Mixed Oligopoly and Market Power Mitigation*

Working Paper

Carlos Suarez

Department of Econometrics, Statistics and Applied Economics, Research Group on Governments and Markets, Universitat de Barcelona

June 10, 2016

Abstract

An important issue in discussions of privatization is the potential benefits to society from state owned enterprises (SOEs). Some economists and policy makers have suggested that SOEs are able to mitigate market power through aggressive pricing strategy. The aim of this work is to exploit the availability of information on price bids on wholesale electricity pools and the empirical techniques proposed by the literature specialized in electricity markets in order to identify the market power mitigation effect of SOEs in the Colombian market.

The results of this research suggest that although private firms exercise less market power than predicted by a profit maximization model, there are important differences in the exercise of unilateral market power between private firms and SOEs that supports the hypothesis of market power mitigation by the latter.

JEL Classification number: L13, L94, C10.

Keywords: Electricity Markets, Market Power, Privatization, Mixed Oligopoly, Regulatory Intervention.

1 Introduction

A key issue in the discussions about privatization is the potential benefits to society from State owned enterprises (SOEs). Advocates of SOEs argue that they are able to be used as economic policy instruments. For instance, in the field of public services, SOEs would be able to bear universal service obligations (USO)[1] and guarantee the supply of services

*Acknowledgements and Thanks: This work is based on the thesis I presented to the Master of Economics, Regulation and Competition on Public Service at the University of Barcelona. I would like to express my very great appreciation to my supervisor Professor Joan-Ramon Borrell. I appreciate the valuable and constructive comments of Professors Frank Wolak, Marc Bettzüge ,Felix Höffler and Luis Cabral. I also appreciate the comments of my colleagues at the Institute of Energy Economics at the University of Cologne and at the program of PhD in economics of the University of Barcelona. All opinions and errors in this document are entirely my own responsibility.

[1]Bel and Calzada (2009) analyses how the size of the universal service obligations (USO) and the mechanisms traditionally used to finance it have prevented privatization in the postal sector

adopting the role of last resource provider. The public policy targets of the principal would define the priority objective of this type of firms.

One might think that in a framework of oligopolistic competition, it is desirable that the public sector retains ownership of some companies as an economic policy instrument to achieve a better allocation of resources and improvements in economic welfare. Particularly, in the context of mixed markets (markets in which private and state owned compete) some economists and policy makers have argued that SOEs are able to mitigate market power through more aggressive pricing. This behavior of the SOEs is what will be called hereafter regulatory intervention. Beato and Mas-Colell (1984) demonstrates that SOEs are able to restore the efficiency of the markets applying the marginal cost pricing rule.

The mixed oligopoly literature have analyzed theoretically the strategic interaction between SOEs and private firms in non-perfect competitive markets[2] in order to establish the welfare effects of privatization. Several works of these types of models have concluded that full privatization is not recommendable because it can have counter-competitive effects in the market and subsequent increases in the dead-weight loss.

This conclusion arises from the assumption that the objective function of SOEs and mixed firms is different from the private ones. In most cases, the mixed oligopoly models assume that private firms aim maximizing profits while the objective function of SOEs (or mixed firms) consider the social welfare . In this type of models, under the assumption of equal productive efficiency of SOEs and private firms, the impact of privatization on welfare is driven by its effect on the intensity of competition. If there is no behavioral difference between private firms (Profit maximizing) and SOEs (Welfare maximizing) the results of mixed oligopoly models are equivalent to those of classical oligopoly models, hence, privatization would be neutral regarding the intensity of competition and allocative efficiency.

However, it is no possible to know a priori which the objective function of SOEs is. It depends of several issues related with the final objective of the government. For instance, if a government wants to solve a problem of fiscal deficit, its SOEs may try to maximizing profits. Conversely, if there are political pressure from voters to decrease prices, SOEs may try to maximize welfare or even sell its output with prices below marginal cost. Given this ambiguity and its importance in order to establish the effect of privatization in competition, the behavioral difference between private firms and SOEs is a matter that deserves empirical analysis.

The perspectives of this kind of analysis in regulated industries have improved during the last three decades due to availability of data and the diverseness of market reforms. Different stages of liberalization reforms and privatization applied to several countries has generated a heterogeneous configuration of markets in terms of levels of competition and types of ownership of competitors. Thus, in some markets there have been quite profound liberalization processes while the state retains ownership of major competitors. Given this type of experiences and the availability of information on these markets, it is possible to pose as an empirical question something that for mixed oligopoly models is an assumption.

[2]The main concern of this group of studies has focused on the optimal level of privatization (De Fraja and Delbono, 1989; Fershtman, 1990; Matsumura, 1998), the role that public companies as an instrument of economic policy (Beato and Mas-Colell, 1984; Bel and Calzada, 2009; Brandao and Castro, 2007; Cremer et al., 1989; Harris and Wiens, 1980) and the incentive compatibility between corporate managers interest and the objectives of the shareholders, in both, private and public companies (Barros, 1995; Fershtman and Judd, 1987).

Do public and private firms behave as if they would have the same objective? And, What can we learn from the empirical analysis of differences between the exercise of market power of private firms and SOEs?.

In the context of mixed oligopoly, the empirical literature is scarce and it has mainly focused in the differences of productive efficiency between private firms and SOEs(Lopez-de Silanes et al., 1997; Netter and Megginson, 2001). Regarding the behavioral differences, to my knowledge, there are only two relevant papers: Barros and Modesto (1999) applied to the banking sector in Portugal, and Seim and Waldfogel (2013) applied to the liquor stores in Pennsylvania.

In this work I address the objectives of public and private firms from an empirical perspective. This paper attempts to shed light on how public and private companies exercise market power. In this paper I apply models of unilateral market power in electricity markets to a framework in which profit-maximizing firms compete (private) with companies that maximize welfare (state owned). Particularly, I extend the analysis of the incentive to exercise market power (IEMP) proposed by McRae and Wolak (2009) to the case of social welfare maximizing firms. This technique uses the information about individual bids (willingness to sell) available in the electricity markets organized as a multi-product auction.I apply this extended methodology to the Colombian wholesale electricity market.

According to McRae and Wolak (2009) the advantage of the availability of detailed information of price and quantity bids, such as the one available in some electricity markets, is that it makes possible to estimate the level of market power without assumptions about i) parametric functional forms of demand function or variable costs function and ii) a model of strategic interaction of firms. These authors made the assumption of profit maximization in order to set up an empirical model for the analysis of the incentives to exercise market power.

The main contribution of this paper is proposing an empirical model for the analysis of the differences between private and SOEs versus the incentives to exercise market power in a multi-unit auction framework. This methodology provides a new analysis tool that contributes to clarify if privatization is a right decision in an environment of imperfect competition. Overall, this methodology is applicable, to any multi-product uniform price auction in which the bids of competitors are observable.

The findings of this research suggest that in Colombian electricity market generation firms have ability to exercise market power, and if all of them were profit maximizing firms, they would have the incentives to exercise it. The empirical analysis performed in this article suggests that there are important differences in the exercise of unilateral market power between private and SOEs that supports the hypothesis of market power mitigation the latter. My results indicate that the behavior of SOEs is very close to welfare maximizing in the spot market.In addition, when I introduce structural elements to the econometric models, I find partial evidence of profit maximization behavior by private firms and mild populist behavior by SOEs. This results are coherent with the behavioral structure of mixed oligopoly models.

This paper is divided into five sections. The second is devoted to explain the theoretical background of incentives of profit maximizing firms and welfare maximizing firms to exercise unilateral market power and point out the differences between them. Thirdly, I propose an empirical approach in order to identify behavioral differences between private firms and SOEs. In section 4 I present the characteristics of the Colombian wholesale electricity market, the structural issues of this market that should be taken account in order to achieve a more suitable identification of parameters and the results of applying the empirical approach proposed in section 3 to this market. The final part summarizes the results, presents some conclusions and proposes new research alternatives.

2 Understanding the incentives to exercise market power in electricity markets

This section is devoted to explain the theoretical background of the analysis of the IEMP of profit maximizing firms . In addition it presents the extension of this analysis to welfare maximizing firms.

The literature specialized in electricity markets have proposed several empirical techniques in order to analyzing market power issues (Borenstein et al., 2002; Bushnell et al., 2008; Green and Newbery, 1992; Hortacsu and Puller, 2008; Reguant, 2014; Wolak, 2000, 2003; Wolfram, 1998, 1999). In this framework, Wolak (2000) and McRae and Wolak (2009) developed a methodology in order to estimate the ability and the incentives to exercise market power based in a simple model of profit maximizing firms.

In the electricity markets framework, the ability to exercise market power is the ability to change the spot price making withdraws of output no matter if this withdraw is profitable or not. The classical concepts of elasticity and semi-elasticity of demand are suitable indicators of this ability (McRae and Wolak, 2009).

Regarding the IEMP, it is the ability to change the spot price making withdraws of output in order to improve the results of an objective function. Depending on this function and the market circumstances these incentives can change radically. For instance, a withdraw of output shifting the equilibrium price from the marginal cost pricing rule to higher values could be desirable for a profit maximizing but not for a welfare maximizing firm.

The theoretical work developed by Allaz and Vila (1993) demonstrated that when profit maximizing firms sell an important share of its output through forward contracts with fixed prices, they have less incentive to increase the prices in spot markets. Furthermore, if the amount of output sold in contracts exceeds the expected output levels (short position), firms have incentives to bid below its marginal cost in order to decrease the spot price .

I will take a account of the caveats described above through a simple static model of profit and welfare maximization. Assuming the generator has previously sold by contracts an amount of energy q^c_{ih} at a fixed price P^c_{ih}, the profit function is defined by the following expression:

$$\pi^e_{ih} = P_h(DR_{ih})(DR_{ih} - q^c_{ih}) + P^c_{ih} q^c_{ih} - C_i(DR_{ih})$$

Where π^e_{ih} represents the profits of the firm i in the hour h in the energy market, P_h the spot price, DR_{ih} is the residual demand of the firm i in the hour h, and $C_i(DR_{ih})$ is the cost function of the firm i. From the first order condition it is possible to obtain the fallowing expression:

$$P_h(DR_{ih}) = \frac{\partial C_i(DR_{ih})}{\partial DR_{ih}} - \frac{\partial P_h(DR_{ih})}{\partial DR_{ih}}(DR_{ih} - q^c_{ih}) \tag{1}$$

It is important to bear in mind that in the market equilibrium point, the residual demand of firm i in hour h DR_{ih} is equal to the total quantity produced by the firm at this hour, therefore $\frac{\partial C_i(DR_{ih})}{\partial DR_{ih}}$ is the marginal cost of the firm i at hour h. This is the first term of the right hand side of equation 1 and the second is the interaction of the inverse of the slope of residual demand curve and the net position in the forward market of the firm. This interaction is the optimal markup of a profit maximizing firm, i.e. its IEMP. Thus, the more the amount of energy sold by the firm through fixed price forward contracts, the less the incentive to increase the spot price. It is important to highlight that in cases in which the generator is in short position, it has the incentive to exercise market power by a reduction instead than an increment of the spot price (McRae and Wolak, 2009).

According to expression 1, the spot price and the marginal cost could be different because the IEMP. That is why the interaction of the inverse of the slope of residual demand curve and the net position in the forward market of the firm evaluated at the market clearing price, i.e. the inverse of the elasticity of the net residual demand, is a suitable measure of the incentive to exercise market power for profit maximizing firms.

Given that welfare maximizing firms have a different objective function, it is expected that it have distinct incentives to exercise market power in comparison with a profit maximizing firm. Hence it is possible that the measure of the incentive to exercise market power that is suitable for profit maximizing firms could not be useful for welfare maximizing firms. In fact, it is necessary to move back one step and clarifying if these types of firms have incentives to exercise market power. The analysis of the first order conditions of a welfare maximizing firm allows me to conclude that this type of agents do not have incentives to exercise market power.

