Effects of fossil fuel prices on the Japanese electricity market during crises

Kentaka Aruga,* Md Monirul Isam**, and Arifa Jannat**

*Graduate School of Humanities and Social Sciences, Saitama University

Email: kentaka.aruga@gmail.com

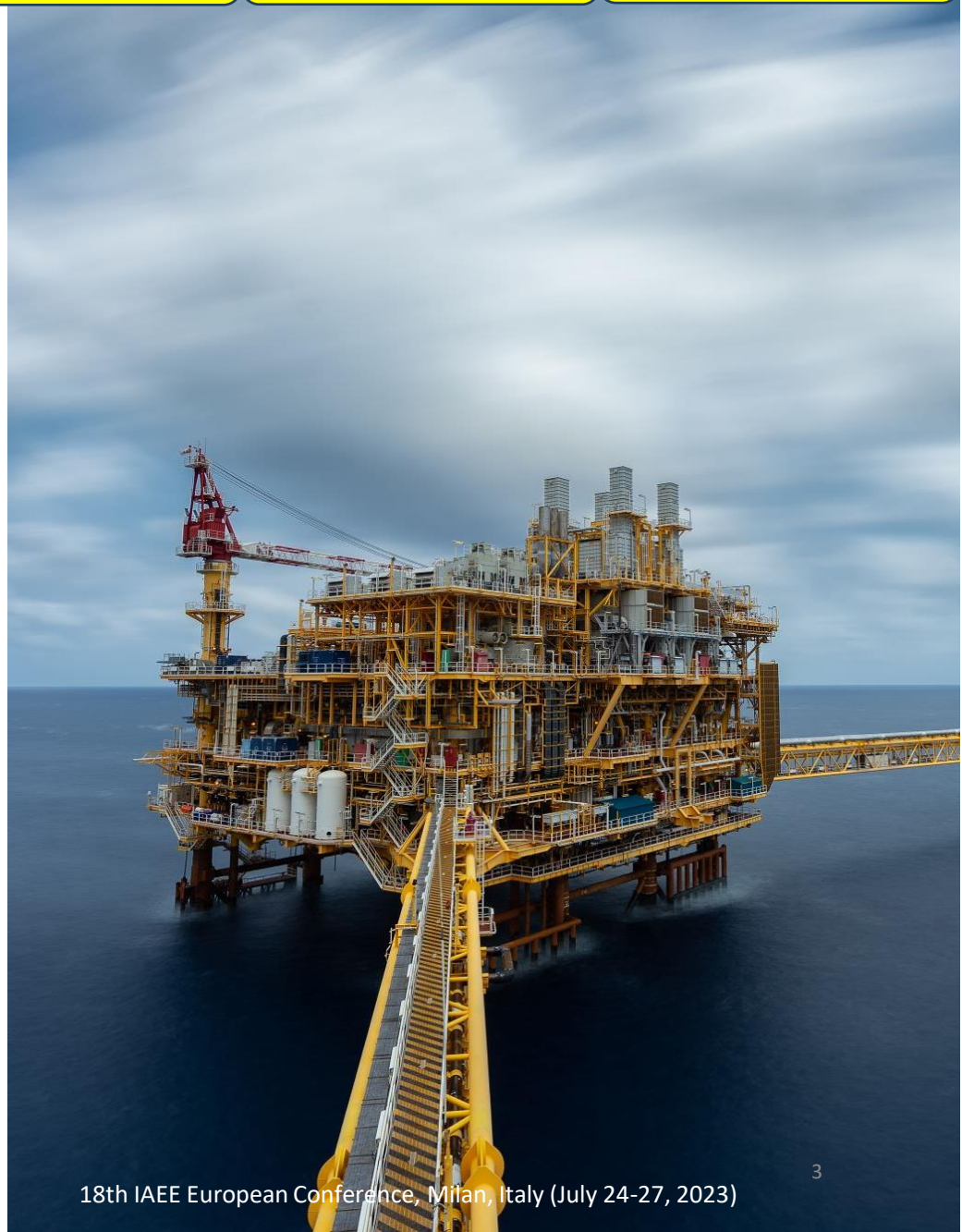
** Bangladesh Agricultural University

Contents

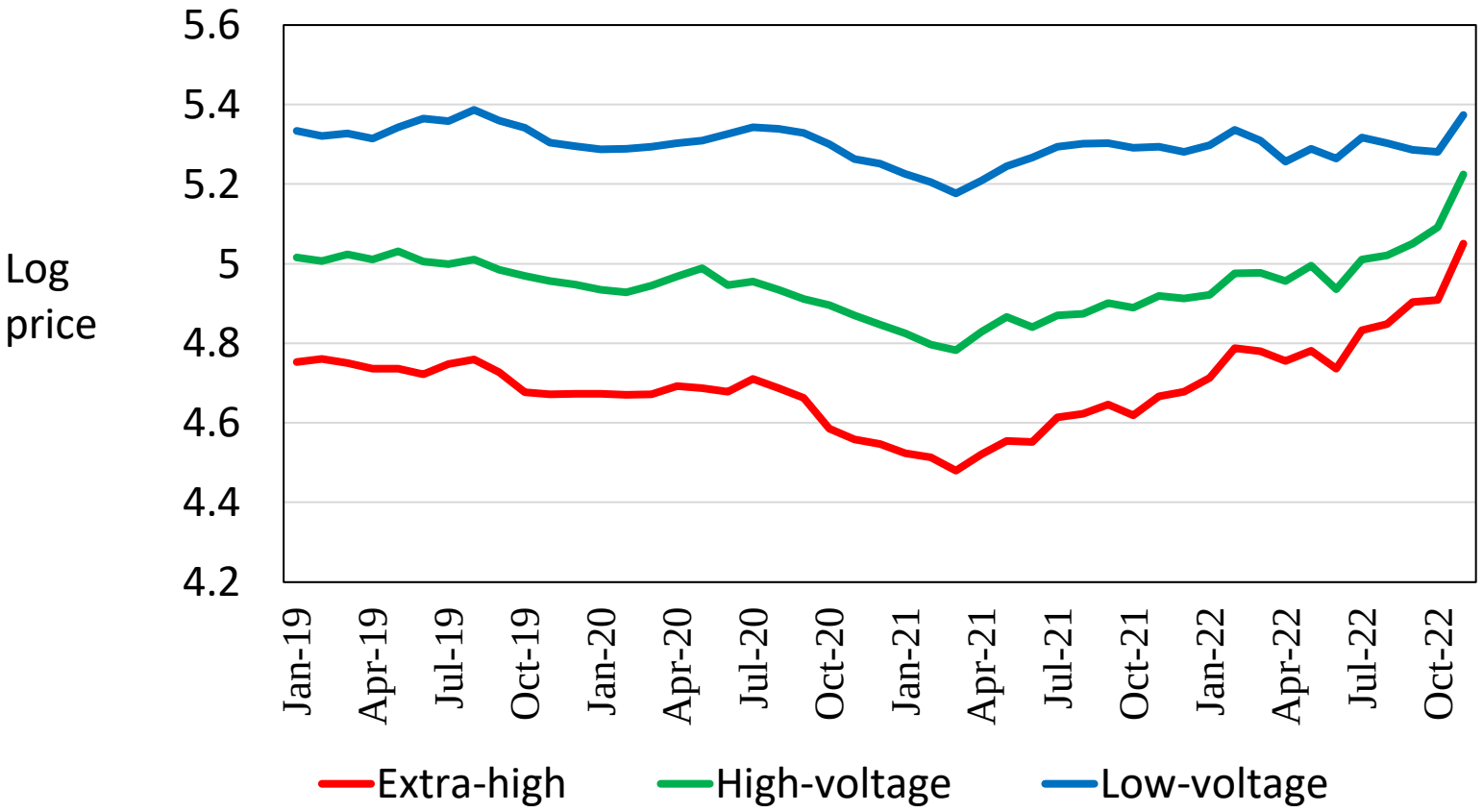
- Study background
- Objectives
- Methods
- Results
- Conclusion

Background

- As fossil fuel has been the major production factor for electricity, many studies investigate the fossil fuel-electricity market relationships (Mohammadi, 2009)
- Recent COVID-19 pandemic and Russia-Ukraine war might have influenced the relationship



