EFFECTS OF FOSSIL FUEL PRICES ON THE JAPANESE ELECTRICITY MARKET DURING CRISIS

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Overview

Japan heavily relies its electricity source on fossil fuel energy. More than 75% of the Japanese energy supply depends on fossil fuels in 2020 (MEXT, 2022); natural gas, coal, and crude oil consisting of 39%, 31%, and 6%, respectively. Under this situation, the spread of COVID-19 after 2019 and the conflict between Ukraine and Russia are causing drastic movements in the fossil fuel market. Currently, these crises are posing a major obstacle for Japan to stabilize its electricity price. In general, the electricity market is closely related to the fossil fuel market because fossil fuel energy has been the primary source for generating electricity in many countries and it is known that fossil fuel prices tend to have a significant impact on the electricity price (Mohammandi, 2009). Thus, understanding the connection between electricity prices and fossil fuel prices is now becoming more important than ever for the Japanese government to devise an energy policy to stabilize its electricity market.

In Japan, electricity is supplied to consumers under three types of contracts: extra-high-, high-, and low-voltage contracts. The extra-high-voltage contract is for consumers whose maximum monthly electricity demand exceeds 2000 kW often provided for customers such as large factories and railway companies. The high-voltage contract is made between companies and small to medium-sized factories whose maximum monthly electricity demand is between 50 kW to 2000 kW. Finally, the low-voltage contract is for customers whose demand is less than 50 kW such as normal households, small shops, and so on.

Although there is a strand of literature exploring the linkage between electricity and fossil fuel markets (Mohammandi, 2009; Nakajima and Hamori, 2013; Bernal et al., 2019) not much has been investigated on whether there is a distinction among the types of electricity contracts regarding their effects from the fossil fuel market. To shed light on this gap, the current study examines the impact of the recent unstable fossil fuel market on the three different types of electricity contracts in Japan.

Methods

The theoretical background of the econometric model analyzed in this study is based on the electricity and fossil fuel price model developed by Mohammandi (2009). In this study, this model has been modified to consider the seasonality effects and the COVID-19 pandemic and Russian-Ukrainian war impacts.

First, to identify structural breaks in the price series the multiple structural break test was conducted following Bai and Perron (1998). If any breaks were determined, a dummy variable, *break*, is created to capture the effect of the breaks in the price series. Using this dummy variable, the electricity and fossil fuel price relationships are tested under the following autoregressive distributed lag (ARDL) model:

$$\Delta electricity_t = a + b_1 electricity_{t-1} + b_2 gas_{t-1} + b_3 coal_{t-1} + b_4 oil_{t-1} + \sum_{i=1}^{p} b_{5i} \Delta electricity_{t-i} + \sum_{i=0}^{q} b_{6i} \Delta gas_{t-i} + \sum_{i=0}^{r} b_{7i} \Delta coal_{t-i} + \sum_{i=0}^{s} b_{8i} \Delta oil_{t-i} + b_9 summer + b_{10} winter + \sum_{j=1}^{n} b_{11j} break + \varepsilon_t \quad (1)$$

where electricity is the type of electricity (extra-high, high, and low voltage). *Gas* is the cost, insurance and freight (CIF) price of imported liquid natural gas price for Japan. *Coal* and *oil* are the Australian imported coal price and the Dubai Fateh crude oil price. These prices are one of the major indicators of imported coal and crude oil prices in Japan. All price series are monthly data. Finally, *summer* and *winter* are dummy variables capturing seasonality effects.

The period covered in this study is from Jan. 2019 to Nov. 2022. All the price variables are obtained from the homepage administered by Energy Information Center, a general incorporated association located in Tokyo, Japan.

Since the ARDL model requires the test variables to be either integrated of order zero or one, three types of unit roots were preliminary conducted on the test variables. For this purpose, the Augmented Dickey-Fuller (ADF) and Kwiatkowski–Phillips–Schmidt–Shin (KPSS) tests were conducted with intercept and trend. In addition to these unit root tests, the Zivot-Andrews (ZA) with a trend break was performed to consider the effect of a structural break in the series.