The mixed oligopoly literature has analyzed models in which SOEs compete with private firms. In several cases the difference between the two types of firms is the objective function. Generally, in these models private companies are profit maximizers, while public or mixed firms regard welfare in its objective function. Several authors have proposed that the objective function of a partially private firm is the linear combination of the social welfare and its own benefits (Hindriks and Claude, 2006; Lee and Hwang, 2003; Matsumura, 1998):

$$V = (1 - \theta)W + \theta\pi_0$$

Where V is the objective function, W is the social welfare, π_0 are the benefits of the SOE and θ is a weight of the benefits. In the case of mixed firms, this weight could be a function of the share of private participation.

For simplicity I will present the special case of a pure welfare maximizing firm. I assume that the welfare maximizing firm, noted with the sub-index *0*, competes with N private firms, that are noted with the sub-index *j*. If the welfare maximizing generator *0* has previously sold an amount of energy q^c_{0h} at a fixed P^c_{0h}, and the private competitors have previously sold an amount of energy, q^c_{ih} at a fixed P^c_{ih} , the objective function of the firm *0* can be expressed as:

$$\begin{aligned} W_h = \int_0^{Q_h} P_h(x)\,dx - P_h \sum_{j=1}^{N} (q_{jh} - q^c_{jh}) - P_h(DR_{oh} - q^c_{oh}) - \sum_{j=1}^{N} P^c_{jh} q^c_{jh} - P^c_{0h} q^c_{0h} \\ + \sum_{j=1}^{N} [P_h(q_{jh} - q^c_{jh}) + P^c_{jh} q^c_{jh} - C_j(q_{jh})] + P_h(DR_{0h} - q_{0h}) - C_0(DR_{0h}) \end{aligned}$$

Where W_h is the social welfare in hour h, $P_h(x)$ Is the inverse demand function in the hour h, q_{jh} are the quantities produced by the generator j in hour h, q^c_{jh} are the quantities committed in forward contracts by the generator j in hour h. It is important to note that when $i = j$, $q_{ih} = DR_{ih}$. From the first order conditions it is possible to obtain:

$$P_h(DR_{0h}) = \frac{\partial C_0(DR_{0h})}{\partial DR_{0h}} \tag{2}$$

This is the marginal cost pricing rule. This implies that a pure welfare-maximizing firm has no IEMP, regardless of their net position in forward contract market and the elasticity of residual demand.

In summary, if private firms behave as profit maximizers, the interaction of the slope of residual demand and the net financial position have an impact in price bids. On the other hand, if SOEs behave as welfare maximizing, they have no IEMP, i.e. their prices will not be affected by this interaction and will be mainly explained by the marginal cost.

The above result is relevant for the analysis of market power in a mixed oligopoly framework. It entails that if SOEs perform welfare maximizing behavior, they will try to restore the marginal cost pricing rule, i.e. conducting market power mitigation. On the other hand, if SOEs are profit maximizing agents or have an identical behavior than private firms, the privatization processes do not have an effect in the intensity of competition.

In the empirical part of this paper I will assume that the objective function of the mixed firms depends on its majority stake. When the majority of shareholding in the firm is private it maximizes profits and when the majority of shareholding is state owned then it maximizes social welfare.

3 Identification and estimation approach

In this section the problem of the difference of private and state owned incentives to exercise market power will be addressed from an empirical perspective. This model adopts the estimation methodology suggested by McRae and Wolak (2009) but includes the interaction between the type of ownership of firms and their IEMP.

The extension of the application of this model in order to establish the differences mentioned above is based on the expression (1) for private companies and expression (2) for SOEs. I propose to estimate several econometric models with the following structure:

$$P^*_{ih} = \beta_0 + \delta(\widehat{CMG}_{ih}) + \alpha_{pri}(D^{pri}_i * \widehat{IEMP}_{ih}) + \alpha_{soe}(D^{soe}_i * \widehat{IEMP}_{ih}) + \sum_{k=1}^{N} \beta_k x_{kih} + \mu_{soe} + \varphi_{year} + \psi_{weekday} + \varepsilon_{ih} \tag{3}$$

Where $P_h i^*$ is the marginal price of generator i in the hour h, $\widehat{CMG}_{ih}$ is the estimation of marginal cost, $\widehat{IEMP}_{ih}$ is the incentive to exercise market power for a profit maximizing firm (the inverse of semi - elasticity of demand discounting the energy committed in forward contracts), D^{soe}_i is a dummy variable that takes the value of 1 when the firm analysed is under state control and 0 otherwise. D^{pri}_i is a dummy variable that takes the value of 1 when the firm analysed is private and 0 otherwise ($D^{pri}_i = (1 - D^{soe}_i)$). The expression x_{kih}

represents the k number of control variables of the model. μ_{soe},φ_{year}, $\psi_{weekday}$ represents SOEs, yearly, and weekday fixed effects, respectively. The term of disturbance ε_{ih} contains the effects of unobservable variables. In section 4 I will do different assumptions about the features of this term of disturbance. β_0, δ, α_{soe}, α_{pri},β_k are the parameters to be estimated.

In the control variables set I included hourly and yearly fixed effects, indicators of supply shocks (availability of the units and water flows related with the reservoirs of hydro units), weather indicators (dry months, Niño and Niña event dummies)and proxy variables accounting for several types of potential incentives arising from sources different to the spot market. In subsection 4.2. I will explain with more detail this sources of remuneration. Likewise, table 4.will show a brief qualitative description of each of the variables included in the model and highlights its most important descriptive statistics.

These econometric exercises aim to obtain empirical evidence that allow verifying several connections which correspond with the behavioral assumptions of the typical theoretical model of mixed oligopoly such as:

1. Relation between differences in the ownership of firms and differences in the impact of the incentives to exercise market power on spot prices.

2. Relation between state owned ownership of the firm and market power mitigation.

3. Relation between private ownership of the firm and the exercise of market power.

For the purposes of disentangling the neutrality of privatization on competition, the key connection of those mentioned above is the first one. It is important to note that in the previous section it was shown that the profit-maximizing firms have incentive to exercise market power and that it can be measured by the interaction of the inverse of the slope of the residual demand and the net financial position of the private firm. If private firms behave as profit maximizers and SOEs perform regulatory intervention, depending on the ownership of each one, the interaction of the slope of residual demand and net financial position will have different impacts on bidding strategy. Therefore empirical evidence is sought on these differences.

In relation to the second connection mentioned above,it should be clarified that regulatory intervention does not necessarily imply that SOEs bid prices lower than private firms. Rather, regulatory intervention entails using the SOE price bids in order to reach levels that minimize allocative inefficiency. So, a firm that exercises perfect regulatory intervention is welfare maximizing. In the previous section we showed that when a firm is welfare maximizing, it has no incentive to exercise market power and its optimal strategy is to bid its own marginal cost. Therefore, if SOEs perform regulatory intervention they have no incentive to exercise market power, i.e. their prices will be mainly explained by the marginal cost and will not be affected by the interaction of its residual demand with its net financial position. Hence, the empirical strategy suggested here looks for evidence that such interaction in the case of SOEs has no effect on their own bid prices and the spot price.

Finally, regarding the third connection,if private firms behave as profit maximizers they will impact the market clearing price according to their incentive to exercise market power. Hence the econometric exercises proposed here look for empirical evidence on the impact of the IEMP of private companies on their own bid prices and the spot price. I propose to test three hypotheses in order to get evidence of the connections listed above.

i Hypoyhesis 1 (H1): The exercise of market power of state owned and private firms is different given their incentives

ii Hypothesis 3 (H3): The SOEs (do not) exercise market power as social welfare maximizing agents.

iii Hypothesis 2 (H2): the private firms exercise market power as profit maximizing agents.

Overall, testing the rationale that the exercise of market power of state owned and private firms are equal given their incentives, would be equivalent to test the Null Hypothesis $\alpha_{pri} = \alpha_{soe}$. In addition, if state owned firms are welfare maximizers it would be expected that the parameter α_{soe} should not be statistically different form zero, i.e.,Null Hypothesis $\alpha_{soe} = 0$. Moreover,according to the theory, if private companies are profit maximizers it would be expected that the parameter α_{pri} should be statistically significant, with positive sign and very close to 1, i.e.,Null Hypothesis $\alpha_{pri} = 1$. I perform these tests after the estimation of several econometric models of the expression (3).

In this work I apply the empirical approach described above to the Colombian wholesale electricity market. In the next section I will describe the most important features of this market and point out the structural elements that must be considered in order to improve the identification of the relevant parameters in this case. In addition, I will explain the details of the methodological procedure for computing the independent variables of the model such as the incentive to exercise market power and marginal costs. Finally, I will outline the econometric method for the estimation and present the most relevant results.

4 Empirical Implementation

4.1 The Colombian wholesale electricity market and mixed oligopoly structure

In order to frame a market in the context of mixed oligopoly one must observe three conditions: i) The market is liberalized, i.e. the price is determined by the competing bids from producers; ii) state owned, private and mixed firms compete in equal conditions, i.e. no discrimination rules; iii) the conditions of competition in the market are not perfect, i.e. high levels of concentration. This section describes the main features of the Colombian generation market that allow classify it as a mixed oligopoly and the main aspects in this market to be taken into account when trying to consider problems of market power.

Regarding the first condition, since the issuance of the Public Utilities Act (Act 142 of 1994) and the Electricity Act (Act 143 of 1994), the generation activity in Colombia is organized in a wholesale electricity market centralized in a pool scheme. Generators can sell their energy through long run bilateral contracts with other agents and directly in the daily-ahead energy exchange. This exchange operates as a multi-product uniform first-price auction, in which each generator reports a price bid (or willingness to sell) for each generation unit valid for the 24 hours of the day[3]. This features allows verify that the Colombian wholesale energy market is not price regulated nor a cost based pool and it obeys to the conditions of competition among producers.

Secondly, with respect to the coexistence of private and state owned companies in the Colombian generation market, it is important highlight that although the spirit of the Colombian electricity sector reform in the early nineties aimed at promoting private entrepreneurship, Colombian generation activity has a high share of state owned or mixed firms that are under the control of state entities. Table 1 shows Market shares in Colombian wholesale electricity market - 2014. In the second column it is possible to observe that 4 of the 7 most important firms are state controlled. According to this information, the ownership structure of the major generation firms operating in Colombia is heterogeneous regarding the private or public nature of its major shareholders[4].

Table 1: Market shares in Colombian wholesale electricity market - 2014

Firm	Majority Shareholding	Electricity Generation (gWh)	%	Cumulative %
EMGESA	Private	13691	21%	21%
EPM	SOE	13626	21%	42%
ISAGEN	SOE	10609	16%	59%
GECELCA	SOE	7508	12%	71%
COLINV.	Private	6711	10%	81%
AES	Private	3982	6%	87%
GENSA	SOE	2436	4%	91%
Others		5764	9%	100%
Total		64328	100%	100%
HH				1422

Source: XM Market Operator

Finally, regarding the third condition, i.e. the level of competition and concentration in the market, the concentration levels of electricity generation activity in Colombia reach levels of moderate oligopoly according to the classification made by the United States Department of Justice. Table 1 presents the participation of the six major generation companies in the Colombian generation market.

4.2 Market features and structural elements

In addition to its features of mixed oligopoly, there are several characteristics of the Colombian wholesale electricity market that have to be considered in order to identify properly

[3]For each hour the National Dispatch Center (NDC) determines the price that equates the supply of generators with total demand and which plants will be dispatched. The dispatch process orders the generation plants ascending according to the price bids (merit order). The spot price is the bid of the plant that equates the generation supply and demand. All generation plants that submitted bids below the equilibrium price are dispatched and all are paid the marginal price that clears the market.