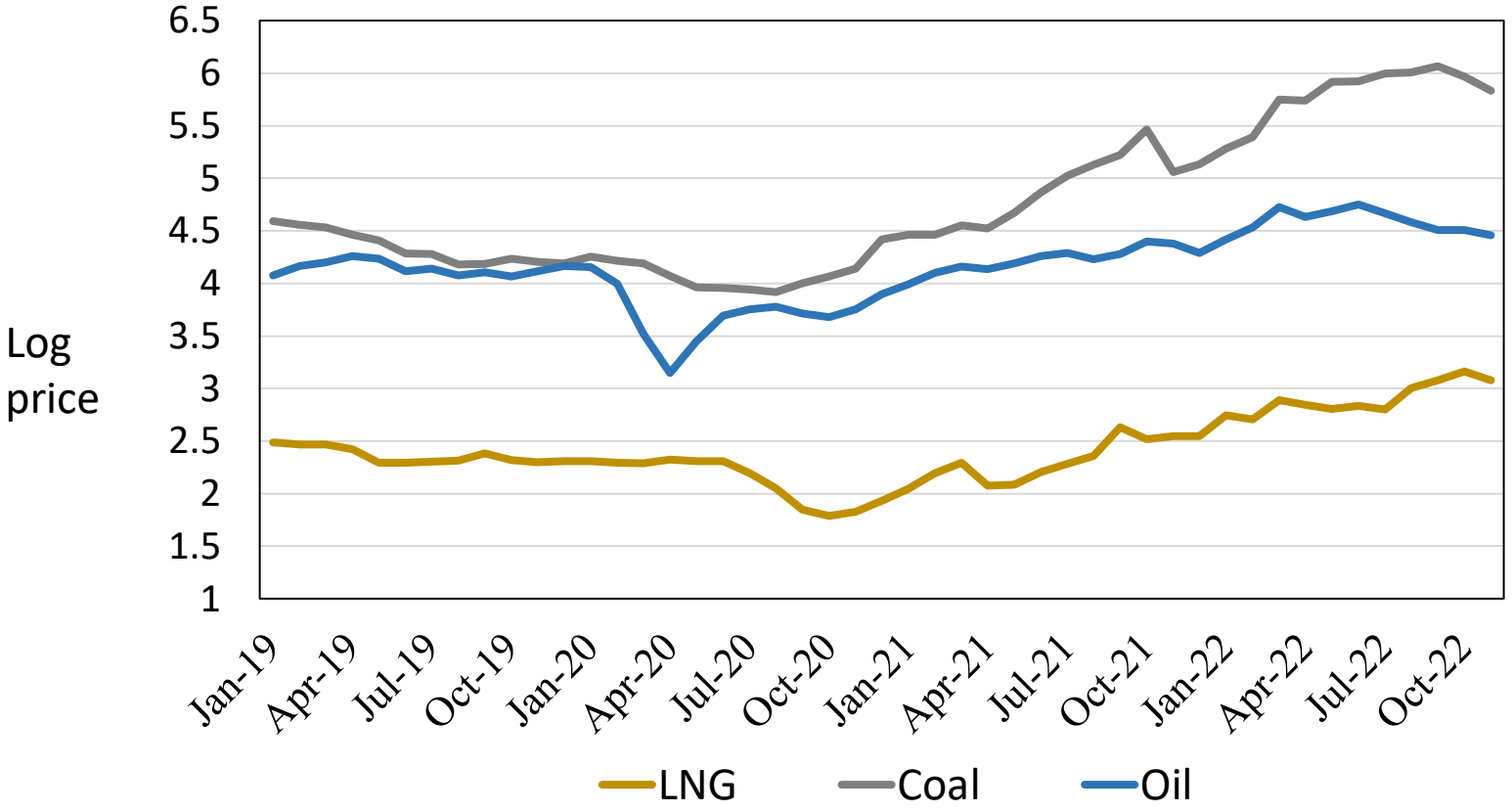
Electricity price



Data source for electricity prices

- Extra-high voltage contract
  - maximum monthly electricity demand exceeding 2000 kilowatt (kW)
  - for customers such as large factories and railway companies.
- High voltage contract
  - maximum monthly electricity demand is between 50 kW and 2000 kW
  - For companies and small to medium-sized factories
- Low voltage contract
  - For demand less than 50 kW
  - For normal households, small shops, and so on.

