Market Power in Electricity Generation Sector:

A Review of Methods and Applications

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Abstract

Energy liberalization is commonly measured by the level of market competitiveness and price reductions. This review applies an alternative method, market power, to give a sense of firms' pricing behaviors in the electricity generation market. In Both Guatemala and Chile, the *ex post* simulation approach suggests a slightly larger price markup ratio for firms with larger market share and more diversified generation technologies. Further, in Chile, the policy reform considering electrical supply bidding framework has been proved tentatively positive towards the mitigation of market power. With the hope of more data availability, this review also explores the possibilities to implement other measures of market power in LAC region as well as the data requirements for different methodologies.

JEL Classification: D01, D21, D43, Q41

Key Words: Market Power; Energy Markets; Electricity Prices; Latin America

Table of Contents

1. Introduction

Implementing market power reforms and materializing their expected benefits has proved challenging in developing countries (Nepal and Jamasb 2015; Jamasb, Nepal and Timilsina 2015). This is particularly the case in Latin American and the Caribbean, where several economies have experience backlash reforms, or have undertaking policy debates on the actual welfare gains derived from such reforms (Jamasb et al. 2014; Balza, Jimenez and Mercado 2013). Therefore, as to inform energy policy, it is necessary to monitor the market performance. A key expected outcome from market liberalization is a reduction of market power, which in turns translate into energy prices that are closer to a competitive benchmark.

In this context, this policy brief has the following objectives. First, it reviews the methodologies to measure market power in the electricity generation sector, discussing their feasibility in terms of the data requirements of each method. Second, it presents the main results from the related empirical literature, gathering evidence on the relationship between market reforms, market power, and energy prices. Third, it implements the Lerner-Index in two case studies, Chile and Guatemala, to explore the presence of market power, and the implication for energy prices.

The methodologies to model market power can be categorized as: Indicators of market concentration, Oligopoly equilibrium models and Ex post simulation models. These three lines of approach differ in whether to include simulations of supply and demand, and whether to use ex ante or post market information to conduct simulations. Though the modelling methods varies largely, the ultimate measure of market power is somewhat unanimous, as in most literature the Lerner Index is selected to represent the capability to influence energy prices.

In LAC countries, this indicator can have specific policy implications due to the highly-regulated wholesale energy markets. The common oligopoly market structure in the LAC region tend to allow more market power to the largest market participants, thus the level of market influence they possess can serve as a significant aspect for competitiveness evaluation. The empirical analysis in this note is mainly focused on the most decentralized electricity market in Central America, the Guatemalan spot market, and one of the earliest reformers, the Chilean energy market. Therefore, the results can be roughly considered as a lower bound for the market power in the LAC electricity markets.

Our case studies agree generally with previous findings on the presence of market power, with some discrepancies in firm powers within the two countries. In Guatemala, although the market as a whole can be considered as a competitive environment, firm-level market power could still be executed at different times within a year. Similar results are reflected in the Chilean spot market: within the two independent dispatch systems, generating firms are entitled some space to execute market power even if the market is highly competitive. Additionally, the launch of the new bidding framework for regulated customers are tested on its tentative effect on market power. The introduction of the new tenders law (Law 20.805) is aimed to reduce electricity tariffs and encourage market competition. Results suggest a significant mitigating effect on market power in the dispatch system where the marginal cost is relatively higher, which indicates that the tenders law cast a positive influence on market competition in that it changes firms' pricing behaviors. Nevertheless, the results in the system with lower costs are not statistically significant, which might be the consequence of a higher level of competition. A final reminder is that the evaluation results only represent partial effect of this new tenders law since the bids are aimed to be effective from 2021, therefore, more robust results will be available after the actualization of the new bidding framework.

Following the structure in introduction, the second session review the three major lines of approach to conduct market power evaluation, with each pros and cons as well as data requirements. The third session provides a summary of related studies and their main findings. Then, two case studies about the electricity markets of Guatemala and Chile are followed in session four, including a background introduction and an application of the *ex post* simulation model and the empirical results. Finally, the last session discuss the policy implications.

2. Methodology Review

Market power usually refers to the ability of a market participant to profitably maintain prices above a competitive level for a significant period of time. In other words, a firm has market power if it can affect the market equilibrium point. Hence to exercise the market power, generators mainly have two channels: economical and physical withholding[1]. Economical withholding indicates rising bids so as not to produce or to raise market clearing price in the spot market, while physical withholding implies a reduction in the capacity. Either way, the amount of energy supply in market will be less than the real-time demand.

When this excess demand occurs, the scarcity of supply will lure generating firms to price higher than the competitive level. The immediate consequence will be the price surge that are passed on to the consumers, on one hand. And on the other hand, if the government does not mediate properly, certain shortage in power supply will occur which leads to bigger economic loss. In this context, the abuse of market power is highly undesirable, as it suggests an uncompetitive market, potential loss of consumer welfare and low economic efficiency.

To evaluate the existence and extent of market power, there are three lines of approach:

a) Indicators of market concentration
b) Oligopoly equilibrium models
c) *Ex post* simulation models

The first method employs the indices directly as the indicator of market power, while the second and third methods conduct simulations to estimate prices, costs, or demand elasticities. In the last two approaches, raw difference in prices or the price markup ratio is usually calculated then based on the simulated data series to imply the market condition.

2.1. Indicators of Market Concentration

[1] Sandsmark and Tennbakk (2010)

The first approach is to estimate market power with market concentration measures, and the most widely-used index is the ***Herfindahl-Hirschman Index (HHI)***, with S_i representing the market share of firm i.

$$\text{HHI} = \sum_{i=1}^{n} S_i^2$$

Dalton (1997) has found that the decline in prices is related to the entry of a second or third participant, but the prices will remain unchanged if there are already three to five participants. Although market concentration can indicate some level of market power, the HHI has its drawbacks in that: (1) it fails to capture the demand elasticity, which is a crucial factor determining the market power in electricity market. The market power of suppliers differs in peak and trough periods. A jump in demand tend to increase the possible abuse of market power, thus the variation of demand elasticities should be considered in the analysis. (2) it does not represent the true competitive position of a generator, as generators with large capacity yet high cost structures will be overrated in their market share.

Another indicator to measure the deviation of price from the firm's marginal cost is the ***Lerner Index (LI),*** the price markup ratio given the competitive price. P and MC are the price and marginal cost at the firm i's profit-maximizing output, and ε represents the elasticity observed by the firm.

$$\text{LI} = \frac{P_i - MC_i}{P_i} = \frac{1}{\varepsilon_i}$$

The LI can also be applied in as an industry-wide indicator when using market price and marginal cost. Since the electricity market is hard to be completely competitive, the difficulty to determine MC and price responsiveness on demand made it impractical to use the LI directly. Other simulations need to be done to employ the index.

There are other indicators adjusted to better represent the power, such as the Must-run ratio (MRR), Nodal must-run share (NMRS)[2]. However, in general, market concentration measures imply the probability and potential abuse of market power. Other accommodated indices or simulation models are needed to examine the exercise of market power.

2.2. Oligopoly Equilibrium Models

The Oligopoly equilibrium models are the commonest method when conducting market power analysis. There are two major types of this category: Cournot equilibrium and Supply Function Equilibrium (SFE). To solve the Nash Equilibrium in traditional Cournot settings, the generators maximize their profits by setting quantities to compete with others. While in the SFE, the strategic variable becomes bid curves, which incorporate the effects of prices into the decision making of firms. Discrepancies between the two approaches are listed below:

[2] See Wang, Xiao and Ding (2004). MMR can provide useful information in a congestion zone. It represents the capacity that must be provided by a generation company to supply a given load in a congestion zone as a percentage of the maximum available capacity of the company. NMRS represents the minimum market share required for a generator in a power market to supply a given market load, considering the geographical difference in each load bus.

