

Estimation of power outage costs in the industrial sector of South Korea

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ABSTRACT

This study estimates the power outage costs of the industrial sector by not only considering production loss but also the customer's inconvenience and various damages. For the estimation, we used a Type II Tobit model with firm-level survey data for 430 firms, and considered factors affecting the outage cost such as outage duration, average annual sales, and average monthly electricity consumption, among others. In addition, we analyzed the effect of the preannouncement of a rolling blackout on outage cost savings, and also examined the value of an emergency generator. From the estimation results, we found that the estimated outage cost is 1.24–1.3 times greater than the simple value of lost load (VoLL), and this difference increases when companies have emergency generator. The commercial and public service sector can reduce the outage cost the most compared to other sectors when a preannouncement is provided, and operating emergency generators can lower the outage cost in these sectors. Finally, we confirm that South Korea's rolling blackout in the predetermined order by the industry is appropriate to minimize the outage costs for the national economy when the outage is preannounced, but is not appropriate when there is no preannouncement.

1. Introduction

It is clear that electricity is one of the most important energy sources in today's society. The electricity consumption of OECD countries is increasing every year, and reached a total final consumption of 9,626.78 TWh in 2013, 0.5% higher than 2012 (IEA, 2015). The manufacturing sector¹ accounts for 30.8% of total electricity consumption and the manufacturing, agriculture, fishing, commercial, and public service sectors all together account for almost 63.0% of total consumption. Commercial and public service, and the industrial sectors have been the most significant end-use sectors for electricity consumption for several years.

Several outages have occurred worldwide, and the risks of large-scale ones and interruption are inevitable and continue to exist. Such risks could possibly cause severe socioeconomic disruptions and economic loss (Schröder and Kuckshinrichs, 2015; Liu et al., 2016). Previous studies on estimating power outage costs were conducted to estimate the value of electricity for the suppliers and consumers, and to implement the cost to operate the electricity market effectively. However, most of the studies estimated outage costs focusing on the production loss, raw materials, and finished production damage, which do not reflect other damage costs such as consumers' inconvenience

cost from the outage. Commonly the power outage cost of the industrial sector has been estimated in terms of value of lost load (VoLL²), using the ratio between gross domestic product (GDP) or gross national product (GNP) and electricity consumption. The VoLL is a measure used to determine the optimal level of service reliability and the wholesale price in electricity planning in the United Kingdom and Australia (Willis and Garrod, 1997; Lee, 2013). This can be interpreted as the consumer's willingness to pay for extra capacity or not to have a risk of losing electricity supply.

This study analyzes the outage costs of individual customers at the sector level which includes their direct and indirect costs as well. In this study, we consider two cases of outage scenarios, with and without two hours prior notice. South Korea experienced a sudden rolling blackout in 2011, which caused unexpected inconvenience to the industrial sectors by cutting off the supply in a certain order. If the outage is announced in advance and industries have some time to cope with the outage to minimize the damage, this prior notice can contribute to the reduction of the economic loss of each sector. In addition, the sequence of the contingency plan to cut off electricity by industrial sector in South Korea is based on the economic loss per hour due to the outage from the highest to lowest order. However, this plan does not have an alternative scenario but just one sequence that assumes that the

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¹ IEA (2015) defines the industrial sector as the manufacturing industry. However, in this study, we use the concept of industrial sector in a broader term, which includes not only the manufacturing industry but also agriculture, fishery, forestry, mining, construction, and commercial and public service sectors.

² VoLL is the value of lost load, and is measured by the value created with one kWh of electricity (Linares and Rey, 2013).

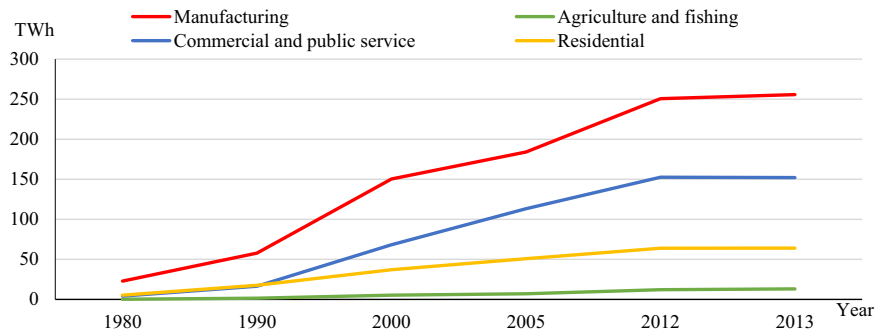


Fig. 1. Electricity consumption by sector in South Korea. (Source: IEA, 2015).

economic loss of each industrial sector is constant. This research also aims to ascertain if the order of the rolling blackout in the contingency plan is reasonable in various situations, such as different time of day or seasons.