Fossil fuel price

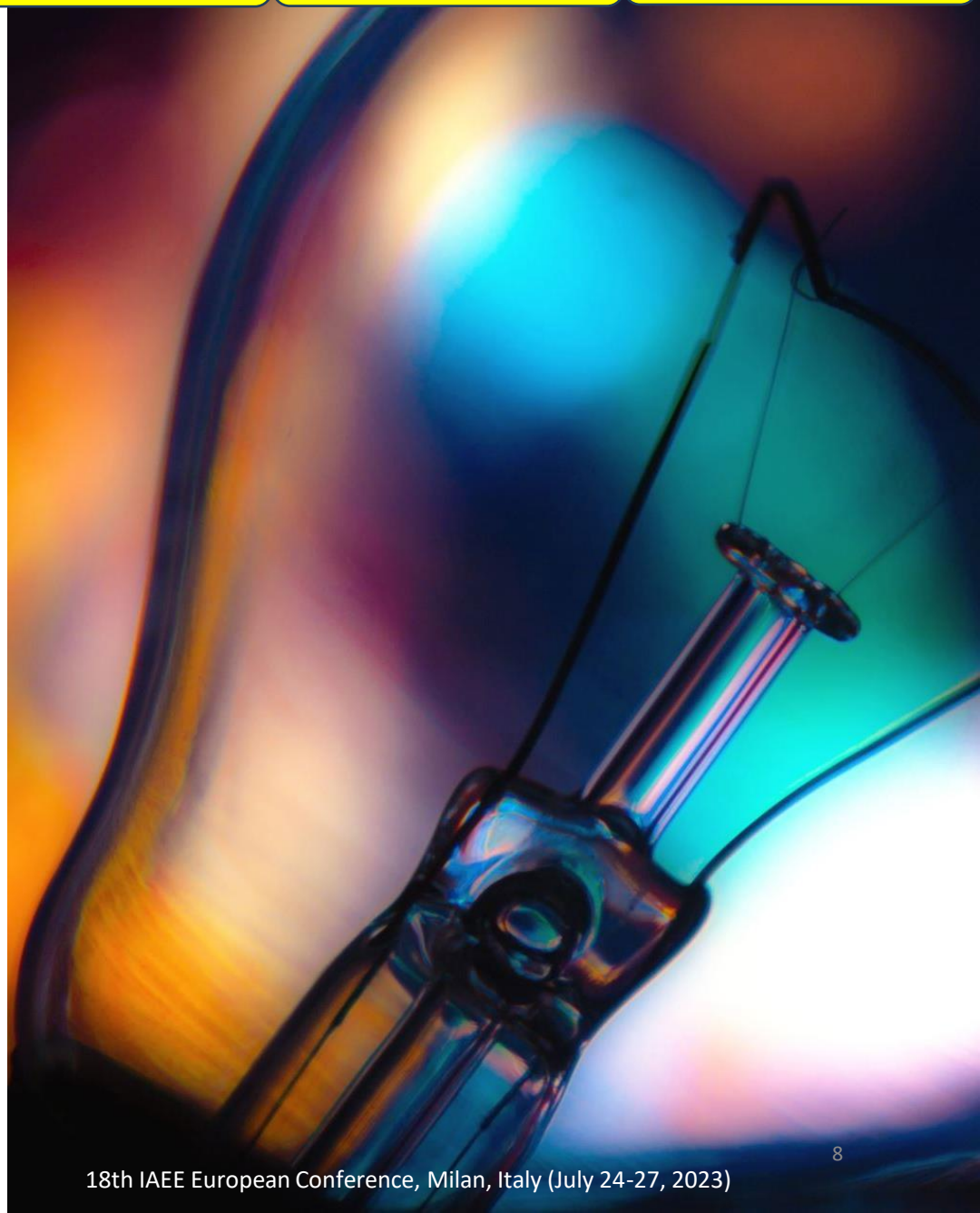


Data source for fossil fuel prices

- LNG
  - Cost, insurance and freight (CIF) price of imported LNG price for Japan
- Coal
  - Australian imported coal price
- Crude oil
  - Dubai Fateh crude oil price

Research objectives

- To examine the impact of the recent unstable fossil fuel market on the three different types of electricity contracts in Japan.
- Identify structural breaks in the Japanese electricity prices during 2019-2022 and consider the effects of these breaks if any.



