TRANSITION AND INTEGRATION OF THE ERCOT MARKET WITH THE COMPETITIVE RENEWABLE ENERGY ZONE PROJECT

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Overview

Renewable energy technologies including wind are promoted and deployed in the U.S. to meet growing electricity demand, to reduce greenhouse gas emissions, and thus to mitigate the climate change impacts of domestic electricity production and consumption. In 2016 wind turbines provide about 8% of total capacity and 6% of electricity generation in the US (EIA 2017). The rapid development of wind power has been supported by technological improvement and reduced costs, renewable electricity policies including federal production tax credits and state renewable portfolio standards, and increased transmission capacity for integrating wind generation into grid.

The Competitive Renewable Energy Zones (CREZ) transmission project was initiated by Texas, the top wind power state in the country, in 2005. The purpose of CREZ is to bring the wind power generated in windy West Texas to the other parts of the state with relatively high power consumption. The CREZ project costed about $6.8 billion and 3,600 miles of high-voltage transmission lines were constructed over the period of 2010-2013 adding 50% more capacity into the electric grid operated by the Electric Reliability Council of Texas (ERCOT). The CREZ project well illustrates the importance of expanding transmission infrastructure for the development of renewable energy. It also provides an excellent case study for understanding the economic impacts and, more importantly, the value of transmission lines, which is the focus of the current study.

The crucial role of and social benefits brought by expanding transmission facility are well recognized in the literature. In a deregulated market, by connecting geographically separate markets, additional transmission capacity not only relieves congestion, but also enhance competition and discourage the exercise of market power (Borenstein et al. 2000). Transmission constraint actively changes market conditions and consequently price and its variation (Birge et al. 2014). Davis et al. (2016) documents the significant impact of binding transmission constraint, which is induced by a nuclear power plant closure, on generation cost when the lost generation was met by plants with higher marginal cost. Relaxing transmission constraint was found to greatly increase market surplus and reduce local market power in Indian electricity market (Ryan 2013). Wolak (2015) quantifies the competitiveness benefits of a transmission expansion policy in Alberta, Canada, resulting from lower wholesale market prices. There is a small but growing body of literature pertaining to integration of electricity market. For example, using PJM interconnection as example, Mansur and White (2012) provides empirical evidence suggesting that an organized electricity wholesale market substantially improved market efficiency by facilitating information sharing and encouraging trade. Various empirical methods are employed to investigate integration of regional electricity markets, including, Principal Component Analysis (Zachmann 2008), GARCH and DCC models (Higgs 2009), and common factor approach, (Apergis et al. 2017).

With the development of CREZ transmission lines, the regional markets of ERCOT, North (hereafter denoted as N), South (S), West (W) and Houston (H), are expected to gradually integrate, which can be reflected into the reduced price spreads between regional markets. The prices are expected to gradually converge as the lines extended sequentially from west to east over time. Furthermore, we hypothesize that the price in the integrated market after CREZ is switched into a relatively lower but more volatile regime, different from that before CREZ. While lower price is resulted from improved market efficiency and low operating cost of wind, large scale incorporation of wind power into the grid should yield higher price variation. This is reasonable as the exogeneity of wind power output may generate price spikes on calm hours/days with no wind and very low, or even negative, prices when wind is the strongest during the early morning hours.

The objective of the study is two-fold: (i) to understand the transition process of regional markets induced by the CREZ project, and (ii) to quantify market integration before and after the transition through wholesale electricity prices in the EROCT market.

Methods

To understand the transition process induced by the CREZ project, correlation coefficient of regional prices are estimated using a 30-day rolling window. The price correlations among four regions, especially the West and Houston, are expected to increase gradually reflecting the construction progress of the transmission project. In addition, a structural change test is applied on three relative price series between the four regions. Given the existing transmission infrastructure between North, South and Houston areas, we hypothesize that the identified structural break point of relative prices of West-Houston will illustrate the end of transition process induced by the CREZ project. This is reasonable given the fact that the South and North are directly but separately linked with the West market by the CREZ, but there is no direct link between the West and Houston before the construction of the CREZ project.

