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An analysis on the effectiveness of a smart grid test-bed project: The Korean case

Sung Tai Kim [a,1], Byung In Lim [b,*,2], Wan Kyu Park [c], Myoung Kyu Kim [d], Sung-Yong Son [e]

[a] Department of Economics, Cheongju University, 298 Daeseong-ro, Cheongwon-gu, Cheongju, Chungbuk 28503, Republic of Korea
[b] Department of Economics, Chungbuk National University, 1 Chungdae-ro, Seowon-gu, Cheongju, Chungbuk 28644, Republic of Korea
[c] Department of Economics, Chung Ang University, 84 Heukseok-ro, Dongjak-gu, Seoul, Republic of Korea
[d] Department of Economics, Cheongju University, 298 Daeseong-ro, Cheongwon-gu, Cheongju, Chungbuk 28503, Republic of Korea
[e] Department of Electrical Engineering, Gachon University, 1342 Seongnamdae-ro, Gyeonggi 13120, Republic of Korea

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ABSTRACT

This study analyzes the effectiveness of Korea's Smart Grid project using Difference-in-Difference (DID) estimation, which utilizes both 2013 survey data on the participating households of the Jeju Smart Grid Test-bed and the actual electricity use of households during 2009–2012. The findings are as follows. First, the Smart Grid project effectively causes a reduction in electricity use. Second, households which have the following characteristics tend to use more electricity: male householder, many family members, income. Third, households which have better understanding about the Smart Grid use less electricity. Based on these findings, we can derive the following policy implications. First, it is necessary to set up a policy which accelerates active participation of both consumers and producers of related equipment in order to promote the Smart Grid. Second, a reform of the electricity pricing system is needed to enhance the effectiveness of the Smart Grid project. Third, publicity activities of the Smart Grid project should be strengthened for wider recognition.

Contents

* Corresponding author.
E-mail addresses: stkim@cju.ac.kr (S.T. Kim), billforest@hanmail.net (B.I. Lim), wanpark@cau.ac.kr (W.K. Park), kolosu@naver.com (M.K. Kim), xtra@gachon.ac.kr (S.-Y. Son).
[1] Phone: +82 43 229 8182.
[2] Phone: +82 43 261 2216.

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1. Introduction

A mass blackout hit California for the first time since World War II on January, 2001, which confused almost all fields throughout California. "The political reaction to this crisis put a virtual halt on additional states adopting restructuring and associated retail competition reforms. It also slowed efforts by the Federal Energy Regulatory Commission (FERC) to push forward its agenda to bring organized wholesale markets, integrating the efficient dispatch[3] and pricing of generation supplied at different locations with the efficient allocation of scarce transmission[4] capacity, to the entire country" [11: p. 29] This implies that even the U.S. did not notice the importance of the Smart Grid at that time, which draws huge worldwide attention nowadays.

On September 15th, 2011, a mass blackout occurred in Korea as well. It is known that the blackout, which happened for the first time in Korea's history, was due to an instantaneous shortage of electricity production compared with its demand. Although various views have been mentioned about the cause of the supply–demand discord which provoked the blackout, electricity prices that were too low and ensuing excess demand are thought to be main reasons. To put it concretely, first the excess demand resulted from the price of electricity, typically secondary energy,[5] which is produced through transforming and processing primary energy,[6] fell short of production cost. This is confirmed by the fact that Korea Electric Power Corporation (KEPCO) announced that its cost compensation ratio was less than 100% in 2011 (in 2010, 96.5% for industry and 93.7% for residential).[7] Second, the per capita amount of electricity use in Korea, 8833 kWh, is greater than that in Japan (7818 kWh) even though Korea imported 96.5% of its primary energy in 2010. Moreover, the increase in the rate of electricity consumption has been 4.66% in the past 10 years, which is the highest among OECD countries and much higher than Germany (0.18%) and Britain (0.23%).

[3] Dispatch is the action of adjusting the generation of power economically and stably to changes in electricity demand.

[4] Transmission means sending electricity produced in a power plant, whose related equipment is a substation and a power transmission line. A substation consists of transformer, circuit breaker, protection switchboard, control board and phase modifying equipment. Power transmission lines are classified as overhead transmission lines and underground transmission lines and the former consists of a pylon insulator transmission line and attached equipment, while the latter consists of a manhole, cable and supporting insulator.

