 2006). In California, a performance-based incentive system has been implemented jointly to the revenues decoupling mechanism, which has been the key for the good results observed. This is because the decoupling mechanism alone is not enough, since under such system DISCOs may not have incentives to reduce their sales (Sullivan et al., 2011). There are also other regulatory systems that foster EE, like the tradable certificates mechanism, whose adequate implementation depends, among other things, on having a certificates market that is liquid and acceptable to all market players (Norero and Sauma, 2012).

Most regulatory policies encouraging EE (e.g., decoupling mechanism, performance-based incentive system, and tradable certificates mechanism) have some embedded payment schemes that allow financing EE programs. In this paper, we focus on these EE-programs' payment schemes that are embedded into the regulatory policies. Accordingly, our aim is not to analyze the implementation of any of the previously mentioned regulatory policies, but only to study the economic effect of these payment schemes. For simplicity, we cluster the payment

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[1] Set of actions producing energy reduction used to generate the same service or activity level. Usually, such energy saving is associated to a technological change. However, that is not always the case, since it could be tied to better management or changes in the community's cultural habits. Information taken from: http://www.worldenergy.org/publications/2838.asp.

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schemes into two types: a fixed compensation payment system and a payment system based on EE program performance. In the former, the government returns to the DISCOs the total or a portion of the fixed costs the DISCOs incur in developing EE programs. Therefore, under this system compensation, payment is unrelated to the amount of energy savings and only varies according to the project magnitude. This compensation scheme is currently present in some developing countries like Chile (Norero and Sauma, 2012). On contrast, in a performance-based incentive system, the compensation is directly related to the amount of energy savings: the more energy is saved by a certain program, the more compensation is given to its implementer.

Although we do not analyze the implementation of any particular regulatory policy, but only focus on the embedded payment schemes, the analysis made in this paper is directly related with some of these regulatory policies from a practical viewpoint. For instance, the California's Risk Reward Incentive Mechanism (RRIM) considers both full program cost recovery (which can be seen as a fixed compensation payment system) and a "share savings rate" mechanism (which is a payment system based on EE programs performance). The latter provides a percentage of net EE program benefits to DISCOs as an incentive to promote energy savings (CPUC, 2007). Therefore, the RRIM combines both payment systems, in a similar manner as done in this paper. On the other hand, in the case of the tradable certificates mechanism, a fixed compensation payment system is not included and the government only pays an indirect compensation based on EE programs performance, where DISCOs and the government share both benefits and risks.

To analyze the economic effects of applying these different payment schemes (fixed compensation payment system as well as a payment system based on EE programs performance), we formulate the regulator's and utility's problems as a Principal–Agent bi-level model, inspired in the idea proposed by Blumstein (2010). In agreement with the Principal–Agent theory, the Principal contracts the Agent to execute a determined service, where the Agent receives a payment in exchange (Perez et al., 2004). Accordingly with bi-level formulations, we formulate a first level (Principal's) problem subject to another (Agent's) optimization problem. In these types of formulations, there are two independent decision makers, ordered within a hierarchic structure, that have opposing or conflicting interests. The decision maker of the first level optimizing problem influences, but does not control, the decision maker on the second level (Gumus and Floudas, 2001).

Bi-level optimizing formulations appear in many economic models (Allende and Still, 2013). An application of this type of formulation in the energy field was developed by Wang et al. (2009). In their work, a Principal–Agent model is formulated between the electricity regulatory institution (Principal) and a power supply enterprise (Agent). The incentive model proposed in (Wang et al., 2009) seeks to motivate the power supply enterprise to supply electricity in remote or very low income zones. In order to do so, it considers both a fixed compensation, as well as economic incentives associated to performance. A similar work within the energy scope is in (Molina et al., 2011), where a similar model is developed and applied to the power transmission expansion planning problem. Another example of a bi-level optimization problem applied to the energy field is the work developed by García-Bertrand et al. (2008). The authors analyze an optimal investment strategy of a generation company (within a competitive framework), taking into account the uncertainty in future demand and the investment decisions of all other generation companies. In their formulation, the generation company determines its generating capacity in the upper level while the market operator decides power generation in the lower level. Gabriel et al. (2012) has recently published a book on complementarity models in energy markets, which contains several other examples of bi-level optimization problems applied to the energy field.