[4]The growth prospects outlined by the results of the reliability charges auctions suggest that although there are new private agents in the generation market, the firms under public control will be the owner of a greater share of the net installed capacity in the Colombian electricity system in 2018. The two biggest expansion projects, built from the implementation of Reliability Charge scheme, hydroelectric Ituango (1200 MW) and Sogamoso hydro (800 MW), belong to companies controlled by public entities, EPM and ISAGEN respectively.

the unilateral market power issue.

i The Colombian generation supply depends importantly on its high proportion of hydroelectric generation resources. Table 2 shows the share of generation by resource type for December 2013 and December 2014. It is possible to see the importance of large hydro plants. In addition to this technological characteristic, the rain regime is subject to the effects of the Nino and Nina events. Particularly, during Nino events there are dry weather conditions, decreasing importantly the contribution of hydroelectric resources, the happens during Nina events. In order to guarantee the reliability of supply during Nino events, Colombia has created a payment for power availability called "reliability charge". This mechanism works as a call option. The product of the option is the obligation to generate firm electricity, which is assigned in a long run multi-unit auction every time the authorities stablish that it is necessary to guarantee higher amounts of back up of power. The reference price is the spot price of the wholesale electricity market and the strike price is the scarcity price. The latter is defined by the regulator and it is a reference of the generation variable cost of the most expensive unit in the system. As a consequence of this, it is possible that the incentives of the reliability charge distort the IEMP in the spot market during critical Niña and Niño events. I cope with this problem, checking the results in sub-samples in which Nina and Nino events are droped. In addition I included in the set of control variables Niño and Niña fixed effects and a dummy that take the value of 1 when the marginal bid price of a firm is greater than the scarcity price (activation of the reliability charge).

Table 2: Generation by type of resource 2013 and 2014

	Generation (gWh)			
Type	December 2013	December 2014	Growth	Share 2014
Hydro	3622	3707	2%	68 %
Thermal	1370	1474	8%	26 %
Small Units	300	305	2%	6%
Cogeneration	32	45	41%	1%
Total	5323	5531	4%	100%

Source: XM Market Operator

ii The most of the energy transactions are performed through long-run fixed-price bilateral contracts, since physical dispatch is centrally coordinated, bilateral forward contracts work as financial hedges against the spot prices (Garcia and Arbelaez, 2002). These contracts are able to serve as a tool of hedging against price spikes due to unforeseeable shocks in hydro resources. Table 3 shows the total energy traded during 2014 and 2013 in the generation market. It distinguish between transactions conducted through price fixed forward contracts and direct transactions in the daily ahead energy exchange. Fortunately, the amounts sold in forward contract by every agent are observable. So, it is possible to compute the net forward market position of the firms as the difference of the ideal programmed generation and the quantity sold in forward contracts

Table 3: Energy sales by trade mechanism 2013 and 2014

	Generation (gWh)			
	2013	2014	Growth	Share 2014
Spot Market	14949	15507	4%	18%
Forward Contracts	71374	69846	-2%	82%
Total	86323	85352	-1%	100%

Source: XM Market Operator

iii It is important to bear in mind that the generators in Colombian electricity market are able to obtain income from the payments for reliability of power, from ancillary services and from remuneration caused by out of merit generation. Hence,if the agents anticipate that they potentially will lost money from the sources of income mentioned above, they could depart from the optimal strategy of exercise of market power in the short run market.

As stated above, Colombian generators earn income for ancillary services, specially the automatic generation control(AGC). This is an issue in this market because according to market regulation, the price bids made for the spot market are the same as those valid for the allocation of AGC. Given that the majority of time the AGC service is provided by hydro plants,which have lower variable costs, it is expected that an increase in the bid prices reduces the amount sold in the AGC market and hence the income from this source decreases. Even when I control for the amount of energy provided to the AGC service, it is possible that the potential unobserved effect of the AGC market incentive arise endogeneity problems and a bias in the OLS estimation. To see this, assume that the total profits of the generator is the sum of the profits from every source of income, i.e the energy market (the spot market and the forward market) and the ancillary services.

$$\Pi_{ih} = \pi^e_{ih} + \pi^a_{ih}$$

Where Pi_{ih} is the total profit of firm i in hour h,π^e_{ih} is the profit of firm i in the energy market in hour h, π^a_{ih} is the profit of firm i from ancillary services in hour h.From the first order condition it is possible to obtain the fallowing expression:

$$P_h(DR_{ih}) = \frac{\partial C_i(DR_{ih})}{\partial DR_{ih}} - \frac{\partial P_h(DR_{ih})}{\partial DR_{ih}}(DR_{ih} - q^c_{ih}) + \frac{\partial \pi^a_{ih}}{\partial DR_{ih}}$$

If $\frac{\partial \pi^a_{ih}}{\partial DR_{ih}}$ is unobservable for the econometrist, as it is in this case, and $\mathbf{E}(-\frac{\partial P_h(DR_{ih})}{\partial DR_{ih}}(DR_{ih} - q^c_{ih})|\frac{\partial \pi^a_{ih}}{\partial DR_{ih}}) \neq 0$ then a problem of endogeneity arises.

In order to handle this issue, it is necessary to find instrumental variables for the IEMP arising exclusively from the energy market and not related with ACG market. The literature of market power estimation in an environment of differentiated products suggest using the observed characteristics of the products produced by rival firms in order to obtain the optimal instruments for a specific product(Berry et al., 1995). Doing an analogy in the framework of electricity market and given that an important assumption of our model is that forward contracts are exogenous, I propose to use as instruments of the IEMP, the forward contracts and the interaction of this variable with the slope of residual demand of others competitors. The assumption that the forward contracts of firm A is no correlated with the unobserved effect of AGC incentives of firm B seems very reasonable. In the next subsection I will give details of the computation of the instruments proposed.

In the case of security generation and positive reconciliation the producer is compelled to generate a fixed amount of electricity no matter if it is in merit or not. This entails that the generator cannot choose any point along its residual demand curve. If the restriction is binding the generator not necessarily applies the pricing rule of expression 1. On the other hand, negative reconciliations are compensations paid by the wholesale electricity market to those generators that are in merit in the ideal generation program but cannot deliver its electricity due system restrictions. The regulations in place in 2008 (Regulation 034 of 2001) established that the price paid by the negative reconciliations would be the semi sum of the bid price and the spot price. If the generator anticipates system restrictions, it could be optimal to bid zero prices in order to maximize the amount of electricity to be compensated by negative reconciliation. Fortunately, the energy provided for security generation, positive reconciliation payments and negative reconciliation payments are observable. I control for these variables in the econometric model.

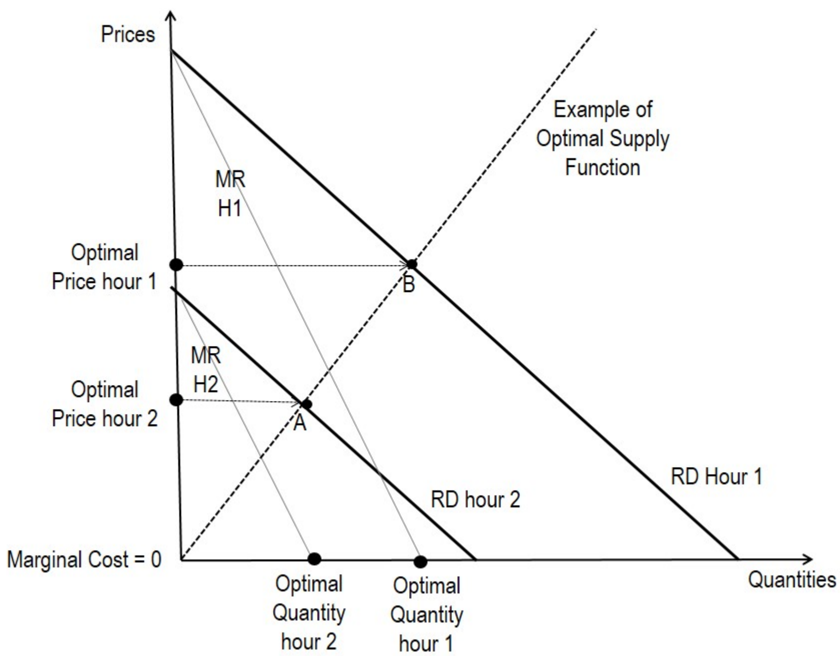
iv Finally, the rules of Colombian electricity exchange market allow only one bid per unit valid for the 24 hours of the day. The daily bid constrain limits the generators ability of choose in a precise way the bid that maximizes its objective function (profits/welfare) in every hour. The generator cannot bid a continuous supply function equilibrium that intersects the maximum profit point, given the different realizations of the residual demand. Instead, the generator must choose a unique price in order to maximize its daily expected profits (McRae and Wolak, 2009) (or daily expected welfare) and it have to do a unique statement about its availability. This entails that hourly incentives to exercise market power are not necessarily the same to daily incentives. That is why, I cope with this problem proposing a daily measurement of the incentive to exercise market power.

As a result of daily bids restriction, the price that maximizes the daily profits (or welfare) not necessarily is the same price that it would have been staked by a generator maximizing hourly profits (or welfare). Under the restriction, the generator has to consider the residual demand of every hour and it has to find an optimal daily price. In on-peak demand period, this daily price is lower than the optimal price that it would be chosen if he had the hourly bid option. The contrary happens in the case of off-peak demand periods.

For instance, in figure 2 and figure 3 it is presented the case in which the firm has only one plant and it have to bid one unique price for two periods. In this example we assume marginal cost equal to zero. For every hour there are different residual demands functions (RD hour 1 and RD hour 2). If the generator could stake an ordered pair (price, quantity) for each hour it would choose the point A for hour 2 and point B for hour 1. The generator will choose the quantities in which the marginal revenue is equal to marginal cost. In the case in which the generator can bid a supply function (no restrictions) it would bid some function similar to the dotted line in figure 3.

Once the generator is restricted he has to find an optimal price for two periods. So it will bid the price that maximize the sum of RD of hour 1 and RD of hour 2. In figure 4. We can observe the case when the generator is restricted. In this figure it is possible to see that the optimal price under the restriction is lower than the no restricted optimal price in hour 2 (On peak period). Conversely, the optimal price under the restriction is higher than the no restricted optimal price in hour 1 (Off peak period).

Figure 1: Optimal decision no restricted generator



The quantities chosen by the generator are different from the quantity that equates marginal revenue and marginal cost. The quantity is lower than the optimal in off-peak demand periods and it is higher than optimal in on peak demand periods. On the other hand, the daily price is higher than the optimal in off-peak demand periods and it is lower than optimal in on peak demand periods.

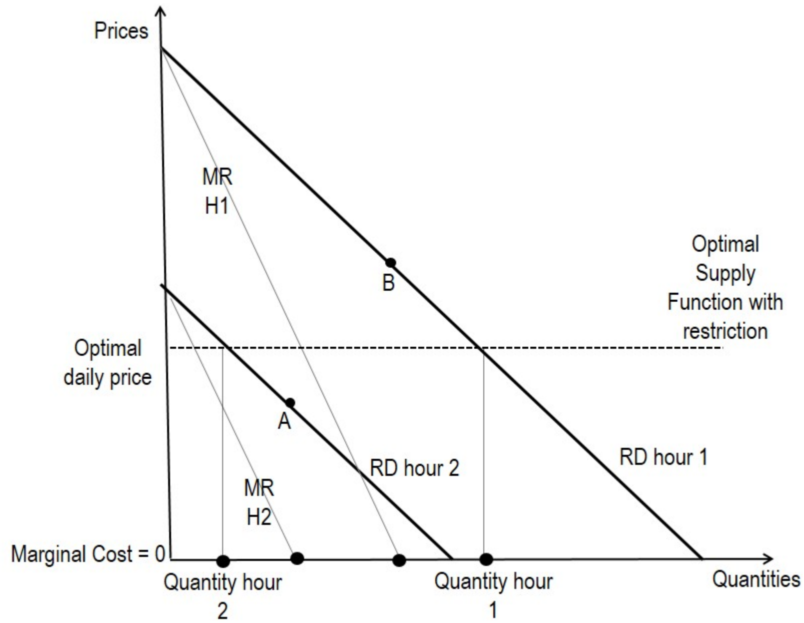
Under the design of Colombian wholesale market and from a residual demand perspective, in order to maximize profits or welfare the generator have to choose:

1. Which plant will fix its marginal price in every hour. It entails defining a merit order for its own plants.

2. It have to choose a bid for the different plants for the whole day.

The problem of the generator is to design a set of daily bids $S = \{s_1, s_2, s_m s_M\}$ where M is the number of units that the generator is able to bid. These bids are ordered from lowest to highest, such that these bids maximize the daily profit (or welfare). If we adopt a residual demand approach, such that the bids of the competitors are given, the generator should choose the bids that clear the market in the (24 hours of the day) T periods of the day, constrained to the capacity of its own plants. According to the

Figure 2: Optimal decision restricted generator



market's rules and the residual demand approach, the equilibrium price of the market (or marginal price) is $pt = min(s_1, s_2, , s_m, , s_M)$ such that:

$$DR_t(s_m) = \sum_{i=1}^{m} q_{it}$$

If the plants are ordered by merit, it entails that the spot price i equal to de bid of the marginal plant of the generator, $Pt = Sm$, if plant m is clearing the market in hour t.

