Auctioning Adequacy in South America through Long-Term Contracts and Options: From Classic Pay-as-Bid to Multi-Item Dynamic Auctions

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***Abstract*— The adequacy problem in electricity market is becoming a very important issue as there is neither theoretical proof nor practical evidence of correct delivering of sufficient and timely generation capacity when it is needed in a real (imperfect) environment. In contrast, classical market design seems to fail when facing high demand growth and/or large hydro share as seen in several Latin American countries such as Chile, Brazil, Colombia and Peru among others. Currently, various mechanisms have arisen across this region with the intention of stimulating energy procurement and new investment. These are mainly based on long-term contract and options obligations, which are allocated through auctions. Auction theory then becomes very important to ensure optimal allocation and efficient prices for both the new generation and the end user. However, difficulties arise when applying pure auction theory because basic hypotheses are not met by most electricity markets. The objective of this paper is to address and discuss the Latin American experience with auction design for long-term contracts focusing on practical design and theory. The different mechanisms and auctions for ensuring supply adequacy are listed along with theoretical justification as part of the potential solution for the adequacy problem that different economies have proposed.**

***Index Terms*-- Power system economics, auction design, power system planning, call options, firm energy, firm capacity.**

I. INTRODUCTION

Although auctions have been used to trade assets from hundreds of years ago, they started to be theoretically analyzed as incomplete information games just during the early 60's through a pioneer paper of William Vickrey [1]. Since this time, auction theory has been developed in several fields. Auctions have been gradually introduced in the energy industry. One of the first types of auctions was introduced to enable an efficient dispatch of the power system [2,3]. In most formal wholesale markets, generation unit owners and loads submit offers and bids to supply and consume energy the following day. Using these bids and offers the market operator sets day-ahead prices at every location in the network and day-ahead schedules for generation units and loads based on (usually) a uniform-price auction mechanism. The product auctioned in this case is the physical delivery of electricity for each hour of the following day.

The trading of longer-term products (such as contracts) has traditionally been carried out through bilateral negotiations and the use of auctions has been limited to some specific cases in energy procurement. Nevertheless, more recently, auctions started to be used more often to trade long-term products. This is the case of Latin America where auctions for long-term contracts have been the main mechanism to stimulate energy procurement with special rules and mechanisms designed to foster new generation investment. Although, the adequacy problem in generation had been tackled before by using other methodologies such as capacity markets/payments, the new method based on auction concepts arises as a parallel alternative that may be attractive for those markets where capacity payments/markets did not work or may not work [4].

The design of auctions of long-term products follows a different dynamic than auctions for efficient dispatch. Several different auction designs have been applied in the region, such as descending price-clock auctions, sealed-envelope pay as bid auctions and hybrid approaches. Results have been mixed, with some positive and negative outcomes which are both offering outstanding opportunities for learning and improvement.

The objective of this work is to describe the approaches adopted and analyze them under the light of the classical auction theory. As long-term trading in electricity markets is subject to several simultaneous particular imperfections (such as collusion, market power, cost asymmetry, etc.), the straightforward application of this theory is not possible and an extension is desired. The inapplicability of the Revenue Equivalence Principle (REP) arises as a good example of these imperfections as proved in [5].

This paper is organized as follows: in Section II the adequacy problem is formalized and tackled by using auction schemes. Then, different theoretical models for auction mechanism are contrasted and analyzed in Section III where

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the auction designs of different countries are described. In Section IV key design aspects are studied from a theoretical point of view. Also, links with the real mechanisms are pointed out. Finally, Section V concludes and Section VI proposes suggestions for proper implementation. This paper was prepared as a contribution to the panel session "Auction Theory for Power Industry Applications" at the 2009 IEEE General Meeting.

II. Energy Auctions for Supply Adequacy

Procurement of energy has been always an important function for electric utilities and power sectors as whole. Old fully centralized electricity markets have evolved to a liberalized environment in which energy is freely traded through contract negotiation for long/mid-term commitments and pool systems for short-term sales. In classical theory, energy-only markets can ensure efficient pricing and allocation, and also stimulate new generation investment in a perfect environment. However, there are no successful evidences of the success of the spot pricing scheme in energy-only markets to drive capacity expansion. Therefore, several mechanisms have arisen on top of the classical theory in order to stimulate generation expansion, such as: capacity payments/markets and back-up/peaker contracts, among others.

The challenge of fostering investment in new generation becomes more critical in fast-growing markets such as Latin American countries, which have fast (and volatile) load growth and where the entrance of new generation is critical to support their growing economies. Investors in these countries need to avoid the price volatility of spot markets and support their projects with stable cash flows, which enable them to get low spreads in their project finance structure.

