FIRST PRICE AND SECOND PRICE AUCTION MODELLING FOR ENERGY CONTRACTS IN LATIN AMERICAN ELECTRICITY MARKETS

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Abstract – The need to stimulate generation investment is a growing challenge in deregulated electricity markets worldwide. Capacity payments and capacity markets have been investigated for this purpose. Latin American markets are exploring energy supply auctions, an avenue that is assessed in this paper. Auction mechanisms are studied through auction theory by using Bayesian equilibrium concepts. Two sealed bid auction formats are reviewed: a single object first-price auction and single object second-price auction. These formats are analyzed under a pseudo common value and symmetric equilibrium framework. In order to solve the first order conditions of the programming models and to compute the price market, numerical and sampling methods are used as Monte Carlo heuristics. The developed models are applied to assess future auctions in the Chilean electricity market.

Keywords: Auctions, electricity market, auction theory, investment, supply contracts

1 INTRODUCTION

The need to ensure sufficient and efficient generation capacity has become a crucial challenge in electricity markets. This is particularly important in developing countries which present a fast and volatile demand growth. Current electricity market designs are being reviewed to avoid supply difficulties and couple the existing outlook of primary energy resources and the investment interest by the private sector. Several countries are progressing into a second stage of reforms with public long term supply auctions. While their primary challenge is to ensure sufficient capacity and investment to serve reliably their growing economies, their secondary one is to achieve low prices of generation.

This second stage of reform has increased the importance of long-term price signals as contract prices and has dropped the short-term ones as spot prices. Thus, in this new framework the key point of the competition is not in the spot market but in the contract market, with demand that stimulates the entrance of new capacity, along with the backing of these contracts by physical generation capacity.

These changes are being observed in the region (Brazil, Chile, Peru, Colombia and others); but also in other areas such as in California, where a similar concept, named "capacity tag" for each plant is being proposed and in the FERC/EU directives in the US and Europe, where the agents should show mid-long term supply coverage to meet future demand [1].

Auctions have been used to trade goods since thousands of years ago. There are many different types of auctions which can be presented in an open format or sealed bid format. The most popular types are: English auction, Dutch auction, first price auction and second price auction. They are designed to optimize measures such as welfare, efficiency or equilibrium prices [2]. In the second stage of reforms, auctions are used to incorporate a real market signal in the price of electricity contracts, and to ensure supply investment.

Fig. 1: Current situation in South and Central America

Game theory has been more and more used to analyze the behavior of the agents or players in an auction [2, 3, 4]. It began in the 60's, employing incomplete information game theory to analyze equilibrium bidding strategies in auctions [5]. At present, auctions are being employed to trade different types of goods: art objects, contracts, buildings, internet services (e.g. Amazon.com, Ebay.com and Deremate.com), telecommunication licenses, mineral rights, etc.

In order to study an auction, it is necessary to compute the Bayesian equilibrium of the incomplete information game which is equivalent to computing the Nash equilibrium of the transformed imperfect information game [6]. In this framework, auctions are classified as one type of Bayesian game. Simple auctions can be solved analytically, but complex auctions can become unmanageable with that approach. Lately, various techniques have been developed, several supported by computer tools, using sampling to find, or at least approximate, the Bayesian equilibrium [7, 8, 9]. Within the conceptual framework, this paper formulates an approach to the bid supply functions of generators which allows studying the behavior of the agents and the convergence of the market under different assumptions.

This work is organized as follows: Section II provides an overview of the market environment where the model is being applied. Section III shows the mathematical formulation of the model and its solution algorithm. Section IV shows some results for the Chilean electricity market, studying different assumptions. Section V provides the conclusions of the study.

2 DESCRIPTION OF THE MARKET FRAMEWORK

Twenty five year ago, Chile successfully faced the first deregulation process of an electricity market in the world. The electricity industry became a market divided into three sectors: generation, transmission and distribution. Electricity companies were privatized and competition in generation was introduced by means of the spot market. Transmission and distribution companies were defined as regulated monopolies. Prices in generation started to be driven by the spot market and prices in transmission and distribution were driven by tariff techniques as Yardstick Competition and Price Cap. Similar processes developed in other countries in Latin America. This first stage of reform produced efficient gains in privatized utilities, an increasing of international interconnections and strong private investments.

However, Latin American energy markets have faced diverse problems in recent years. A crude example was the severe rationing faced in 2001 in the Brazilian power sector, due to a severe drought [10]. In the Chilean case, serious power supply problems have occurred since 2004 due to restrictions of natural gas transfers from Argentina, which previously supplied gas to all of the combined cycle plants in the two Chilean main interconnected systems (SING and SIC). Restrictions of natural gas are shown in Fig. 2. Nowadays, Argentina does not export natural gas to Chile.