This paper is organized as follows: Section 2 briefly presents the background information about the electricity industry of South Korea and reviews the previous literature relating the economic loss from a power outage in various industries. Section 3 explains the Tobit model and the survey data that are used in this study. Section 4 shows the estimation results and their interpretations. Finally, Section 5 discusses the implications and limitations of this study.

2. Background and literature review

2.1. Current state of the electricity industry of South Korea

IEA (2015) reports that the low economic growth rate caused a structural change due to the economic crisis in 2009, and the energy efficiency improvements in the manufacturing industries led to a decrease in electricity consumption. However, OECD industrial electricity consumption increased by 0.6% in 2013 compared to 2012. For most of the countries in the OECD, the electricity consumption of the industrial sector is constantly increasing or maintaining a similar level. Japan and Germany show a gradual increase from 1980 to 2012, and a very slight decrease in 2013, but the electricity consumption of South Korea has increased from 76.7 TWh in 1990 to 423.2 TWh in 2013.

Fig. 1 shows a constant increase of South Korea's electricity consumption by sectors. The manufacturing sector consumes a large amount of electricity, and also constantly increases electricity consumption. This rapid increase in electricity consumption in South Korea compared to other countries is caused by not only the increase in industrial production but also mainly the fast electrification of the industrial sector. This fast electrification is due to the lower price of electricity compared to other energy sources, which is caused by a distorted energy price system (Kim et al., 2015; Kim and Shin, 2016). Fig. 2 shows that the electricity price indices of South Korea have not

fluctuated since 1994, and have also remained lower than other energy sources from 2008. The reason why South Korea is maintaining this low electricity price policy is for price stability and enhancing the export competitiveness of industry (Kim et al., 2015). In addition, the electricity intensity (EI) in the manufacturing sector in South Korea has been stagnant since 2010, although continuing to remain higher than that of the other sectors, as shown in Fig. 3. The EI of the Korean industry has not improved because there is no incentive for companies to improve their energy efficiency due to the low electricity price.

Since the rolling blackout on September 15, 2011, the supply reserve margin went up to 11.5% in 2014, which the government is planning to use to alleviate the electricity shortage in South Korea (KPX, 2014). To meet the high electricity demand, the Korean government plans to increase the supply capacity by establishing new coal and nuclear power plants. However, the concerns about the plan still remains due to local conflicts on constructing the new power plants and transmission grid, and also the technical difficulties of the transmission grid.

The industrial sector is the highest electricity consumer group at the moment, and will remain so in the future as the economy grows. In 2013, the residential sector consumed only 13.1% of total electricity, but the industrial sector consumed 86.9%. Therefore, when considering large electricity consumption, high EI, and the proportion of electricity to total energy consumption in the industrial sector, it could be concluded that the industrial sector may incur large damage costs in case of a power outage. Of course, these damage costs could be varied by flexibility and mitigating measures of companies, such as emergency generators.

2.2. Literature review

Various research on the estimation of the outage cost of the industrial sector has been performed. Previous studies can be divided into two categories by the data used to estimate the economic loss from the electricity outage. The first is to estimate economic loss based on publicly available data (Bental and Ravid, 1982; de Nooij et al., 2007;

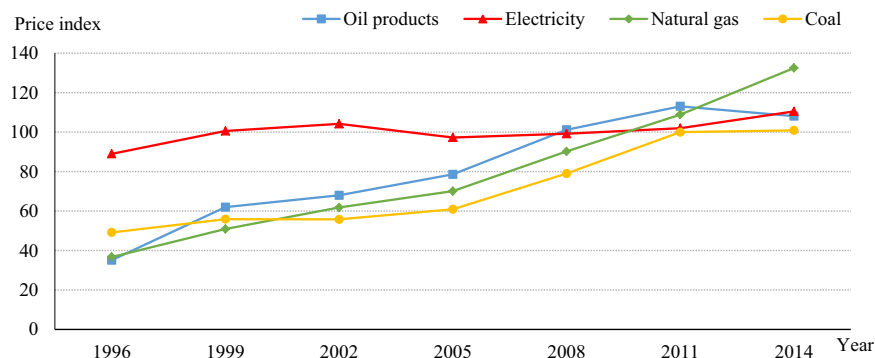


Fig. 2. Energy retail price trends of South Korea (2002=100). (Source: IEA, 2015).

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