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Estimation of the inconvenience cost of a rolling blackout in the residential sector: The case of South Korea

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HIGHLIGHTS

- We estimate the inconvenience cost of a rolling blackout in households in South Korea.
- We use a contingent valuation method to measure the WTP to avoid a rolling blackout.
- People have more WTP to avoid an unannounced rolling blackout than an announced one.
- We estimate the value of preannouncement of the blackout by the difference in WTPs.

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ABSTRACT

South Korea is experiencing a serious imbalance in electricity supply and demand, which caused a blackout in 2011. The Korean government has planned to perform a rolling blackout to prevent large-scale blackouts when the electricity supply reserve margin reaches less than 1 million kW. This study attempts to estimate the inconvenience cost of household customers from a rolling blackout by using survey data. To this end, we apply a contingent valuation method (CVM) to measure their willingness-to-pay (WTP) in order to avoid a rolling blackout, i.e. the suspension of electricity supply. In this study, we estimate the inconvenience costs stemming from both an unannounced and an announced rolling blackout. As a result, we find that the inconvenience cost of a sudden rolling blackout is estimated at 3900.67 KRW (3.56 USD) per month per household, while that of an announced rolling blackout stands at 3102.95 KRW (2.83 USD). This difference in costs shows that people place value in receiving prior notice of a blackout, and that inconvenience costs of between 166.0 billion KRW (151.6 million USD) and 174.3 billion KRW (159.2 million USD) per year can be reduced nationwide by giving households advance notice of a planned rolling blackout.

1. Introduction

1.1. Research background and objective

The world's electricity consumption and the global GDP are constantly growing, with a compound annual growth rate (CAGR) of 2.8% and 4.0% per year, respectively, between 2008 and 2012 (Enerdata, 2013; The World Bank, 2014a). Moreover, the ratio of electricity in the total energy consumption mix has also shown an increase from 17.2% in 2008 to 17.7% in 2011 (IEA, 2010; 2013a). Electricity demand is positively connected to economic growth and it is expected that the two will continue to be closely linked in the future (IEA, 2013b). However, a rapid growth in electricity demand without a sufficient capacity in supply, i.e. a low supply reserve margin, increases the risks of blackouts, which can bring a big loss to the economy and significant inconvenience to people (The World Bank Group, 2009).

Some countries have recently experienced blackouts owing to an imbalance between electricity supply and demand, which usually occurs when demand goes up because of severe weather conditions. The state of California in the United States experienced a rolling blackout[2] in mid-march 2001. Rising temperatures increased the demand for electricity in order to run air conditioners and the demand came to exceed supply. There was no additional generation capacity due to very strict and limited restrictions on plant construction in California for over a decade (American Nuclear Society, 2001). In order to prevent a crash of the entire electrical grid, the independent

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[2] A rolling blackout is the intentional outage of electricity during peak demand periods in non-overlapping regions to maintain the balance between supply and demand (Maqbool et al., 2011).

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Table 1
Electricity supply alarm levels in South Korea.

Supply reserve margin (million kW)	Status	Actions
≤ 5	Ready	• Government starts on the power saving regulations, energy use restrictions, and controls the operation of industry, etc.
≤ 4	Attention	
≤ 3	Caution	• Electricity is suspended to the cooling (250 thousand kW) in about 19,600 public institutions, excluding institutions related to people's life and safety.
≤ 2	Alert	• 28 Coal plant operates to supply 300 thousand kW.
≤ 1	Serious	• Rolling blackout starts from the first group.

system operator (ISO) eventually decided to cut power usage in the state. Tajikistan experienced the coldest winter in January 2008, causing the national energy grid to nearly collapse and occasioning blackouts in most of the country. As a consequence, residential areas received only one or two hours of electricity per day and no electricity overnight (Najibullah, 2008). In February 2011, there was a statewide rolling blackout in Texas, United States, following an increase in electricity demand due to cold weather which shut down 7000 MW of power generators (Baltimore, 2011). This incident had little impact on the major oil and gas operation companies, while it affected more than one million households who were left in the dark and without heat for up to an hour. In Canada, hot and humid weather also caused such heavy demand on the power grid that six generating plants failed to operate during peak demand times. Thus, residences in Edmonton, Calgary, Red Deer and Lethbridge experienced a rolling blackout in July 2012 (CBC News, 2012). The occurrence of a blackout causes direct and indirect damage to industries, transportations and households, bringing significant economic loss and inconvenience to people.