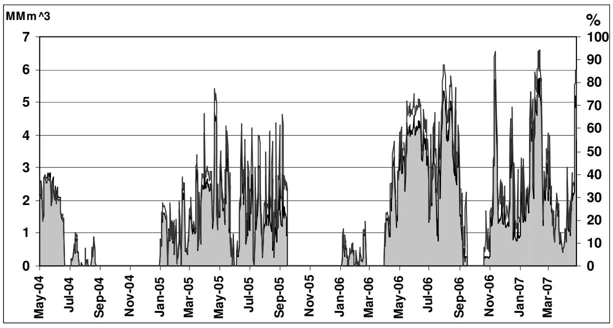

Fig. 2: Restrictions imposed on natural gas from Argentina to SIC

Other similar problems have arisen in Bolivia, Colombia and Peru. Although these problems produced lack of energy, investors did not react to solve the problem due to the spot price unpredictability.

An important fact to highlight is the large participation of hydro resources in the Chilean and Brazilian markets, which produce high variability of spot prices because of the hydrology correlation (see Fig. 3).

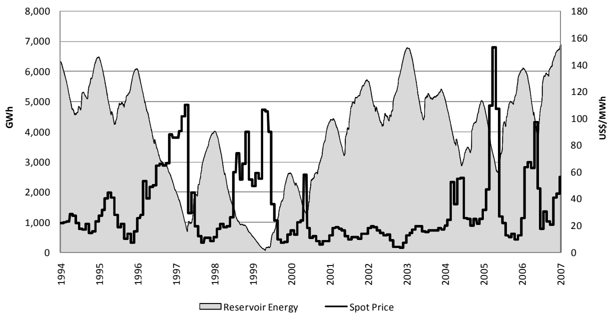

Fig. 3: Hydro energy stored in reservoirs and monthly average of spot prices in the main interconnected Chilean system

This volatility of the spot price does not allow investors to identify the optimum time of investment, even facing expected electricity shortage scenarios [11].

Other characteristics of the electricity markets analyzed in this paper are:

- Spot market restricted to generators (demand cannot participate in the spot market)
- Minimum cost centralized dispatch (short term energy production does not depend on private decisions)
- Spot price equal to the marginal cost of generation
- Expansion of generation according to private decisions
- Prices of regulated contracts based on marginal (real or expected) cost of generation (before the second stage of reform)
- Capacity payments in some countries (Argentina, Peru, Chile)

Thus, Brazil and Chile are trying to solve part of their problems by increasing the importance of long-term market signals for the regulated contract prices by means of auctions mechanisms. Bolivia, Colombia, Peru and Central America are studying similar solutions.

The key ingredients of the new reform are:

- 100% of demand must be contracted all the time
- Contracts need firm capacity certificates
- Contracts are allocated amongst generators by means of auction mechanisms
- In order to reduce risk and ensure profitability, new investments need durable contracts (up to 15 years)

Overall, new demand requirements need to install new capacity which is assigned in a competitive process: an auction. Also, auctions have the additional advantage of making markets more contestable for potential investors often restricted to the spot market [12].

3 FORMULATION OF THE SINGLE OBJECT MODELS

This study focuses on two different types of sealed bid auctions used to trade supply contracts between generators and distributors: single object first price sealed bid auction and single object second price sealed bid auction.

The analysis assumes the existence of a central Poolco operator, as in many Latin American power markets, which decides the production of each plant based on variable costs and without consideration of commercial contracts. Each generator can sell its energy in three main sub markets: the spot market, the regulated market and the non-regulated market (the last two through contracts). Thus, in order to analyze the profitability of a new contract, each generator only needs to consider:

- How much energy it should sell in the spot and contract market
- The price of the new contract

The study presented in this paper does not take into account portfolio theory or risk analysis concerning the optimum combination of spot and contracted energy. In addition, it is assumed that the spot price is the only variable which is needed to estimate the optimum value of a future contract. Consequently, each generator does not sign any contract at a price lower than the expected market spot price. Therefore, the auctions analyzed in this study are in a (pseudo[1]) common value scheme.

In the spot market, generators can buy or sell energy among them according to a balance concept. If a generator is requested, by the Poolco, to generate less energy than its contracted energy, it is named a "deficit generator", and it has to buy energy in the spot market in order to complete its contracted energy. On the contrary, if a generator is requested to generate more energy than its contracted energy, it is named a "surplus generator", and it sells the surplus energy in the spot market. Regarding the price in the spot market, it is fixed by the marginal cost of the system, in other words, by the variable cost of the most expensive generator which is dispatched.

In the regulated market, generators sell energy to distributors by means of a contract. In the second stage reforms, these contracts have to be auctioned by distributors. Thus, generators have to compete in an auction scheme to trade a contract with a distributor. The final price is defined by the bid competition.

In the non-regulated market, large customers freely negotiate contracts with generators by means of bilateral negotiations.

