MARKET AND WELFARE ANALYSIS OF NUCLEAR POWER PLANT

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Overview

This research aims to analyze economic and welfare consequences of electricity shortages and blackouts in South Korea, which followed the shutdown of multiple nuclear power plants from June 2013 to January 2014. Nuclear power plants require huge construction cost but needs zero marginal cost. Thus, they are base load power sources to consistently meet minimum electricity demand. As many countries consider an option of increasing nuclear power generation, this research will show what might be market and welfare impacts when base load power plants suddenly stop generation.

Methods

Our state-space model describes how sectorial electricity prices are determined not only by unobserved production costs but also by cross subsidization between sectors. First, the following measurement equations explain how sectoral electricity prices are determined by common cost factor and individual sectoral cost factors. Let

$$\begin{pmatrix} y_{1t} \\ y_{2y} \\ y_{3t} \end{pmatrix} = \begin{pmatrix} z_1 w_{0t} + w_{1t} \\ z_2 w_{0t} + w_{2t} \\ z_3 w_{0t} + w_{3t} \end{pmatrix} + \begin{pmatrix} e_{1t} \\ e_{2t} \\ e_{3t} \end{pmatrix}, \qquad (1)$$

where y_{it} is percentage change (divided by 100) of the ith sector electricity price (seasonally adjusted), w_{0t} is the unobserved common factor, and w_{it} for $i = 1,2,3$ is the unobserved ith sector idiosyncratic factor, where $i = 1,2,3$ represent residential, commercial and industrial sectors, respectively, and t is the monthly time index.

For the idiosyncratic factors w_{it} for $i = 1,2,3$, we impose a company-wise budget constraint so that the weighted idiosyncratic factors add up to zero, i.e, we have

$$k_1 w_{1t} + k_2 w_{2t} + k_3 w_{3t} = 0$$

for all $t > 0$, where k_i for $i = 1,2,3$ is the sectoral sales weight given by k_i =(ith sector electricity sales)/(total electricity sales). These weights are obtained as $k_1 = 0.19$, $k_2 = 0.23$ and $k_3 = 0.58$. This budget constraint implies that the total revenue and total cost for all electricity production are equivalent. That is, it means break-even profit for the public enterprise.

For the common and idiosyncratic factors of the model that are not observed but we recover through the model, we define them such that

$$\begin{pmatrix} w_{0t} \\ w_{1t} \\ w_{2t} \\ w_{3t} \end{pmatrix} = \begin{pmatrix} u_0 \\ u_1 \\ u_2 \\ u_3 \end{pmatrix} + \begin{pmatrix} b_{00} & 0 & 0 & 0 \\ 0 & b_{11} & 0 & 0 \\ 0 & 0 & b_{22} & 0 \\ 0 & 0 & 0 & b_{33} \end{pmatrix} \begin{pmatrix} w_{0t-1} \\ w_{1t-1} \\ w_{2t-1} \\ w_{3t-1} \end{pmatrix} \qquad (2)$$

$$+ \begin{pmatrix} c_{11} & c_{12} & c_{13} & c_{14} & c_{15} & c_{16} & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & c_{27} & c_{28} & c_{29} & c_{210} \\ 0 & 0 & 0 & 0 & 0 & 0 & c_{37} & c_{38} & c_{39} & c_{310} \\ 0 & 0 & 0 & 0 & 0 & 0 & c_{47} & c_{48} & c_{49} & c_{410} \end{pmatrix} x_t + \begin{pmatrix} v_{0t} \\ v_{1t} \\ v_{2t} \\ v_{3t} \end{pmatrix},$$

where x_t is a vector of the

- percentage change of the average wage,
- percentage change of the uranium price,
- percentage change of the coal price,
- (percentage change of the oil price)/(electricity power reserve rate),
- (percentage change of the LNG price)/(electricity power reserve rate),
- (changes in nuclear power plant failure rate)/(electricity power reserve rate),
- percentage change of the IAIP (index of all industry production),

- percentage change of the producer price index,
- percentage change of the Dallor/Won exchange rate,
- percentage change of the unemployment rate.

All values in x_{it} are the percentage changes divided by 100.

Results

Our estimates of the coefficients in equations (1) and (2) are as follows:

$$z = \begin{pmatrix} 0.27 \\ 0.39 \\ 0.001 \end{pmatrix}, u = \begin{pmatrix} 0.0263 \\ -0.0057 \\ 0.0059 \end{pmatrix}, B = \begin{pmatrix} -0.18^* & 0 & 0 \\ 0 & -0.17^* & 0 \\ 0 & 0 & -0.33^* \end{pmatrix},$$

$$C = \begin{pmatrix} -0.017 & 0.228^* & -0.106^* & -0.736^* & 0.717^* & 0.400^* & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & -0.114 & 0.977^* & -0.049 & 0.0001 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0.001 & -0.326^* & -0.007 & 0.0004 \end{pmatrix}$$

Note: for B and C, estimates with superscript * are statistically significant.

From the estimates of z, we learn the common cost factor influences on residential and commercial electricity price positively, however, rarely on industrial price. This supports a notion that industrial sector receives the benefit of cross subsidization by not paying for its fair share of production cost. The negativite coefficients of B reveals mean reversion property of cost factors. The coefficient 0.400 in the first row of C shows that nuclear power plant failure significantly raises the production cost when the electricity reserve rate is low. The coefficient 0.717 in the first row of C implies that the marginal plants are often LNG fired, and thus the LNG price upon low power reserve rate significantly increases production cost.

Conclusions

We model the relationship of sectoral prices and unobserved costs of electricity production in Korea. Our results show how nuclear power electricity generation failure and shutdowns can raise production costs, but sectoral price outcomes imply the conspiring cross subsidization from residential/commercial to industrial sectors.