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Market Efficiency and Market Power in Vietnam Competitive Generation Market

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ABSTRACT

Market efficiency and market power are two major aspects in studying any type of market. Most of researches concentrated on either market power or market inefficiency rather than two in combination. In this study, the Vietnam Competitive Generation Market which has been operated from 2012 as a platform for day ahead competitive trading of electricity in Vietnam is analyzed for market efficiency and market power analysis to determine market performance. From empirical testing, evidence of market inefficiency is found. In addition, market power is also revealed by studying of the bidding behaviour of the biggest generating company.

Keywords: Market Efficiency, Market Power, Vietnam Competitive Generation Market
JEL Classification: Q4

1. INTRODUCTION

The electricity industry in Vietnam is now over a century old. The open economy policy of the government in 1990s led to the consolidation of the industry in order to expand its output capability to match the high demand of economy. Total energy was 160GWh in 2016. The total installed capacity reached 40,000 MW while the demand reached maximum capacity of 28,000 MW. The power sector in Vietnam is currently going through restructuring which is a recent trend over the world. Figure 1 shows the road map of electricity reform approved by the Government of Vietnam in 1993.

According to the road map, the first stage of power market development in Vietnam, Vietnam Competitive Generation Market (VCGM) began on 1st July 2012. In this stage, the competition on generation was started by using a bidding mechanism. The bidding mechanism creates a merit order based on the cheapest to highest bidding price considering transmission losses and constraints where generating units are located. Energy is traded through an integrated pool. All generators sell electricity to the electricity of Vietnam (EVN) which is Single Buyer in the power market. EVN provides electricity to Power Companies (PCs) on the basis of the bulk supply tariff. The PCs supply power to the end users based on regulated uniform tariff set by the government.

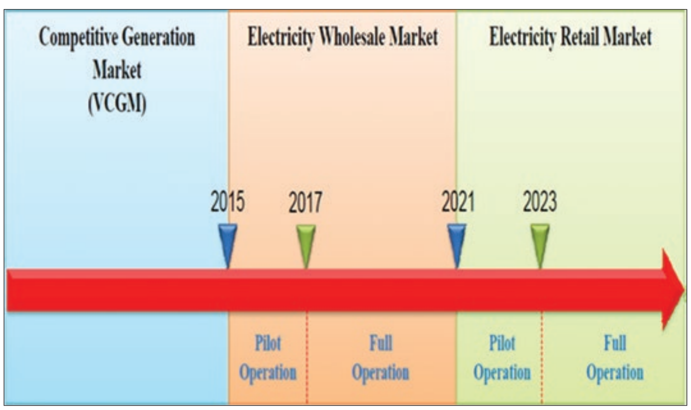
EVN is a state-owned vertical integrated utility in Vietnam that occupies 100% of transmission, distribution assets of Vietnam. On the generation side, EVN has around 55% of total system installed capacity. The rest belongs to independent producers. According to the road map of the electricity reform set by the government, the percentage of EVN generation assets would be reduced from time to time when the government gradually sells state-owned assets.

VCGM is a cost-based compulsory pool market where all electricity is traded through a day ahead market. Bidding revision during the trading day is not allowed. The day ahead bidding package of each generating unit includes five price-capacity range. The bidding price of one unit shall be lower than its cap price approved by the Regulatory Authority based on the short run marginal cost (SRMC) plus start up cost of the unit. The market settlement price is determined based on ex-post pricing mechanism on an hourly basis where cost to supply the last MW of electricity to meet the actual/metered demand without considering constraints of the generating units as well as transmission. Day ahead market price and hour ahead market price are indicative. The existence of contract for difference contract is to help both buyer and seller managing the risk of market price volatility (Marckhoff and Wimschulte 2009). The market price is set equal to the uniform marginal cost that does not take into account the transmission congestion. If the unit is dispatched based on the congestion at that time the offer price is higher than the market price, and the payment is made according to the offer price (constraint on payment).

Since it became fully operated from 1st July 2012, there have been many adjustments of market rules in order to improve the market performance. The VCGM explicitly causes many concerns about performance efficiency. The market price movements have indicated some abnormalities such as discreteness and deviations from SRMC of marginal units (vary from 600 VND/kWh to 1100 VND/kWh) and frequently fall to the floor price (0 VND/kWh). Actual market prices of VCGM from January 2013 to September 2014 are plotted in Figure 2.