To focus the analysis on the new contract decision, it is assumed that the produced energy, which is not sold through a contract in the regulated market, will be sold in the spot market. In addition, the latter means that prices in the non-regulated market closely follow the spot market tendency. In other words, with the purpose of computing the optimum bid in a long term contract auction, the analysis considers the following selling options: i) to distributors in the regulated market, or ii) to other generators in the spot market. Therefore, a contract is attractive for a generator if its payments are higher than the payments associated to the energy sold in the spot market. Consequently, the condition to trade the contract (generators' point of view) is that the present value of the cash flows in the scenario with the contract has to be higher than the present value of the cash flows in the scenario without the contract. This condition to trade the contract is shown in Fig. 4.

It is important to consider that auctions determine only the energy price, which is used to remunerate mainly the operational cost of a generator. Investment in most Latin American markets is partially remunerated by means of a capacity payment[2].

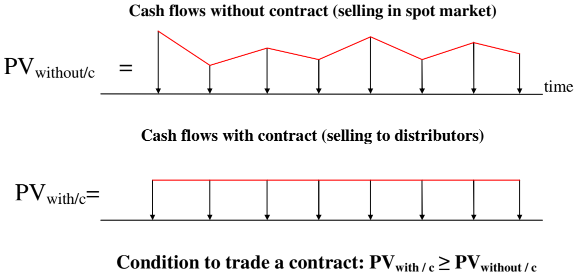

Fig. 4: Scenarios of payments with the new contract and without the new contract[3]

The future spot price or the long-term marginal cost of the system is a very difficult and risky variable to estimate. In hydrothermal markets, this variable changes depending on several conditions, such as hydrology, fuel prices, natural gas or liquefied natural gas availability, and generation expansion (private investment), amongst others. Although these variables are uncertain, it is considered that the evolution of almost all of them can be estimated by any generator with the same precision given public common information. However, regarding the generation expansion, it is possible to assume that each private investor may have access to additional information (e.g. the investment plan of the company, potential new plants, etc.), which may allow it to build its own private information database, and make a singular estimation of the spot price evolution.

As mentioned, each generator trades a contract if and only if the present value of the cash flows in the scenario with the contract is higher than the present value of the cash flows in the scenario without the contract. Thus, with the intention of computing the optimal bid (contract price – decision variable), each generator maximizes:

$$
\begin{aligned}
&Max\ \{\text{ExpectedValue}(\text{Payoff} \mid \text{PrivateInformation})\} \Leftrightarrow \\
&Max\ \{(\sum_{t=T}^{T+D} \frac{P_c^t Q^t}{(1+r_c)^t} - \sum_{t=T}^{T+D} \frac{P_s^t Q^t}{(1+r_s)^t}) \bullet \text{Prob}(Win) \mid type_i\} \Leftrightarrow \qquad (1)\\
&Max\ \{(P_c \sum_{t=T}^{T+D} \frac{Q^t}{(1+r_c)^t} - P_s \sum_{t=T}^{T+D} \frac{Q^t}{(1+r_s)^t}) \bullet \text{Prob}(Win) \mid type_i\} \Leftrightarrow \\
&Max\ \{(P_c - P_s) \bullet \text{Prob}(Win) \mid type_i\}
\end{aligned}
$$

Where:

T:	Beginning of the contract period
D:	Contract duration
P_c^t:	Contract price at time t
P_s^t:	Spot price at time t
Q^t:	Contract demand at time t
r_c:	Discount rate of contract cash flows
r_s:	Discount rate of spot cash flows
Prob(Win):	Probability of winning the auction
$type_i$:	Private information of generator i
P_c:	Equivalent constant price of the contract
P_s:	Equivalent constant price of the spot market

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[1] Although, the spot price defines a pure common value scheme, there are also some private information components taken into consideration in the formulation

[2] The exception is the Brazilian case, where energy prices must also remunerate the capacity costs.

[3] In the figure, PV means present value

As mentioned before, this study does not have any financial consideration, thus the discount rate of the contract is considered equal to the discount rate of the spot market. Nevertheless, it is possible to observe that the analysis does not change with this assumption.

By using Bayesian theory, it is possible to write equation (1) as follows:

$$\mathrm{Max}_{b_i}\ \{\Pi_i = \int_{\beta^{-1}(b_i)}^{W^S_{Y|X}} (b_i - Va(x_i)) \times f_{Y_i|X_i}(y_i \mid x_i)\, dy_i\} \qquad (2)$$

Where:

Π_i:	Objective function of generator i
b_i:	Bid of generator i
$Va(x_i)$:	Function that represents the best estimation of the equivalent constant spot price of generator i based on public and private information.
x_i:	Estimation of the (equivalent constant) spot price of generator i based only on its private information
y_i:	Minimum value of the variable set x_{-i} (minimum estimation of the spot price of the rest of the generators)[4]
$\beta(x_i)$:	Bid function that depends on the private information
$f_{Yi\|Xi}$:	Density function of Yi given Xi
$W^S_{Y\|X}$:	Maximum value of the range where $f_{Yi\|Xi}$ is non-null

In equation (2), the first subtraction represents the price differential shown in equation (1) and the conditional density function represents the probability of winning the auction. The latter assumes that the winner is the generator with the lowest private spot price estimation (given the public information is the same for everyone).

