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Article

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Provided in Cooperation with:
International Journal of Energy Economics and Policy (IJEEP)

Reference: Hakam, Dzikri Firmansyah (2018). Market power modelling in electricity market : a critical review. In: International Journal of Energy Economics and Policy 8 (5), S. 347 - 356.

International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2018, 8(5), 347-356.

Market Power Modelling in Electricity Market: A Critical Review

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ABSTRACT

This paper presents a critical review of market power modelling in the electricity market. This research provides a coherent guideline to determine suitable modelling for market power in electricity market. This research also includes market power index application in competition policy enforcement. An ideal market power index is one which provides the most straightforward number to measure the market power exercise. However, a more sophisticated approach is needed to mitigate market power since traditional indexes have limitations in representing the complexity of the power system. Cournot modelling has the main weakness in large-scale power system modelling with transmission constraint. However, the Cournot model continues to develop as a tool to analyse player behaviour due to the analytical connectivity between a real power market and microeconomic engineering theory, e.g. DC load flow, reserve margin, transmission constraint, forward contract, demand elasticity, and RSI.

Keywords: Market Power, Electricity Market, Competition Policy
JEL Classifications: D470, L160, L400

1. MARKET POWER AND DESIGN IN ELECTRICITY MARKET

Market power is defined as the ability to alter prices away from competitive levels (Stoft 2002; Mas-Colell and Whinston 1995, 383). The objective of the electricity operator is to secure demand whilst maintaining the efficient operation of the electricity system. However, market power has the capability to affect this goal adversely by withholding input, and thus leading to short-term supply shortages. Also, it could produce price signal distortion causing inaccurate generation dispatch and investment decision making. Market power is a major concern in electricity market restructuring. Wolak (2014) confirmed that a key lesson from decades of liberalisation or restructuring is that the prospect of costly market failure, often due to unilateral market power exercise, is much higher in the electricity industry than in other formerly regulated industries. As explained by Stoft (2002), there are incentives and opportunities to remove generation capacity from the market, through physical withholding (e.g. scheduling maintenance outages during peak demand or over-scheduling transmission lines to cause artificial congestion) or economic withholding (e.g. offering a high price to benefit the rest of the generation fleet or a financial position). The likely causes of market power exercise, as inferred by Joskow (2008), are the presence of transmission constraints, an excessive reliance on spot markets rather than forward contracts, the very low elasticity of demand, the lack of economical electricity storage, flaws in wholesale market design, exclusionary behaviour potentially arising from the vertical integration between transmission and generation, and limited demand participation in wholesale spot markets.

Electricity market design is a multi-stage process, where free-entry regulation and divestiture usually occurs as a step performed by electricity regulator to fix market failure that has occurred due to suboptimal electricity market design. As explained by Newbery (1998), entry in the UK duopoly electricity market has remained contestable and has reduced the market power of the network, with market power exercise itself caused by the inefficiencies of the generators and the non-competitive number of players. The highest market power decrease is more likely to occur in the change of market structure from monopoly to duopoly (Newbery, 1998). The larger the number of players in the market, the more

competitive the electricity market will be. However, it is unrealistic to design a competitive wholesale market where a large number of players exists, considering the unlikelihood in creating an atomic electricity market (Joskow and Tirole 2005). Although the creation of market monitoring agencies could minimise the market power exercise, market mitigation could lead to a generation investment signal reduction in the long run (Joskow and Tirole 2005). Wilson (2002) described methods to limit market power in the electricity industry by breaking up a vertically integrated company, hedging through contract implementation for monopsony market, and establishing re-regulation in a case where market power exercise is predicted to occur in the market as in the California case.

Market power studies focused on post restructuring when market power arose dominate market power research especially in US and UK electricity market (Joskow, 2001; Borenstein et al., 2002; Wolfram, 1999). The success of market restructuring in the electricity industry depends on how the market structure post restructuring affects market performance. A sound market design should provide sufficient competition for each type of power plant: Baseload, intermediate and peaking. Divestiture of the mid-merit power plant in the UK electricity market in 1994 is due to the lack of intermediate power plant competition. In contrast, nuclear power plants are considered competitive with other baseload power plants (Green 1996).

The objective of this research is to presents a critical review of market power modelling in electricity market and explores which market power index and modelling that suitable to represent the complexity of power system. This research expounds the advantages and disadvantages of market power indices and modelling. The main research contribution is to provide coherent guideline in market power assessment and assist policy makers in the modelling and mitigation of market power. This paper is structured into five sections as follows. Section 1 provides an overview of market power and market design in in electricity market. Section 2 explores the market power modelling in electricity market. Section 3 provides the list of market power indices in electricity market, including the traditional and sophisticated indices. Section 4 focuses on the implementation of market power index in competition policy enforcement. Finally, conclusion is provided in Section 5.

2. MARKET POWER MODELLING IN ELECTRICITY MARKET

There are numerous methods to represent electricity markets in a model. There are three types of electricity market modelling based on Ventosa et al. (2005) which are: (1) optimisation techniques for a single firm; (2) equilibrium models for multiple players in the market; and (3) simulation models. The optimisation models optimise a specific objective (usually profit) by considering specific techniques and economic constraints. The market price is exogenous if the market is in a perfect competition state. However, a firm can influence the market price in an imperfect market. Here, equilibrium models are considered the best techniques to analyse an electricity market with several players, especially in the imperfectly competitive market. Thus, the models have the capability to combine multiplayer behaviour. One difference with optimisation models, equilibrium models can address profit maximisation from multi players simultaneously. Simulation models are applied for more complex problems in the market, using specific rules and assumptions; thus, they represent multiplayer agent modelling. Among the equilibrium models reviewed here, the SFE model was determined as the most computationally demanding in comparison to other models (e.g. the Cournot and Bertrand models). However, the Cournot model continues to develop as a tool to analyse player behaviour due to the analytical connectivity between a real power market and microeconomic engineering theory, e.g. DC load flow, reserve margin, transmission constraint, forward contract, demand elasticity, and RSI.