	Cournot	SFE
Pros	• Solely quantity competition (highly sensitive to assumptions on demand elasticity) • Good for short term analysis • Include more market details	• Less sensitive to calibration parameters (i.e. percentage of contracts) • More realistic results • Good for long term analysis
Cons	• Prices are too high; Output is too low	• Hard to calculate, might have multiple equilibria

In the electricity market, SFE seems to be a better solution as it simulates the reality better when firms submit their bid curves continuously. However, the Cournot approach can include more market details, e.g. network constraint, and it is easier to compute mathematically, therefore, within oligopoly models, most of the literature are based on the Cournot competition.

Borenstein (1999) has evaluated the market power of generating firms in the Californian electricity wholesale market using standard Cournot-based simulations. Using an iterative algorithm, generators adjust their strategic outputs to the optimal level given the production of the remaining competitors fixed. By repeating this process, the equilibrium quantity is reached when not a single generator has the incentive to deviate from the optimal level and improve its profit. Marginal cost is calculated by plant-level heat rate and operating cost, while demand curve is simulated with 6 representative hours in 4 representative months of the year. The simulation equilibria conclude that large firms might have an incentive to restrict output to raise price, especially during the high demand hours of a day. The availability of hydroelectric production, though oversimplified in this model, and the elasticity of demand are proved to be the most significant factors determining market power.

Green and Newbury (1992) followed the SFE method introduced by Klemperer and Meyer (1989), and examined the British electricity market as a symmetric duopoly in generation ownership. Supply functions state the amount firms would be willing to produce (q) at any price (p). Then the price at each period is determined by a market-clearing condition. The iteration process in the SFE is similar to Cournot, except that the strategic variable is now the supply functions for each firm rather than the quantities. In the case of the English and Whales market, without a threat to entry or exit, the two dominant suppliers can sustain a non-collusive equilibrium with a 50% markup of price above the competitive level. When the duopoly is asymmetric, the larger firm will gain more through submitting a steeper supply function, and the smaller firm will face an inelastic residual demand thus tend to raise its own prices.

To detect the potential market power in electricity market, oligopoly models are preferred as they represent the realistic firm behaviors based on their cost and demand levels. However, the potential for execution is not a sign of presence.

2.2.1. Methodology

Here a simplified implementation of the SFE model is addressed. Cournot model will have similar process and yet the data requirement will be the same.

2.2.1.1. Suppliers

Using plant operating costs and heat-rate, we can construct the marginal cost for each utility (aggregating from each plant) in the generation sub-sector. Only the bidding behaviors of the large strategic firms should be considered relevant when deciding market equilibria. Other relatively small firms can be treated as fringe firms, assuming they act as price takers in the electricity market. The marginal cost function of all the small generator can be integrated into one single supply function: $S^{fringe} = \sum_{i=1}^{F} S_i(p)$, where F is the number of fringe firms.

To analyze the market behavior of large strategic firms, we need to subtract the supply of fringe from the market demand. What we need to consider as well is the amount of imported electricity. Therefore, the residual demand for a strategic firm at a certain price is:

$$D_r(p) = D(p) - S^{fringe} - \sum_{j=1}^{I} Min(S_j^{import}(p), TR_j)$$

TR represents the transmission constraint between region j and Guatemala, and I is the number of importing countries. All the imports are also considered as price-taking fringe.

In addition, the marginal costs of different power plants are treated differently. While hydro stations are modeled as one class, the thermal stations are differentiated as several categories, characterized by type of fuel (oil, coal and natural gas) and the energy conversion rate. Hydro resources should be modeled separately because water planning is more of a resource planning problem: more water used today indicates less reserves available for tomorrow, thus this adds some dynamic considerations into the typical thermal-based static oligopoly model.[3] With cost curves and the elasticity of demand, we will be able to calculate the supply functions.

2.2.1.2. Demand

The electricity spot markets are usually day ahead markets. The prices for each level of demand are determined one day ahead. Generators submit a whole schedule of prices (supply function) and the market determines the prices according to the expected demand the following day. In this case, the strategic behaviors of generators might differ significantly in peak and off hours. The probability to exercise market power is higher during peak hours, since it is easier for large firms to influence market prices when capacity is scarce. Hourly demand in needed in order to detect market power in different times in a day.

There are several ways to incorporate the daily demands into monthly or annual averages, and the most important thing is to identify the peak and off periods as precisely as possible yet not to include too much extremity. One approach is to consider March, June, September and December

[3] The water scheduling strategy will be closer to traditional supply-demand profit-maximization solutions as the 'inter differences' in demand elasticities become fewer.

in a single year, Borenstein and Bushnell (1999), with 6 individual hours from each month (including peak hours, 150th highest, 300th highest and until 720th highest). Then with different demand elasticities, we can simulate 24 equilibrium prices for each case, so we can evaluate the market power based seasonal and peak-and-off periods. Another approach, as in Green and Newbury (1992), is to aggregate daily demands into a weighted average annual amount. By using demand level in a typical summer day, a typical winter day, and a 'midyear' day (averaging the load curves in summer and winter), they calculated a typical year as 100 winter days, 115 summer days and 150 midyear days. Then they change the elasticity of demands, presuming the shape of demand curve remains the same, to solve equilibria under different demand elasticities.

2.2.2. Data

Availability of plant-level data is the foundation of *ex ante* analysis. Different fuel types and different generating technologies all add to the variations in marginal costs. It is necessary to compute accurate firm-level cost curves with data of all its generating units available. As for the amount of supply, it is crucial to define the actual strategic space for large generating firms, since not all of the generation amount can be decided by the companies. Must-run generation, self-consumption, spinning reserve, long-term contracts and transmission constraints need to be adjusted to obtain firms' real strategic space, so that market power can be simulated based on the amount that firms can take control of. Finally, data are preferred in high frequency (hourly or half-hourly) in order to simulate the actual bidding procedure in spot and future market.

The data required for oligopoly simulation are listed in detail as a general reference. Items need to be adjusted to fit in specific electricity markets in different countries. GAMS/CONOPT is used to compute all iterations above.

Table 1: Data Requirement for Oligopoly Simulation

		Periodicity	Aggregation	Definition
Supply	**Marginal Cost**	monthly	plant level	If already calculated by the authority
	Type of generation		plant level	Hydro (reservoirs/run-of-rivers), thermal (coal/gas/oil, etc.) and alternative energy all have different MCs, please include the type of power plants in the plant-level data
	Categorized Marginal Cost	monthly	firm level	If plant-level data is not available, firm level data with classifications (hydro, thermal, solar, cogeneration, etc.) would be helpful
	If the direct marginal cost is not available:			
	Fuel Cost	monthly	plant level	Differs in coal, gas and oil-based plants; Thermal plants only
	Thermal Efficiency	monthly	plant level	Differs in coal, gas and oil-based plants; Thermal plants only

	Environmental Cost	monthly	plant level	Including emission allowance, price of permits etc.
	Operation & Maintenance Cost	monthly	plant level	
	Installed Capacity	monthly	plant level	Also needs to be classified into hydro, thermal, etc.
	Generation	monthly	plant level	Also needs to be classified into hydro, thermal, etc.
	Plant property	yearly		Needs to be classified by economic group (utility), public/private, technology, Sistema Interconectado, Distributed generation.
	Hydro Flow Constraints		plant level	Maximum and Minimum flow constraints for hydroelectric plants
	Maintenance Period	monthly	plant level	Records of when plants are in maintenance (out of market)
	Maintenance Rate	monthly	plant level	If detailed records above cannot be obtained, an average rate of plants is desirable
	Auto Consumption	monthly	plant level	Self-consumption
	Spinning Reserve	monthly	plant level	Amount needed to maintain system stability during emergency operating conditions and unforeseen load swings
	Must-run generation	monthly	plant level	Minimum generation in order to keep the system operating
	Transmission Constraints			Import and export capacity of the grid (lines and nodes)
	Transmission Loss			A percentage of the total volume
	Length of transmission lines			together with transmission loss, we can calculate the adjusted MC: electricity produced at node A and consumed at node B should be adjusted for a transmission charge.
	Penalty Factor		plant level	If date above not available, 'Penalty Factor' sometimes are calculated such that MC*Penalty=Adjusted MC
	Long-term Contracts		plant level	The amount of generation offered to large consumers
Demand	**Market Demand**	Hourly	market level	
	Spot Market Price	Hourly	market level	
	Demand Elasticity		market level	Average elasticities of the electricity market

2.2.3. Market Power Estimation

Market power is defined as the ability to withhold the production amount in order to increase prices. After the equilibrium prices are obtained, we can either consider the Lerner Index using the simulated prices, or to compare the raw differences in oligopoly and competitive prices to have a sense of the potential market power.