In the formulation each generator considers private and common (public) information to build its spot price estimation. Thus in theory, every generator can have slightly different expectations about the spot price evolution. The public information can be, for example, the estimation of the authority, which usually manages confidential information of the players.

The expected spot price (Va) is modeled by using two variables (Ps, Xi) as follows:

$$\begin{aligned} &Va(x_i) = E\{P_s \mid x_i\} \\ &\text{Where} \quad P_s \sim N(\mu, \sigma) \quad \text{and} \\ &X_i \mid P_s \sim U((1-\xi)\times p_s\,, (1+\xi)\times p_s) \end{aligned} \qquad (3)$$

With the intention to simulate the market equilibrium, P_s is assumed normally distributed in order to incorporate that:

- It is equally likely to obtain a higher value than the expected spot price and a lower value than the expected spot price.
- The probability to obtain values close to the expected spot price is higher than the probability to obtain other values.
- The spot price estimations (Va) are correlated.

The private estimation is assumed uniform conditional to P_s.

In order to solve the auction game, the first order condition of the optimization problem must be calculated. Then, the following differential equation results:

$$0 = (Va(x_i) - \beta(x_i)) \times f_{Y_i|X_i}(x_i \mid x_i) + (1 - F_{Y_i|X_i}(x_i \mid x_i)) \frac{\partial \beta(x_i)}{\partial x_i} \quad (4)$$

So as to solve it, it is necessary to consider the boundary condition of the problem. If the auction has a reserve price, such boundary condition is indicated in Fig. 5

In formal terms:

$$\beta(Va^{-1}(Pr)) = Pr \qquad (5)$$

where Pr represents the reserve price (or the price cap) of the auction.

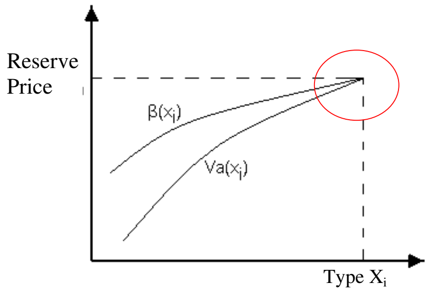

Fig. 5: Border condition

On the other hand, if distributors want to auction a single energy block by means of a second-price auction, generators have to solve a similar optimization problem than in the first-price auction. This is:

$$\mathrm{Max}_{b_i}\ \{\Pi_i = \int_{\beta^{-1}(b_i)}^{W^S_{Y|X}} (\beta(y_i) - Va(x_i)) \times f_{Y_i|X_i}(y_i \mid x_i)\, dy_i\ \} \qquad (6)$$

Where the price that is paid to the auction winner is now $\beta(y_i)$, which is the second minimum price or the minimum bid of the rest of the generators.

In order to solve it, it is necessary to compute the first order condition of the optimization problem. Then, it is possible to obtain the following equality:

$$\beta(x_i) = Va(x_i) \qquad (7)$$

It can be observed from equation (7) that the bid of generator i reflects its own spot price estimation. This means that generators do not need to speculate for bidding in the auction as in the first price auction case. In this sense, this result fits in with the general second price auction theory [2]. Due to the simplicity of equation (7), bid functions can be computed by means of algebraic methods. On the other hand, the bid function for the first price auction is computed by solving the differential equation (4) and its boundary condition (5). For this purpose, standard numerical methods are used.

Given the bid functions of both the first price and the second price auction formats, the equilibrium of the auctions can be computed through sampling methods such as Monte Carlo heuristic. Basically, different random numbers that represent the spot price expectations are generated. So by using these values, the bid functions can be evaluated, and consequently, the players' behavior and the auction equilibrium. Fig. 6 and 7 show the sequence chart of the algorithms used to obtain the equilibrium of the first and second-price auction.

In the particular case of the Chilean auction mechanism, if

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[4] Xi represents the private spot price estimation of generator i (one single value) and X-i is the set of private spot price estimations of every generator except i

there are no bids in the auction, a new round of bids is required. In this new round, the reserve price is incremented. It is important to highlight that the fact of not obtaining any bid (bid absence) in the first round of the auction modifies the behavior of the bidders for the next round, because they can upgrade the common spot price estimation (each bidder knows that the others do not want to bid less than Pr^1, where Pr^1 represents the reserve price in the round number one). Consequently, in the sequence chart, Cr is the cost associated to the condition of not obtaining any bid during the first round. In other words, it is the estimated final price that will result in the following rounds with the incremented reserve price ($Cr \geq Pr^1$). C_D shows the equilibrium price of the auction.