In the restructured electricity market, GenCos submit their optimised strategic supply offer to maximise the profit. Thus, it is crucial to analyse the strategic behaviour of this bidding behaviour in an oligopoly market. Li et al. (2011) divided the bidding strategy analysis in the electricity spot market into four groups which are: Single player optimisation, game theory, agent-based and hybrid model. Single player optimisation could be modelled using a numerical programming, e.g. Mixed Integer, Non-Linear, and Dynamic Programming. In game theory, presenting a player's strategic behaviour consists of Bertrand, Cournot and SFE modelling. The agent-based model is categorised based on learning algorithms such as model-based adaptation, genetic, Q-learning, computational learning and Ant-Colony optimisation. There is a chance that the system does not dispatch the supply offer from a particular generation company due to the competitive behaviour of other players, uncertain demand and power system pressure from renewable energy entry. The detail of the model's representation in the supply behaviour is important since it needs to incorporate risks and constraints in the bidding and strategic behaviour.

The strategic interaction differentiation involving game theory and the industrial organisation concept, hence it depends on firm anticipation from other players regarding decisions on the price and quantities (Day et al. 2002). Day et al. (2002) classified the strategic interaction of firms into seven categories: (1) Pure competition/Bertrand: The decision variable of the firm is only of the quantity, and each firm simply accepts the fixed price. Hence, there is no market power in this strategic behaviour model (2) Generalised Bertrand strategy: Gaming in price, the strategic interaction is based on the price offered by the firm. (3) Cournot strategy: Gaming in quantity, the strategic interaction is based on the supply by the company. (4) Collusion: The strategic interaction is based on joint profit maximisation from colluding firms. (5) Stackelberg model: Defines a "leader" whose decision correctly takes into account the reaction of "followers", who do not recognise how their reactions affect the leader's decision. (6) Supply Function Equilibrium: The decision variable for each firm is the parameters of its bidding function. (7) General Conjectural Variations.

A monopoly is considered as the simplest example of market power where there is only one player (Mas-Colell and Michael, 1995). Monopoly is not efficient in producing output since the market price is above the marginal cost. Oligopoly is another type of market where there are a few players, thus involving strategic

interaction between firms and choosing a profit-maximising output for itself. Oligopoly price is low, while the output is high, compared to Monopoly. Oligopoly is a type of market where the interaction is between several players. Static Oligopoly models only consider one strategic action and ignore repeated interactions over time between firms. In the Cournot equilibrium, profit maximisation is derived by setting a firm's output. Hence, the market clearing price is a result of the output of the company and the competitors. The enterprise acknowledges the demand function before bidding the output to the market. Cournot produced a unique Nash equilibrium which is a straight outcome of price and quantity for a given demand function: The inefficiency in welfare maximisation also occurs in a Cournot market. The competitive industry is the industry that maximises utility minus cost while a monopoly only maximises profits. Thus, a Cournot market maximises these two objectives depending on the number of firms. If n increases, then more weight is given to the consumer surplus as compared to the producer surplus.

Transmission constraint lies at the heart of market power issues in a restructured electricity market. Borenstein et al. (2000) showed that a firm is less likely to have sufficient market power to increase electricity prices in the absence of transmission constraint, by implementing Cournot modelling for the California electricity market. The study concluded that transmission capacity expansion in an area suffering market power is significantly related to price decreases, energy consumption increases and deadweight losses minimisation. However, the model is a one-shot Nash equilibrium and could have different results with dynamic behaviour in the real market. Further, the model should provide a free entry in the dual market region, to replicate the competitive behaviour effect. Although the model only uses two markets to represent the complicated California electricity market, the analysis provides a broad insight into competitive behaviour with transmission constraints and social benefits provided by a transmission facility.

Another transmission-constrained Cournot study by Cunningham et al. (2002) evaluated three market players in a looped constrained network and a non-constant marginal cost. Dispatcher and power system planners have difficulties in performing Transmission Expansion Planning (TEP) since the strategic behaviour of the firm alters the electricity flow in the electrical system. Thus, it is crucial to implement specific congestion management protocols. The study by Cunningham et al. (2002) showed that transmission constraints could affect strategic behaviour although the non-constraint equilibrium flow is less than the network limit. Cournot competition in a constrained network implies the importance of power system matching strategy (Willems 2002). In cases where the consumer has low bargaining power, e.g. low demand elasticity, the dispatchers could conduct a competition for transmission capacity to increase market competitiveness. Willems (2002) suggested that the power system operator should not tax the congestion rent of the generator, which in this case will lead to the players adapting their strategic behaviour to the transmission congestion.

The main challenge in Cournot oligopoly market formulation is to model GenCos strategic behaviour incorporating the transmission constraint. There are two approaches in modelling generator strategic behaviour according to their nature of transmission charges. The first approach is to assume that all generators do not have the capability to influence transmission rent. As such, the firms behave naively to accept the locational transmission prices. In this case, GenCos behave a la Bertrand and naively behave as a transmission price taker. The market operator charges GenCos that utilise the same network service with equivalent marginal valuation. This approach results in a convex formulation and is easy to solve. Furthermore, it is considered realistic in the real complex power system. In contrast, the Bertrand approach assumes that each generator could influence the transmission charge, i.e., the generators have market power in transmission congestions and fees by performing congesting and de-congesting transmission lines in the electrical system through generation capacity withholding (Hobbs and Udi 2003). The first approach results in an Equilibrium Problem with Equilibrium Constraint, which leads to multiple equilibrium prices and profits and a non-convex problem. In contrast, the Bertrand approach leads to a more tractable analysis since the simulation has a single equilibrium result and a convex equation[1].

The Cournot model takes quantities as a firm's strategy while the Bertrand model of oligopoly takes price as a strategic variable. Assuming the products are homogeneous, and all companies have the same marginal cost, the competitive behaviour produces a condition where the price equals the marginal cost although there are only two players in the market. This is known as the Bertrand "paradox". The Bertrand model is a one-shot game and not standard practice in the real market. The Bertrand model could be considered as sealed competitive bidding where the player bid's the price once and then the game ends. Thus, the producer with the lowest bid gets the consumers. SFE has the capability to model the electricity market more realistically because SFE assumes the bidding-supply function from generator firms by incorporating demand uncertainty under an oligopoly market. Klemperer and Margaret (1989) performed the first study on this model while Green and Newbery (1992) applied the SFE model on England and Wales's electricity pool. The SFEs application by Green and Newbery (1992) showed that the equilibrium price is above marginal cost, which implies high markup and substantial deadweight loss in the market. Green (1996) utilised linear SFE with asymmetric firms to analyse competition in England and Wales Pools. He found that splitting up the dominants leads to deadweight loss reduction.