If the day has T periods with different residual demands, the generator owns M plants and $M < T$, in $T - M$ periods the generator would not be able to choose the exactly bid that clears the market in the profit maximizing (or welfare maximizing point) point of every hour. In fact, the generator is compelled to clear the market with one bid, let s_m , for several hours of the day.

Given that the decision of the generator is continuous in the level of the bids but discrete in the combination of plants, we can make the assumption that the decision process of the generator is as follows:

i) Firstly, the generator calculates the corresponding set S^* which maximizes profit (or welfare) for each possible combination of the M plants in the T periods,($(M + 1)T$ combinations).

ii) Once the generator estimates the set S^* for the $L = (M+1)T$ possible combinations of plants, it can compare the profits (or welfare) of each different combination. The generator will choose the combination of plants with higher profits (welfare). Hence if the generator choose a specific combination, say a^*, the set of bids S_a^* corresponding to that combination, it should be profit (or welfare) maximizing.

The case of profit maximization: Let a^* be the optimal combination and $S_a = \{s_{m1}, s_{m2}, , s_{mt}, , s_{mT}\}$ the set of bids for that specific combination, where the first sub-index indicates the plant, and the second sub-index indicates the period. Let DR_t^i be the residual demand at hour t (subindex) which corresponds to plant i in the combination a^*.
In the case it is considered the forward contracts, maximization problem is:

$$max_{s_{1t},s_{2t},\ldots,s_{Mt}} \sum_{m=1}^{M} [s_{mt}(\sum_{i=m} DR_t^i(s_{mt}) - q_t^c) + \sum_{i=m} p_t^c q_t^c - \sum_{i=m} C_t^i(DR_t^i(s_{mt}))]$$

Subject to the capacity constraints and the non-negativity conditions:

$$0 \leq q_{mt} \leq \overline{q_{mt}}$$

If the restrictions are not binding, the first order conditions of this problem are:

$$\sum_{i=m}(DR_t^i(s_m) - q_t^c) + s_m \sum_{i=m} \frac{\partial DR_t^i(s_m)}{\partial s_m} - \sum_{i=m} \frac{\partial C_t^i}{\partial DR_t^i} \frac{\partial DR_t^i(s_m)}{\partial s_m} = 0$$

The optimal bids s_m^* for a private firm should be such that:

$$s_m^* = \frac{\sum_{i=m} \frac{\partial C_t^i}{\partial DR_t^i} \frac{\partial DR_t^i(s_m^*)}{\partial s_m^*} - \sum_{i=m}(DR_t^i(s_m^*) - q_t^c)}{\sum_{i=m} \frac{\partial DR_t^i(s_m^*)}{\partial s_m^*}}$$

If constant marginal cost of the plant m is assumed, the optimal bid of a daily profit maximizing firm can be expressed s_m^* as:

$$s_m^* = MC_m + \frac{-\sum_{i=m}(DR_t^i(s_m^*) - q_t^c)}{\sum_{i=m} \frac{\partial DR_t^i(s_m^*)}{\partial s_m^*}} \tag{4}$$

Where MC_m is the marginal cost of plant m. The second term of the right hand side is a weighted version of the inverse of the semi elasticity of the residual demand, this will be the incentive to exercise market power of a firm that maximize daily expect profits. I will compute the daily IEMP of the firms for the daily model according to this expression.

The case of welfare maximization: The problem of a welfare maximization firm is different. I will adopt a simplistic approach in which the welfare maximizing firm give the same weights to the consumer surplus and the firm's profits. In addition, it gives the same weight to its own profits and those of other firms. If there are K+1 profit maximizing firms (private) in the market and the welfare maximizing firm (public firm) is identified with the index *0*, the objective function of this firm (The welfare function) for the period t can be expressed as:

$$W_t = CS_t + \sum_{k=0}^{K} \pi_{kt}$$

The welfare function for a day can be expressed as:

$$W_d = \sum_{t=1}^{T} CS_t + \sum_{k=0}^{K} \pi_{kt}$$

In the residual demand approach the firms take the actions of others as given, that is why the public firm is going to try to maximize welfare given the demand and the bids of others. So the firm will try to maximize the consumer surplus as the area between price and the residual demand function instead of the area between price and total demand. Assuming that $P_h(x)$ is the inverse demand function in the hour h, it is possible to express the welfare as:

$$W_t = \int_0^{Q_t} P_h(x)\,dx - P_t(Q_t - \sum_{k=0}^{N} q_{kt}^c) - \sum_{k=0}^{N} P_{kt}^c q_{kt}^c + P_t \sum_{k=0}^{N} (q_{kt} - q_{kt}^c) + \sum_{k=0}^{N} P_{kt}^c q_{kt}^c - \sum_{k=0}^{N} C_k(q_{kt})$$

Given that $Q_t = \sum_{k=0}^{K} q_{kt}$ it is easy to show that W_t simplifies to:

$$W_t = \int_0^{Q_t} P_t(x)\,dx - \sum_{k=0}^{N} C_k(q_{kt})$$

Given the residual demand approach, we know that q_{kt} for $k \neq 0$ are given, and that $q_{0t} = DR0t^m(s_m)$ if the unit m is marginal in the hour (period) t. As in the case of profit maximization, we will identify the periods in which the plant m is marginal with the super-index i. Applying this to the equation of W_t and integrating in the T periods and M units, the maximization problem of daily expected welfare is:

$$max_{s_{1t},s_{2t},\ldots,s_{Mt}} \sum_{m=0}^{M} \sum_{i=m} \int_0^{Q_t} P_t(DR_{0t}^i(s_{mt}))\,dDR_{0t} - \sum_{k=1}^{N} \sum_{t=1}^{T} C_k(q_{kt}) - \sum_{m=0}^{M} \sum_{i=m} C_t^i(DR_{0t}^i(s_{mt}))$$

Subject to the capacity constraints and the non-negativity conditions:

$$0 \leq q_{mt} \leq \overline{q_{mt}}$$

If the restrictions are not binding, the m first order conditions of this problem are:

$$\sum_{i=m} P_t(DR_{0t}^i(s_m)) \frac{\partial DR_t^i(s_m)}{\partial s_m} - \sum_{i=m} \frac{\partial C_t^i}{\partial DR_t^i} \frac{\partial DR_t^i(s_m)}{\partial s_m} = 0$$

Rearranging the M first order conditions I have:

$$\sum_{i=m} P_t(DR_{0t}^i(s_m)) \frac{\partial DR_t^i(s_m)}{\partial s_m} = \sum_{i=m} \frac{\partial C_t^i}{\partial DR_t^i} \frac{\partial DR_t^i(s_m)}{\partial s_m}$$

This means that the bid of unit m should be such that spot prices of the periods in which the plant m is marginal weighted by the slope of the residual demand equals the marginal cost of the firm in the same periods weighted by the same slope.
Given that $pt = min(s_1, s_2, , s_m, , s_M)$ such that $DR_t(s_m) = \sum_{i=1}^{m} q_{it}$,the spot price in period t is equal to de bid of the marginal plant of the generator, $P_t = s_m$, if plant m is clearing the market in hour t. Replacing $P_t(DR_{0t}^i(s_m))$ with s_m in the first order conditions I have:

$$s_m = \frac{\sum_{i=m} \frac{\partial C_t^i}{\partial DR_t^i} \frac{\partial DR_t^i(s_m)}{\partial s_m}}{\sum_{i=m} \frac{\partial DR_t^i(s_m)}{\partial s_m}}$$

In addition if the the marginal cost of the plant m is constant during the day it is possible express the optimal bid of a daily welfare maximizing firm as:

$$s_m = MC_m \tag{5}$$

Where MC_m is the marginal cost of plant m. It was shown that a firm that maximizes the expected daily welfare maximizing firm will bid each plant at its marginal cost, i.e. it does not have incentive to exercise market power.

4.3 Data

I analysed hourly and daily data of 23 firms in the Colombian wholesale electricity market during the period 2005 to 2014.

In order to test the hypothesis H1, H2 and H3 through the estimation of the parameters α_{soe} and α_{pri} of the model proposed in expression 3, we need the data of marginal costs and the IEMP. Unfortunately, it is not possible to observe directly these variables, so we have to trust in indirect estimations of them.

Regarding marginal cost, I assume an accounting approach similar to other previews works in the field of market power in electricity markets (Borenstein and Bushnell, 1999; Borenstein et al., 2002; Green and Newbery, 1992; Wolak, 2000; Wolfram, 1998, 1999). I computed the variable costs of thermal plants taking account of the technical parameters of the plants (Heat Rate), fuel costs and fuel transportation costs. The variable cost was built as the multiplication of heat rate (MBTU / MWh), fuel costs (US $ / MBTU) and the exchange rate (Colombian pesos / US $).

For marginal cost estimation of gas fired plants I consider the regulated price of the gas from the Guajira well. In adittion, I take account for the transportation costs according to administrative acts of the Regulatory Comission of Energy and Gas (CREG 70 and 125 of 2003), given the location of the plants and taking a fare of transportation charges of 50% fixed and 50% variable. For coal fired plants I took the FOB export price of thermal coal available in the databases of the Mines and Energy Planning Unit (UPME). The price in dollars per ton was transformed to dollars per MBTU units, multiplying for a calorific value of the Colombian thermal coal of 1,370 btu per pound (Source: regulation 2009 180507 Colombian Ministry of Energy and Mines). For transportation cost of coal I assume an exportation parity approach,this means that transportation cost are the difference of the transport cost from the source of coal production to the generation unit minus the transport cost from the source of production to the exportation port (Source: System of

Information of Efficient Costs for Road Freight Transportation, Transportation Ministry of Colombia). I calculated and imputed daily marginal cost for 21 thermal plants belonged by 21 firms. For hydro plants I make the assumption of zero marginal cost[5].

On the other hand, concerning to the incentives to exercise market power, it is important to remember that this incentive is related to the elasticity of residual demand. Since in the Colombian wholesale electricity market is possible to observe price bids and commercial availability of each plant as well as the actual demand of electricity, it is feasible to replicate the residual demand of each generator. The result of this exercise is a decreasing step function of residual demand on which its partial derivative is zero or is indeterminate (McRae and Wolak, 2009)). Therefore, to calculate the inverse of the net semi-elasticity of demand is necessary to make an approximation to the slope of this function around the market equilibrium price. Wolak (2003) suggests calculating the elasticity of residual demand using the points of the function with prices closer, above and below the market equilibrium price.

For each of the firms analysed and each of the hours, I calculated the inverse of semi-elasticity of residual demand, i.e. the hourly IEMP, according to the formula:

$$\widehat{HIEMP}_{ih} = \frac{P_h^{above}(1+\delta) - P_h^{below}(1-\delta)}{DR_{ih}(P_h \times (1+\delta)) - DR_{ih}(P_h \times (1-\delta))} \times (IG_{ih} - q_{ih}^c) \tag{6}$$

Where $\widehat{HIEMP}_{ih}$ is the incentive to exercise market power,$P_h^{above}(1+\delta)$ is the price of the next step of the residual demand curve above the price $P_h \times (1+\delta)$, $P_h^{below}(1+\delta)$ is the price of the previous step of the residual demand curve below the price $P_h \times (1-\delta)$, $DR_{ih}(.)$ is the residual demand function of generator i in the hour h, IG_{ih} is the actual generation of producer i in hour h and q_{ih}^c is the quantity of energy committed in long run fixed price contracts[6]. In Colombian wholesale electricity market this quantity is observable ex-post. Finally I assume a parameter $\delta = 0,05$ (5%). Previous works using this methodology (McRae and Wolak, 2009; Wolak, 2000) argued that that changes in δ does not effects dramatically the results. I computed the $\widehat{HIEMP}_{ih}$ for δ of 10%, 25% and 50% and the most important qualitative conclusions remains unchanged. Figure 3 illustrates this calculation technique.