This paper studies two models of the Principal–Agent bi-level type in order to analyze the economic effects of implementing different payment schemes to foster EE in DISCOs. The main difference between both models is that uncertainty in energy savings is considered by the electricity regulatory institution in only one of the models. The consideration of risk management is an important issue when dealing with EE programs since uncertainty arises from many different sources and it is usually difficult to identify and quantify the effect of all potential sources (National Action Plan for Energy Efficiency, 2007). Some of the most common sources of potential bias in energy savings measurement include (CPUC, 2004): uncertainty about the baseline energy consumption; misinterpretation of association as causal effects (spillover effects[2]); biased estimates of free ridership[3] (difficulties associated with the determination of what the behavior of the participants would have been in the absence of the program), among others. One of the biggest challenges in evaluating the performance of EE programs is the complexity in the direct measurement of energy savings. Energy savings are the difference between energy consumption and what energy consumption would have been in the absence of the program. Many times uncertainty on estimated savings is underestimated since it is calculated only through the consideration of random sampling error (National Action Plan for Energy Efficiency, 2007). A comprehensive analysis of the risk management in electricity markets in presented in (Conejo et al., 2010).

In this paper, uncertainty is considered by using the theory of Conditional Value at Risk (CVaR). The concepts of Value at Risk (VaR) and CVaR have been extensively used in finance. In the financial scope, Rockafellar and Uryasev (1999) proposed a methodology to optimize a portfolio of financial instruments to reduce risk by means of simultaneously minimizing the CVaR and VaR calculation, instead of grounding optimization according to minimizing the VaR, as had been done in literature up to that time. In (Krokhmal et al., 2002), the methodology that Rockafellar and Uryasev (1999) established was extended to problems where the expected return is maximized subject to the CVaR constraints. Thus, under the focus established, the optimization model can be implemented using multiple CVaR constraints with different trust levels. More recently, in (Krokhmal et al., 2011), a survey was performed on the latest progresses within the context of making decisions under uncertainty.

Despite the fact that the CVaR theory has been mainly used within the field of finance, its application has been extended to other areas. Specifically, in (Pousinho et al., 2011), the concepts are used within the energy field. In that work, the problems the wind energy generator faces are modeled considering uncertainty in both prices and energy production (considering the inherent intermittency of wind power generation). In (Morales et al., 2010), uncertainty related to wind availability is also considered using CVaR. Another example of applying CVaR in the energy area is the work by Molina (2012), where a model that determines the optimal value of a risky investment portfolio, formed by several power transmission line projects, is proposed.

The models in this paper assume that there is one DISCO and one regulatory institution. In the first model, neither the DISCO (Agent) nor the electricity regulatory institution (Principal) considers the uncertainty associated with EE programs. The second model is a more sophisticated version of the former, where the Principal considers that energy savings are subject to uncertainty, which is modeled through the concept of CVaR. Specifically, the linear approach that Krokhmal et al. (2002) developed was used to define CVaR. In this paper, CVAR is used, instead of VaR, mainly due to the fact that VaR is not a measure of coherent uncertainty, since it does not comply with sub-additive property in case of probability distributions other than Normal distribution (Artzner et al., 1999).

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[2] According to National Action Plan for Energy Efficiency (2007), "Spillover occurs when there are reductions in energy consumption or demand caused by the presence of the energy efficiency program, but which the program does not directly influence".

[3] According to National Action Plan for Energy Efficiency (2007), free-riders are "program participants who would have implemented the program measure or practice even in the absence of the program".