Berry et al. (1999) studied the strategic behaviour of generators using SFE with two nodes and four nodes networks. From the study, it was found that transmission constraint in the mesh network would increase the market price. The study also showed that divestiture action does not always increase the social welfare, even in the case of efficiency improvement. Genc and Reynolds (2011) incorporated the capacity constraint in the supply function in the global convex formulation. The research

1 See B. E. Hobbs (2001) and Tanaka (2009) for examples of the first approach, while B.F. Hobbs, Metzler, and Pang (2000), Borenstein, Bushnell, and Stoft (2000) and Cunningham, Baldick, and Baughman (2002) give insights on the second method.

finding provided an interlink between capacity production and sets of supply function equilibrium to show the unilateral effect from the pivotal player in the market due to power generation constraints from the rival players. Petoussis et al. (2013a, 2013b) analysed the parameterisation of firm behaviour in an Alternative Current (AC) SFE model. The SFE model assumed that the players could perform market power exercise through the gaming of supply bidding function, e.g. change in slope, intercept and supply-intercept. Petoussis et al. (2013a, 2013b) found that different parameterisation of supply bids resulted in a similar equilibrium point for non-congestion transmission lines. However, as the constrained transmission is at a low level, the intercept parameterisation deviates from other equilibriums. While in high level constrained transmission lines, the slope-intercept parameterisation is dissimilar from the rest of the supply bid parameters. Brandts et al. (2014) related the market power index (RSI) with SFE and the Multi-Unit Auction model by using a market power experiment to study supply function competition in the electricity market. This study provided evidence from a laboratory experiment on the effects of pivotal players in the electricity market and then linked the analysis of the experimental result to RSI as the market power index.

3. MARKET POWER INDICES IN ELECTRICITY MARKET

Market Share and HHI is a standard market power index. Market designers have applied these indexes to analyse market structure for many decades. It is a simple version of market power assessment since the formulation only requires sales or capacity data. A market share concentration ratio measures the supplier concentration in the market by dividing the producer share with the market share of the largest *n* companies in the industry. In the electricity market, firstly, several electricity market characteristics should be defined, e.g. energy production, energy plus reserve, short-term capacity and long-term capacity. The trigger level for market share is 20%. The difficulty of this index is in determining the appropriate geographic region, e.g. Small but Significant and Non-Transitory Increase in Price (SSNIP) test, and the Hub-and-Spoke test. The Market Share index also ignores many power system factors including demand side, strategic incentives and often congestion issues. Hence, an electricity market entails time dimension and geographical boundary differentiation (Newbery et al., 2004).

Two traditional approaches have been introduced based on the Market Share index. The first approach is SSNIP test while the second is the "hub and spoke" approach. The SSNIP test examines whether the price could increase if all of the generator firms in a specific area merged into a single company. The "Law of one price" defines a market as a geographic area where similar commodities are sold at the same price ignoring transmission losses. Introduced by the Federal Energy Regulatory Commission (FERC), the "Hub and Spoke" approach was where market size was defined as the total capacity controlled by the firm plus all of the utilities directly interconnected with that firm and ignoring transmission constraints. FERC introduced a trigger level of 20% of the market share. However, there are other cases where the thresholds lie above 20%, i.e., European case law and the Dutch Competition Company set the trigger level at 25% and 30%, respectively (Newbery et al., 2004).

The drawback of the Market Share index is that firms with the same market share could have different market power exercise depending on the characteristics of the market (e.g. the number of companies, the rank of companies in the market). HHI covers this issue by determining the sum of the squares market share of all companies in the market.

$$HHI = S_1^2 + S_2^2 + \ldots + S_i \qquad \text{Herfindahl-Hirschman Index} \quad (1)$$

Where *Si* is the market share percentage of firm *i*. If the trigger level for HHI is below 1,000, then the region is unconcentrated; if the HHI level is between 1,000 and 1,800 then the region is concentrated; thus, a HHI level higher than 1,800 will result in a highly concentrated region (Newbery et al., 2004; FTC and DOJ, 1992). The revision of the US Merger Guidelines revised the theoretical limit for market concentration: HHI below 1,500 for unconcentrated, HHI between 1,500 and 2,500 for concentrated, and above 2,500 for highly concentrated (Shapiro, 2010; FTC and DOJ, 2010).

Several market power studies on electricity markets applied HHI as a tool to mitigate market competitiveness, e.g. Küpper et al. (2008) in the Belgian market; Hellmer and Linda (2009) in the Nordic market; Asgari and Monsef (2010) in the Iranian market; Shukla and Ashok (2011) in the India electricity market. These studies acknowledged the limitation of HHI in its static behaviour in measuring market power. Therefore, these mitigation studies incorporated other tools, e.g. the pivotal supplier index (PSI), LI and RSI. The critic of the HHI application is the reliability for measuring dynamic markets such as electricity market. HHI ignores the transmission flow, cable constraint, and forward contract, yet these factors affect market concentration. The primary drawback of HHI, and also market share, is that a firm with a small market share of <10% could perform market power exercise and become pivotal, i.e., in peak load conditions. During the California crisis, no company in the market owned a market share of more than 20% (Sheffrin 2001). Thus, other methods such as PSI and RSI take place to mitigate real-time activities.

Electricity market monitoring agencies still apply a traditional market index to measure the competitiveness of electricity markets, i.e., application of HHI in the New England Independent System Operator (NEISO) market monitoring reports.[2] According to NEISO (2016, 23), the result of structural competitiveness analysis in New England is that the system-wide concentration remains low, i.e., the HHIs for the past nine seasons ranged from 706 in Winter 2014 to 835 in Winter 2016, although NEISO acknowledged in their report that market power still exists during certain system condition. Therefore, NEISO applies a set of mitigation rules[3] to

2 See http://www.iso-ne.com/static-assets/documents/2016/05/q1_winter_2016_qmr_final.pdf for the latest quarterly NEISO report.