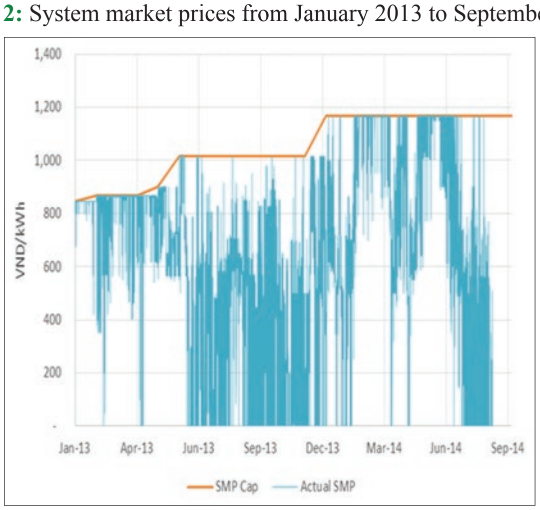
In this paper, an empirical analysis of the market data is used. Hourly market prices and the hourly bidding prices of all units of the biggest generating company in VCGM during 4 years from July 1st, 2012 are used to assess both the market efficiency and market power of VCGM. The outcomes from evaluating the actual market data are consistent with the market efficiency theory.

Figure 1: Vietnam road map for power market development



Source: Decision No. 63-2013- QD-TTd

Figure 2: System market prices from January 2013 to September 2014



Data source: EVN

2. CONTEXT OF THE RESEARCH

Market inefficiency and market power are often considered as the main cause of the problems experienced by many electricity markets (Borenstein and Bushnell, 1999; Brown and Olmstead, 2017; Baldick, 2016). A market is efficient when all the related information is fully and immediately reflected in market prices. In an efficient market, all market players are equally well–informed and control their bidding or offer strategies continuously to take advantageous opportunities. While the fundamental measure of market power is the price cost margin which measures the degree of how much the price exceeds the marginal cost. Market power is typically defined as the ability to profitably alter prices beyond competitive levels (Stoft, 2002; Pham, 2015). The price above marginal cost results in inefficient allocation because consumption would be too low in response to prices that are too high.

Research on market efficiency usually analyzes historical market prices in order to evaluate efficiency level. This indicates whether intervention activities from the market regulator to improve the market performance are effective or not. However, this kind of analysis does not provide alternative solutions to improve efficiency. In this case, an analysis of market power is required.

2.1. Efficiency Analysis

The efficient market hypothesis (FMH) is based on information availability (Fama, 1970). FMH proposes that when faced with new information, some investors may overreact and some may underreact. All that is required by the FMH is that investors' reactions be random and follow a normal distribution pattern so that the net effect on market prices cannot be reliably exploited to make an abnormal profit, especially when considering transaction costs including commissions and spreads(Fama, 1970).

According to Fama (1970), there are three different types of efficiency related to how efficient a market is in terms of information availability including weak-form efficiency, semi-strong-form efficiency and strong-form efficiency which are summarized in Table 1.

However, the strong form efficiency is somewhat impractical due to the limitations of private information in the real world.

2.2. Market Power Analysis

There are many methods of detecting market power in commodity markets. Unlike those markets, electricity markets have some distinctive characteristics to be considered as key aspects for market power measurement including market price reversion, the sudden fluctuation in consumption, fuel supply limitations, energy storage limitations and low elasticity in demand which is reflected in price spikes. In other markets, the concentration measures such as the Herfindahl-Hirschman Index (HHI) (Rhoades, 1993) are used. This was the first approach for detecting the potential market power. In the electricity market, the HHI measure is used to analyze power sector reform in many countries particularly the horizontal separation of generation. HHI is not perfectly suitable to investigate the market power in electricity market(Newberry, 2009). In recent years, many studies of market power monitoring

Table 1: Three forms of market efficiency (Fama, 1970)

Efficiency form	Explanation
Weak form efficiency	Market prices fully incorporates historical price movements in future one
Semi form efficiency	Market prices adjusted to publicly available new information rapidly and in an unbiased fashion, no excess returns can be earned by trading on that information
Strong form efficiency	Prices reflect all public and private information and no one can earn excess returns

have used two methods which seem to be the most suitable. Firstly, the residual supply index (RSI) (Sheffrin, 2002) which is a structural index in order to recognize the periods at which the generators exercise their market power is applied. Secondly, a more complex behavioural analysis is used typically based on real cost data or cost estimation, such as the price-cost mark-up (Hortacsu et al., 2017).

3. FRAMEWORK

3.1. Model 1: Market Efficiency Test

The methodology to analyse market efficiency in power markets follows related studies that focus on the market price movement of the power market. In order to determine a market which is efficient or not, the weak form should be first evaluated before other forms. This paper tests the weakest form of market efficiency called "weak form efficiency" according to Fama's efficiency forms (Fama, 1970). Specifically, a market is considered efficient when price changes follow a random walk model where future changes are independent of historical data. However, random walk theory only considers correlation in prices during different periods without considering the information availability or the transparency. It is only suitable to identify market efficiency in the weak form.