Thus, so as to tackle the adequacy problem in a competitive way, auctions of long-term contracts are arising along the region as a good solution to conciliate the risk reduction for new investors with efficiency in energy procurement for regulated users. As discussed in [4], this scheme initially started in Brazil and Chile during 2004 and 2005. The general proposal consists of calling energy auctions subject to terms and conditions such as:

1) Winners should have enough time to develop its investment and a minimum revenue guaranteed for a number of years. This means that the auctions should be carried out in advance and the product should be a long-term contract. This drives less risk for new generation, facilitates project finance and allows tariff adequacy
2) The regulator should have a measure that allows the auctioneer to assess the offers received so as to guarantee that the winners are those with the best price/reliability ratio. In Chile and Brazil, this measure is defined as the "firm capacity" or "firm energy", which is the maximum amount of capacity or energy that a project can deliver under extreme conditions, such as in a dry year

These auctions are primordially focused and justified by the willingness of the regulator to ensure a minimum reserve margin by incorporating new investments in competitive conditions. For this reason, from this point onwards, we refer to this type of auction as "auctions to ensure investment in generation". The core of the new scheme lies on three main rules:

a) All consumers, both regulated and free, should be 100% contracted at any time (consumers cannot trade in the spot market)
b) All contracts, which are financial instruments, should be covered by "firm energy" or "firm capacity" certificates. The firm capacity certificate of a generator is therefore a MW rating that reflects the generator's contribution to the overall system supply reliability. It can be calculated by the Regulator and the calculation process is out of the scope of this paper
c) Regulated users must acquire their energy supply contracts through auction. The process must be competitive (open and public) and carried out in advance of time for meeting future demand. Free users can contract energy as they please, provided they are 100% contracted

Although these core aspects do not change across the different countries in Latin America, ways of how to carry out this proposal in practice differ:

1) In Chile, only energy contracts are auctioned and Gencos can differentiate different products defined by Discos. Capacity payments are fixed by the regulator before the auction and remain constant (but indexed) across the contract period. Auction is carried out by using a sealed-price and pay-as-bid design
2) In Brazil, a centralized scheme is adopted where a single auction is carried out to contract distribution company's needs. The auction demand is based on the Disco's projection and the product auctioned is a standardized energy contract[1]. The auction is carried out by using a hybrid design, which mixes a simultaneous descending clock scheme with a final pay as bid round
3) Peru followed an approach similar to Chile until 2008, when changes were introduced to organize the auctions as a centralized process following the Brazilian approach
4) In Colombia, an energy call option is auctioned with a fixed strike price. Therefore, the auction mechanism clears the premium price. The auction is also carried out by using a simultaneous descending clock scheme

A more detailed description and analysis is presented next.

III. Auctions Designed So Far – Practical Analysis

This section describes the key aspects of each country with respect to the design and functioning of their contract auctions. We do not provide in this section the economic rationale for the adoption of the auction scheme.

[1] Actually two types of financial agreements are arranged: contracts (where one single price is paid) and options (where two payments are negotiated: strike and premium prices).

A. The Chilean Case

One of the most important aspects of the Chilean framework is that distributors design and manage their own auctions. Discos are free to call auctions whenever they want. They are also free to design the product auctioned (contract type, term, conditions, etc), but subject to the final approval by the regulator.

The Chilean bidding process allows distributors to auction their demand in one single simultaneous process, in which every generator bids for a specific set of products (a Chilean product corresponds to a specific block of demand from a distributor). In addition, so as to increase the level of competition, generators can bid for a net amount of demand higher than their firm capacities. However, allocation respects the latter.

Because the auction trades different products, all blocks of demand are allocated to every generator at the same time by means of a combinatorial sealed bid mechanism as shown in Figure 1.

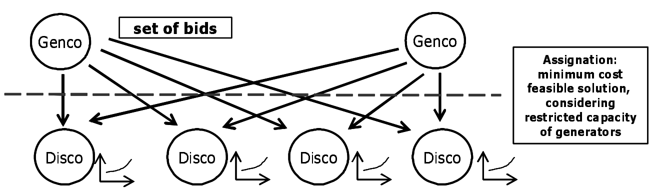


Figure 1- Chilean auction mechanism

This mechanism has led to a large price differential among different products and distributors as generators can choose different strategies for each auctioned contract.

B. The Brazilian Case

In Brazil, auctions are jointly carried out by all distribution utilities. The joint contracting scheme is a mechanism which takes account of economies of scale in the contracting process, specially beneficial for small Discos as well as for equalizing tariffs among consumers aiming at assuring tariff adequacy. Each separate winner of an auction will sign individual bilateral contracts with each distributor participating in the auction, being the energy amount of each contract proportional to the Disco's declared demand, and the total contracted quantity for each generation company (Genco) matches its offered quantity. This allows consumers to enjoy the benefit of cheaper energy to be shared by all. Although a "central procurement" is made, Discos are responsible for deciding how much energy they want to contract (i.e., responsible for load projections). This fact avoids the 'optimistic' government bias that in many countries has led to over-capacity and expensive energy contracts. It is important to notice that this is not a single buyer model, the Government does not interfere in the contracts nor provides payments guarantees.