3 In the quarterly report, NEISO did not explain further regarding this suite of mitigating rules.

mitigate the effect of market power exercise in the spot and forward market. Modelling electricity market using classical market power index, i.e., HHI, will not fully describing the real interaction of a power system. Thus, a reliable market power index must be applied to model the uniqueness of electricty market.

The PSI incorporates not only supply capacity but also demand conditions, thus overcoming the drawback in market supply and HHI. Here, the firm is considered as pivotal if the index is one, where the GenCo is dispatched to meet the total demand. Otherwise, the generation system is at a shortage condition. However, if the firm is considered as non-pivotal if the index is zero, electricity demand could be satisfied using the output from other generators alone. Binary value determination in the PSI from each hour then aggregated in a particular period is used to calculate time percentage where the firm is pivotal:

$$PSI=I(Q-K^T+K_i) \qquad \text{PSI function} \qquad (2)$$

Q= electricity demand; is metred load plus purchased ancillary services
K_i= generation capacity minus contract obligation of firm
K^T= total generation capacity in the market plus total net imports

RSI is an equivalent concept to the PSI, but rather than using a binary scale, RSI uses a continuous scale. Thus, the continuous scale application overcomes the critique in the PSI, i.e., the company that has market power exercise ability, but is not pivotal:

$$r_i = \frac{k^T - k_i}{Q} \qquad \text{RSI function} \qquad (3)$$

When RSI is >100%, the firm has little influence on the market. On the contrary, if RSI is <100%, the firm generation output is needed to satisfy the demand, and therefore, firm is categorised as a pivotal player in the market. The PSI is the indicator function applied to 1 minus the RSI:

$$\begin{aligned} PSI_i &= I\left(Q - k^T - k_i\right) \\ &= I\left(1 - \frac{k^T - k_i}{Q}\right) = I(1 - r_i) \end{aligned} \qquad \text{Relationship between RSI and PSI function} \qquad (4)$$

The traditional measure of market power is HHI, but the index is not suitable for electricity markets with low elasticity demand. Thus, RSI is considered a more reliable market power index in the wholesale electricity market, especially in the California electricity market (Sheffrin 2001, 2002; Rahimi and Anjali 2003) and Europe (London Economics 2007; Newbery 2009; Swinand et al., 2010). CAISO developed the RSI method and demonstrated the linkage between hourly RSI with PCM. Sheffrin (2001) showed that RSI averaged at 120% followed by a nearly competitive market price benchmark. RSI could also be utilised to find the advantages in TEP, i.e., the power import using transmission lines caused RSI to increase and the market price to reduce. Also, the power system operator could test the reserve margin level to meet the competitive market condition. The rule regarding RSI based on Sheffrin (2002) is to make sure that RSI is <120% for more than 5% of the hours in a year, and vice versa.

The EU Commission DG Competition conducted a competition and market power study on the EU electricity market in 2005-2007 on six of the EU's big electricity markets covering Belgium, France, Germany, the Netherlands, Spain and the UK. Published by London Economics (2007), the study used regression analysis and showed the relationship between market structure and market outcomes, which permitted the empirical examination of the market power of the largest company in the network. This showed that the largest company in the network played a significant role in determining price in the EU electricity market. The study also suggested that ex-ante competition analysis in the electricity sector, e.g. merger and acquisition and divestiture effects, could apply RSI as the market power index. Newbery (2009) extended the London Economics (2007) study by including forward contracting and capacity constraints on the Cournot model, then re-derived the formulation and found that the model is more suitable for electricity markets with a single pivotal player (Dutch power system). However, the model seems to fit markets with more than one pivotal player (German and Spain). Thus, expanding the model to include more than one pivotal player was suggested.

RSI is evolving as a suitable and reliable market power index in European countries. Using ex-post data in the ex-ante analysis, Mulder and Lambert (2013) performed competition to study the Dutch electricity market on the effect of the firm level (merger and acquisition, changing generation portfolio), market-integration events (market coupling and netting) and demand events on competition levels by using the decomposition method of RSI. Since there are no merger and acquisition events in the Dutch electricity market during the period 2006-2011, the firm-level events did not significantly influence the competition level in the market. Also, in that period, there were relatively low changes in the generation portfolio. Market integration events, e.g. market coupling and netting, seems to have had a similar impact on the competition level with generation or transmission expansion events. Moreover, the change in residual demand due to the European economic crisis influenced the number of pivotal generation companies in the region. Hence, demand events are as equally important as market integration events.

A similar approach in ex-ante analysis considering transmission constraint, the so-called transmission-constrained residual supply index, was studied by Lee et al. (2011). The study argued that basic RSI formula ignored the influence of transmission constraint. As such, it is not suitable for electricity market modelling considering the existence of locational marginal prices with transmission constraints. Thus, an ad-hoc market power analysis for each power plant incorporating simple linear programming was conducted to measure the extent of generation supply to meet demand with transmission congestion. The linear programming function is to minimise the market power by maximizing R_F. The index is calculated hourly only during peak periods since transmission congestions primarily arise during peak demand times. The

TRSI is useful in analysing bottleneck transmission line points. Thus, TRSI application is helpful for power system planners to perform TEP.

4. MARKET POWER INDEX APPLICATION IN COMPETITION POLICY ENFORCEMENT

Anticompetitive mergers are different from other anti-competitive actions such as cartel and collusion. Analysing anticompetitive mergers requires ex-ante method rather than ex-post method. Merger Guidelines should forecast the merger activity and analyse the impact on the market price if a merger proposal is allowed. The fundamental problem with an anticompetitive merger is that the market price increases and consumer welfare decrease due to the output reduction from combining companies. The non-merging players respond to this action by increasing their production. The system could not avoid the adverse effects since the dispatch growth has weaker effects than output reduction, therefore the horizontal merger does not create synergies raising the price (Farrell and Shapiro 1990). However, Farrell and Shapiro (1990) showed that the traditional merger analysis under HHI could be misleading.