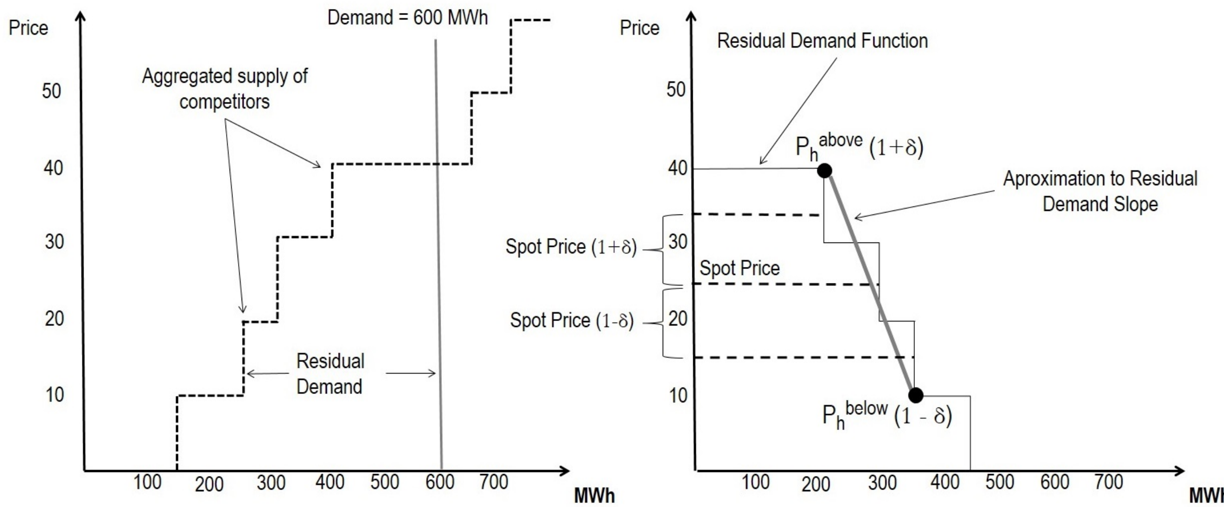
The information about daily price bids, hourly spot prices, hourly ideal generation and hourly sales in forward contracts, necessary for the computation of the IEMP was taken from the web site of the Colombian wholesale electricity market operator XM.

Figure 4 shows the average hourly Incentive to exercise market power considering contracting levels of the most important generation firms in Colombia. The x–axis represents

[5]There are two reasons that make this assumption reasonable. Firstly the empirical exercise proposed in this work is based in a static model. From a static perspective there is no opportunity cost of water if there are no other alternative uses of this resource in the same moment t. The reservoirs accounted in this exercise are not multipurpose and they are exclusively dedicated to electricity generation, so the water stored in them has not an alternative use. Secondly the regulation capacity of the Colombian reservoirs is very limited, excepting the reservoir El Peol corresponding to the Guatape plant which paradoxically shows lower prices than others reservoir with less regulation capacity.

[6]From a supply function equilibrium approach (Klemperer and Meyer, 1989), the marginal price bid is the best response of a generation firm given the actions taken by its competitors (it sets its generation level and the spot price). This optimal bid price is associated with an optimal generation quantity, so the residual demand of a generator i in the equilibrium price should be equal to its ideal generation. That is why I propose to estimate the inverse of semielasticity of residual demand as the product of the slope of the residual demand and the ideal generation of firm i.

Figure 3: Calculation technique of IEMP



the hours of the day, which are equivalent to de clearing price periods in Colombian electricity market, and y–axis represents the IEMP, expressed as the lerner index, i.e. the inverse of semi elasticity of net residual demand divided by the marginal price.

From figure 4 it is possible to conclude that during the time of analysis the 6 most important firms in the Colombian generation market had the incentives to exercise market power during the major part of the day.

As stated above, I computed a daily version of the IEMP which accounts for the fact that the generators in Colombian electricity market maximizes a daily profit instead hourly profits. This index was computed according to the next formula:

$$\widehat{DIEMP}_{md} = \frac{-\sum_{k=m}(IG^k_{ih} - q^{ck}_{ih})}{\sum_{k=m} \frac{DR^k_{ih}(P_h \times (1+\delta)) - DR^k_{ih}(P_h \times (1-\delta))}{P^{abovek}_h(1+\delta) - P^{belowk}_h(1-\delta)}} \tag{7}$$

Where $\widehat{DIEMP}_{md}$ is the incentive to exercise market power of the day d for the unit m which is marginal during several hours of the day in which the super index k which identifies the unit is equal to m,$P^{abovek}_h(1+\delta)$ is the price of the next step of the residual demand curve above the price $P^k_h \times (1+\delta)$, $P^{belowk}_h(1+\delta)$ is the price of the previous step of the residual demand curve below the price $P^k_h \times (1-\delta)$, IG^k_{ih} is the actual generation of producer i in hour h and q^{ck}_{ih} is the quantity of energy committed in long run fixed price contracts

Finally, the information about control variables: daily water inflows, hourly commercial availability, hourly security generation, hourly positive and negative reconciliations was taken from the web site of the Colombian wholesale electricity market operator XM. The information about Niño and Niña event was extracted from the NOAA homepage. As stated above, Table 4 highlights the most important descriptive statistics of each of the variables included in the model

Figure 4: Estimations IEMP

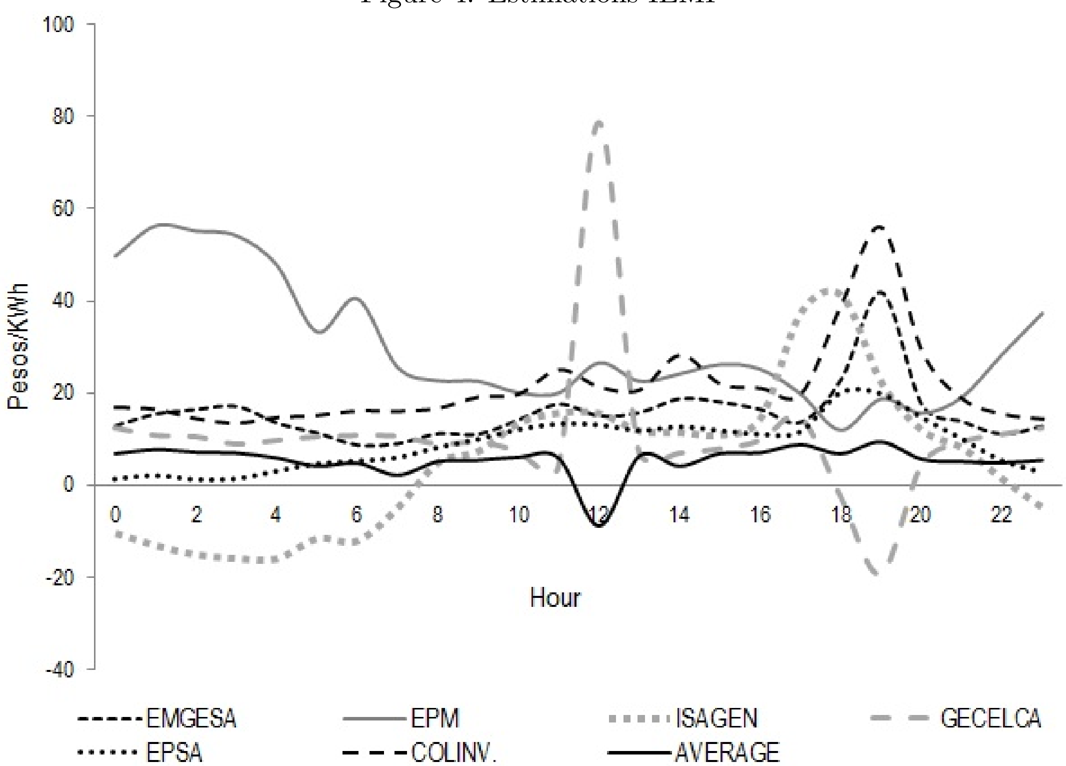


Table 4: Variables in the econometric model.

Variable	Description	Units	Obs.	Mean	Std.Dev.	Min.	Max
Marginal Price	It is the bid price of the marginal plat for each generator, i.e. the bid of the most expensive plant in merit of each generator	Pesos/KWh	821710	68.70	64.46	0	999.64
IEMP	Is the inverse of elasticity of demand taking account the net contract position of the generator.	Pesos/%	821710	7.86	1745.92	-641081.4	1140270
Marginal Cost	Estimated marginal cost. Is zero for hydro plants.	Pesos/KWh	821710	20.23	34.89	-1.40	198.9064
Security Generation	Genaration necessary to keep stability and reliability of the interconected electricity national system.	KWh	821710	24122.95	93248.33	0	1582000
Negative Reconciliation	Energy associated with generation displaced by out of merit security generation. It is a compensation due to negative differences between the ideal and the actual generation dispatch.	KWh	821710	48562.46	127797.9	0	1240000
Positive Reconciliation	It is the energy that has to be compensated due to positive differences between the ideal and the actual generation dispatch.	KWh	821710	5539.75	37667.71	0	1189689
Availability of the marginal unit	It is the statement of availability about how much power can generate a power unit in a certain time.	KW	821710	316664.5	353832.4	1	1270476
Total availability of firm i	It is the sum of the statement of availability of the firm i.	GW	821710	1.03	0.94	0.00002	3.25
Water flows of marginal unit	It is the amount of new energy stored daily in the reservoir of the marginal unit of generator i.	GWh	821710	3.31	7.28	0	130.19
Total Water flows of firm i	It is the amount of new energy stored daily in all the reservoirs of generator i.	GWh	821710	3.31	7.28	0	130.18
AGC service of marginal of marginal unit	It is the amount of energy provided for AGC by the marginal unit of the firm under analysis.	GWh	821710	0.011	0.045	0	.41
AGC service of firm i	It is the amount of energy provided for the AGC service by all the units of the firm under analysis.	GWh	821710	0.031	0.071	0	0.45
Equivalent Real Cost of Energy of Reliability Charge	It is a reference of the minimal spot price in order to create price expectatives of the bidders in the spot market	Pesos/KWh	821710	28.72	3.25	22.35	37.48
SOE Dummy	Is a dummy variable that take the value of 1 if firm i is under state control and 0 otherwise	Dummy	821710	0.54	0.50	0	1
Niño event Dummy	Is a dummy variable that take the value of 1 if the month was clasified as Nio event (warm anomaly) according to the Oceanic Nio Index (ONI) and 0 otherwise.	Dummy	821710	0.17	0.38	0	1
Niña Event Dummy	Is a dummy variable that take the value of 1 if the month was clasified as Nia event (cold anomaly) according to the Oceanic Nio Index (ONI) and 0 otherwise.	Dummy	821710	0.22	0.41	0	1
Dummy AGC service	Is a dummy variable that take the value of 1 if the marginal unit of the generator under analysis provided the AGC service and 0 otherwise.	Dummy	821710	0.15	0.36	0	1
Dummy AGC availability	Is a dummy variable that take the value of 1 if the marginal unit is able to provide the AGC service and 0 otherwise.	Dummy	821710	0.46	0.50	0	1
Dummy reliability charge	Is a dummy variable that take the value of 1 if the bid of the marginal unit is greater than the scarcity price of the reliability charge scheme and 0 otherwise.	Dummy	821710	0.15	0.36	0	1
Dummy Capacity Restriction	Is a dummy variable that take the value of 1 if the ideal generation of all the units of the firm i is greater than the sum of the commercial availability and 0 otherwise.	Dummy	821710	0.12	0.33	0	1
Dry Month Dummy	Is a dummy variable that take the value of 1 if the month is one of the most dry months in the year (January, Fabruary and March) and 0 otherwise.	Dummy	821710	0.25	0.43	0	1
Weekend Dummy	Is a dummy variable that take the value of 1 if the day is in weekend and 0 otherwise.	Dummy	821710	0.28	0.45	0	1

4.4 Estimation procedures and results

Given the estimates of the marginal cost of each plant and the incentives to exercise market power under the assumption of profit maximization, it is possible to advance towards the estimation of the econometric model of expression (3) and testing the hypothesis formulated in section 3.