Related studies

- Mohammadi (2009)
  - Identify the existence of long-run relationship between coal, natural gas, and crude oil for the US for 1960-2007.
  - https://doi.org/10.1016/j.eneco.2009.02.001
- Bernal et al. (2019)
  - Fossil fuel prices have a positive impact on electricity price in Mexico during 2006:1-2016:1.
  - https://doi.org/10.1108/JES-07-2017-0198
- Aruga (2022)
  - Reduced human mobility during the COIVD-19 reduced electricity demand in Japan
  - https://doi.org/10.3390/jrfm15100422

Methods

Identifying endogenous breaks in the electricity price series

Bai-Perron multiple structural break test with AR(1) model

Investigating the effects of fossil fuel prices on electricity prices

ARDL with control variable (seasonal dummy and breaks)

Unrestricted ARDL model

$$\Delta electricity_t = a + b_1 electricity_{t-1} + b_2 LNG_{t-1} + b_3 coal_{t-1} +$$

$$b_4 oil_{t-1} + \sum_{i=1}^{p} b_{5i} \Delta electricity_{t-i} + \sum_{i=0}^{q} b_{6i} \Delta LNG_{t-i} + \sum_{i=0}^{r} b_{7i} \Delta coal_{t-i} +$$

$$\sum_{i=0}^{s} b_{8i} \Delta oil_{t-i} + b_9 summer + b_{10} winter + \sum_{j=1}^{n} b_{11j} break + \varepsilon_t$$

Bai-Perron test

	Extra-high voltage	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	

Unit root tests

Variables	Levels			First differences		
	ADF	ZA	KPSS	ADF	ZA	KPSS
Extra-high voltage	0.945	-2.821	0.211 **	-3.245 *	-7.199 ***	0.160 **
High voltage	1.362	-1.788	0.211 **	-2.999	-8.294 ***	0.157 **
Low voltage	-1.592	-2.786	0.139 *	-5.314 ***	-5.990 ***	0.067
LNG	-1.679	-4.803 **	0.217 ***	-2.495	-6.297 ***	0.086
Coal	-2.030	-4.793 **	0.214 **	-6.295 ***	-7.558 ***	0.125 *
Crude oil	-1.710	-4.782 **	0.173 **	-5.757 ***	-6.117 ***	0.098

Note: ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively. All unit root tests are performed with intercept and trend. ADF, ZA, and KPSS represent the Augmented-Dickey–Fuller, Zivot–Andrews, and Kwiatkowski–Phillips–Schmidt–Shin test statistics.

ARDL bound test

	Extra-high voltage	High voltage	Low voltage
F-statistic	6.73***	7.33***	5.23**
I(0)		4.27, 3.08	
I(1)		5.41, 4.02	

Note: *** and ** denote significance at the 1% and 5% levels, respectively. Critical values for the I(0) and I(1) denote those at the 1% and 5% significance levels, respectively.

Long-run coefficient estimation

Models	Variables	Coefficient		Std. Error
Extra-high voltage	Const.	4.123	***	0.082
	LNG	0.046		0.133
	Coal	0.166		0.052
	Oil	-0.065		0.368
High voltage	Const.	6.969	**	2.065
	LNG	0.485	**	0.233
	Coal	-0.217		0.226
	Oil	-0.432		0.345
Low voltage	Const.	5.818	***	0.390
	LNG	0.208	***	0.016
	Coal	-0.147	**	0.061
	Oil	-0.061	**	0.026

Note: *** and ** denote significance at the 1% and 5% levels, respectively.