The US Department of Justice (DOJ) analyses merger cases based on the framework derived from the 2010 Horizontal Merger Guidelines (HMG). According to the DOJ, the primary goals of the 2010 HMG is "…to help the agencies identify and challenge competitively harmful mergers while avoiding unnecessary interference with mergers that either are competitively beneficial or likely will have no competitive impact on the marketplace"[4]. The HMG defines two types of merger effects in competition policy (FTC and DOJ 2010), i.e., coordinated and unilateral effect. The coordinated effect occurred due to firms in the industry performing a merger by engaging some coordination in increasing price and decrease competition. In contrast, the unilateral effect resulted from the merger process without coordination between firms in the industry. The DOJ determined the anticompetitive effects by analysing the post-merger concentration and applying HHI as market power index.[5] A Higher HHI of post-merger indicates a higher concentration in the market structure which more likely lead to anticompetitive effects.[6]

The Horizontal Merger Guidelines (HMG) year 2010 has different approaches in analysing the merger process compare to the HMG year 1992 (See FTC and DOJ (1992, 2010)). The 2010 guidelines use a variety of tools, instead of a single method, in analysing competition. The 2010 guidelines also introduced an "Evidence of Adverse Competitive Effects" section where the agencies discussed the source of evidence that is informative in predicting the merger effects on competition. The 2010 guidelines expanded the discussion on unilateral and coordinated effects, and provided a discussion on agencies evaluation on determining the degree of market power where entry is considered easy (FTC and DOJ 2010; Shapiro 2010). The 2010 guideline also updated the concentration threshold that determined what level of market power index agencies should use to conduct an investigation (FTC and DOJ 2010). Merger guidelines in HMG 1982 was applied by establishing rules on post-merger and Delta HHI thresholds. The revision of section 5 of the Merger Guidelines in 2010 stated that Market Participants, Market Shares and Market Concentration retain the usage of the HHI threshold (Shapiro 2010).

An antitrust agency, i.e., the DOJ, has several key considerations for analysing the competitiveness of merger action in electricity generation markets. First criteria are market boundaries/definitions which are determined by the power system network and geographical limitations. The way for antitrust agencies to define a relevant geographic market and power system boundaries affects the nominal of generation and demand faced by particular GenCos. For example, in the case of the proposed acquisition of PSEG by Exelon in 2006, the post-merger company would account for more than 35% in the area of central and eastern Pennsylvania, New Jersey, Delaware, the District of Columbia, and parts of Columbia (PJM Central/East). In another area, i.e., Northern New Jersey and Philadelphia areas (PJM East), the post-merger Company would account for more than 45% of the total generating system of this area. It is important to note that the PJM power system network,[7] i.e., the transmission network and congestions[8] of PJM, determined the market boundaries and definition.

The PJM East boundaries are defined by the "Eastern Interface" which is identified by five extra high voltage (EHV) transmission lines that separate the New Jersey and Philadelphia subsystem from the main PJM power system. Any congestion in the "Eastern Interface" in peak load condition will result in PJM dispatchers to generate electricity from power plants in the PJM East area, thus resulting in higher electricity prices in the East compared to the west of the interface. In contrast, PJM Central/East boundaries are characterised by two EHV transmission lines from western and central Pennsylvania. The two major transmission lines separate the PJM Central/East from the PJM main power system. If congested, the PJM will call for additional generation from the East area of the interface, thus resulting in higher electricity prices in the East area of the interface compared to the West area.

The power system is developed according to transmission and generation expansion planning. The development of a transmission

4 Press Release, Department of Justice (Aug. 19, 2010). Available at https://www.justice.gov/sites/default/files/atr/legacy/2010/08/19/261642.pdf.

5 Although market concentration is considered as a traditional measurement in calculating market power index, market concentration is a trivial and useful indicator as a preview in analysing the market structure.

6 FTC and DOJ (2010, 19) expressly states that "The higher the post-merger HHI and the increase in the HHI, the greater are the Agencies' potential competitive concerns and the greater is the likelihood that the Agencies will request additional information to conduct their analysis".

7 PJM is the largest transmission grid operator in the United States that providing electricity to approximately more than 51 million people (year 2006) in PJM interconnection area (Federal Register 2006).

8 For a detailed explanation see (Federal Register 2006). Interregional data map of PJM could be seen at http://www.pjm.com/markets-and-operations/interregional-map.aspx. Power system operation of PJM including power transfer and limit could be seen at http://www.pjm.com/pub/operations/reactive-transfers/2016-flows.xls.

network, i.e., building and upgrading transmission lines, eliminates transmission congestion and reduces the constrained area. In the case of the proposed acquisition of Constellation Energy Group, Inc. by Exelon in 2011, the DOJ defined PJM Mid-Atlantic North as a constrained area bounded by the Keystone-Juniata 5004 and the Conemaugh-Juniata 5005 transmission line. PJM Mid-Atlantic North is a constrained area that includes the populated areas of eastern Pennsylvania, eastern Maryland, Delaware, and the District of Columbia. A second constrained area is PJM Mid-Atlantic South that includes eastern Pennsylvania, eastern Maryland, District of Columbia, Delaware and Virginia. The power system interface affecting PJM Mid-Atlantic South is the AP South Interface which includes Mt. Storm - Doubs 512 line, the Mt. Storm - Meadowbrook line, Mt. Storm - Valley 550 line, and the Greenland Gap - Meadowbrook 540 line (Federal Register 2011). Thus, based on Section 7 of the Clayton Act,[9] the DOJ defines PJM Mid-Atlantic North and PJM Mid-Atlantic South as a relevant geographic market.