There are hypothesis tests to assess the random walk characteristics of a series but unit root tests are mainly used (Pham, 2015). Unit root tests identify whether a time series is stationary or non-stationary. A stationary test is used for evaluating the efficient market theory because it measures how data from different points in time depend on each other. In an electricity market, the weak market efficiency theory means that if market is weakly efficient, the future market prices cannot be predicted through analysis of historical market prices.

In this paper, the Augmented Dickey-Fuller (AFD) test is used for unit root tests (Glynn et al., 2007) where relationships among system marginal price (SMP) and day-ahead price are modelled by regression equations.

The AFD test requires the estimation of the following regression equation (Arciniegas et al., 2003):

$$\Delta P_t = \alpha+\beta_0 P_{t-1}+\sum\beta_1\Delta P_{t-1}+e_t \quad (1)$$

Where ΔP_t is the change in the electricity price at time t, P_{t-1} is the electricity price at time t−1, α and β_0 are the coefficients, e_t is residual.

Root tests are applied to the SMP, the day-ahead SMP. Moreover, the relationship between SMP and day-ahead SMP is also evaluated using co-integration analysis (Arciniegas et al., 2003). Two series are co-integrated if they grow at the same rate. In case of co-integration, market participants cannot make abnormal profits from day-ahead SMP data.

In order to test the relationship between the SMP and the day ahead SMP, two regressions using ordinary least squares method (Benoit, 2010) are used to test for bias:

$$SMP_t = C+\beta^*DASMP_{t-k}+e_t \quad (2)$$

$$SMP_t = C+\beta^*DASMP_{t-k}+e_t \quad (3)$$

Where:

- C is constant acting as intercept in linear regression.
- β is coefficient.
- e_t is random term at time t.
- SMP_t is actual spot price at time t.
- k is lag number determined by above lag determination section.

If the DASMP is a good predictor of SMP, the β coefficient will not be significantly different between equation 2 and 3.

3.2. Model 2: Market Power and Market Efficiency Test

The quantitative methodology based on historical market price data from VCGM and short run marginal unit costs as well as the bidding data of analysed firm is used in this paper. Firstly, RSI analysis will be implemented for the biggest generating company by using the hourly market prices, hourly market actual demands, hourly actual output of all other market generating companies. The result of RSI analysis will provide specific hours that the biggest generating company has market power. Secondly using actual SRMC, hourly bidding prices, declared capacity, actual available capacity and hourly metered energy for checking the real market power that the firm has actually exercised compared to the literature on market power in electricity (not including transmission congestion impacts). This analysis compares two results and evaluates the reliability of RSI in the VCGM.

4. RESULTS

4.1. Max-lag Determination

Outcomes obtained from AFD are sensitive to the choice of lag. Schwert's equation is to find maximum number of lag then specific number of lag is determined for selection using some criteria (Akaike information criterion, Schwarz information criterion) in order to optimize the AFD model.

Using the suggested formula from Schwert (Schwert, 2002), the maximum lag number is calculated as follows:

$$\text{Maxlag} = 12*\left(\frac{N}{100}\right)^{\frac{1}{4}} \quad (4)$$

Where N is number of observations.
With N = 26256, max-lag = 48.

4.2. Lag Determination

4.2.1. SMP series

Table 2 shows lags by periods. The full lag numbers are in Appendix 1. The number of lag is selected in such a way that criteria values are minimum.

Using LR, FPE, AIC, SC, HQ criteria to choose lag number for SMP series is selected lag number of 48 based on the principle that the lowest value is the most appropriate one (Table 3).

4.2.2. DASMP series

Similar to the SMP series, DASMP's lag number is selected of 48 based on the criterion of satisfying most indicators. The full lag numbers are shown in Appendix 2.

4.3. Testing for Stationarity

The ADF test is a common test for stationarity of time series because it can handle autoregressive time series which has an order higher than 1.

The null hypothesis is: H_0: The series is non-stationary.

The alternative hypothesis is: H_a (H_1): The series is stationary.

Both SMP and Day-ahead SMP are tested by intercept-no trend ADF.

4.3.1. SMP series

In this case, the P-value is less than all three significant levels. The Null hypothesis is rejected and the alternative hypothesis is accepted. This indicates that the SMP series is stationary, detailed in Table 4.

4.3.2. Day-ahead SMP (DASMP)

Based on the analysis applied for the SMP series, the day-ahead SMP series also is stationary according to Table 5.