Finally, to capture the dynamic causal effects between electricity and fossil fuel prices, we estimated the cumulative dynamic multipliers under the ARDL model. The robustness of the models is tested by CUSUM and CUSUM-square stability tests.

Results

The Bai-Perron test suggested that in all three electricity contracts, three breaks were the statistically optimal number of breaks (Table 1). Dummy variables to capture the breaks were created using the breaks identified by this test. *B1* denotes the first break, which is the period before Oct. 2020 for extra-high voltage contact and before Oct. 2019 for the high and low voltage contracts. *B2* is the second break which represents the period between Oct. 2020 to Jul. 2021 for the extra-high contract and between Oct. 2019 and Apr. 2021 for the high and low contracts. *B3* signifies the third structural break, containing the period after May 2022 in all contracts.

Table 1 Bai-Perron structural break test

	Extra-high		High voltage		Low voltage		
Break test	Scaled F-stat.		Scaled F-stat.		Scaled F-stat.		Critical Value
0 vs. 1	230.73	**	540.77	**	1331.09	**	18.23
1 vs. 2	33.16	**	159.19	**	37.96	**	19.91
2 vs. 3	34.75	**	120.62	**	269.87	**	20.99
Identified breaks	Oct. 2020, Jul. 2021, May 2022		Oct. 2019, Apr. 2021, May 2022		Oct. 2019, Apr. 2021, May 2022		

Table 2 Long-run coefficient estimation

Models	Variables	Coefficient		Std. Error
Extra-high	Const.	4.123	***	0.355
	LNG	0.046		0.125
	Coal	0.166		0.124
	Oil	-0.065		0.075
High voltage	Const.	6.969	**	2.929
	LNG	0.485		0.463
	Coal	-0.217		0.400
	Oil	-0.432		0.483
Low voltage	Const.	5.818	***	0.548
	LNG	0.208	***	0.067
	Coal	-0.147		0.105
	Oil	-0.061		0.062

The stationarity tests indicated that all price variables were either I(0) or I(1), supporting the use of the ARDL model for analyzing the price series.

The ARDL bound test confirmed that all three electricity contract models had a cointegrating relationship. However, for the extra high and high voltage contracts, the long-run relationship was not held by the fossil fuel price (Table 2). Meanwhile, the low-voltage contract model demonstrated that the long-run relationship was led by the natural gas price (Table 2). As seen in Table 2, the natural gas price had an increasing effect on the low-voltage contract.

The ARDL short-run estimation revealed that natural gas did not have a short-run impact in all three contract models but the result indicated that the change in crude oil price had a negative impact in the high contract model. It also revealed that the coal price had a negative impact on the low-voltage model. This negative impact of the fossil fuel price on electricity prices in the short-run might be reflecting the drop in the electricity demand when fossil fuel prices rise, leading to a temporary decrease in the electricity price. The shock in Oct. 2019 detected by the Bai-Perron test showed that electricity prices declined from Oct. 2019 to April. 2021, which is a period when Japan was in the middle of the COVID-19 pandemic. The structural shock detected after May 2022 had an increasing effect on the electricity price indicating that the Russian-Ukrainan war led to an increase in the electricity price.

Finally, the cumulative dynamic multiplier suggested that the shock from natural gas had an increasing effect on all three electricity contracts while crude oil had a decreasing impact. Coal had a different influence among the three contracts where there was a rising shock in the extra-high contract model while high and low contracts revealed a declining shock.

Conclusions

The study investigated how the severe changes in fossil fuel during the COVID-19 pandemic and the 2022 Russian-Ukrainian war have influenced the Japanese electricity market. The ARDL model estimation suggested that the natural gas increase has been leading the electricity price in the long run, especially for the low-voltage contract which is primarily for small shops and normal households. This indicates the importance of providing special subsidies or support for low-voltage electricity consumers when a surge in fossil fuel energy is soaring the electricity price.

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