At the beginning, I let at side some structural elements of the Colombian market and the estimation of the models was performed by the methods of ordinary least squares (OLS). This first version of the model entails two assumptions that may be unrealistic. First, it is assumed that the generator is able to bid optimal hourly price bids, although the daily bid pricing rule of Colombian electricity market. Secondly, I will assume that the term of disturbance ε_{ih} is uncorrelated with the IEMP and is supposed to have zero mean, but not necessarily independent and identically distributed. Later I will relax this assumptions and introduce the structural elements related with the daily day bid rule and the potential endogeneity of IEMP. I will show that the introduction of the introduction of these elements improves the fit of the value of the parameters predicted to those expected theoretically by mixed oligopoly models. In all cases the White correction was performed with the purpose of obtaining robust standard errors. Table 5 presents the result of the estimations.

As stated above, from a supply function equilibrium perspective (Klemperer and Meyer, 1989), the marginal price bid is the best response of a generation firm given the actions taken by its competitors. That is why I propose as dependent variable in order to estimating the model described in expression 3 the marginal price of each generator i in each hour h. I estimated several forms of the hourly model. In the first form I include as control variables, the marginal costs and dummy variables of state ownership and vertical integration. In the second version I include the same control variables plus hourly and yearly fixed effects and the other controls for supply shocks, weather indicators, out of merit generation and those other described above in table 4. In addition for each of this forms, I estimated a pooled regression, in which I include the observations of private firms and SOEs and independent regressions for private firms and SOEs

With respect to H1, The results in table 5 suggest that there are important differences in the exercise of unilateral market power between private and State owned firms. The coefficient of the interaction of the incentive to IEMP with de SOE dummy is statistically significant at the conventional levels just in the case of the independent regression without controls, but the magnitude of this coefficient is very close to the value of perfect regulatory intervention. On the other hand, the coefficient of the interaction of the incentive to IEMP with de private dummy are statistically significant at the conventional levels in all the cases and the magnitude of this coefficient is economically significant, positive and greater than those of SOEs. The test of the no difference of coefficients hypothesis yields rejection results at the conventional levels.

Regarding H2, as stated above, I only find that there are statistical evidence to reject the null hypothesis of perfect welfare maximization in the case of model in the case of the independent regression for SOEs without other control variables. Although, it is important to note that that the coefficient is very close to the perfect regulatory behavior (0.00003) even if it is statistically significant.These results support the hypothesis of regulatory intervention by SOEs in Colombian Electricity Market.

Regarding H3, the results indicate that the IEMP have impact in the pricing strategy

Table 5: Hourly Model - OLS regression results

Group	Pooled	Private	SOE	Pooled	Private	SOE
Private IEMP	**0.1147*** **	**0.1139*** **	-	**0.0844*** **	**0.0819*** **	-
	(0.0193)	(0.01899		(0.0140)	(0.0135)	
SOE IEMP	**-0.0000004**	-	**0.00003*** **	**-0.00003**	-	**-0.00002**
	(0.00002)		(0.00001)	(0.00003)		(0.00003)
Marginal Cost	0.4777***	0.2179***	1.0888***	0.4873***	0.2880***	0.8843***
	(0.0026)	(0.0028)	(0.0037)	(0.0024)	(0.0036)	(0.0043)
SOE fixed effect	8.3003***	-	-	9.8155***	-	-
	(0.2578)			(0.1914)		
Constant	53.9750***	61.7041***	54.9241***	39.8040***	39.6358***	52.4753***
	(0.2524)	(0.2574)	(0.0988)	(0.8223)	(1.2446)	(0.9684)
Other control variables	NO	NO	NO	YES	YES	YES
Observations	821710	380982	440728	821710	380982	440728
Joint Significance Test - F	9031.62***	3160.72***	45219.64***	9716.47***	4131.31***	8176.05***
R2	0.0744	0.0423	0.191	0.4147	0.4013	0.5069
chi2(1) - Test No Diff	35.49***	-	-	36.16***	-	-
chi2(1) - Test PMP	2114.13***	-	-	4254.06***	-	-

*Note 1: Statistical significance at standard levels (*** at 1%, ** at 5% and * at 10%).*

Note 2: Robust standard errors in brackets.

Note 3: Test No Diff: $H_0 : \alpha_{pri} - \alpha_{soe} = 0$ *and Test PMP (Profit maximization by private firms):* $H_0 : \alpha_{pri} = 1$-

of private firms. Although, there are statistical evidence to reject the null hypothesis of perfect profit maximization behavior[7], the coefficient of private firms shows positive sign and are statistically and economically significant. According with these results, private firms exercise from 8,19% to 11,47% of the market power predicted by theory.

4.5 Robustness checks and structural issues

(McRae and Wolak, 2009)estimated the regressions of the bid price on IEMP through independent regressions by firm. I estimated expression 3, for the most important multi-unit private firms and SOEs in order to check the potential effects of cross section heterogeneity. The firms analysed account for more than 80% of the energy generated and 89% of time they set the spot price. The results of these econometric estimations are summarized in Table 6 for the hourly estimation without controls and Table 7 for the hourly estimation with controls.

According to table 6 the coefficients of SOEs are not statistically significant. In the case of table 7 just the coefficient corresponding to the SOE EPM is statistically significant, although it is in other magnitude order from those of private firms and very close to the perfect regulatory intervention value. On the other hand, in tables 6 y 7 the coefficients of private firms are statistically significant.Even when these coefficients are different for each of the private firms, these are greater than those from SOEs. These results support the hypothesis of behaviorlal differences between private firms and SOEs (H1) and perfect regulatory intervention by SOEs in Colombian Electricity Market (H2).

As stated above, there are several structural issues that should be taken account for a more suitable identification of the behavioral parameters of SOEs and private firms. First I will relax the assumption that the generator is able to bid optimal hourly price bids. Given the fact that in Colombian Electricity Market, generators are constrained to bid

[7] I performed conventional wald test in order to test the null Hypothesis: $H_0 : \alpha_{pri} = 1$ for private firms.

Table 6: Hourly Model by Firm - Without Control Variables - OLS

Firm	EMGESA	COLINV.	EPSA	EPM	ISAGEN	GECELCA
Ownership	Private	Private	Private	SOE	SOE	SOE
IEMP	**0.0650*** **	**0.1948*** **	**0.0528*** **	**-0.00003**	**-0.0015**	**-0.0041**
	(0.0151)	(0.0626)	(0.0065)	(0.00002)	(0.0010)	(0.0044)
Marginal Cost	1.27***	1.61***	1.76***	1.02***	0.23***	1.33***
	(0.0167)	(0.0261)	(0.0069)	(0.0207)	(0.0068)	(0.0153)
Constant	72.83***	53.43***	41.41***	93.75***	84.01***	48.86***
	(0.3470)	(0.9744)	(0.2093)	(0.22045)	(0.2407)	(0.9719)
Other control variables	NO	NO	NO	NO	NO	NO
Observations	87230	60388	43080	87239	86371	32551
Joint Significance Test - F	2878.54***	12266.19***	32304.83***	1214.36***	583.74***	3757.39***
R2	0.187	0.3202	0.1282	0.0217	0.0091	0.3055

*Note 1: Statistical significance at standard levels (*** at 1%, ** at 5% and * at 10%).*
Note 2: Robust standard errors in brackets.

Table 7: Hourly Model by Firm - With Control Variables - OLS

Firm	EMGESA	COLINV.	EPSA	EPM	ISAGEN	GECELCA
Ownership	Private	Private	Private	SOE	SOE	SOE
IEMP	**0.0546*** **	**0.0894*** **	**0.0076*** **	**0.00002*** **	**-0.0009**	**0.0007**
	(0.0129)	(0.0304)	(0.0022)	(0.000004)	(0.0008)	(0.0005)
Marginal Cost	1.12***	0.96***	0.91***	0.74***	-0.04	0.07***
	(0.0238)	(0.0162)	(0.0205)	(0.0242)	(0.0134)	(0.0226)
Constant	60.21***	148.63***	73.96***	200.08***	45.48***	195.74***
	(7.0443)	(5.1314)	(2.8082)	(3.6069)	(7.4906)	(3.9411)
Other control variables	YES	YES	YES	YES	YES	YES
Observations	87230	60388	43080	87239	86371	32551
Joint Significance Test - F	1925.99***	2711.1***	2894.76***	1073.76***	1158.98***	2349.37***
R2	0.5285	0.5994	0.6194	0.4496	0.4362	0.7769

*Note 1: Statistical significance at standard levels (*** at 1%, ** at 5% and * at 10%).*
Note 2: Robust standard errors in brackets.

the same price for the whole day for every generation unit, I computed the daily IEMP according to the details explained in subsection 4.3 and expression 7. It is important to note that once I collapsed the data for daily I have one observation for each of the marginal units marginal during at least one hour during the day. Table 8 shows the results of the pooled and independent OLS regressions.

There are not important differences in the results regarding the coefficients α_{soe} and α_{soe}. Regarding H1, the test of the no difference of coefficients hypothesis indicates that there are economically and statistically significant differences between the behavior of SOEs and private firms. In relation to H2, for the models without controls, the coefficient of the interaction of the IEMP with the SOE dummy still being not statistically significant at the conventional levels and shows similar magnitudes to the hourly model. For the models with controls the coefficient of the interaction of the IEMP with the SOE dummy is negative and statistically significant at the conventional levels, although they are very close to the perfect regulatory intervention levels. Regarding H3, the results of the daily models indicate that the IEMP still having impact in the pricing strategy of private firms. These models show coefficients slightly higher than those of hourly models. However, I found statistical evidence to reject the null hypothesis of perfect profit maximization behavior by private firms in all the cases.

In addition,I estimated the daily model for the most important multi-unit private firms

Table 8: Daily Model - OLS regression results

Group	Pooled	Private	SOE	Pooled	Private	SOE
Private IEMP	**0.1385*** **	**0.1407*** **	-	**0.1130*** **	**0.1138*** **	-
	(0.0127)	(0.0128)		(0.0104)	(0.0106)	
SOE IEMP	**-0.0039**	-	**0.0029**	**-0.0096** **	-	**-0.0083** **
	(0.0035)		(0.0032)	(0.0039)		(0.0037)
Marginal Cost	0.7015***	0.3982***	1.1950***	0.7635***	0.5582***	1.0741***
	(0.0099)	(0.0124)	(0.0110)	(0.0094)	(0.0134)	(0.0142)
SOE fixed effect	4.460***	-	-	8.9385***	-	-
	(0.5577)			(0.5081)		
Constant	60.28***	68.38***	58.18***	51.72***	43.54***	63.56***
	(0.4791)	(0.5201)	(0.3838)	(5.5211)	(4.8953)	(3.6090)
Other control variables	NO	NO	NO	YES	YES	YES
Observations	68978	30939	38039	68978	30939	38039
Joint Significance Test - F	1278.77***	557.23***	5873.88***	1350.27***	535.35***	1148.28***
R2	0.1236	0.0872	0.2089	0.3872	0.364	0.469
chi2(1) - Test No Diff	117.06***	-	-	121.56***	-	-
chi2(1) - Test PMP	4605.73***	-	-	7231.59***	-	-

*Note 1: Statistical significance at standard levels (*** at 1%, ** at 5% and * at 10%).*

Note 2: Robust standard errors in brackets.

Note 3: Test No Diff: $H_0 : \alpha_{pri} - \alpha_{soe} = 0$ *and Test PMP (Profit maximization by private firms):* $H_0 : \alpha_{pri} = 1$-

and SOEs. The results of these econometric estimations are summarized in Table 9 for the daily model without controls and Table 10 for the daily models with controls. The results are very similar to those in tables 6 and 7 and they support the hypothesis of behavioral differences between SOEs and private firms and perfect regulatory intervention by SOEs.