4.4. Relationship between SMP and Day-ahead SMP

The following regressions using ordinary least squares method are used to test for bias:

$$SMP_t = C+\beta*DASMP_{t-k}+e_t \quad (5)$$

$$SMP_t\text{-}SMP_{t-k} = C+\beta*(DASMP_{t-k}\text{-}SMP_{t-k})+e_t \quad (6)$$

Where:
- C is constant acting as intercept in linear regression.
- β is coefficient.
- e_t is random term at time t.
- SMP_t is actual spot price at time t.
- k is lag number determined by above lag determination section.

If the DASMP is a good predictor of SMP, the β coefficient will not be significantly different between equation 5 and 6.

Table 6 indicates β coefficient in equation 5 (0.621754) is neatly double compared to that in equation 6 in Table 7 (0.310730). This indicates that DASMP is not a good estimation of SMP.

5. MARKET POWER ANALYSIS

Market power (Twomey et al., 2006; Stoft, 2002) is defined as the ability to profitably raise prices in the power market because perfectly completive markets are impractical. Every generator attempts to exercise market power whenever it is available. Nevertheless, based on market power theory, a large-scale generating unit has more impact on the market price compared to small-scale one. In this paper, largest generator (Phu My EVN complex) is tested.

Table 2: Brief description of lag determination on SMP series

Lag	LogL	LR	FPE	AIC	SC	HQ
0	−191146.3	NA	126635.4	14.58694	14.58726	14.58705
12	−164562.3	25.94821	16668.69	12.55916	12.56322	12.56047
24	−163127.8	68.43436	14953.99	12.45061	12.45841	12.45313
36	−162190.9	0.584158	13934.93	12.38003	12.39157	12.38376
48	−161834.2	70.61675*	13573.17*	12.35373*	12.36901*	12.35866*

*Indicates lag order selected by the criterion. LR: Sequential modified LR test statistic (each test at 5% level), FPE: Final prediction error, AIC: Akaike information criterion, SC: Schwarz information criterion, HQ: Hannan-Quinn information criterion

Table 3: Brief description of lag determination on DASMP series

Lag	LogL	LR	FPE	AIC	SC	HQ
0	−190083.5	NA	116769.6	14.50584	14.50615	14.50594
12	−169904.7	23.32750	25058.78	12.96686	12.97091	12.96817
24	−167812.6	367.4963	21380.66	12.80812	12.81592	12.81064
36	−166831.0	1.441162	19855.78	12.73413	12.74567	12.73785
48	−166471.6	208.7474*	19336.24*	12.70761*	12.72290*	12.71255*

*Indicates lag order selected by the criterion, LR: Sequential modified LR test statistic (each test at 5% level), FPE: Final prediction error, AIC: Akaike information criterion, SC: Schwarz information criterion, HQ: Hannan-Quinn information criterion

Table 4: Hypothesis test on SMP series

Null hypothesis: SMP has a unit root exogenous: Constant		
Lag length: 48 (automatic - based on AIC, max-lag=48)		
ADF test statistic	t-statistic	P*
Test critical values	−6.479239	0.0000
1% level	−3.430429	
5% level	−2.861459	
10% level	−2.566767	

*MacKinnon (1996) one-sided P values

Table 5: Hypothesis test on DASMP series

Null hypothesis: DASMP has a unit root		
Exogenous: Constant		
Lag length: 48 (automatic - based on AIC, max-lag=48)		
ADF test statistic	t-statistic	P*
Test critical values	−6.880209	0.0000
1% level	−3.430429	
5% level	−2.861459	
10% level	−2.566767	

*MacKinnon (1996) one-sided P values

Table 6: Regression statistic for equation 5

Dependent variable: SMP				
Method: Least squares				
Date: 11/23/15 time: 08:12				
Sample (adjusted): 49 26256				
Included observations: 26208 after adjustments				
Variable	Coefficient	Standard error	t-statistic	P
C	281.6295	3.633968	77.49918	0.0000
DASMP (−48)	0.621754	0.005156	120.5948	0.0000
R^2	0.356894	Mean dependent variable		664.8530
Adjusted R^2	0.356869	SD dependent variable		355.8519
SE of regression	285.3770	Akaike info criterion		14.14558
Sum squared residual	2.13E+09	Schwarz criterion		14.14620
Log likelihood	−185361.6	Hannan-Quinn criteria		14.14578
F-statistic	14543.10	Durbin-Watson stat		0.288833
Prob (F-statistic)	0.000000			

In the context of presence of vesting contract in VCGM, RSI is determined by the following equation (Sheffrin, 2002; Lin and Bitar, 2017).

$$\text{RSI} = \frac{\text{Total supply-Supply of largest seller}}{\text{Total demand}} \quad (7)$$

Where:

- Total supply: Total available capacity of all direct trading generators.
- Largest seller: Phu My power company consists of Phu My 1, Phu My 21, Phu My 4 power plants with total of 2400MW installed capacity. All units are Gas Combine Cycle using natural gas in southern Vietnam.
- Supply of largest seller: Largest seller's available capacity - contracted capacity.
- Total demand: Aggregated actual (metering) output of all direct trading generators.
- By calculating RSI of VCGM in all hours from 2012 to 2015, the number of hours which RSI lower than 110% are summarized I Table 8.