2.3. Ex post Simulation Models

The third line of approach is the *ex post* simulation models. This method is based on historical data, and utilizes statistical techniques to simulate market information. Compared to the *ex ante* simulations, this market monitoring approach are considered a better way to diagnose existing market condition. Econometric regression and mathematical simulation are the two major applications.

Evans and Green (1998) tested the effect of market concentration on spot prices. They conducted linear regression analysis on historical prices and found substantial linkage between reduction in prices and reduction in concentration. In Sandsmark and Tennbakk (2010), the Nordic electricity prices were monitored to assess market power. The marginal cost of water, "water value", is represented using different proxies in public data and a new index was derived based on Lerner Index to detect short-term market power abuse.

While statistical techniques offer credible information in steady and mature market, they are less useful when there is a structural change, e.g. deregulation and divestiture. The incentives for generators might change dramatically during policy reforms. Therefore, the *ex post* methods are supposed to have retrospective indications, not necessarily a prospective one. This evidence of existence, instead of the potential to perform market power, can provide the regulatory agencies with more policy implications about the execution of market rules.

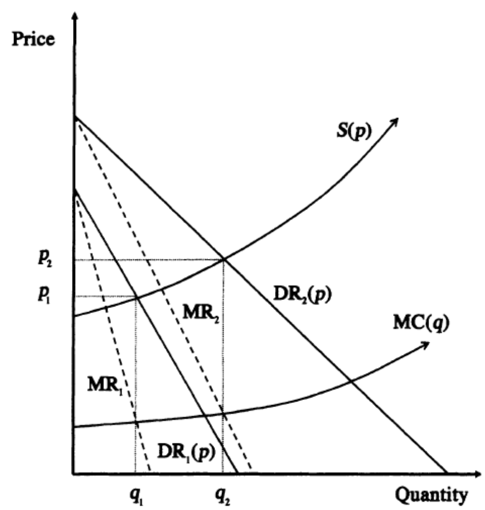
2.3.1. Methodology

The case study for Guatemalan electricity industry in section 4 are based on the following methodology. It should be noticed that the construction of new indexes, regression analysis and application of proxies are all alternatives of *ex post* simulation. The methodology here is on the premises of mathematical transformation and statistical theories.

In the perspective of *ex post* market monitor analysis, a firm's expected profit-maximizing bidding strategy is computed by finding the set of profit-maximizing price and quantity pairs for all possible residual demand realizations that the firm might face. Under the above bidding strategy, it is possible to assess firms' ability to influence prices with the market-clearing price and quantity pairs. The Lerner Index states that a firm's price markup over its cost of production is a function of the market power it possesses. It is selected in this study to capture the market power in electricity markets.

The bidding curve of each firm is an aggregation of all its generating units. Therefore, considering its different units and their generating costs, a firm will formulate its cost curve (MC) with ascending marginal costs of all generating units. Then, with different expected residual demand, the firm submits a supply function to represent the strategic moves for the entire firm.

As the figure below from Wolak (2003), the bidding curve S(p) is formulated by different realizations of residual demand, for example $DR_1(p)$ and $DR_2(p)$. To perform as a profit-maximizing entity, a firm will choose the price and quantity pairs when marginal revenue equals marginal profit, (p_1, q_1) and (p_2, q_2), where p represents the price in the market and q represents the quantity of production the firm chooses to realize. A supply function is then formulated to connect all possible circumstances of *ex post* price and quantity pairs. In this way, the firm can guarantee its profit maximization under each realization of different demand levels. If a firm can find such a supply function that intersects with all possible residual demands given the supply of all other firms, it cannot increase its profit by deviating from this supply curve. S(p) will be comprised of all possible bids that a firm may submit.



The hourly realization of price and quantity pairs then can be used to indicate the market condition within the short period of time. As long as the profit-maximizing expectation holds, LI_{jh}, a measure of the market power of firm j in hour h, can be defined as the inverse of elasticity ε_{jh}.

$$LI_{jh} = \left(\frac{P_h - MC_{jh}}{P_h}\right) = -\frac{1}{\varepsilon_{jh}}$$

Where P_h is the market price in hour h, MC_{jh} is the short-term marginal cost of the generating unit with highest cost within firm j, and ε_{jh} is the price elasticity of demand faced by firm j in hour h. The average hourly value of LI_{jh} is a measure of the unilateral market power of a firm.

The elasticity of demand is one channel to calculate the Lerner Index, since it represents the relative response of demand to changes of price. When consumers are price sensitive, they tend to change their purchasing behaviors quickly in response to prices. The elasticity of demand will be large, and thus the Lerner Index will be small indicating a small markup space of market prices. Similarly, when the consumers are insensitive about electricity prices, they will be less likely to adjust their behaviors according to higher prices, which gives the generating companies the incentive to price high.

To obtain the value of Lerner Index, the elasticity of the residual demand curves needed to be calculated. Then the inverse of elasticity can be used as an indicator of market power. One caveat is that the residual curves should all be step functions. However, since there are sufficient observations in the neighborhood of the equilibrium price, the following function can be used to simulate the elasticity of residual demand:

$$\varepsilon_{jh} = \frac{DR_{jh}(P_{h+}) - DR_{jh}(P_{h-})}{(P_{h+}) - (P_{h-})} * \frac{(P_{h+}) + (P_{h-})}{DR_{jh}(P_{h+}) + DR_{jh}(P_{h-})}$$

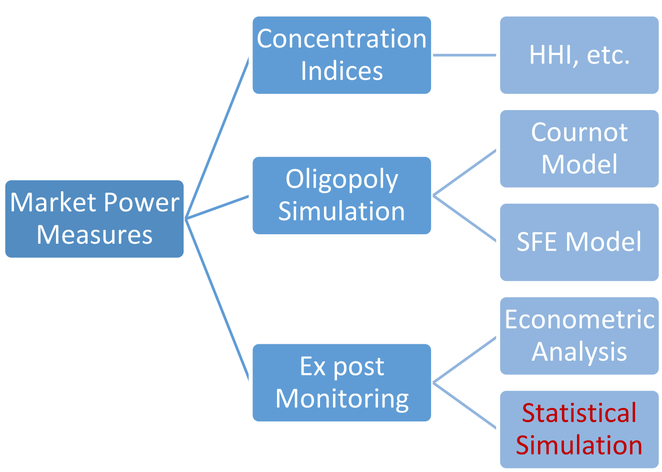
For each hour's market price P_h, two sets of price and quantity pairs are found to simulate the point estimate of the residual demand slope. P_{h+} is the closest price larger than P_h so that the residual demand $DR_{jh}(P_{h+})$ is less than the residual demand at P_h. Likewise, P_{h-} is the closest price below P_h so that the residual demand $DR_{jh}(P_{h-})$ is more than the residual demand at P_h. Such interval can guarantee a negative elasticity of residual demand so that its inverse, Lerner Index, has realistic implications.

2.3.2. Data

There is less data required under *ex post* simulations, which is another advantage of this third line of approach. Normally, market prices, consumptions and sales are needed in high frequency data, and other detailed data requirements vary among models. In addition, information describing the market is also easier to acquire since it is better aggregated than the micro-level cost data.

The three lines of approach can be combined or used independently. Market monitoring method will be applied here in the Guatemala case study to simulate elasticity of demand, and the Lerner Index was reported as an indicator of market power.

Figure 1: Methodologies for Market Power Analysis



In conclusion, most literature analyzing competition in the electricity market suggests that market power does raise prices above their competitive level, and it is inevitable in almost all regional markets although with deregulation and policy reforms. This study hence expects to evaluate the existence and severity of market power in the Guatemalan electricity market, and to examine its effect on the electricity prices.