To futher understand the dynamic transition process and evaluate the extent of market integration, a Structural Vector Autoregression (SVAR) model is estimated before and after the structural break identified above:

$$AY_t = \sum_{j=1}^{p} \alpha_j \mathbf{Y}_{t-1} + \boldsymbol{\beta}\mathbf{X_t} + \mathbf{u}_t,\ \mathbf{u}_t \sim N(0, \boldsymbol{\Omega}_t).$$

where $Y_t = [P_t^W\ P_t^N\ P_t^S P_t^H]'$ is the vector of regional electricity prices, A and α_j ($\mathbf{u}_t$ is the vector of structural shocks, . The vector X_t includes region-specific control variables such as load and wind forecast. The contemporaneous restrictions are imposed on cross equation parameters as the price response matrix is assumed to be symmetric. This will impose six constraints on the SVAR system and make the system exactly identified. The prices are aggregated from 15 minutes day-ahead wholesale prices of respective ERCOT load zones. We generated three price series, daily average, daily peak, and daily off-peak, which are averages of 24-hours, peak-hours, and off-peak hour prices, respectively. Based on the definitions of ERCOT, peak hours refer to 7am-10pm from Monday through Friday excluding NERC holidays. Impulse responses (IRF) generared from the estimated SVAR model will be used to understand the dynamics of price shocks. Forecast error variance decomposition (FEVD) will disclose the relative importance of price shocks for fluctuations in other neighboring regions.

As we see, SVAR model focuses only on conditional expectation or the first moment of prices. To better understand the entire conditional distribution of regional electricity prices, a Gaussian mixture autoregressive (GMAR) model, which is closely related to STAR model, will be estimated for each individual price series (Glasbey 2001). The conditional distribution is specified as a combination of Gaussian distributions of linear AR models with weights being functions of historical prices. The GMAR(1,m) model with 1 lag and m components is specified as:

$$P_t \sim N\left\{\mu_{I_t} + \phi_{I_t}(P_{t-1} - \mu_{I_t}), \sigma_i^2(1-\phi_{I_t}^2)\right\},\ p(I_i = i) = g_i(P_{t-1}),\ g_i(P_{t-1}) = \frac{(\pi_i / \sigma_i)\exp\left\{-(P_{t-1} - \mu_i)^2 / 2\sigma_i^2\right\}}{\sum_j (\pi_j / \sigma_j)\exp\left\{-(P_{t-1} - \mu_j)^2 / 2\sigma_j^2\right\}},\ i = 1, ..., m.$$

Here component i has mean μ_i, variance σ_i^2 with probability g_i. I_t is the indicator variable and ϕ_I the autocorrelation coefficient. The characteristics of regional price P_t will be assessed through the number of components (regimes) and distributional properties of individual regimes. We hypothesize that the post-CREZ regime has lower mean, higher variance and skewness.

Results

Rolling window estimates of linear correlation coefficients gradually increase over time, especially between the West and other three regions. This illustrates the transition process of regional electricity markets in ERCOT with the development of the CREZ project. Structural breaks are identified around March 2012 and May 2013. This is coincident with the time period when the large portion of the transmission lines of the CREZ project finished construction and started to put into use. So for the SVAR model estimation, we treat the period before March 2012 as the period before transition and that after May 2013 as the period after. The IRF and FEVD results based on the SVAR estimates well illustrate the transition and integration process of the ERCOT regional markets. With the transmission capacity in place, the West and Houston markets are well integrated and a much larger portion of the price variation in West/Houston market can be explained by the other compared to the period before the CREZ project was done.

Conclusions

Transmission infrastructure is critical for the future development of renewable energy. CREZ provides a good example. By connecting the regional ERCOT markets, it reduces prices in intensive demand areas, increases inter-regional trade and therefore significantly benefits local consumers and improves market efficiency. One side effect might be the increased price uncertainty and consequently higher costs of risk hedging and supply balancing by traditional fossil fuel generators.