According to international experiences (Sheffrin, 2002; Asgari and Monsef, 2010), RSI must not be <110% for more than 5% of hours in a year (about 438 h). With a high contracted capacity (around 90%), the high possibility that market power exists in VCGM in 2014.

With the SMP setting methodology of VCGM, Phu My can exercise market power through bidding in two ways. Firstly, if it can manipulate the SMP, by raising at least the bidding price of the last band of the most expensive unit more than its SRMC. Secondly, it can do the same for any unit during the time those units are dispatched because of system congestion. If both bidding strategies succeed, Phu My would have much more benefit from raising the price because the dispatched production of all units are paid with the same SMP that is higher than the highest bidding price. In the second scenario, only the unit which has the bidding price higher SMP and was dispatched would be paid at this bidding price (pay as bid) and other unit's production would not be impacted.

Table 7: Regression statistic for equation 6

Dependent variable: SMP-SMP (−48)				
Method: Least squares				
Date: 11/23/15 time: 08:25				
Sample (adjusted): 49 26256				
Included observations: 26208 after adjustments				
Variable	Coefficient	Standard error	t-statistic	P
C	16.18522	1.619039	9.996808	0.0000
DASMP (−48) – SMP (−48)	0.310730	0.006171	50.35311	0.0000
R^2	0.088215	Mean dependent variable		1.619994
Adjusted R^2	0.088181	SD dependent variable		270.0693
SE of regression	257.8871	Akaike info criterion		13.94300
Sum squared residual	1.74E+09	Schwarz criterion		13.94362
Log likelihood	−182707.0	Hannan-Quinn criteria		13.94320
F-statistic	2535.436	Durbin-Watson stat		0.324941
Prob (F-statistic)	0.000000			

Table 8: Number of hours that RSI lower than 110% in VCGM

Year	2012 (half year)	2013	2014	2015 (half year)
Number of hours that RSI lower than 110%	220	318	1013	270

In this analysis, the action of raising the bidding price of the last band of the most expensive unit higher than SRMC is considered to impact the SMP and if that band is then dispatched and the SMP is equal to or higher than the bidding price, it is considered to be successful. By reviewing SRMC of the last band of bidding packages of all units during the sample time (35.000 h) in all hours from 2012 to 2015, with the constraint of RSI <110%, the number of hours that the maximum submitted bid prices are higher than the SRMC of the most expensive unit are clarified in Table 9 and also among those hour the number of hours Phu My succeed (the bidding price is lower than SMP) are showed in Table 10. The findings are that, 72.8% h Phu My submitted the highest bidding price higher than the SRMC of the most expensive unit and of which, 71.9% of times they succeed. In addition, in 2014 Phu My exercised market power only 65% of times but 94.2% of those times they did successfully. This result supports to the RSI theory because the more frequently that the VCGM capacity was scarcity the more chances for Phu My predicted the SMP better then they bided better.

During that time, at least 63% of hours that any generating unit from Phu My company successfully exercise its power to gain beneficial constraint-on payment (average price from constrain-on payment dominates SMP price), detailed in Table 11.

6. CONCLUSION AND RECOMMENDATION

The market power exercised by Phu My - the biggest market generator happened almost all of time that RSI <10% (72.8%) but less in the year during which RSI is <10% with the time of more than 5% (65%). This result can be explained that during the time of more serious system scarcity like 2014, the error of market demand forecast of Phu My is much higher compared with other periods. This made Phu My have a more conservative bidding strategy with the rate of successful bidding during this time higher compared with average level (94.2% vs. 71.9%). With the feature of a cost-based market like VCGM in which not any generator has the ability to exercise market power. The cap price of every generating unit regulated by the Regulatory Authority is also not high. The vesting contract coverage level is regulated at a high level (between 80% and 90% of overall energy production). The empirical findings demonstrate that the biggest generator tried to dominate SMP almost all of time they had a chance to consistent with the power market analysis in this section.

Because of market rules that regulate different cap prices for generating units with different SRMC, the Phu My company did achieve market power with the support of other generating companies with higher unit cap price. During those hours SMP were not always set by Phu My highest bidding price but by the higher bidding price of other companies. This finding demonstrates that smaller generating companies with higher SRMC may exercise market power during time of system capacity scarcity.