Short-run coefficient estimation

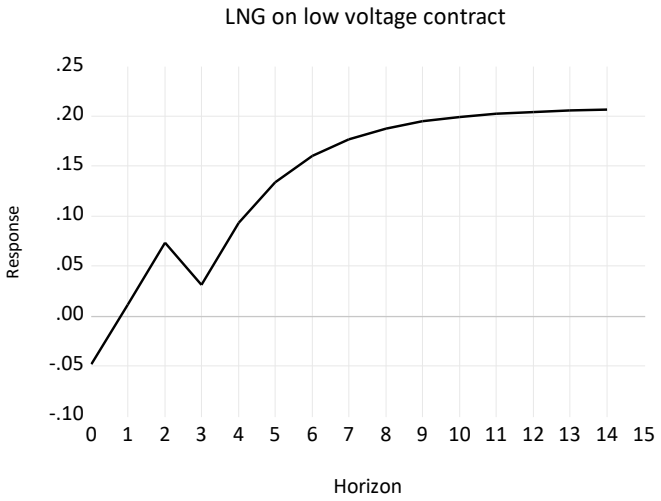
	Extra-high voltage		High voltage			Low voltage		
Variable	Coefficient	Std. Error	Coefficient		Std. Error	Coefficient		Std. Error
ΔLNG	0.017	0.046	0.061	*	0.036	-0.048		0.042
Δcoal	-0.023	0.044	-0.035		0.034	-0.052	**	0.025
Δoil	-0.024	0.026	-0.054	**	0.021	-0.022		0.020
Winter	0.001	0.012	-0.001		0.011	0.013		0.010
Summer	-0.004	0.013	-0.024	***	0.008	0.013	***	0.009
B1	-0.004	0.029	-0.044		0.026	-0.035		0.022
B2	-0.034	0.025	-0.075	**	0.030	-0.064	**	0.024
B3	0.034	0.032	0.054	**	0.024	0.021		0.027

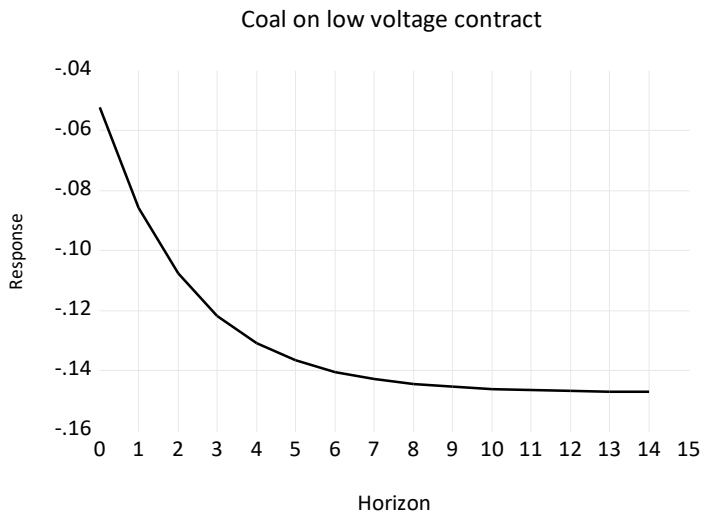
COVID-19

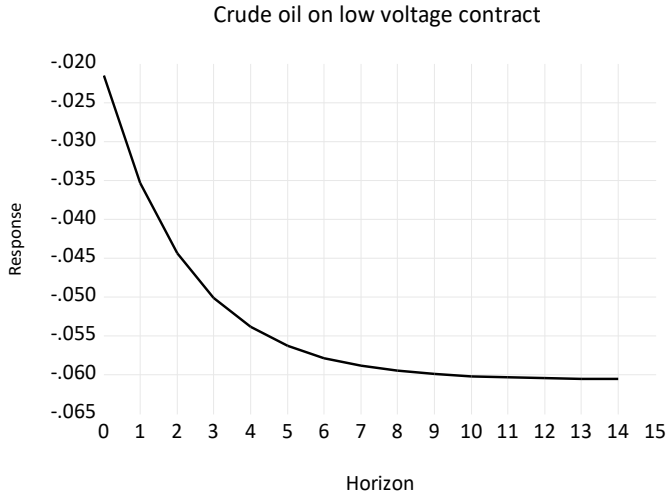
Ukrainian war

Note: ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Cumulative dynamic multiplier: low voltage







Conclusions

- An increase in the natural gas price during the 2019-2022 period was driving the electricity price to rise in the long run for the low and high-voltage contracts.
- Electricity price was decreasing during COVID-19 while it was increasing after the Russia-Ukraine war.

Implications

- Energy price is susceptible to shocks.
- Importance of providing special subsidies or support to mitigate the shocks on the electricity price.
- Power companies need to diversify their electricity generation mix.

Thank you for your attention!

For further questions:
kentaka.aruga@gmail.com