Table 9: Daily Model by Firm - Without Control Variables - OLS

Firm	EMGESA	COLINV.	EPSA	EPM	ISAGEN	GECELCA
Ownership	Private	Private	Private	SOE	SOE	SOE
IEMP	**0.0866*** **	**0.1308*** **	**0.1048*** **	**-0.0131*** **	**0.0134**	**-0.0935*** **
	(0.0129)	(0.0225)	(0.0323)	(0.0024)	(0.0128)	(0.0208)
Marginal Cost	1.10***	1.35***	1.87***	1.31***	0.20***	1.05***
	(0.0329)	(0.0283)	(0.0417)	(0.0444)	(0.0226)	(0.0307)
Constant	77.07***	73.60***	41.67***	94.65***	91.67***	72.05***
	(0.8844)	(1.5399)	(0.8348)	(0.7721)	(0.9450)	(2.3504)
Other control variables	NO	NO	NO	NO	NO	NO
Observations	8777	5820	3547	9301	7664	3119
Joint Significance Test - F	561.04***	1232.98***	1031.91***	451.95***	38.7***	602.34***
R2	0.1968	0.2774	0.136	0.0547	0.0059	0.3068

*Note 1: Statistical significance at standard levels (*** at 1%, ** at 5% and * at 10%).*

Note 2: Robust standard errors in brackets.

In subsection 4.3 I warned about the potential problems of endogeneity arising from the the relation of the bid price and the incentives of the AGC market. Hence, the results of OLS estimations should be considered with caution due to the potential bias. The intuition and my knowledge of the Colombian wholesale electricity market suggest that the correlation of the incentives to exercise market power and the income from AGC market is negative. It entails that the OLS regressions would yield attenuation bias. Therefore, the OLS results would be a conservative measure of the behavioral differences between private firms and SOEs. The results about H1 and H2 could be valid but not those for H3.

Table 10: Daily Model by Firm - With Control Variables - OLS

Firm	EMGESA	COLINV.	EPSA	EPM	ISAGEN	GECELCA
Ownership	Private	Private	Private	SOE	SOE	SOE
IEMP	**0.0788*****	**0.1143*****	**0.0369****	**-0.0019**	**0.0293*****	**-0.0361**
	(0.0114)	(0.0184)	(0.0173)	(0.0016)	(0.0135)	(0.0101)
Marginal Cost	1.31***	1.00***	1.08***	1.27***	0.02	0.41***
	(0.0454)	(0.0417)	(0.0835)	(0.0620)	(0.0437)	(0.0671)
Constant	97.03***	195.41***	54.88***	182.57***	101.50***	159.99***
	(14.6936)	(17.9504)	(9.4618)	(13.5638)	(23.2027)	(12.3655)
Other control variables	YES	YES	YES	YES	YES	YES
Observations	8777	5820	3547	9301	7664	3119
Joint Significance Test - F	208.16***	338.51***	320.45***	154.12***	113.41***	205.11***
R2	0.4724	0.4618	0.6479	0.4354	0.342	0.6245

*Note 1: Statistical significance at standard levels (*** at 1%, ** at 5% and * at 10%).*

Note 2: Robust standard errors in brackets.

However, I coped with the problem of endogeniety of the IEMP using instruemntal variables techniques. As I stated before, given that an important assumption of our model is that forward contracts are exogenous, I propose to use as instruments of the IEMP the sum of forward contracts of others competitors and the sum of the interaction of forward contracts with the slope of residual demand of others competitors.

For the hourly model I computed the sum of the forward contracts of those competitors that were considered in the merit dispatch according to the formula:

$$Q^c_{-ih} = \sum_{\substack{j=1 \\ j \neq i}}^{N} q^c_{jh}$$

Where Q^c_{-ih} is the sum of the forward contracts of the competitors of generator i that were considered in the merit dispatch, N is the number of firms considered in the merit dispatch and q^c_{jh} is the amount of energy sold in forward contracts by generator j in hour h.

In addition, I computed the sum of the interaction of forward contracts with the slope of residual demand of others competitors that were considered in the merit dispatch according to the formula:

$$\Omega^c_{-ih} = \sum_{\substack{j=1 \\ j \neq i}}^{N} \frac{P_h^{above}(1+\delta) - P_h^{below}(1-\delta)}{DR_{jh}(P_h \times (1+\delta)) - DR_{jh}(P_h \times (1-\delta))} q^c_{jh}$$

Where Ω^c_{-ih} is the sum of the interaction of forward contracts with the slope of residual demand of others competitors of generator i considered in the merit dispatch, N is the number of firms considered in the merit dispatch, $P_h^{above}(1+\delta)$ and $P_h^{below}(1-\delta)$ have the same interpretation as stated in subsection 4.3 for generator j in hour h, $DR_{jh}(.)$ is the residual demand function of generator j in the hour h and q^c_{jh} is the amount of energy sold in forward contracts by generator j in hour h.

I have two endogenous variables in the hourly model, the interactions $D_i^{pri}\widehat{HIEMP}_{ih}$ and $D_i^{soe}\widehat{HIEMP}_{ih}$ the first stage equation for these variables is:

$$D_i^{owner} \times \widehat{HIEMP}_{ih} = \gamma_0 + \gamma_1 Q^c_{-ih} + \gamma_2 (D_i^{soe} \times Q^c_{-ih}) + \gamma_3 \Omega^c_{-ih} + \gamma_4 (\widehat{CMG}_{ih}) + \sum_{k=1}^{N} \phi_k x_{kih} + \mu_{soe} + \varphi_{year} + \psi_{weekday} + \eta_{ih} \quad (8)$$

Where *owner* can be private (*pri*) or state owned (*soe*).

I estimated this model by 2sls for different samples. In section 4.3. I highlight the relevance of critical hydrological events, such as Niño and Niã events in the incentives to exercise market power. I argued that due to incentives arising from reliability charge scheme and ancillary services market, incentives to exercise market power may be distorted in extreme weather conditions. I propose as an alternative to cope with this distortion, drop those observations corresponding with this periods. I will show the most relevant results for three different samples. The total sample which includes the whole data excluding outliers that exhibited extremely high values for the IEMP (values higher than 2 million Colombian pesos), the no Niña sample which excludes the observations during Niña events[8] and the the No Niña 2011 sample which excludes the observations during Niña event during 2011, which was the most critical period of hydro resource abundance in the history of the Colombian wholesale electricity market. The results of these 2sls estimations for the hourly model are shown in table 11.

Table 11: Hourly Model - 2SLS regression results

Sample	Total	No Nina	No Nina 2011	Total	No Nina	No Nina 2011
Private IEMP	**7.52*****	**10.77*****	**8.91*****	**5.32*****	**6.24*****	**5.69*****
	(0.51)	(1.04)	(0.70)	(0.25)	(0.35)	(0.29)
SOE IEMP	**-0.01**	**0.03**	**-0.01**	**-0.01**	**0.02**	**-0.01**
	(0.01)	(0.03)	(0.01)	(0.01)	(0.02)	(0.01)
Marginal Cost	0.56***	0.64***	0.60***	0.46***	0.45***	0.48***
	(0.03)	(0.04)	(0.02)	(0.02)	(0.02)	(0.02)
SOE fixed effect	94.02***	138.32***	108.82***	62.86***	74.78***	66.27***
	(6.01)	(13.12)	(8.19)	(2.68)	(3.88)	(3.00)
Other control variables	NO	NO	NO	YES	YES	YES
Observations	821710	641037	771878	821710	641037	771878
Joint Significance Test - F	121.9	86.41	146.94	793.67	545.32	706.51
Underidentification test	234.38***	105.83***	182.58***	475.10***	326.23***	403.87***
Weak identification test	78.32	35.32	60.97	159.18	109.12	135.17
Overidentification test	520.19***	299.59***	623.49***	10.68***	0.04	0.61
chi2(1) - Test No Diff	219.99***	106.36***	160.85***	439.27***	307.08***	379.06***
chi2(1) Test PMP	165.17***	87.54***	126.88***	290.18***	218.60***	258.08***

*Note 1: Statistical significance at standard levels (*** at 1%, ** at 5% and * at 10%).*
Note 2: Robust standard errors in brackets.
Note 3: Test No Diff: $H_0 : \alpha_{pri} - \alpha_{soe} = 0$ *and Test PMP (Profit maximization by private firms):* $H_0 : \alpha_{pri} = 1$*-*
Note 4: The test statistic for underidentification is the Kleibergen-Paap rk LM
Note 5: The test statistic for weak identification is the Kleibergen-Paap rk Wald F. H0:Instruments are weak.
The critical value for two endogenous variables and three excluded instruments is 13.43 according with Stock-Yogo (2005)
Note 6: The test statistic for overidentification is Hansen J statistic

Regarding H1 and H2, the 2sls estimation yields qualitatively similar results to OLS regressions. The null hypothesis of no difference of the coefficients of private firms and

[8] I performed the 2sls estimation for only Niño events periods and their results are very similar to the results for the No Niña sample, that is why I did not presented the results.

SOEs is rejected and the coefficients of private firms are positive, statistically significant and greater than those of SOEs. In addition, it was not possible to reject the null hypothesis of perfect regulatory intervention by SOEs ($\alpha_{soe} = 0$). However, it is important to note that these estimations differ quantitatively from those obtained by OLS. The coefficients from 2sls estimations yield greater values in order of magnitude, specially those of private firms. They show values from five to ten times the value expected from theoretical predictions of profit maximization. Hence,the null hypothesis corresponding to H3 ($\alpha_{pri} = 1$) is amply rejected. Given the suspicion of endogeneity of the variable IEMP and the negative correlation of this variable and the income from AGC services, these results are coherent with attenuation bias problem in the OLS estimators. Although, it should be recognized that the instruments proposed are coherent just for the model with other controls variables and the sub-samples No Niña and No Niña 2011, the result of the remaining models do not show opposite results. Finally, the values of the Kleibergen-Paap rk LM statistic and Kleibergen-Paap rk Wald F statistic suggest that the model do not show problems of under-identification and the instruments are not weak.

However, I have argued above that the assumption of generators able to bid optimal hourly price bids is unrealistic in the framework of Colombian electricity wholesale market. In order to apply instrumental variables for a model based in the daily IEMP proposed in section 4.3 it is necessary to formulate economically and statistically coherent instruments for this variable.

For the daily model I computed the sum of the forward contracts of those competitors that were considered in the merit dispatch according to the formula:

$$Q^c_{-i\,md} = \sum_{k=m} \sum_{\substack{j=1 \\ j \neq i}}^{N} q^{ck}_{jh}$$

Where Q^c_{-md} is the sum of the forward contracts of the competitors of the generator under analysis (i) in the hours in which the unit m was marginal (they are distinguished by the superscript k),N is the number of firms considered in the merit dispatch in the in the hours in which the unit m was marginal, $q^k_{jh}c$ is the amount of energy sold in forward contracts by generator j in hour h in the hours in which unit k was marginal.

Finally,I computed the daily sum of the interaction of forward contracts with the slope of residual demand of others competitors that were considered in the merit dispatch in the hour in which unit m was marginal according to the formula:

$$\Omega^c_{-i\,md} = \sum_{k=m} \sum_{\substack{j=1 \\ j \neq i}}^{N} \frac{P_h^{above\,k}(1+\delta) - P_h^{below\,k}(1-\delta)}{DR^k_{jh}(P^k_h \times (1+\delta)) - DR^k_{jh}(P^k_h \times (1-\delta))} q^{c\,k}_{jh}$$

Where Ω^c_{-md} is the sum of the interaction of forward contracts with the slope of residual demand of others competitors of generator i considered in the merit dispatch in the hours in which the unit m was marginal (they are distinguished by the superscript k), N is the number of firms considered in the merit dispatch in the in the hours in which the unit m was marginal, $P_h^{above\,k}(1+\delta)$ and $P_h^{below\,k}(1-\delta)$ have the same interpretation as stated in subsection 4.3 for generator j in hour h, $DR^k_{jh}(.)$ is the residual demand function of generator j in the hours h in which the unit m was marginal and q^c_{jh} is the amount of energy sold in forward contracts by generator j in in the hours h in which the unit m was marginal.