Table 9: Number of hours that RSI < 110, max bidding > max SRMC

Year	Hours
2012	220
2013	181
2014	659
2015	267
2016	0

Table 10: Number of hours that RSI<110, SMP>max bidding, max bidding>max SRMC

Year	Hours
2012	28
2013	39
2014	621
2015	267
2016	0

This paper demonstrates that the VCGM is inefficient because evidence from 35,000 sampling hours indicates that VCGM's efficiency is not demonstrated to be the weak form regarding to the Fama theory shown in Table 1.

From the findings, in order to improve the market performance of the VCGM, the recommendations are:

Firstly, the contract vesting mechanism that is set the same for all market companies should be changed into a varying vesting mechanism, depending on the total capacity of each generating company. The higher vesting levels should be set for companies having bigger capacity and the lower should be set for lower capacity size limits. This methodology would reduce the opportunity for big generating market company like Phu My to exercise market power.

Secondly in the longer term, the difference cap price mechanism that is set different for each generating unit should be changed into using one cap price for the whole market. This means the hybrid market design of VCGM now (combination of cost based model and price based model) should be changed into a pure price based model. This change would avoid the situation of company having lower capacity size but higher SRMC to exercise market power. It would also avoid the risk of regulatory intervention that may happen during the process of setting too many cap prices for all generating units in the market.

Lastly, all market information and the regulatory processes should be informed equally to all market participants to increase market efficiency with limit market power in the VCGM.

Table 11: Market power in terms of getting beneficial constraint-on payment

Unit	Number of hours with presence of Qcon and Rcon/Qcon>SRMP	Number of hours with precense of Qcon	Market power exercise-success rate (%)
GT11	4621	7072	65.34
GT12	4469	6810	65.62
GT13	4417	6992	63.17
GT21	5273	7926	66.53
GT22	5632	8356	67.40
GT24	5751	8413	68.36
GT25	5664	7933	71.40
GT41	4981	7825	63.65
GT42	4683	7144	65.55

REFERENCES

Arciniegas, I., Barrett, C., Marathe, A. (2003), Assessing the efficiency of US electricity markets. Utilities Policy, 11, 75-86.

Asgari, M.H., Monsef, H. (2010), Market power analysis for the Iranian electricity market. Energy Policy, 38, 5582-5599.

Baldick, R. (2016), Mitigate market power to improve market efficiency. Power Grid Operation in a Market Environment: Economic Efficiency and Risk Mitigation, 53, 43.

Benoit, K. (2010), Ordinary Least Squares Regression. Consultado Em, 5.

Borenstein, S., Bushnell, J. (1999), An empirical analysis of the potential for market power in California's electricity industry. The Journal of Industrial Economics, 47, 285-323.

Brown, D.P., Olmstead, D.E.H. (2017), Measuring market power and the efficiency of alberta's restructured electricity market: An energy-only market design. Canadian Journal of Economics/Revue Canadienne D'économique, 50, 838-870.

Fama, E.F. (1970), Efficient capital markets: A review of theory and empirical work. The Journal of Finance, 25, 383-417.

Glynn, J., Perera, N., Verma, R. (2007), Unit root tests and structural breaks: A survey with applications. Revista de Métodos Cuantitativos Para la Economía y la Empresa, 3, 63-79.

Hortacsu, A., Luco, F., Puller, S.L., Zhu, D. (2017), Does Strategic Ability Affect Efficiency? Evidence from Electricity Markets. NBER Working Paper No. 23526.

Lin, W., Bitar, E. (2017), A Structural Characterization of Market Power in Power Markets. IEEE Transactions on Network Science and Engineering, Under Review.

Marckhoff, J., Wimschulte, J. (2009), Locational price spreads and the pricing of contracts for difference: Evidence from the Nordic market. Energy Economics, 31, 257-268.

Newbery, D. (2009), Predicting Market Power in Wholesale Electricity Markets. EUI Working Papers No. RSCAS 2009/03.

Pham, T. (2015), Market power in power markets in Europe: The Cases in French and German woholesale electricity markets. Economics and Finances. Paris: Université Paris Dauphine.

Rhoades, S.A. (1993), The herfindahl-hirschman index. Federal Reserve Bulletin, 79, 188.

Schwert, G.W. (2002), Tests for unit roots: A Monte Carlo investigation. Journal of Business and Economic Statistics, 20, 5-17.

Sheffrin, A. (2002), Predicting Market Power Using the Residual Supply Index. In: FERC Market Monitoring Workshop, December. Available from: http://www.caiso.com/docs/2002/12/05/2002120508555221628.pdf.