[5] The secondary energies are electricity, LPG, coke and so on.

[6] The primary energies, which refer to energy supplied in a non-processing state, are petroleum, coal, nuclear energy, hydraulic power, geothermal heat, firewood, charcoal, and so on.

[7] The cost compensation ratios of electricity charge in 2009 and 2010 are summarized in the table below (Ministry of Knowledge Economy, July 30, 2010).

Type	Adjustment rate	Compensation ratio	
		After adjustment ('10)	Before adjustment ('09)
Average	3.5	93.7	91.5
Residence	2.0	93.7	92.2
General	Freeze	99.4	100.7
Agriculture	Freeze	36.5	37.2
Education	5.9	90.1	84.4
Industry	5.8	96.5	90.9
Street Lamp	5.9	88.0	80.4
Midnight	8.0	73.9	66.1

Note: (1) When the government announced the demand response policy in June, 2009, it was decided that midnight power charge would increase 8% annually until 2014.
(2) The compensation ratio after adjustment (93.7%) is an estimated value.

Table. Cost Compensation Ratios of Electricity Charge in 2009 and 2010.

Korea's supply–demand discord in electricity is still continuing and the most fundamental remedy to solve this problem seems to be to reduce excess demand by increasing electricity prices. However, it is not easy to increase the prices because of political circumstances. If one tries to solve the problem of excess demand without price increases, there is no way to do so apart from constructing additional power plants or increasing production capacity. These need large contributions from the government budget and are not easy considering the current budget situation. Therefore, we need a method to link demand to supply effectively and to adjust the supply–demand discord in electricity. The best scheme based on the current level of technology to achieve this goal is known to be the Smart Grid.

The Smart Grid is a next-generation power grid that integrates Information Technology with the existing power network to optimize energy efficiency through the interactive exchange of real-time information between the supplier and the consumer. Eventually, the supplier of electricity can grasp the real-time electricity use situation by virtue of IT and the consumer of electricity can adjust the time and the amount of use to save money.[8]

Smart grid studies are surveyed, and related technologies are catagorized [22]. In the work, smart grid infrastructure is divided into three systems: infrastructure, management system, and protection system. And the infrastructure is divided into three subsystems: energy, information, and communication. The study shows research trends for smart grid by categorizing related issues and technologies for each subsystem or system. There are some researches about the impact of smart grid. The potential impacts on distribution system from the design perspective are discussed [18]. A reliability perspective of the smart grid is also discussed [12]. In the studies, it is discussed that the smart grid contributes to increasing reliability for future grids. In this paper, however, the economic and sociological impact of the smart grid is focused rather than power quality and grid reliability.

Now our interest is as follows: will the amount of electricity use really decrease if we introduce the Smart Grid? There have been many debates on this issue. Although it is not a smart grid, in a previous study, it is shown that the energy feedback to customers have the effect of energy reduction as much as 1.2% to 2% depending on cases [10]. And in another study, the adoption of real-time energy feedback and home energy display has 7% energy reduction effect in average [2]. The results imply the user energy feedback using smart grid infrastructure will bring the similar result. Several studies predict a decrease in electricity use [16,7,9], but sufficient empirical results have not been presented on the positive effects of the Smart Grid. The main reason for this is a lack of relevant data which proves the effectiveness of the Smart Grid. In this regard, it is meaningful for Korea to build the largest test-bed complex and to test the effectiveness of the Smart Grid.

The purpose of this research is to empirically analyze the reductions in the use of electricity due to the application of the Smart Grid by using Korea as a case study. Korea has built a Smart Grid test-bed and has been operating it since 2009. In this study, we use both survey data collected from residents and non-residents in the Jeju Smart Grid test-bed in 2013 and an actual electricity usage data provided by KEPCO.

This paper is composed as follows. Following the introduction, we sum up the Jeju Smart Grid test-bed, which is the first test-bed of its kind in the world. In the third section, we first explain the Difference-in-Difference (DID) estimation method adopted in this paper and then we present and discuss the empirical results of the reduction in electricity use. Finally, we summarize the findings and conclude by stressing the main points in our analysis.

[8] For reference, Korea has not introduced a real-time charge system yet.