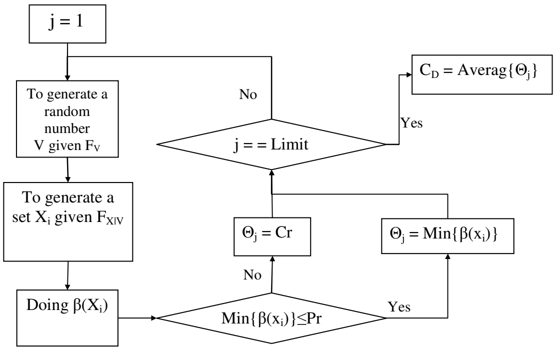

Fig. 6: Sampling method used to compute the equilibrium in a first-price auction

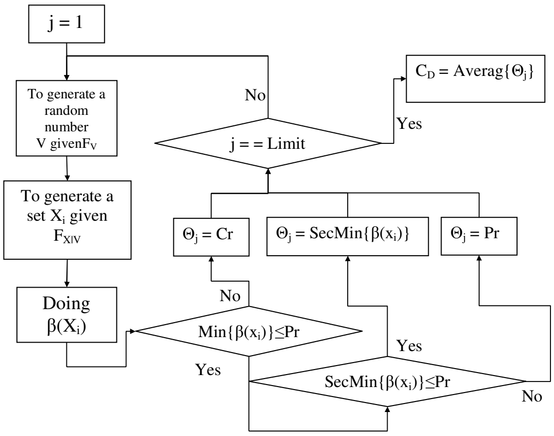

Fig. 7: Sampling method used to compute the equilibrium in a second-price auction

4 APPLICATION AND RESULTS

These models are used to assess the potential behavior of the agents in the main interconnected system in Chile (SIC). The analysis shows how generators bid in a single object first-price and second-price auction. Different conditions are analyzed.

4.1 Inputs of the model

The main Chilean interconnected system, SIC, has three main generating holdings, as shown in Fig. 8. It is assumed that the distributor that is auctioning its supply is located at a busbar in Santiago, called Cerro Navia 220, and it consumes a quarter of the total demand of this node. The public information regarding the future demand and spot price at that node is based on the regulator reports. It is also assumed that the distributor is auctioning its supply from January 2007 to December 2015 (108 months). Fig. 9 and 10 show the auctioned demand and the expected spot price for every month, respectively.

Taking into consideration this information and assuming a discount rate of 10% (value usually assumed), it is possible to compute the expected equivalent constant spot price as follows (according to equation (1)):

$$P_s = \frac{\displaystyle\sum_{t=1}^{108} \frac{P_s^t \times Q^t}{(1+0.7974\%)^t}}{\displaystyle\sum_{t=1}^{108} \frac{Q^t}{(1+0.7974\%)^t}} = 60.17 \quad [\mathrm{US\$/MWh}] \tag{8}$$

By carrying out a sensitivity analysis of this value, a standard deviation of 5 [US$/MWh] is estimated.[5]

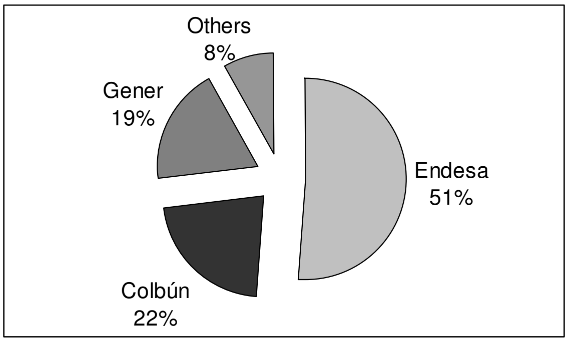

Fig. 8: Installed capacity at SIC

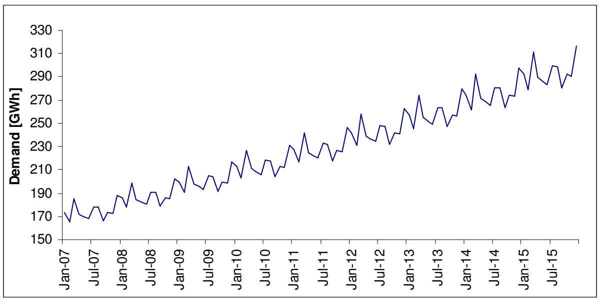

Fig. 9: Expected demand evolution Cerro Navia 220

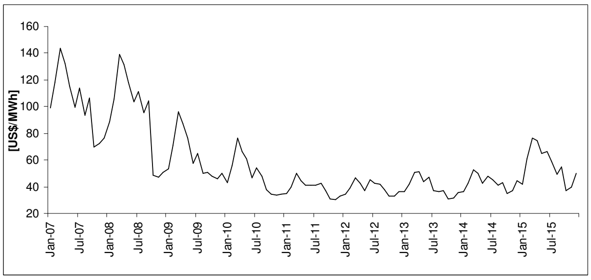

Fig. 10: Expected marginal cost evolution Cerro Navia 220

For computing the market equilibrium without any information from the agents, it is also assumed that the pure private spot price estimation of each generator is contained into an interval of +-15% uniformly distributed around the pure public spot price expectation. Thus, the best spot price estimation of