Stoft, S. (2002), Power System Economics: Designing Market for Power. Piscataway. NJ: IEEE Press.

Twomey, P., Green, R.J., Neuhoff, K., Newbery, D. (2006), A Review of the Monitoring of Market Power the Possible Roles of Tsos in Monitoring for Market Power Issues in Congested Transmission Systems. Journal of Energy Literature 11(2), 3-54.

APPENDIXS

Appendix 1: Lag determination for SMP series

Lag	LogL	LR	FPE	AIC	SC	HQ
0	−191146.3	NA	126635.4	14.58694	14.58726	14.58705
1	−165043.2	52202.35	17277.22	12.59502	12.59564	12.59522
2	−165031.4	23.44107	17263.08	12.59420	12.59514	12.59450
3	−165014.3	34.22535	17241.87	12.59297	12.59422	12.59338
4	−164949.8	128.9998	17158.50	12.58813	12.58969	12.58863
5	−164904.3	90.90500	17100.38	12.58473	12.58660	12.58534
6	−164898.7	11.19601	17094.38	12.58438	12.58657	12.58509
7	−164892.1	13.18420	17087.08	12.58396	12.58645	12.58476
8	−164882.9	18.39664	17076.39	12.58333	12.58614	12.58424
9	−164840.2	85.46959	17022.07	12.58014	12.58326	12.58115
10	−164671.6	337.0134	16805.77	12.56735	12.57079	12.56846
11	−164575.3	192.6030	16683.94	12.56008	12.56382	12.56129
12	−164562.3	25.94821	16668.69	12.55916	12.56322	12.56047
13	−164560.5	3.511674	16667.73	12.55911	12.56347	12.56052
14	−164549.7	21.70657	16655.19	12.55835	12.56303	12.55987
15	−164505.6	88.10920	16600.53	12.55507	12.56006	12.55668
16	−164297.3	416.2227	16340.05	12.53925	12.54455	12.54096
17	−164167.2	260.0653	16179.83	12.52940	12.53501	12.53121
18	−163999.3	335.6152	15975.02	12.51666	12.52258	12.51857
19	−163905.1	188.2922	15861.78	12.50955	12.51578	12.51156
20	−163831.6	146.9073	15774.25	12.50401	12.51056	12.50613
21	−163594.2	474.3838	15492.24	12.48597	12.49283	12.48819
22	−163324.4	539.0214	15177.75	12.46546	12.47264	12.46778
23	−163162.1	324.4537	14991.98	12.45315	12.46063	12.45557
24	−163127.8	68.43436	14953.99	12.45061	12.45841	12.45313
25	−162307.0	1639.921	14047.15	12.38805	12.39616	12.39067
26	−162224.6	164.6632	13960.14	12.38184	12.39026	12.38456
27	−162199.9	49.43380	13934.87	12.38003	12.38876	12.38285
28	−162198.7	2.427250	13934.64	12.38001	12.38905	12.38293
29	−162198.6	0.008437	13935.70	12.38009	12.38944	12.38311
30	−162196.0	5.217272	13933.98	12.37996	12.38963	12.38309
31	−162192.8	6.540947	13931.57	12.37979	12.38977	12.38301
32	−162192.7	0.133358	13932.56	12.37986	12.39015	12.38318
33	−162192.7	0.008714	13933.62	12.37994	12.39054	12.38336
34	−162191.5	2.420441	13933.39	12.37992	12.39084	12.38345
35	−162191.2	0.515247	13934.18	12.37998	12.39120	12.38360
36	−162190.9	0.584158	13934.93	12.38003	12.39157	12.38376
37	−162188.8	4.306715	13933.70	12.37994	12.39179	12.38377
38	−162187.7	2.207849	13933.59	12.37993	12.39210	12.38386
39	−162187.0	1.370407	13933.92	12.37996	12.39243	12.38399
40	−162167.7	38.41006	13914.55	12.37857	12.39135	12.38270
41	−162134.9	65.64050	13880.74	12.37613	12.38923	12.38037
42	−162108.3	53.01008	13853.71	12.37419	12.38760	12.37852
43	−162103.3	10.11037	13849.41	12.37388	12.38760	12.37831
44	−162094.0	18.56409	13840.65	12.37324	12.38728	12.37777
45	−162037.7	112.2465	13782.44	12.36903	12.38337	12.37366
46	−161970.3	134.7022	13712.71	12.36396	12.37861	12.36869
47	−161869.6	200.9374	13608.82	12.35635	12.37132	12.36118
48	−161834.2	70.61675*	13573.17*	12.35373*	12.36901*	12.35866*