3. Empirical Findings

Previous findings unanimously concluded about the presence of market power in the generation subsector, but the severity, in terms of Lerner Index, varies in different markets and countries. The competitive position of different firms also varies accordingly. For example, in Californian electricity market, the top five suppliers were found the symmetric ability to raise prices in the spot energy market (Wolak, 1998). And in Chile, the generating firm with largest capacities are found a significant advantage over other two major participants (Arellano 2003).

Most studies are conducted in well-developed wholesale energy market, for example, the US and Britain. In these regions, electricity markets are determined by supply and demand, and firms are allowed to submit bids freely and usually hourly, an important assumption that *ex ante* simulations are based on. If markets are not completely liberalized, for example in Chile and early Nordic region, the same market rules must be presumed. Considering the various market regulations, the three major methods, summarized in the last section, are applied to examine the market condition.

Aside from the difference in methodologies, the studies below also adjust to the difference in generating units. Most of the generating plants are based thermal technologies, while generators in Nordic area are 90% hydroelectric. The unit variations matter since intertemporal considerations should be applied when water serves as the main resource for electric supply. Some LAC countries have significant portion of hydro plants in operation, thus studies concerning hydro-based markets are also listed as reference.

In sum, previous studies focused on modeling the *ex ante* energy market extensively, and the investigation period are mainly around 2000. In this context, to add to the market analysis in LAC region as well, this note tries to answer the question from the perspective of *ex post* market monitor, and provides some evidence in the more recent energy market undergoing major liberalization changes.

Table 2: Summary of Related Studies

Studies	Regions	Method	Findings
Borenstein and Bushnell, 1999	Western US (California)	Cournot	The potential for market power is high in high-demand hours. Levels of hydroelectric production and elasticity of demand are the two most important factors determining the severity market power.
Borenstein Bushnell and Knittel, 2000	Western US (California)	Cournot	Compared the difference between HHI and Lerner Index. Applied the price markup ratio (LI) to represent market power for different divestiture strategies.

Bushnell, Mansur and Saravia, 2004	3 US markets	Cournot	Compared the market performance in California, New England and PJM (Eastern US). Simulated price reductions indicate the similar effects of vertical arrangements on all three markets
Andersson and Bergman, 1995	Swedish	Cournot	The simulated price under a freely-trade market mechanism is 36% higher than the current market price. Deregulation of the spot market is not a sufficient condition for equilibrium prices to approach marginal costs.
Arellano, 2003	Chile	Cournot	Conducted market simulation as if the energy market is liberalized and found evidence of potential market power increase after liberalization.
Green, 1996	British	SFE	Simulated the market equilibria assuming potential policy reforms. Divestitures might lead to a substantial reduction in deadweight loss, while encouraging competitive entry tend to reduce welfare.
Baldick et al, 2004	British	SFE	Under medium demand elasticity, the market price will decrease 25% after the divestiture from duopoly to three firms.
Evans and Green, 2003	British	SFE	Between 1997 and 2004, the relationship between the simulation and actual prices are unchanged. This indicates an insignificant effect of decentralization.
Halseth, 1999	Nordic	SFE	Investigated the potential of market power and found that the largest producer has incentives to withdraw some nuclear capacity from the market in order to raise spot price.
Wolak, 2000	Australia	SFE	Simulated market prices considering the combination of contracts and spot sales. Results show that the financial hedge contracts are an effective approach to mitigate market power during initial stages of operation.
Willems et al, 2009	Germany	SFE/Cournot	Compared the market results using both simulation method and discovered potential market power in both cases. Additionally, this study proposes using Cournot for short-term analysis and SFE for longer periods.
Joskow and Kahn, 2001	Western US (California)	SFE/Monitor	Compared the simulated and actual prices and found evidence of price markup. The strategic behaviors for firms to withhold supply is further identified.

Wolak, 1998	Western US (California)	Market Monitor	Computed the unilateral market power for each generating firm and found a symmetric ability to raise prices for the top five suppliers in California.
Evans and Green, 1998	British	Market Monitor	Conducted a linear regression analysis to evaluate the effect of a market reform on the prices. The decrease in market concentration was proved the chief reason.
Sandsmark and Tennbakk, 2009	Nordic	Market Monitor	Presents market monitoring procedure based on hydro-dominated market. Water value is assessed to evaluate the marginal costs of generators.
Tangeras and Mauritzen, 2014	Nordic	Market Monitor	Used market data to analyze hydro-based real-time and day-ahead market. Both spot and future prices are not at competitive level.

4. Case study

<u>Guatemalan Generation Market</u>

4.1. Background in Guatemalan electricity market

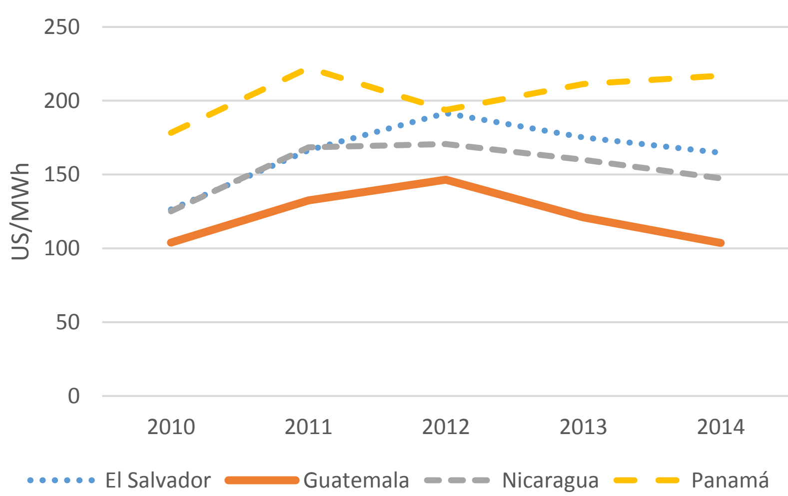
Since 1998, the electricity sector in Guatemala has been decentralizing to introduce more competition. After the launch of General Electricity Law (Decree No. 93-96), the Wholesale Market Administrator (AMM), a private entity, is created with the objective to coordinate the operations of power plants, international interconnections, transmission lines and minimize the costs in the spot market.

For now, the transmission and distribution sub-sectors are still dominated by state-owned enterprises, while the generation sector is already recognized as a competition environment. The Guatemalan generation sub-sector has a consistent and investment-friendly legislative framework, making it an attractive for international companies to invest in. In addition, the SIEPAC, Central American Electrical Interconnection System, has contributed to mitigate the technical gaps (differences in grid capacities, voltage of transmission lines, etc.) between the Regional Electrical System (SER) and with Mexican Electricity System (SEM), enhancing the openness of the wholesale market in Central American countries as well as Mexico. All the above factors add to the competitive environment in Guatemalan energy market.

4.1.1. Price Formation

Spot energy prices are relatively low in Guatemala, in comparison with other Central American electricity markets. Historical price data further implies a steady price reduction since 2012, translating into the reduction of tariff faced by final users.

Figure 2: Average Annual Spot Electricity Prices in CA: 2010-2014



Source: ECLAC, 2014.

As seen from the prices in the wholesale market, the spot prices in the electricity market have declined from 147 $/MWh in 2012 to 71 $/MWh in 2015. Nonetheless, the reduction in market prices do not necessarily suggest a more competitive market condition. There is a need to examine market power that generators practically possess in the wholesale market.