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[5] The spot price evolution is an average value that takes into account different hydraulic and fuel price scenarios. Thus an average and a standard deviation can be calculated

each generator is (according to equation (3)):

$$Va(x_i) = E\{P_s \mid x_i\} \quad \text{Where} \quad P_s \sim N(60.17\,, 5) \quad \text{and} \quad X_i \mid P_s \sim U(0.85 \times p_s\,, 1.15 \times p_s) \qquad (9)$$

Finally, different experiments are carried out as follows:

- Case 1: Base case, without reserve price
- Case 2: Pr = 77 [US$/MWh]
- Case 3: Pr = 73 [US$/MWh]
- Case 4: Pr = 69 [US$/MWh]
- Case 5: Pr = 65 [US$/MWh]

4.2 Results

For the single object first-price auction case, the bid functions shown in Fig. 11 are obtained. The figure shows how generators, with a low value estimation of the spot price (Va), bid according to a large spread. This is because they can take advantage of their private information, while the rest of the competitors (according to the public information) have a higher expectation of the spot price. On the contrary, generators with a high Va bid according to a small spread. If they try to bid a higher value, their probability of winning becomes zero, given that the remaining generators have lower expectations of the spot price and, consequently, can bid less.

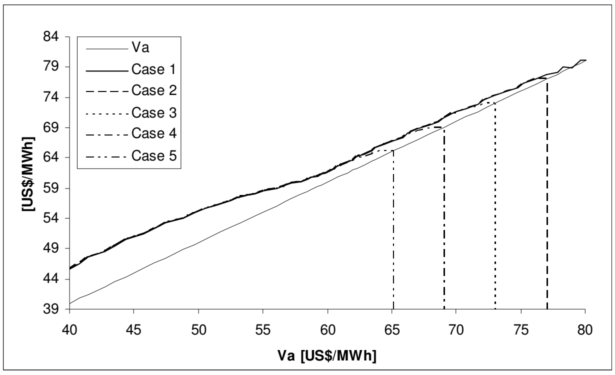

Fig. 11: Bid functions for the five cases of reserve prices and 3 competitors – first price auction

From Fig. 11, it can be observed that different reserve price levels affect the bid function in the sense that:

- Generators cannot bid higher than the reserve price value
- The bid curves change in the neighborhood of Pr (Va = Pr).

As mentioned, an iterative method is used to compute the equilibrium. The final result is an average of a particular number of iterations defined by the value of Limit indicated in Fig. 6. Thus, Fig. 12 shows the solution of the auction by considering different values of Limit (iterations).

For the base case, the equilibrium price is very close to the public expected spot price (60.4 [US$/MWh]).

Fig. 12 shows that the equilibrium price in case 5 is higher than the equilibrium price of the rest of the cases. Basically, this is due to an increase in the probability of not obtaining any bid in the auction, where contracts are not allocated during the first round. This event has an associated cost equal to Cr (see Fig. 6) that represents the final price of the contract during the following rounds with higher reserve prices.

For the second price auction case, the bid functions shown in Fig. 13 are achieved.

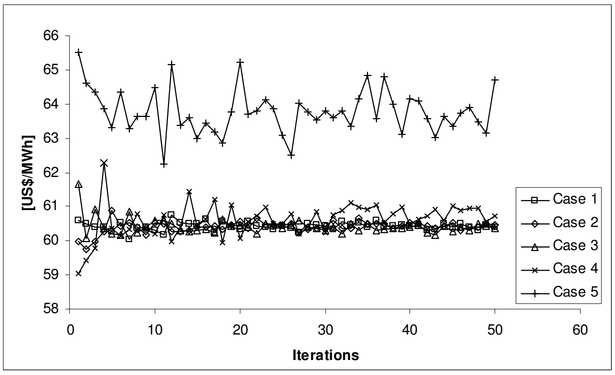

Fig. 12: Equilibrium price for the five cases of reserve price and 3 competitors – first price auction