*Indicates lag order selected by the criterion, LR: Sequential modified LR test statistic (each test at 5% level), FPE: Final prediction error, AIC: Akaike information criterion, SC: Schwarz information criterion, HQ: Hannan-Quinn information criterion

Appendix 2: Lag determination for DASMP series

Lag	LogL	LR	FPE	AIC	SC	HQ
0	−190083.5	NA	116769.6	14.50584	14.50615	14.50594
1	−170413.3	39337.31	26028.68	13.00483	13.00545	13.00503
2	−170371.6	83.32656	25948.02	13.00173	13.00266	13.00203
3	−170366.8	9.770553	25940.33	13.00143	13.00268	13.00183
4	−170254.7	224.1497	25721.33	12.99295	12.99451	12.99346
5	−170165.7	177.9745	25549.17	12.98624	12.98811	12.98684
6	−170149.4	32.54858	25519.39	12.98507	12.98725	12.98578
7	−170121.0	56.69612	25466.17	12.98298	12.98548	12.98379
8	−170120.9	0.205965	25467.92	12.98305	12.98586	12.98396
9	−170086.3	69.28034	25402.60	12.98048	12.98360	12.98149
10	−169988.4	195.6735	25215.49	12.97309	12.97652	12.97420
11	−169916.4	143.9773	25079.19	12.96767	12.97141	12.96888
12	−169904.7	23.32750	25058.78	12.96686	12.97091	12.96817
13	−169896.1	17.19376	25044.25	12.96628	12.97064	12.96769
14	−169894.6	2.890606	25043.40	12.96624	12.97092	12.96775
15	−169869.9	49.47344	24998.04	12.96443	12.96942	12.96604
16	−169720.4	298.7527	24716.41	12.95310	12.95840	12.95481
17	−169472.1	496.2622	24254.33	12.93423	12.93984	12.93604
18	−169281.3	381.3917	23905.49	12.91974	12.92567	12.92165
19	−169197.8	166.9086	23755.43	12.91344	12.91968	12.91546
20	−169164.5	66.49451	23696.99	12.91098	12.91753	12.91310
21	−168883.0	562.4595	23195.19	12.88958	12.89644	12.89179
22	−168393.8	977.6529	22346.84	12.85232	12.85949	12.85463
23	−167996.5	793.7688	21681.22	12.82208	12.82956	12.82450
24	−167812.6	367.4963	21380.66	12.80812	12.81592	12.81064
25	−167131.6	1360.693	20299.43	12.75623	12.76433	12.75884
26	−166961.5	339.7593	20039.23	12.74332	12.75174	12.74604
27	−166881.4	160.0758	19918.59	12.73729	12.74602	12.74011
28	−166864.0	34.67245	19893.75	12.73604	12.74508	12.73896
29	−166861.2	5.768472	19890.88	12.73589	12.74525	12.73892
30	−166849.8	22.59367	19875.24	12.73511	12.74478	12.73823
31	−166842.2	15.18700	19865.23	12.73460	12.74458	12.73783
32	−166841.7	1.153874	19865.87	12.73464	12.74493	12.73796
33	−166839.3	4.781950	19863.75	12.73453	12.74513	12.73795
34	−166836.8	4.836134	19861.60	12.73442	12.74534	12.73795
35	−166831.7	10.22498	19855.36	12.73411	12.74533	12.73773
36	−166831.0	1.441162	19855.78	12.73413	12.74567	12.73785
37	−166826.0	10.00648	19849.70	12.73382	12.74567	12.73765
38	−166823.3	5.362924	19847.15	12.73369	12.74586	12.73762
39	−166822.9	0.864256	19848.01	12.73374	12.74621	12.73776
40	−166813.7	18.28319	19835.66	12.73311	12.74590	12.73724
41	−166796.1	35.25550	19810.46	12.73184	12.74494	12.73607
42	−166778.2	35.60170	19785.03	12.73056	12.74397	12.73489
43	−166772.5	11.40059	19777.92	12.73020	12.74392	12.73463
44	−166771.1	2.888483	19777.25	12.73016	12.74420	12.73470
45	−166731.9	78.31295	19719.64	12.72725	12.74159	12.73188
46	−166655.2	153.0643	19606.10	12.72147	12.73613	12.72621
47	−166576.1	157.8082	19489.67	12.71552	12.73049	12.72035
48	−166471.6	208.7474*	19336.24*	12.70761*	12.72290*	12.71255*

*Indicates lag order selected by the criterion, LR: Sequential modified LR test statistic (each test at 5% level), FPE: Final prediction error, AIC: Akaike information criterion, SC: Schwarz information criterion, HQ: Hannan-Quinn information criterion