According to Bailey (2015), the pricing formation of Guatemala's electricity tariff, for regulated customers, consists of three parts:

Electricity tariff = average cost of electricity supply

(both through the wholesale market and direct contracts with generators)

+ a charge for the use of the national transmission system

+ a charge for the value added on the distribution system (VAD)

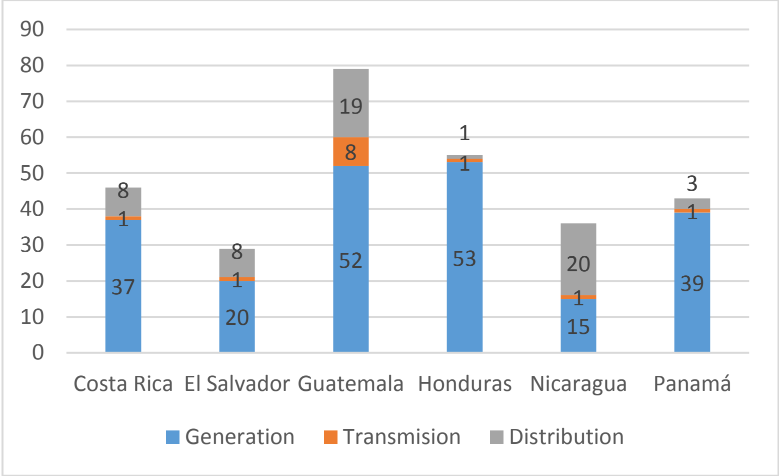
For unregulated customers with large demands (more than 100kW), they can bypass the transmission and distribution system and purchase electricity through contracts with generators as well as intermediaries. **The hypothesis of this study is that the market power in the generation subsector will have effects on the bidding behaviors of firms (as explained bellow), therefore influencing the average cost of generators and subsequently the end-user prices.** For Guatemala, the average cost of suppliers is reflected through the spot prices in the market, and it takes up 60 to 70 percent of the final electricity tariff in composition.

4.1.2. Market Composition

Compared to other countries in the Central American area, Guatemala has the largest number of firms in the generation, transmission, and distribution subsectors. Gross generation in 2015 amounted to 10886 GWh, with a Herfindahl-Hirschman Index (HHI) of 0.11 for the largest 7 generating firms in the industry[4]. The results indicate a potentially competitive environment in the electricity industry, benefiting from the investment-friendly legislations that local government promotes. The number of competing firms the Guatemalan generation market implies a weaker incentive to perform market power in pricing behaviors.

[4] The standard for HHI from US Department of Justice: An HHI below 0.01 indicates a highly competitive industry; An HHI below 0.15 indicates an unconcentrated industry; An HHI between 0.15 to 0.25 indicates moderate concentration; An HHI above 0.25 indicates high concentration.

Figure 3: Number of Firms in CA Countries, 2013



Source: Centroamérica estadísticas del subsector eléctrico, 2014

Specifically, there is a competitive mix of private the public-based generating plants in Guatemala. As of the generating technology, in 2014, thermal stations take up about 30% of all the electricity production, while hydroelectric stations contribute 48%, cogeneration stations contribute 18%, and the rest 4% are consisted of geothermal, solar and biomass. Overall, the private sector and hydroelectric plants have a strong presence in the electricity generation market of Guatemala.

Table 3: Private and Technology Participation:

Electrical Companies	# Plants	Installed Capacity (kW)	Generation (MWh)	Share of Generation
National Interconnected System	257	3,134,120	9,780,657	-
Wholesaler	211	3,089,437	9,639,087	99%
Public Company	26	558,780	2,513,902	26%
Hydro (EGEE)	24	481,930	2,513,488	26%
Thermal (EGEE)	2	76,850	414.4	0%
Private Companies	185	2,530,657	7,125,185	73%
Hydro	48	544,642	2,175,697	22%
Geothermal	9	49,200	246,600	3%
Cogeneration	19	669,153	1,731,719	18%
Biogas	3	1,300	1,275	0%
Thermal	106	1,299,362	2,971,169	30%
Distributed Generation	46	44,683	141,570	1%
Hydro	41	39,683	134,471	1%
Solar	5	5,000	7,099	0%

Source: ECLAC, 2014

The firm-level and plant-level evidence suggest a possible presence of competition in the Guatemalan generation subsector. Still, the presence of market power needs to be assessed to evaluate the market condition.

4.2. Empirical Implementation

4.2.1. Model Adjustments

In Guatemala, generating firms perform transactions with two kinds of entities: distribution companies and large users. For large users, either through bi-lateral contracts or intermediate marketers, their end-user prices are equal to the wholesale market price reflecting the ability to purchase directly from generators. Meanwhile, the end-user prices for customers purchasing from distribution companies will suffer an increase due to the value added from extra services.

Of the amount of energy sold to distribution companies, about 60% the annual sales, there is still a portion of transactions completed under contracts with generators. Therefore, only the rest of the distribution amount can be considered as flexible amount for the generation of energy. This takes up 40%, about 4123GWh, of the wholesale market sales in 2015.

Nonetheless, the market size is not adjusted in this study to compute the elasticity of demand. The bi-lateral contracts only peg the end-user price as the market-clearing price for the electricity purchasers, while the amount of demand under contract is still incorporated in the companies' bidding curves. Firms consider the overall supply amount when submitting the supply function, not only the strategic flexible amount of demand. Thus, both the demand via market and directly from generators are included in the *ex post* market monitoring evaluation, in consonance with the calculation of energy prices by the wholesale market administrator.

Currently, spot market prices are determined by the market regulator on an hourly basis, but they are not a reflection of dynamic free bids from the generating companies. Although the Guatemalan electricity market is considering moving towards liberalization, it is now still a regulated spot market in that the regulator calculates market prices solely based on the parameters of generating units. To proceed with the analysis regarding market power, assumption of an unregulated spot market needs to be made. **Therefore, in this study, all calculations are conducted as if the market was determined by the dynamics of supply and demand.** The monitoring results reveal the possible scenarios in a fully liberalized market in Guatemala.

Market monitoring method is applied here to simulate the elasticities of residual demand, and the Lerner Index is reported as an indicator of market power.

4.2.2. Data

The hourly demand and spot prices are both taken from the Wholesale Market Administrator (AMM) for the year 2015. The electricity price after the operation of National Interconnected System is chosen to represent of *ex post* analysis.

4.2.2.1. Prices

The price of hourly spot market (POE) in Guatemala, calculated after the operation of National Interconnected System (S.N.I.), is determined as the maximum variable cost of the generating units which were operating in the given hour. It is also the value of short term marginal cost of energy faced by the suppliers considering the level of demand and transmission constraints.

The wholesale market regulator gathers all the cost structure of generating units in merit order, and then determines the market-clearing prices(POE) at each hour as the maximum unit cost in operation. The purchases and sales of the electricity are also organized by the market regulator through contracts or the Energy Opportunity Market.

For the generating units, every hour the energy sold to the AMM is remunerated at the price of energy at its node (PN):

$$PN_{hn} = POE_h * FPNE_{hn}$$

Where POE_h is the market opportunity price at hour **h**, and $FPNE_{hn}$ is the nodal energy loss factor for node **n** at hour **h**. In this study, only the POE (at the reference node[5]) is taken into consideration because the goal is to evaluate the firm-level market power and the differences in nodal price will not affect the market-clearing condition. It is the expected market-clearing prices that determine firm bids instead of the prices at each node. After the POE at each hour is decided, each generating unit will then be remunerated at the price PN.

4.2.2.2. Demand

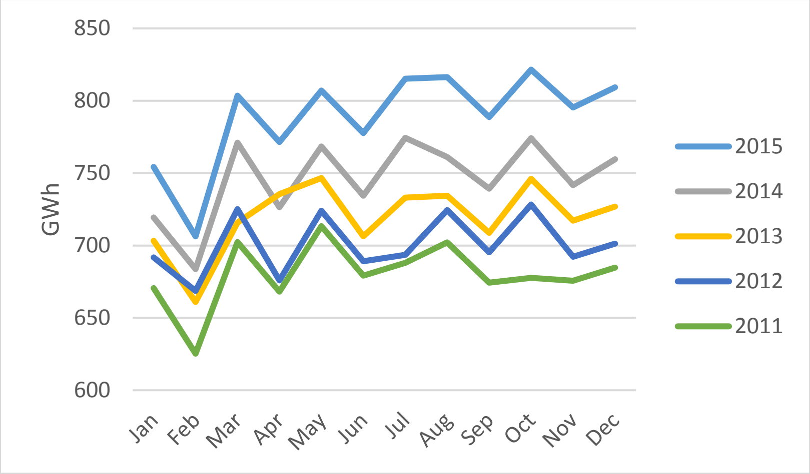
In response to the hourly spot market, the consumption in the National Interconnected System (SNI) varies hourly and therefore monthly, yet the seasonal trends within each year are similar. The transaction amount in the Regional Electricity Market and through transmission to Mexico are deducted since they are excluded from the national spot market.