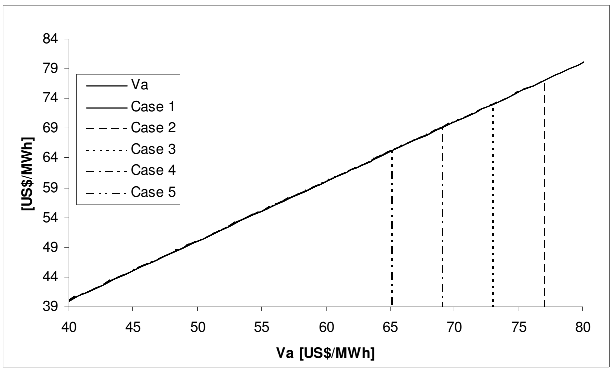

Fig. 13: Bid functions for the five cases of reserve prices and 3 competitors – second price auction

Fig. 13 shows that the generators' bidding strategy is the same for any Pr. In this type of auction, generators do not have to add any spread on their spot price expectation in order to bid. This is because the winner sells the energy at the second lowest bid price.

The equilibriums for these cases are shown in Fig. 14. As in the previous case, case 5 presents a high equilibrium price due to the high probability of not obtaining any bid in the first round.

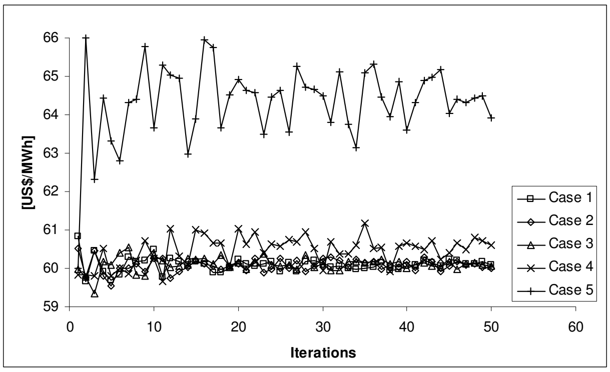

Fig. 14: Equilibrium price for the five cases of reserve price and 3 competitors – second price auction

Observing the difference between the equilibriums in the first-price and second-price auctions, it is possible to conclude that, although there is a small price differential equal to 0.3 [US$/MWh] in average,

the equilibrium price in the second-price auction is lower than the equilibrium price in the first-price auction for most of the iterations (see Fig. 15)[6]. In conclusion, there is evidence that a second price auction can be better for the consumer in the sense that the final prices are lower.

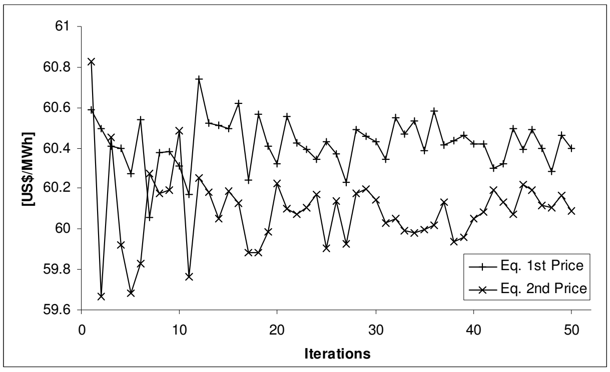

Fig. 15: Comparison between first price and second price equilibrium

An interesting case to analyze is how the equilibrium price changes for both auction types if there are more participants in the auctions. It is assumed that, besides the existing three generator holdings, there are 3 additional international investors bidding in the auctions. In this case, Fig. 16 and 17 show the bid functions and the equilibrium prices for the first price auction format, respectively. Fig. 16 illustrates that bids are more aggressive than the cases with 3 competitors.

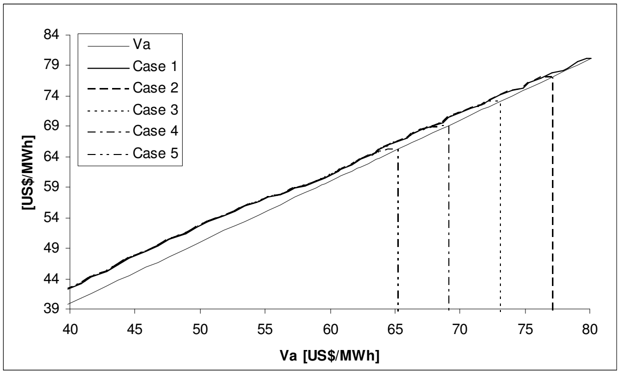

Fig. 16: Bid functions for the five cases of reserve prices and 6 competitors – first price auction

Fig. 17 shows an obvious situation: equilibrium prices in these cases are lower than the previous ones (3 competitors). Fig. 18 shows the price differential between the scenarios with 3 competitors and with 6 competitors for the base case.