The second criteria is the nominal of HHI post-merger to determine market concentration. In PJM East, the Exelon and PSEG merger case in 2006 would yield a post-merger HHI more than 2,700 with delta HHI more than 1,100. In PJM Central/East, the post-merger HHI is approximately 2,100 with Delta HHI approximately 800. According to the US Merger Guidelines 1992, post-merger of more than 1,800 with Delta HHI more than 100 indicates the urgency of investigation from antitrust agencies. In another merger case in 2011, the post-merger company of Exelon and Constellation had a post-merger of HHI of 1,600 with an increase in HHI of almost 400 in PJM Mid-Atlantic North.[10] In the PJM Mid-Atlantic South post-merger company,[11] HHI was 1,800 with Delta HHI approximately 250. According to the revised Merger Guidelines 2010, the HHI post-merger between 1,500 and 2,500 with Delta HHI above 100 potentially raises significant competitive concerns and often warrant scrutiny (FTC and DOJ 2010).

Table 1 shows the threshold of market concentration using HHI applied by the European Commission (EC Merger Guidelines) and US Antitrust agencies (US HMG).

The third consideration of antitrust agencies in analysing anticompetitive behaviour in the power generation market is the post-merger power generation system/portfolio.[12] Post-merger generation system/portfolio refers to the balance of ownership in generation technologies, i.e., peaking, intermediate and baseload Power Plant. A GenCo could have a tolerable market power calculated from the total installed capacity but have high-level market power in a particular generation technology, for example, a GenCo A with a generation capacity of 1,000 MW peaking power plant. Total power plant capacity in the power system is 10,000 MW, consisting of 1,000 MW peaking PP, 3,000 MW intermediate PP, and 6,000 MW baseload PP. From a total generation perspective, GenCo A only has 10% of market share. However, from the peak load system perspective, GenCo A has 100% of market share that gives the company the ability to raise electricity prices under peak load conditions.

Looking at the Exelon and PSEG merger case in 2006, the DOJ concluded that there are anticompetitive effects in the merger action by analysing the post-merger generation portfolios. The merger action increased the market share of mid-merit and peaking capacity. Thus, Exelon could increase the electricity price by bidding high auctions to the PJM so that PJM would not call the bid which resulted in a higher market clearing price. The merger action also increased the market share of baseload and mid-merit capacity in PJM East and PJM Central/East. The post-merger GenCo could withhold the output of baseload PP and then raise the market clearing price (Federal Register 2006). The DOJ also concluded the existence of anticompetitive effects in the Exelon and Constellation merger in 2011 by examining the ability of the post-merger company to raise the price by withholding the output of high cost and low cost generating unit in PJM Mid-Atlantic North and PJM Mid-Atlantic South (Federal Register 2011).

The DOJ concluded that the merger between Exelon and PSEG conducted on December 20, 2004, and between Exelon and Constellation on April 28, 2011, would substantially lessen competition in violation of Section 7 of the Clayton Act, 14 U.S.C. 18. Therefore, the proposed final judgement of Exelon-PSEG and Exelon-Constellation merger was to order the divestiture of assets[13] within 150 days after the merger transaction. The divestiture of mid-merit and peaking PP as a proposed judgement in the Exelon-PSEG merger reduced the market concentration of the post-merger company from 49% to 32% in PJM East, and from 40% to 29% in PJM Central/East. After the divestiture, the generation capacity of Exelon still provides an incentive to exercise market by withholding output especially from low-cost PP, i.e., Nuclear PP. However, the divestiture of six units of mid-merit and peaking PP substantially limits Exelon's ability to withhold output (Federal Register 2006). In the Exelon-Constellation merger case, although the proposed final judgement ordered the post-merger company to divest the three baseload PP, this does not merely restore the market share and HHI to the merger level. However, the divestiture assures that the merger is not likely to lead to consumer detriment (Federal Register 2011).

9 Section 7 application of the Clayton Act requires a determination of definition in the product and geographic dimensions of the relevant market.

10 Exelon owns 18% of the total generating capacity in the PJM Mid-Atlantic North subsystem while Constellation owns 100% of the total power generation in the PJM Mid-Atlantic North subsystem.

11 The total generation capacity of Exelon in the PJM Mid-Atlantic South subsystem is approximately 14% while Constellation accounts for 9% of the PJM Mid-Atlantic South total generation.

12 Except one or more of the following factors present (European Commission 2004): 1. A potential/recent entrant with a small market share; 2. Merging parties are important not reflected in market share; 3. Significant cross-shareholdings; 4. Merging firms are maverick firms; 5. Past or on-going coordination; 6. One of the merging parties has 50% or more pre-merger market share.

13 Many scholars also expressly emphasise the importance of generation system/portfolio related to the ability of a generation company to raise the electricity price, e.g. (Green 1996; Wolfram 1999; Green and Newbery 1992) in England and Wales Market, (Diaconu, Oprescu, and Pittman 2009) in Romanian electricity market, and (Tanaka 2009; Pollitt 2004; Arellano 2003) in the Chilean electricity market. However, these studies were more focused in the post-divestiture of GenCo.

Table 1: EC and US Merger Guidelines applying HHI threshold

Guidelines	HHI Post merger	ΔHHI	Analysis
EC Merger Guidelines	HHI_{post}<1000		Unlikely to identify horizontal competition concerns. Does not require extensive analysis.
	1000<HHI_{post}<2000	ΔHHI<250	Unlikely to identify horizontal competition concerns.[12]
	HHI_{post}<2000	ΔHHI<150	
	HHI_{post}<2000	ΔHHI<250	Investigation required.
US 1992 HMG	HHIpost<1000		Mergers are unlikely to have adverse competitive effects.
	1000<HHI_{post}<1800	ΔHHI<100	Requires no further analysis.
	1000<HHIpost<1800	ΔHHI<100	Potentially raises significant competitive concerns.
	HHI_{post}>1800	ΔHHI<50	Mergers are unlikely to have adverse competitive effects. Ordinarily requires no further analysis.
	HHI_{post}>1800	50<ΔHHI<100	Potentially raises significant competitive concerns.
	HHI_{post}>1800	ΔHHI<100	Likely to create market power or facilitate market power exercise.
US 2010 HMG	HHI_{post}>1800	ΔHHI<100	Mergers are unlikely to have adverse competitive effects.
	1500<HHI_{post}<2500		Ordinarily requires no further analysis.
	1500<HHI_{post}<2500	ΔHHI<100	Potentially raises significant competitive concerns and often warrants scrutiny.
	HHI_{post}>2500	ΔHHI<100	Mergers are unlikely to have adverse competitive effects. Ordinarily requires no further analysis.
	HHI_{post}>2500	100<ΔHHI<200	Potentially raises significant competitive concerns and often warrants scrutiny.
	HHI_{post}>2500	ΔHHI<200	Likely to enhance market power.