Annually, 90% of the sales of electricity is conducted on the Electricity Opportunity Market, and the other 10% are deviations and losses. Therefore, the loss of energy is deducted from the gross demand data. To calculate the residual demand for each firm, the firm-level fraction of supply is estimated from monthly data from AMM statistical report. The supply from other companies are subtracted from the hour market demand to get the hourly residual demand for each generating firm.

The combination of dry season and the reliance on hydroelectric generation plants indicates a valley in February, and the overall consumption increases intermittently until the peak amount in October. Based on the monthly patterns, this study investigates the market power in the regime supposing generating firms adjust their bidding behaviors monthly.

[5] The reference node is at 230 KV Bar of the S / E Guatemala-South.

Figure 4: Monthly Patterns in Market Demand



Source: Informe Estadístico de AMM, 2015

The residual demand of each firm can be calculated straightforwardly as subtracting the amount of supply from all other competitors at the given hour.

$$DR_{jh}(p) = D_h(p) - \sum_{i=1}^{I} S_{i \neq j,h}(p)$$

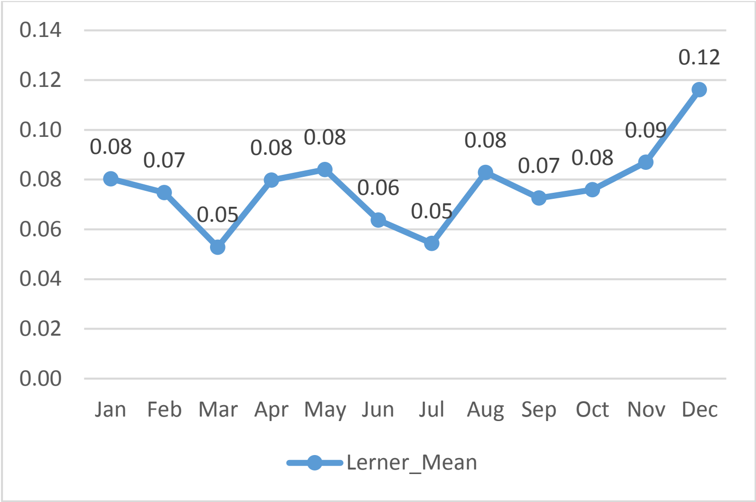
In an unregulated spot market, generators submit a whole schedule of prices (supply function) and the market determines the prices according to the expected demand the following day. This mechanism allows the firms the flexibility to adjust supply plans in a daily basis. Firms are inclined to execute market power when demands are high or in peak season.

4.3. Results

4.3.1. Market-level Power

Considering the electricity market as a whole, the measure of market power is calculated within each month. Here, the assumption here is that all companies are allowed to adjust their supply curves once in a month. Figure 4 lists the mean value of the inverse of demand elasticity, LI, in each month. There is a clear increase at the beginning from September to December, corresponding to the increase in the net amount of domestic market demand.

Figure 5: Average Hourly LI from January to December, 2015



Source: AMM

However, the electricity market in Guatemala is a 'simulated' spot market, which is different from a real unregulated market in that generator cannot bid arbitrarily. The bid of a generating unit is calculated as its maximum generation power adjusted by the availability of the unit, where the coefficient of availability is examined by the regulator each year. The market regulator then adjusts hourly prices though Long-term Programming (PLP) considering firms' bids for a seasonal year, hence it is reasonable to assume the bidding behaviors, and subsequently the supply function, does not change in the context of a year.

Based on similar computation, by stretching the decision period to one year, **the generating subsector has a yearly averaged Lerner Index of 0.02, which indicates a highly competitive environment**[6]. The discrepancy of Lerner Index between the monthly and yearly frameworks is due to the flexibility of adjustments. When firms are allowed to change their bidding strategies more frequently, they are likely to capture more market power to increase their profits.

4.3.2. Firm-Level Market Power

To further examine the unilateral power of each firm, the same logic is followed to obtain the elasticity of each firm's residual demand. The focus is on the periods where demand level is high and the elasticity of demand is low, in this case, from August to December.

Table 3 displays the mean value of hourly inverse residual demand elasticity by firm and by month. Generally, the existence of firm-level market power corresponds to the level of residual demand. During December, the Lerner Indices for all firms increase, suggesting the presence of market power and a potential reduction in market efficiency. Meanwhile, the differences in market

[6] According to US DOJ, markets are considered competitive when Lerner Index is less or equal to 0.05.

power between firms are widened in the second half of the year, from July to November. This implies different abilities for firms to bid and supply under different market demand and supply conditions.

Table 4: Average Monthly Value of LI_{jh} in 2015

Month	Firm 1	Firm 2	Firm 3	Firm 4	Firm 5	Firm 6	Firm 7
Jan	0.05	0.05	0.05	0.05	0.05	0.06	0.06
Feb	0.04	0.04	0.04	0.02	0.02	0.02	0.02
Mar	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Apr	0.03	0.02	0.03	0.04	0.03	0.04	0.04
May	0.05	0.03	0.04	0.03	0.03	0.03	0.05
Jun	0.04	0.03	0.04	0.03	0.03	0.02	0.03
Jul	0.05	0.02	0.02	0.02	0.02	0.02	0.02
Aug	0.07	0.02	0.02	0.02	0.02	0.02	0.02
Sep	0.06	0.02	0.03	0.03	0.06	0.03	0.03
Oct	0.07	0.03	0.04	0.04	0.05	0.04	0.04
Nov	0.07	0.03	0.04	0.03	0.04	0.04	0.03
Dec	0.07	0.06	0.07	0.06	0.07	0.07	0.07

Specifically, Firm 1 possesses more significant influence on market prices than all other companies, in the regime of almost all months. The market power of other firms' peaks in different times as in the difference in the delivery of their contracts.

The ownership of large amount of installed capacity and a significant portion of hydroelectric plants enable Firm 1 the market advantage during peak hours. It is the firms who can adjust production during high demand periods that are able to execute the influence on market. Other firms will have no choices but to operate at full capacity to meet the high level of market demand.

Hydroelectric plants participate in the production as "peak shaving" devices. They are rendered as backup generation when demand levels are high because of the instability of water resources. Therefore, the ownership of hydro-based plants also adds to a company's market power. Firm 1 operates as the only generating firm with both sufficient capacity and hydroelectric units, thus its size and composition of plants entitle the firm a large space to make strategic supply decisions.

Chilean Generation Sector

4.4. Background in Chilean energy market

4.4.1. Market Composition

Chile is considered the initiator of power sector reforms as it began its divestiture and privatization in early 1980s. Till now, its generation, transmission, and distribution subsector have 100% private participation. The installed electricity generation capacity as of 2015 reaches 19,742 MW. Of these, 58% of the country's total installed capacity is represented by thermoelectric generation, while 29.6% is hydroelectric and 12.4% corresponds to NCREs (Non-conventional renewable energy).

There are two large interconnected systems operating in Chile, Central Interconnected System (SIC) and the Norte Grande Interconnected System (SING). They are coordinated by their respective System Operators (CDEC) to minimize generating costs and guarantee constant power supply. The other two minor systems, Aysén and Magallanes, are considered system without a coordinator since they only take up less than 1% of the total installed capacity. The four systems are not connected yet but the National Commission of Energy (CNE) is planning to form a nationally-interconnected system in 2018, in order to introduce additional source of competition.

The two interconnected systems differ in generation composition and types of consumers. The generating units in SING are almost 100% thermoelectric and 90% of the purchases through this grid are from industrial and large consumers. Meanwhile, the SIC has a more complex mix of generating technologies, with 55% from thermal, 43% from hydro and 2% from wind. The consumers in the SIC system are mostly regulated customers through the intermediaries of distribution companies. As in power generation, SIC reached a total of 52,901GWh (73.3% of the total) while the SING contributed 18,805GWh (26% of total).