In recent years, the rapid increase in electricity consumption has been a critical issue in South Korea. From 2000 to 2012, the electricity consumption of South Korea grew at an average rate of 5.4% per year, compared to an average increase of 0.9% per year in OECD countries over the same period (Enerdata, 2013). In particular, between 2011 and 2012 the electricity consumption of South Korea increased by 2.4% while OECD countries showed a −0.5% decline, and the growth rates of electricity consumption in the United States, Spain, and Germany were −1.7%, −1.1% and −1.5%, respectively (Enerdata, 2013). In contrast with other countries, South Korea has experienced a very rapid increase in electricity consumption, and the country was ranking 11th in the world in terms of electricity consumption in 2012 (Central Intelligence Agency, 2013).

As electricity demand increases rapidly, concerns about the risks of imbalance between supply and demand are also rising in South Korea. To prepare for emergency situations such as incidences of blackouts, and to maintain a stable level of supply reserve margin, the South Korean government has put in place a contingency plan based on the electricity supply reserve margin, as shown in Table 1. This contingency plan demands the implementation of a rolling blackout depending on the level of supply reserve margin in order to prevent larger-scaled blackouts. When the electricity supply reserve margin reaches "serious status", that is to say around 1 million kW, the supply of electricity is interrupted for an hour, starting from the first group – namely, the residential and commercial sector. If the electricity supply reserve margin continues to drop after cutting out the first group, the blackout is extended to the second group, i.e. the industrial sector, and subsequently to the third group, which comprehends the activity sectors most sensitive to power outage, such as agriculture, livestock, and large industry using over 66 kV. This sequential shutting off of electricity reflects the government's intention to minimize social and economic loss, based on the assumption that the effect of power outage on individual consumers carries less significant economic consequences than its effect on the industry.

In light of the above, this study examines the inconvenience cost to individual users by measuring the consumers' willingness-to-pay (WTP) to avoid a few hours of blackout using a contingent valuation method (CVM). In this study, we consider two cases of a rolling blackout with and without prior notice. A blackout without prior notice, such as the one South Korea experienced in 2011[3], can cause very sudden inconvenience to people. However, if the blackout is announced in advance and people are warned of the need to cope with a few hours of power outage, the inconvenience to those affected will decrease as they can minimize the damage caused by the blackout, even with very limited time to prepare for it. The main research objective of this study is to estimate the economic loss in the residential sector for both an announced and an unannounced blackout, using CVM. We also measure the value of issuing prior notice by measuring the difference between the WTPs derived from the two situations. In general, estimations of outage costs in the residential sector are closely related to the electricity pricing scheme based on reliability differentiation (Siddiqi and Baughman, 1993; Woo et al., 2014), as well as rationing according to the demand response and consumers' WTP levels (Brown and Johnson, 1969; Doucet et al., 1996; de Nooij et al., 2009) as part of the effort to reduce the total social costs from blackouts. In South Korea, there is currently much debate on the reorganization of the electricity market structure, including the introduction of competition in the wholesale, retail, and distribution areas, and on the introduction of new pricing policies in the electricity market to increase market efficiency and to control electricity demand levels. Under these circumstances, estimations of the inconvenience costs of electricity outages have great meaning in South Korea.

This paper is organized as follows: Section 1.2 gives an overview of the status of electric power in South Korea, focusing on the imbalance of supply and demand. Section 2 reviews the previous literature dealing with estimating economic loss from a power outage, and explains the CVM model and data. Section 3 shows the estimation results and their interpretations. Finally, Section 4 discusses the implications and limitations of this study.

1.2. The status of electricity supply and demand in South Korea

Fig. 1 shows the year-by-year trend of the electricity supply reserve margin[4] of South Korea, which can be taken to represent the stability of electricity supply. This figure reveals that the electricity supply

[3] South Korea's rolling blackout in 2011 was caused by an imbalance in the electricity supply and demand level, occurring for the first time over the last few decades. Moreover, the rolling blackout was perceived as a sudden blackout to customers, as it occurred without any advance notice. Other electricity outages in South Korea were caused by technical defects in power distributors, electricity transmission or distribution lines, or by natural disasters.

[4] There are two types of electricity reserve margin: the operating reserve margin and the supply reserve margin. Fig. 1 shows the latter one. The electricity supply reserve margin is calculated via {(dependable capacity − peak load)/peak load} × 100, and 'dependable capacity' is defined as the load-carrying ability of a system under adverse conditions for a specific period of time U.S. Environmental Protection Agency (EPA), 2004; Korea Energy Management Corporation (KEMCO), 2013).