Conversely to the horly model, the first stage equation for the variables the interactions $D_i^{pri}\widehat{DIEMP}_{md}$ and $D_i^{soe}\widehat{DIEMP}_{md}$ is:

$$D_i^{owner} \times \widehat{DIEMP}_{md} = \rho_0 + \rho_1 Q^c_{-i\,md} + \rho_2(D_i^{soe} \times Q^c_{-i\,md}) + \rho_3\Omega^c_{-i\,md} + \rho_4(\widehat{CMG}_{i\,md}) + \sum_{k=1}^{N}\phi_k x_{k\,i\,md} + \mu_{soe} + \varphi_{year} + \psi_{weekday} + \vartheta_{i\,md} \quad (9)$$

Where $owner$ can be private (pri) or state owned (soe).

I estimated this model by 2sls for the total sample,the no Niña sample and the No Niña 2011 sample. The results are shown in table 12.

Table 12: Daily Model - 2SLS regression results

Sample	Total	No Nina	No Nina 2011	Total	No Nina	No Nina 2011
Private IEMP	**1.43*** **	**1.62*** **	**1.62*** **	**0.95*** **	**0.90*** **	**0.96*** **
	(0.13)	(0.22)	(0.18)	(0.11)	(0.16)	(0.14)
SOE IEMP	**-0.06**	**-0.24**	**-0.13**	**-0.19***	**-0.20***	**-0.20***
	(0.10)	(0.15)	(0.11)	(0.10)	(0.11)	(0.10)
Marginal Cost	0.64***	0.58***	0.61***	0.72***	0.65***	0.66***
	(0.02)	(0.03)	(0.03)	(0.02)	(0.02)	(0.02)
SOE fixed effect	26.94***	27.13***	27.46***	20.52***	17.86***	18.72***
	(1.98)	(3.04)	(2.50)	(1.61)	(2.16)	(1.83)
Other control variables	NO	NO	NO	YES	YES	YES
Observations	68978	52920	63900	68978	52920	63900
Joint Significance Test - F	315.50***	245.99***	219.21***	678.81***	724.10***	686.42***
Underidentification test	185.90***	95.46***	122.40***	123.98***	69.66***	95.24***
Weak identification test	62.20	31.91	40.92	41.43	23.27	31.82
Overidentification test	45.78***	7.35***	17.91***	25.74***	0.16	3.02
chi2(1) - Test Diff	82.61***	55.20***	68.94***	61.59***	32.98***	49.32***
chi2(1) - Test PMP	10.61***	8.23***	11.42***	0.22	0.42	0.07

*Note 1: Statistical significance at standard levels (*** at 1%, ** at 5% and * at 10%).*

Note 2: Robust standard errors in brackets.

Note 3: Test No Diff:$H_0 : \alpha_{pri} - \alpha_{soe} = 0$ *and Test PMP (Profit maximization by private firms):*$H_0 : \alpha_{pri} = 1$-

Note 4: The test statistic for underidentification is the Kleibergen-Paap rk LM

Note 5: The test statistic for weak identification is the Kleibergen-Paap rk Wald F. H0:Instruments are weak.

The critical value for two endogenous variables and three excluded instruments is 13.43 according with Stock and Yogo (2002)

Note 6: The test statistic for overidentification is Hansen J statistic

The results of this estimation related with H1 remain unchanged.The null hypothesis of no difference of the coefficients of private firms and SOEs is rejected and the coefficients of private firms are positive, statistically significant and greater than those of SOEs. Although for the models with controls and the samples No Niña and No Niña 2011 I found that at a significance level of 10% the null hypothesis of perfect regulatory intervention is rejected, the coefficients for SOEs are negative. At a significance level of 5% the null hypothesis of perfect regulatory intervention is not rejected. Regarding H3, it should be noted that for the models with controls and samples No Niña and No Niña 2011 it is not possible reject the hypothesis of profit maximization behavior by private firms. In addition for the same models and sub-samples the J- Hansen statistic suggest that the model is coherently over-identified. On the other hand, the Kleibergen-Paap rk LM statistic and

Kleibergen-Paap rk Wald F statistic suggest that the models presented in table 2 do not show problems of under-identification and the instruments are not weak. Although for the total sample and the models without controls the instruments proposed do not perform properly the underidentification test, the result of the remaining models do not yields to conclusions contradictory with previous estimations.

To summarize, the results of the econometric exercises performed in this paper suggest that in the Colombian wholesale electricity market the private firms are more responsive to the incentives to exercise market power than SOEs. In addition I found empirical evidence that supports the hypothesis of perfect regulatory intervention (welfare maximizing behavior) by SOEs in Colombian Electricity Market. The introduction of structural elements in the identification strategy allow me to find indications of attenuation bias in the OLS estimators and partial evidence of profit maximization behavior of private firms in the Colombian spot market. Overall, this indicates that privatization of electric generation SOEs is not neutral regarding competition.

5 Conclusions

In this work, the availability of information on bid prices in the Colombian electricity market was used in order to understand the differences between private and SOEs regarding the exercise of market power. The methodology proposed by Wolak and Mcrae (2009) was adopted as a basis and it was developed an extension in order to cope with welfare maximizing firms. It was proposed a new interpretation of the impact of incentives to exercise market power on prices in order to obtain evidence of profit maximizing behavior by private firms and welfare maximization by SOEs.

Estimation of semi elasticity of demand and contracting information suggest that the generators analysed, state owned and private, had incentives to exercise market power. It was conducted an econometric analysis in order to find statistical evidence of: i) Differences between of state owned and private firms in the impact of incentives to exercise market power on bids and prices; ii) the non-exercise of market power of SOEs according to the welfare maximization behavior; iii)the exercise of market power by private firms according to the profit maximization behavior.

Overall, from these econometric estimations I am able to draw two relevant conclusions: 1) I found important differences in the exercise of unilateral market power between private and State owned firms, i.e. Private generators of Colombian market are more responsive to the IEMP than private firms. 2) I found empirical evidence which supports the hypothesis of regulatory intervention by SOEs in Colombian electricity markets, i.e. SOEs are not responsive to the IEMP.

This suggests that the property regime of firms in the electricity industry in Colombia is not neutral regarding the exercise of market power. These findings have several important implications for the regulation of electricity markets and the privatization of SOEs. On the first point, it should be considered that besides the increased competition there is another way to achieving efficiency, which is the mitigation of market power by state owned companies. Likewise, regulators must be clear about the nature of the market that are facing and determine whether public companies conduct market power mitigation. Regarding the second aspect, the non-neutrality in the exercise of market power implies that privatization has indirect effects on the competitiveness of markets. This entails that the government should take account of the possible anti-competitive effects that privatization entails and include these undesirable cost in the valuation of the sale operation.

References

Allaz, B. and Vila, J.-L. (1993). Cournot competition, forward markets and efficiency. *Journal of Economic Theory*, 59(1):1–16.

Barros, F. (1995). Incentive schemes as strategic variables: An application to a mixed duopoly. *International Journal of Industrial Organization*, 13(3):373–386.

Barros, F. and Modesto, L. (1999). Portuguese banking sector: a mixed oligopoly? *International Journal of Industrial Organization*, 17(6):869–886.

Beato, P. and Mas-Colell, A. (1984). The marginal cost pricing rule as a regulation mechanism. *in M. Marchand, P. Pestieau and H. Tulkens (eds), The Performance of Public Enterprises, Amsterdam: North-Holland*, pages 81–100.

Bel, G. and Calzada, J. (2009). Privatization and universal service obligations. *Journal of Institutional and Theoretical Economics (JITE)*, 165(4):650–669.

Berry, S., Levinsohn, J., and Pakes, A. (1995). Automobile prices in market equilibrium. *Econometrica*, 63(4):841–90.

Borenstein, S. and Bushnell, J. (1999). An empirical analysis of the potential for market power in california's electricity industry. *Journal of Industrial Economics*, 47(3):285–323.

Borenstein, S., Bushnell, J., and Wolak, F. A. (2002). Measuring market inefficiencies in california's restructured wholesale electricity market. *American Economic Review*, 92(5):1376–1405.

Brandao, A. and Castro, S. (2007). State-owned enterprises as indirect instruments of entry regulation. *Journal of Economics*, 92(3):263–274.

Bushnell, J., Mansur, E., and Saravia, C. (2008). Vertical arrangements, market structure, and competition: An analysis of restructured us electricity markets. *American Economic Review*, 98(1):237–66.

Cremer, H., Marchand, M., and Thisse, J. (1989). The public firm as an instrument for regulating an oligopolistic market. *Oxford Economic Papers*, 41(2):283–301.

De Fraja, G. and Delbono, F. (1989). Alternative strategies of a public enterprise in oligopoly. *Oxford Economic Papers*, 41(2):302–11.

Fershtman, C. (1990). The interdependence between ownership status and market structure: The case of privatization. *Economica*, 57(227):319–28.

Fershtman, C. and Judd, K. (1987). Equilibrium incentives in oligopoly. *American Economic Review*, 77(5):927–40.

Garcia, A. and Arbelaez, L. E. (2002). Market power analysis for the colombian electricity market. *Energy Economics*, 24(3):217–229.

Green, R. and Newbery, D. M. (1992). Competition in the british electricity spot market. *Journal of Political Economy*, 100(5):929–53.

Harris, R. and Wiens, E. (1980). Government enterprise: An instrument for the internal regulation of industry. *Canadian Journal of Economics*, 13(1):125–32.

Hindriks, J. and Claude, D. (2006). Strategic privatization and regulation policy in mixed markets. *The IUP Journal of Managerial Economics*, IV(1):7–26.

Hortacsu, A. and Puller, S. (2008). Understanding strategic bidding in multi-unit auctions: a case study of the texas electricity spot market. *RAND Journal of Economics*, 39(1):86–114.

Klemperer, P. and Meyer, M. (1989). Supply function equilibria in oligopoly under uncertainty. *Econometrica*, 57(6):1243–77.

Lee, S.-H. and Hwang, H.-S. (2003). Partial ownership for the public firm and competition. *The Japanese Economic Review*, 54(3):324–335.

Lopez-de Silanes, F., Shleifer, A., and Vishny, R. (1997). Privatization in the united states. *RAND Journal of Economics*, 28(3):447–471.

Matsumura, T. (1998). Partial privatization in mixed duopoly. *Journal of Public Economics*, 70(3):473–483.

McRae, S. and Wolak, F. A. (2009). How do firms exercise unilateral market power? evidence from a bid-based wholesale electricity market. RSCAS Working Papers 2009/36, European University Institute.

Netter, J. M. and Megginson, W. L. (2001). From state to market: A survey of empirical studies on privatization. *Journal of Economic Literature*, 39(2):321–389.

Reguant, M. (2014). Complementary bidding mechanisms and startup costs in electricity markets. *Review of Economic Studies*, 81(4):1708–1742.

Seim, K. and Waldfogel, J. (2013). Public monopoly and economic efficiency: Evidence from the pennsylvania liquor control board's entry decisions. *American Economic Review*, 103(2):831–62.

Stock, J. and Yogo, M. (2002). Testing for weak instruments in linear iv regression. NBER Technical Working Papers 0284, National Bureau of Economic Research, Inc.

Wolak, F. (2000). An empirical analysis of the impact of hedge contracts on bidding behavior in a competitive electricity market. *International Economic Journal*, 14(2):1–39.

Wolak, F. A. (2003). Measuring unilateral market power in wholesale electricity markets: The california market, 1998 2000. *American Economic Review*, 93(2):425–430.

Wolfram, C. D. (1998). Strategic bidding in a multiunit auction: An empirical analysis of bids to supply electricity in england and wales. *RAND Journal of Economics*, 29(4):703–725.

Wolfram, C. D. (1999). Measuring duopoly power in the british electricity spot market. *American Economic Review*, 89(4):805–826.