Corresponding to the independence of the two interconnected systems, the market prices and demand level differ. This case study compares the market condition in both the SING and SIC system, since they incorporate different information about industrial and residential sectors.

4.4.2. Forward and Spot Market

The spot market in Chile takes advantage of financial instruments to stabilize the price and supply. Long-term contracts in Chile are pure energy forward contracts, and they separate the electricity market into the forward market and spot market. Forward contracts reduce the risks of price volatility in spot markets and incentivize the investment in generating units by providing a predictable cash flow to the generating firms. Meanwhile, firms will have less incentive to withhold energy production in order to hedge for forward contracts, and this will add to the market competitiveness and therefore a reduction in market power. The most important function of the forward market is to mitigate the market power of generators in the spot market. The prices of contract and spot market will be perfectly equivalent if market participants cannot influence the spot market equilibria.

As a result of the introduction of forward contracts, the generation companies are the only participants in the electricity spot market. On one hand, they sell energy at the marginal cost on the wholesale market; On the other hand, they are also the purchaser of energy as the suppliers of forward contract. Generating companies must be able to provide the amount of electricity demanded by their clients even if their generating units are not in operation, so they usually enter into forward contracts by purchasing the same amount of energy on the spot market, to ensure the stability of supply. As for distribution companies and large consumers, though they do not have access to the spot market, they are free to sign long-term contracts with generating firms and receive fixed or regulated prices for a long-term period upon negotiation.

The functions of forward contracts are a different question here. To model firm's behavior in an intertemporal market, more data inputs, such as risk aversion and discount rates, need to be estimated. Hence, for simplicity reasons, **in this study, only the market power in the spot market is examined, thus the future market is not in consideration.**

4.4.3. Price Formation

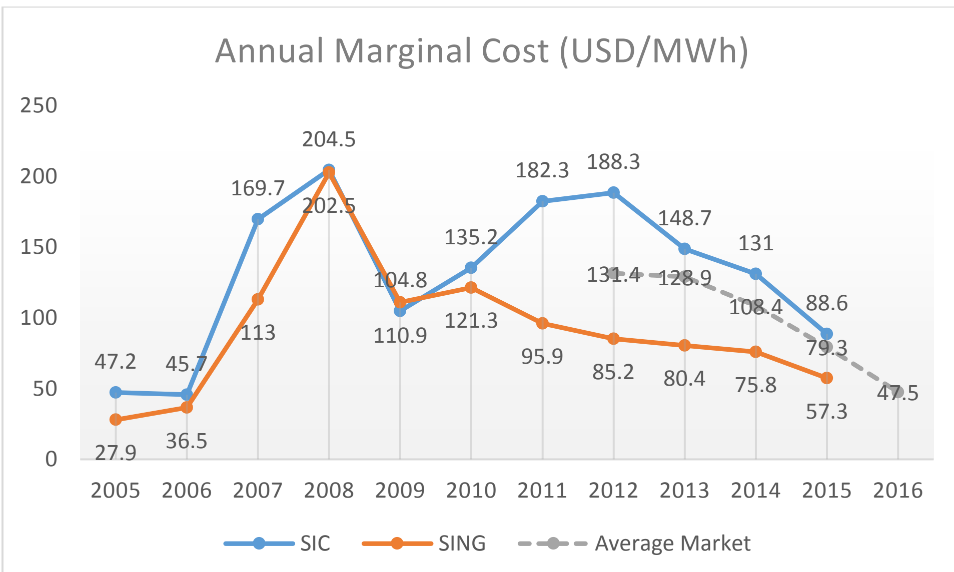
The remunerations of generators differ regarding which above markets they participate in:

a) The Economic Dispatch Center for the respective system (CDEC), at marginal hourly cost;
b) Market for large consumers, at a freely agreed price;
c) Market for distribution companies, at the regulated price (Nodal price)

Similar to the spot market in Guatemala, the electricity market in Chile is semi-regulated. The spot price at the Dispatch Center is determined by the marginal hourly cost instead of the supply function submitted by each firm. The short-term nodal price equals the marginal cost plus a capacity charge which varies in peak and off hours. This regulated nodal price is adjusted every 6 months by the CDEC of each interconnected system.

SIC and SING has different marginal costs and thus different nodal prices to illustrate the difference in market participation. The *Quillota 220 kV busbar* was used as the reference to obtain the marginal cost in the SIC while the *Crucero 220 kV busbar* was used as the reference in the SING. Since 2012, both price series has been declining, with a trend towards a unanimous annual price.

Figure 6: Historical Marginal Costs. 2005-2015



Source: CNE Statistical Yearbook, 2015

In the residential sector, the electricity tariff for regulated consumers is aimed to represent the actual costs of the subsectors, so the price formation of end-user price is as follows:

Price to end user = Price of Node

+ Value Added of Distribution

+ Single Charge for the Use of Trunk System

4.4.4. Progress in the Supply Bidding System

Chile launched the new Tenders Law (No. 20.805) to improve the electric supply bidding system for regulated customers. The program "National and International Public Bidding for Power Supply and Electrical Energy to supply the consumptions of customers subject to price regulation (Supply Tender 2015/01)" was enacted in January 2015 with the first attempt to call for both domestic and international tenders. Subsequently, the National Energy Commission (CNE), together with Empresas Eléctricas, carried out an international roadshow in the United States, Brazil and Asia with the objective of promoting this tender, where, the CNE is in charge of its design, coordination and direction.

With the introduction of this new litigation, 84 domestic and foreign generation firms entered into the competition for 12,430 GWh per year of energy supply in the national grid system 20 years from the year 2021. One immediate outcome is the price reduction in 2016 (Figure 6), averaging 47.5 USD/MWh, which decreased about 63% since 2013. Another desirable outcome will be the deduction in market power ensuing from a more competitive bidding environment.

4.5. Empirical Implementation

Since the spot market in Chile is also semi-regulated, the same assumption must hold for the following analysis: all calculations are conducted as if the market was determined by the dynamics of supply and demand.

4.5.1. Data

Marginal cost, net of capacity charge, serves as the market prices in this study, since it contains more variations and are less regulated than the nodal prices, which is adjusted by CDEC every 6 months. In addition, it is more accurate to evaluate the market power of generating companies as it only reflects the information from the power units.

Hourly market demand and supply are obtained on CDEC-SING and CDEC-SIC. The hourly supply in both systems are adjusted after self-reserve generation. Residual demands are calculated similarly to the case of Guatemala, as the hourly demand minus the supply from all other generating firms.

4.5.2. Determinants of Market Power

To identify the determinants of price markup ratio, a regression model is further tested to address the possible causes using monthly data from 2012 to 2015:

$$\textbf{\textit{Lerner Index}} = \beta_0 + \beta_1 \textbf{\textit{HHI}} + \beta_2 \textbf{\textit{HHI}}^2 + \beta_3 \textbf{\textit{demand/capacity}} + \beta_4 \textbf{\textit{Law}}$$

where the *demand-capacity ratio* picks up the seasonality, and the *HHI* and its square are both included to represent the non-linear relationship between the number of firms and their supply functions[7]. The monthly HHI representing firms' market share are reckoned the most relevant characteristic to determine their ability to price the generation. The more concentrated the market is, the more pricing space the firms will have. And to include the variations in the market as well as adjust the demand seasonality detected in previous sections, the demand-capacity ratio is also included as a potential determinant.

Law acts as a dummy variable indicating the launch of Law No.20.805. It takes up the value as 1 after January and 0 before the launch of this policy. The new tenders law is expected to introduce more competition in the generation sector effectively from 2021, yet it is also expected to change the bidding behaviors of the current generating firms for an alteration in future market expectation. Only the potential effect of this reform is evaluated since it is not yet functioning.

The introduction of the new bidding law is expected to increase the competitiveness of the energy market and further decrease the electricity tariffs. If the law can affect the bidding strategies of firms in that it changes their pricing behaviors, the dummy variable would pick up this effect and the sign would indicate the direction of the influence, expectedly negative.