Source: FTC., DOJ. (1992), Horizontal Merger Guidelines, FTC., DOJ. (2010), Horizontal Merger Guidelines, European Commission (2004)

5. CONCLUSIONS

The success of electricity market design depends not only on our understanding of the general principle of economics but also on how we apply the knowledge in microeconomic engineering. The economists' role is not only to analyse the market but also to design them. However, instead of enforcing the competition legislation and institutions, it is not often that politicians and lawyers take the first step in designing the market and are deeply involved in the market creation. The electricity market is one example of a market where economists play a major role in the market model, apart from designing labour clearinghouses and auctions (Roth 2002). In the context of the electricity market, economists need to consider the electricity market structure and the complications in detail, and not just the principal features, to achieve optimal configuration and maximum welfare for society. Therefore, an engineering insight is substantial rather than incorporating simple conceptual models into the specific working of the market.

Electricity market modellers widely use the Cournot setting due to its tractability and compatibility with power system characteristics, e.g. generation and transmission constraints, voltage and stability condition, generation ramp-up and ramp-down, contingency analysis and commodity flow PTDF. It is convenient to incorporate forward contracting to a large scale Cournot power system. Forward contracting reduces the ability of pivotal players to exercise market power (Willems, 2002). Thus, forward contracting could help the model to become more realistic (Willems et al., 2009). The criticism regarding Cournot modelling is that the model is relatively inaccurate in representing the electricity market due to the high value of demand elasticity. On the one hand, in an electricity industry where the elasticity demand is relatively inelastic, the equilibrium price is too high and the output is too low. On the other hand, SFE modelling also contains weaknesses since the model could produce several market equilibriums, which is relatively difficult to calculate compared to Cournot modelling, which needs simplification in the market structures. Thus, in the end, the analysis of the electricity market should provide a tractable analysis which Cournot model is the most suitable for applying in the electricity market.

Electricity market designers have learned from two-decades of experience that one of the most significant problems in the wholesale electricity market post-restructuring process is the so-called market power which is the capability of the successor companies (companies exist after restructuration) to increase the price above the market price. It is not possible to eliminate market power completely since market power brings positive investment signals to investors. However, market power could be mitigated and assessed using a specific method. Market power assessment is a significant effort to avoid the adverse effects from generating firm strategic action. Hence, it could detect and prevent excessive deviations of prices from competitive levels. Also, it has the capability to guide market design choice. An ideal market power index is one which provides the most straightforward number to measure the market power exercise. However, a more sophisticated approach is needed to mitigate market power since traditional indexes have limitations in representing the complexity of the power system. Economist tends to minimise market power ex-ante rather than ex-post by using market power indexes such as the Price Cost Markup (PCM), Lerner Index (LI) or RSI, i.e., forecasting how the divestiture and merger action could affect the market price and using the analysis to make a decision.

6. ACKNOWLEDGMENT

The author acknowledged the support from Indonesia Endowment Fund for Education (LPDP).

REFERENCES

Arellano, MS. (2003), Diagnosing and Mitigating Market Power in Chile's Electricity Industry. WP. MIT. Cambridge, United States. p3-10.

Asgari, M.H., Monsef, H. (2010), Market power analysis for the Iranian electricity market. Energy Policy, 38(10), 5582-5599.

Berry, C.A., Benjamin, H., William, A.M., Richard, P.O.N., William, R.S. (1999), Understanding how market power can arise in network competition : A game theoretic approach. Utilities Policy, 8(1999), 139-158.

Borenstein, S., James, B., Frank, A.W. (2002), Measuring market inefficiencies in californisa's restructured wholesale electricity market. The American Economic Review, 92(5), 1376-1405.

Borenstein, S., James, B., Steven, S. (2000), The competitive effects of transmission capacity in a deregulated electricity industry. The RAND Journal of Economics, 31(2), 294-325.

Brandts, J., Stanley, S.R., Arthur, S. (2014), Pivotal suppliers and market power in experimental supply function competition. Economic Journal, 124(579), 887-916.

Cunningham, L.B., Ross, B., Martin, L.B. (2002), An empirical study of applied game theory: Transmission constrained cournot behavior. IEEE Transactions on Power Systems, 17(1), 166-172.

Day, C.J., Benjamin, H., Senior, M., Jong-shi, P. (2002), Oligopolistic competition in power networks : A conjectured supply function approach. IEEE Transactions on Power Systems, 17(3), 597-607.

Diaconu, O., Gheorghe, O., Russell, P. (2009), Electricity reform in romania. Utilities Policy, 17(1), 114-124.

Economics. (2007), Structure and Performance of Six European Wholesale Electricity Markets in 2003, 2004 and Structure and Performance of Six European Wholesale Electricity Markets in 2003, 2004 and 2005 : Cross Country Comparison and Conclusions. Global Energy Decision. London.

European Commission. (2004), Guidelines on the Assessment of Horizontal Mergers under the Council Regulation on the Control of Concentrations between Undertakings. Official Journal of the European Union. p5-18.

Farrell, J., Carl, S. (1990), Horizontal mergers: An equilibrium analysis. The American Economic Review, 80, 107-26.

Federal Register. (2006), United States of America v. Exelon Corporation and Public Service Enterprise Group Incorporated; Proposed Final Judgment and Competitive Impact Statement. Vol. 78. Washington DC, USA: Department of Justice, Antitrust Division.

Federal Register. (2011), United States v. Exelon Corporation; Proposed Final Judgement and Competitive Impact Statement. Vol. 76. Washington DC, USA: Department of Justice, Antitrust Division.

FTC., DOJ. (1992), Horizontal Merger Guidelines.

FTC., DOJ. (2010), Horizontal Merger Guidelines.

