NEGAWATT TRADING AND ENERGY EFFICIENCY IN ADJUSTMENT MARKETS

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Overview

Improvement in energy use efficiency makes it possible for electricity customers to obtain greater benefits with equal or less electricity consumption. On the other hand, marginal costs of reducing electricity consumption (supplying negawatt) increases with a rise in energy efficiency, and will induce a higher negawatt price in the adjustment market. The purpose of this paper is to consider simultaneously the effects of energy use efficiency on baseline electricity demand and on the adjustment market which includes negawatt trading to investigate the interrelationship between these effects, and impacts on social welfare.

Related literature can be classified into two categories. The first category focuses on the effectiveness of regulatory policies on energy efficiency (Abrardi and Cambini, 2015; Chu and Sappington, 2013; Wirl, 1995; Wirl, 2015). The second category focuses on consumer behavior in the event of demand response where the consumer gets paid for demand reduction (Chu and DePillis, 2013). The model we developed in this paper combines these two categories to investigate the interrelationship between energy efficiency and consumer behavior in the event of demand response.

This paper investigates the impacts of demand side energy efficiency on cost efficiency in an adjustment market which includes negawatt trading. Comparative statics about the determinants of optimal energy efficiency is also carried out. It is shown that improvements in energy efficiency increase consumer benefit in energy use, but, on the other hand, raises negawatt cost and consequently lowers cost efficiency in an adjustment market. In the presence of externality of fossil fuel power generation, a declining proportion of fossil fuel generation in electricity for baseline demand increases the relative impact of thermal generation in an adjustment market, and decreases the optimum level of efficiency in energy use. For the same reason, higher external costs decrease the optimum level of energy efficiency if the rate of fossil fuel generation for the baseline demand is sufficiently low. Finally, comparing the case where an optimal carbon tax is implemented with the case where a carbon tax is not implemented reveals that the latter induces an excessive level of energy efficiency.

Methods

We analysed a stylized model consisting of an electricity utility, a representative customer, and a system operator. We investigate a situation where the electricity utility and the customer set a baseline supply and demand, but supply shortage due to the fluctuations of renewable energy sources causes an imbalance between the prearranged baseline supply and demand. The system operator is in charge of adjusting the supply-demand balance, paying for demand reduction (buying negawatt) and buying electricity generated from fossil-fuels in the adjustment market.

In our model, negawatt price in the adjustment market rises with an increase in energy use efficiency. This is because benefit loss from reducing electricity demand gets larger with improvement in energy use efficiency. Since the system operator pays for demand reduction proportionate to increased benefit loss, a higher efficiency induces a higher negawatt price and consequently increases share of fossil-fuel generations in the adjustment market.

At first, we derive a market equilibrium in the adjustment market where the shrare between negawatt and fossil-fuel power generation is determined. Then, we conduct comparative statics about the optimal energy efficiency. Finally we investigate impacts of implementation of carbon tax.

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Results

~~1.~~ Marginal cost of negawatt rises (falls) with an increase (decrease) in energy efficiency. It results in a shift from negawatt (fossil-fuels) to fossil-fuels (negawatt) in the adjustment market. Consequently, it induces an increase (decrease) in carbon emissions and total adjustment cost in the adjustment market.

~~2.~~ The optimal energy efficiency level increases (decreases) with a rise (fall) in the proportion of renewable energy sources in the baseline supply.

~~3.~~ If significant proportion of baseline supply is from renewable energy sources, the optimal energy efficiency level decreases (increases) with a higher (lower) marginal external cost of fossil-fuels.

~~4.~~ The optimal energy efficiency level decreases with imposing a carbon tax on fossil-fuels.

Conclusions

Increasing shares of renewable energy sources in recent years produce larger fluctuation in electricity supply and make it more difficult to maintain ~~(keep, sustain)~~ the supply-demand balance. Designing flexible energy systems to respond to the supply fluctuations is one of the major issues in the recent electricity industry. One of the ways to deal with this problem is to enhance the demand-side flexibility and adjust electricity consumption to respond to the supply fluctuations.

In this study, we focused on the effect of energy use efficiency on the flexibility of electricity consumption. Specifically we investigated a case of demand reduction under unpredicted supply shortage due to fluctuations of renewable energy sources. Although theoretical considerations suggest that energy use efficiency may affect flexibility of electricity consumption, it has been drawn little or no attention.

We showed that an increase in energy efficiency induces a higher cost of reducing electricity consumption. Consequently, it reduces demand flexibility and enhance the adjustment cost. We demonstrated that an increase in energy efficiency causes a shift from negawatt to fossil fuels, and increases carbon emissions in the adjustment market. If significant proportion of baseline supply is from renewable energy sources, improving energy efficiency has little impact on carbon emissions in baseline supply, but rather increases emissions in the adjustment market.

Conventional discussions on energy efficiency primarily ~~(mainly, principally)~~ focuses on the effects it has on energy usage; a higher efficiency enables consumers to generate greater benefit with equal or less energy consumption. Our study shed some light on the other aspect; impacts on demand flexibility. As we demonstrated in this paper, energy use efficiency may has impacts on the costs of demand reduction, which in turn reduces demand flexibility and affect the outputs of adjustment markets. The analyses in this study provides broader perspective that includes the impacts of energy efficiency on adjustment markets, which is one of the important factors in designing flexible and efficient energy systems in the future.

References

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