This specification of model tends to bias estimations in several aspects. Firstly, other regulatory reforms might blur the real effect of the new law on Lerner Indexes. For example, the interconnection of SING and SIC, which is expected to put into use in 2018. However, the current operating mechanism remains the same in SING and SIC, which still operate independently from each other. Therefore, the regression does not include other variables representing structural changes, though with a risk of overestimation. And secondly, a more dynamic view can be introduced into the process when firms are making price decisions. With more data and resources available, this model can be adjusted to have more robust results.

4.6. Results

4.6.1. Market-level Power

Table 5: Average Lerner Index in SIC and SING

	SIC	SING
Min.	0.001	0.000
1stQu.	0.007	0.002
Median	**0.015**	**0.007**
Mean	**0.054**	**0.035**
3rdQu.	0.042	0.024
Max.	0.993	0.995

The HHI in SIC is 0.09, consisting of the top 3 firms with largest generation, whereas the HHI of SING is 0.20, consisting of the top 6 largest generating firms. The generation subsector is much more concentrated in the SING since the largest generating firm takes up 35% of the total market share.

[7] See Newbury and Green, 1992

The annual average Lerner Index contradicts with the results from HHI in that SIC is more concentrated than SING. Firms under SIC system are inclined to raise prices more, though the average LIs in both systems indicate a competitive spot market. This divergence in LI and HHI reveals different aspects of the market condition: Larger market shares do not necessarily lead to higher market prices. Additionally, the slightly larger Lerner Index in SIC might indicate the existence of a Cartel, where individual market shares are combined to form a larger economic group with unanimous market behaviors. However, the case of tacit collusion is not taken into consideration here because such structure is usually restricted in electricity markets.

4.6.2. Firm-level Market Power

Table 6: Firm-level Monthly Averaged Lerner Index, SIC

	Frim 1	Firm 2	Firm 3
Jan	0.12	0.09	0.09
Feb	-	0.08	-
Mar	-	0.08	-
Apr	-	0.07	0.09
May	-	0.05	0.04
Jun	-	0.11	0.08
Jul	-	0.05	0.05
Aug	0.01	0.05	0.05
Sep	-	0.03	0.04
Oct	-	0.02	-
Nov	0.03	0.03	0.03
Dec	-	0.04	0.03

Table 7: Firm-level Monthly Averaged Lerner Index, SING

	Firm 1	Firm 2	Firm 3	Firm 4	Firm 5	Firm 6
Jan	0.11	0.05	0.09	0.09	0.04	0.05
Feb	0.13	0.05	0.10	0.08	0.05	0.05
Mar	0.09	0.04	0.07	0.05	0.03	0.03
Apr	0.12	0.04	0.10	0.06	0.03	0.04
May	0.10	0.03	0.09	0.03	0.04	0.03
Jun	0.13	0.07	0.11	0.10	0.09	0.07
Jul	0.09	0.04	0.06	0.08	0.06	0.04
Aug	0.12	0.05	0.10	0.10	0.06	0.05
Sep	0.10	0.04	0.09	0.08	0.02	0.04
Nov	0.18	0.10	0.16	0.12	0.10	0.11
Dec	0.13	0.07	0.13	0.11	0.04	0.07

For Both SIC and SING systems, the generating firms with the largest market share are most inclined to have market power. The all-thermal generators rule out the relative advantage of different generating technologies in SING, thus larger market share will directly leave the firm with more strategic space to influence prices. On the contrary, the mixture of thermal and hydro plants in different companies will disperse the effect of market share, thus the unilateral market power is less observed in the SIC system.

4.6.3. Determinants of Market Power

In both cases, serial correlation was detected according to Durbin-Watson test. Generalized Least Square is utilized to mitigate the serial correlation in modeling disturbances. Estimators and corresponding estimates are derived from moments of method (MM) approach.

Variables	(1) SIC	(2) SING
Demand/Capacity	-0.0251	5.54e-05***
	(0.161)	(5.76e-06)
HHI	-0.0629	-1.097
	(2.717)	(0.906)
HHI^2	4.581	2.650
	(16.91)	(1.831)
Law	-0.0295*	0.00265
	(0.0163)	(0.00645)
Constant	0.0457	0.118
	(0.133)	(0.112)

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

In the case of SIC system, the coefficient of Law is significant at the 10% level. This negative effect on the Lerner Index indicates the effectiveness of the new tender law to reduce market power in electrical sector. Moreover, the magnitude of this effect is relatively large since the average LI will fall under 0.05, and become a highly competitive bidding market. As for the effect of HHI and its square, the Herfindahl Index of the top 3 firms in SIC is positively related to the price mark-up ratio. Suppose the market HHI jumps from 0.25 to 0.15 (from highly concentrated to unconcentrated according to US DOJ), the Lerner Index will decrease 0.04 correspondingly, which implies major reduction in market power. This fits the expectations that a more concentrated market will allow more space for firms to raise prices.

However, except for the demand/capacity ratio, all independent variables are statistically insignificant in the SING system. The unresponsiveness to the new tender law might due to the lower price markup ratio in the SING before. Since the price markup ratio is already low, it is reasonable to expect a less significant influence in the energy spot market of SING than SIC.

The evaluation of the new law would be better represented after the actual realization of new supply mix after 2021. The results here simply demonstrate the potential changes in firms' bidding behaviors in SIC and SING separately. With more information after the harmonized system, the influence of the new tender plans could shed clearer insights.

5. Conclusions

With the intention to simulate pricing behaviors of generation companies, this brief uses Guatemala and Chile as two examples to model the presence of market power in the electricity markets. Due to the extensive experiences both countries have obtained in energy liberalization, the findings can be roughly treated as a lower bound for the LAC region in terms of market power.

As a result of the extensive divestitures in the generation subsector, the spot prices in the Guatemalan electricity market has been decreasing since 2012. The reduction in spot prices directly decreases the end-user prices for large users and indirectly leads to the decrease in final tariffs faced by regulated consumers. In the sense of tariff reduction, large-scale divestitures in the electricity sector could be a good approach to liberalize the regulated market. Nevertheless, there is still positive sign of market power based on the level of demand, frequency for firms to adjust bids and firm-level capacity. Considering the current regulation of the spot market, the biggest firm has significant advantage over other generation firms as in the ability to raise prices.

In the Chilean electricity spot market, similar circumstances exist in that firms with biggest market shares tend to have more advantage in pricing behaviors. Nonetheless, the two independent bidding systems and grids within the Chilean market may induce different firm behaviors, and this drives the launch of new bidding framework (No. 20.805) which is planned by the CNE to further reduce end-user costs. As seen from the historical trends in market power, the implementation of the new tenders law has significant influence towards a competitive pricing strategy. Further effects upon completion can be evaluated as when it is expected to put into use in 2021.

A caveat of this study is that the it assumes that the market-clearing prices are determined solely by the bids and demand on the market, which is barely true in regulated markets. Although the governmental agencies are working towards a more unregulated spot market, the results can only serve as a possible outcome where the largest generating firm will have the most unilateral power over market prices. This could be a reminder when considering the deregulation in market mechanism in the energy spot market.

There are several directions for improvement, which will further generalize this model for more LAC countries. First is with more extensive data. With hourly firm-level data in the spot market, the elasticity of residual demand can be estimated more accurately to reflect the level of market power. Second, external factors could be incorporated into the assessment about generation, for example, the transmission congestion and the effect of financial contracts. If the hourly data of congestion were available, the residual demand will be more inelastic in congesting hours therefore indicating the estimates in this study should be a lower bound of market power. Finally, it is possible to evaluate firms' potential to execute market power with more plant-level data. *Ex ante* simulations can be conducted with plant-level data within short periods of time. It can provide an alternative measure for the potential of market power possessed by the generating companies.

Overall, the empirical analysis for LAC electrical sectors are scarce as a result of the semi-regulated market mechanism, but it is important to monitor the process along in order to obtain feedback and evaluation from the market. This study reviews the general methodologies when evaluating market power and tries to give a sense of the current market condition in LAC region. Implying from the two case study results, more efforts should be directed to devastating large generating firms in order to maintain a more balanced and competitive energy market.

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