Genc, T.S., Stanley, S.R. (2011), Supply function equilibria with capacity constraints and pivotal suppliers. International Journal of Industrial Organization, 29(4), 432-442.

Green, R. (1996), Increasing competition in the British electricity spot market. The Journal of Industrial Economics, XLIV(2), 205-216.

Green, R., David, N. (1992), Competition in the British electricity spot market. Journal of Political Economy, 100(5), 929-953.

Hellmer, S., Linda, W. (2009), On the evaluation of market power and market dominance-the nordic electricity market. Energy Policy, 37(8), 3235-3241.

Hobbs, B., Udi, H. (2003), Complementarity-based equilibrium modeling for electric power markets. In: Bunn,D.W., editor. Modeling Prices in Competitive Electricity Markets. Vol. 32. London, UK: J.Wiley. p54–55.

Horizontal Merger Guidelines. (1992), U.S. Departement of Justice and Federal Trade Commission. April 2, 1992.

Horizontal Merger Guidelines. (2010), U.S. Departement of Justice and Federal Trade Commission. August 19, 2010.

Joskow, P. (2001), California's electricity crisis. Oxford Review of Economic Policy, 17(3), 365-388.

Joskow, P. (2008), Lessons learned from electricity market liberalization. The Energy Journal, 2, 9-42.

Joskow, P., Jean, T. (2005), Merchant transmission investment. The Journal of Industrial Economics, 53(2), 233-264.

Klemperer, P.D., Margaret, A.M. (1989), Supply function equilibria in oligopoly under encertainty. Econometrica, 57(6), 1243-1277.

Küpper, G., Erik, D., Bram, D., Leonardo, M., David, B. (2008), Increasing Competition in the Belgian Electricity Market Does More International Transmission Capacity Help ? Working Paper Do Not Quote Introduction 1. Previous Studies on Market Power in the Belgian Electricity Market. p1-25.

Lee, Y.Y., Ross, B., Jin, H. (2011), Firm-based measurements of market power in transmission-constrained electricity markets. IEEE Transactions on Power Systems, 26(4), 1962-1970.

Li, G., Jing, S., Xiuli, Q. (2011), Modeling methods for genco bidding strategy optimization in the liberalized electricity spot market–a state-of-the-art review. Energy, 36(8), 4686-4700.

Mas-Colell, A., Michael, D.W. (1995), Microeconomic Theory. New York, USA: Oxford University Press.

Mulder, M., Lambert, S. (2013), Decomposing changes in competition in the dutch electricity market through the residual supply index. Energy Economics, 39, 100-107.

NEISO. (2016), ISO New England's Internal Market Monitor Winter 2016 Quarterly Markets Report. New England, US. Available from: https://www.iso-ne.com/static-assets/documents/2016/09/a5_imm_spring_2016_qrtly_markets_report.pdf.

Newbery, D. (1998), Competition, contracts, and entry in the electricity spot market. The RAND Journal of Economics, 29(4), 726-749.

Newbery, D. (2009), Predicting Market Power in Wholesale Electricity Markets. 821. Cambridge, UK.

Newbery, D., Richard, G., Karsten, N., Paul, T. (2004), A Review of the Monitoring of Market Power : The Possible Roles of TSOs in Monitoring for Market Power Issues in Congested Transmission Systems. Brussels, Belgium.

Petoussis, A.G., Xiao-ping, Z., Savvas, G.P., Keith, R.G. (2013a), Parameterization of linear supply functions in nonlinear ac electricity market equilibrium models-Part I : Literature review and equilibrium algorithm. IEEE Transactions on Power Systems, 28(2), 650-658.

Petoussis, A.G., Xiao-ping, Z., Savvas, G.P., Keith, R.G. (2013b), Parameterization of linear supply functions in nonlinear ac electricity market equilibrium models Part II : Case studies. IEEE Transactions on Power Systems, 28(2), 659-668.

Rahimi, A, Anjali, S. (2003), Effective market monitoring in deregulated electricity markets. IEEE Transactions on Power Systems, 18(2), 486-493.

Pollitt, M. (2004), Electricity reform in chile-lessons for developing countries. Journal of Network Industries, 5(3-4), 221-262.

Roth, AE. (2002), The economist as engineer: Game theory, experimentation, and computation as tools for design economics. Econometrica, 70(4), 1341-1378.

Shapiro, C. (2010), The 2010 Horizontal Merger Guidelines : From Hedgehog to Fox in Forty Years. Antitrust Law Journal 77. Washington DC, USA. p701-759.

Sheffrin, A. (2001), Critical Actions Necessary for Effective Market Monitoring : Draft Comments of Anjali Sheffrin FERC RTO Workshop, California, USA.

Sheffrin, A. (2002), Predicting Market Power Using the Residual Supply Index. Presented to FERC Market Monitoring Workshop. California, USA.

Shukla, U.K., Ashok, T. (2011), Analysis of competition and market power in the wholesale electricity market in India. Energy Policy, 39(5), 2699-2710.

Stoft, S. (2002), Power System Economics: Designing Markets for Electricity. New York, USA: IEEE/Wiley.

Swinand, G., Brian, K., Stuart, F., Derek, S. (2010). Modeling EU electricity market competition using the residual supply index. The Electricity Journal, 23(9), 41-50.

Tanaka, M. (2009), Transmission-constrained oligopoly in the Japanese electricity market. Energy Economics, 31(5), 690-701.

Ventosa, M., Álvaro, B., Andrés, R., Michel, R. (2005), Electricity market modeling trends. Energy Policy, 33(7), 897-913.

Willems, B. (2002), Modelling cournot competition in a electricity market with transmission constraint. The Energy Journal, 23(3), 95-125.

Wilson, R. (2002), Architecture of power markets. Econometrica, 70, 1299-1340.

Wolak, F.A. (2014), Regulating competition in wholesale electricity supply. In: Rose. N.L., editors. Economic Regulation and Its Reform: What Have We Learned? 1st ed. Chicago: University of Chicago Press.

Wolfram, CD. (1999), Measuring duopoly power in the British electricity spot market. American Economic Review, 89(4), 805-826.