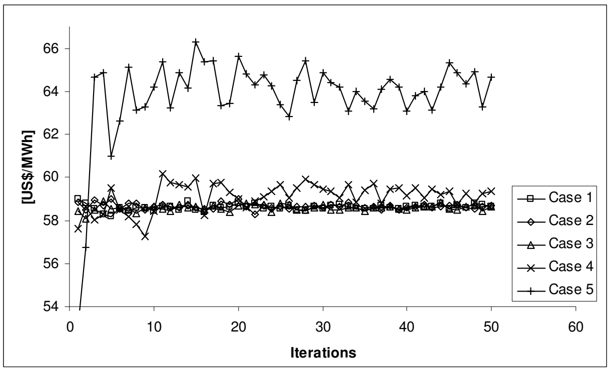

Fig. 17: Equilibrium price for the five cases of reserve price and 6 competitors – first price auction

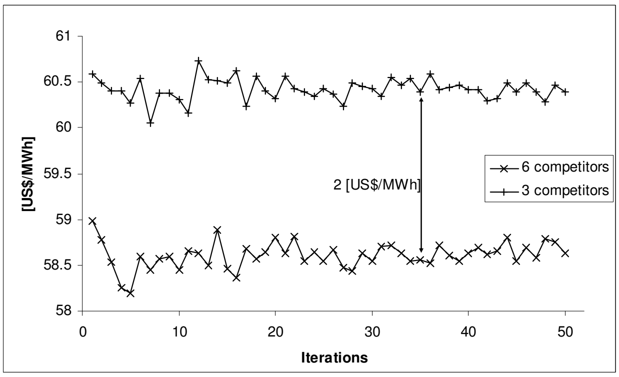

Fig. 18: Equilibrium prices comparison between 3 and 6 competitors in a first price auction

Thus, the difference between the two equilibrium prices (see Fig. 18) is 2 [US$/MWh]. In consequence, in a competition with more generators it is possible to obtain a lower equilibrium price, but the difference produced is not dramatic according to the average values. The main consequence of having more competitors is that the probability of obtaining prices higher than the mean value decreases (as mentioned, the mean value also decrease, thus a double effect is obtained). This fact is shown in Fig. 19, through a 1000 sampling points histogram.

Finally, it is pertinent to consider that the resultant equilibrium price is an equivalent monthly price of the bid. Thus, it is necessary to assume an indexation formula for the prices to get the real bid in the corresponding period.

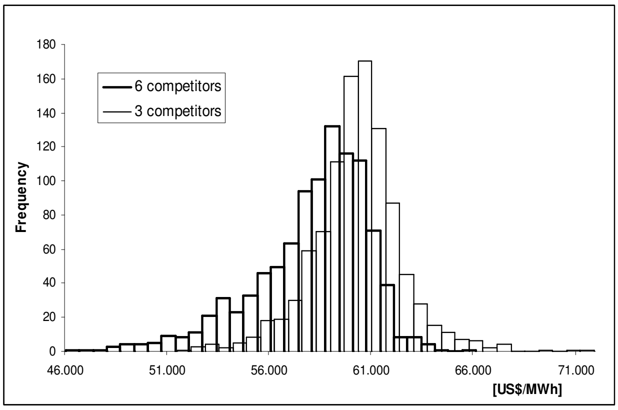

Fig. 19: Histogram of the equilibrium prices of 3 and 6 competitors in a first price auction

4.3 *Winner's curse*

In Fig. 18, it is possible to see how the winner's curse operates. While the equilibrium price in the 3 competitor case is higher than the expected spot price (pure public expected value), in the 6 competitor case the equilibrium price is lower than the pure public expected spot price. This situation occurs due to the fact that the winner has the lowest estimation of the future spot price of all generators. Thus, private optimistic information can lead to low bids. It is possible to conclude that the effect on the winner's curse is higher in a scenario with more competitors.

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[6] For the first ten iterations the price curves behave differently, but for these cases the sampling is still small

5 CONCLUSIONS

The paper contributes with an analytical approach to a problem not studied before: auctions of electricity long-term supply contracts (up to 15 years) in power markets with energy and capacity prices. The scheme arises in the new auction processes being implemented in Latin America.

Two different auction schemes are studied, where diverse elements such as the reserve price and the bid strategy are analyzed. The Chilean market is used to illustrate the models.

In general terms, it is concluded that different auction schemes imply different solutions in a real electricity market, thus the revenue equivalence theorem does not apply. For this analysis, second price auctions show lower prices than the first price format.

The existence of more competitors in an auction drives two benefits in term of prices. Firstly, it results in lower average prices, and secondly, most importantly, the probability to obtain equilibrium prices lower than the average value becomes higher.

Quantitatively, having more competitors drives better prices than changing from the first to the second price auction type.

An important fact for the reserve price is derived: very low reserve prices can produce high final market prices in a multi-round process. The auction designer must take this into account.

The need for a careful design of the auction process and the need to aggressively search for new entrants must be first priority objectives by distributors that call for a contract auction.

6 ACKNOWLEDGEMENTS

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