Auctioned demand is divided mainly in two products: new and existing capacity. In both existing and new energy auction, the objective is to contract energy at the lowest possible cost after Gencos have bid desirable prices. In order to do so, auctions carried out so far have used a two-phase hybrid auction: in the first phase an iterative descending-price clock auction design is applied and then the auction ends with a final round, named second phase, of bids using a pay-as-bid scheme.

During the first phase, generators bid quantity for a given price. Prices move down iteratively as long as there is more supply than demand. When the supply amount meets demand, the accepted bids go to the next phase. As the demand in the first phase is made slightly higher than the "real" declared demand of the Discos, some of the bids will not win the auction. The fact of hiding or increasing demand during the first phase ensures competition in the second phase. Figure 2 shows the prices of the first and second phases of the new energy auction in 2007, for energy delivery in 2010. We can observe that during the first phase, the energy price dropped from 140 to 137 R$/MWh. In the pay-as-bid phase, out of twelve accepted bids, six were equal, which may indicate collusion. The maximum discount with respect to the first phase's closing price was 3%.

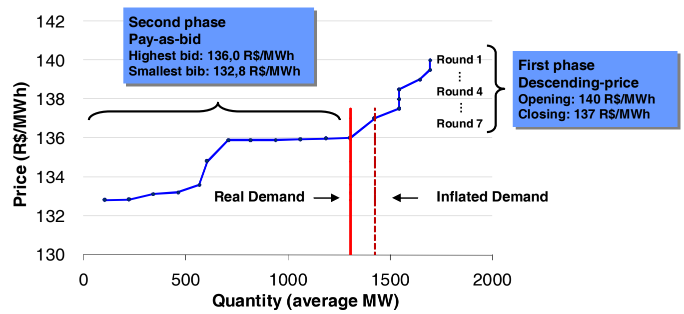


Figure 2- Auction results for energy delivery in 2010

Figure 3 shows the result of the new energy auction in 2007, for energy delivery in 2012. The first phase price started at 136 R$/MWh and decreased to 132.5 R$/MWh. In the second phase, there was no evidence of collusion and some agents gave a discount of 5% over the clearing price of the first phase.

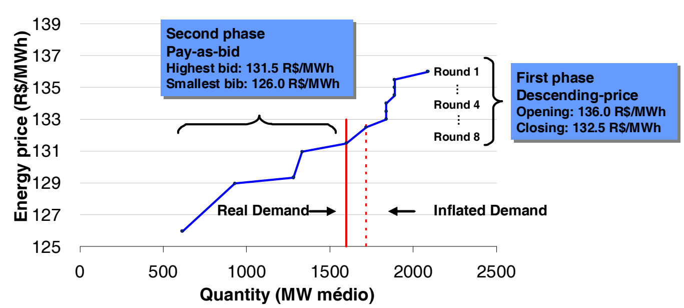


Figure 3- Auction result for energy delivery in 2012

Although there is an evidence of collusion in the second phase, the discounts over the first phase's clearing price have shown that this mechanism has contributed to increase competition.

C. The Peruvian Case

The Peruvian power system implemented an auction-based system in 2006. The implementation followed the Chilean approach, in which distribution companies could design their own auctions and products. The regulator sets a maximum price for the award of the contracts, which should encourage efficient investment in generation, taking into account the period of supply required. The aforementioned maximum price is only revealed if no bids are received to cover all the demand put out to tender at a price below or equal to the maximum price and when at least one of the bids received exceeded the maximum price. Finally, in the event that 100% of the demand required is not covered in the bidding process, it will be declared partially or totally cancelled and a new invitation to bid will be made to contract the shortfall. In this new invitation to bid, the maximum price is different. Currently there is no restriction to participate in a new invitation to bid for the same process: if a company participates in the first invitation to bid it is not obliged to continue participating. Therefore, the main conditioning factors that can affect the behavior of agents in tenders in Peru are: (i) Sealed envelope bidding in which each bidder may submit more than one bid; (ii) New invitation to bid if the tender does not cover all the demand required; (iii) Disclosure of the maximum price if the bid is annulled and at least one of the bids has exceeded the maximum price.

There are two characteristics of the processes conducted: the high level of processes that were annulled and a significant number of invitations to bid for the same tender, with the subsequent revelation of the maximum adjudication. These are characteristics of a process that has not been efficient and been successful for the contracting of energy. In 2008, this scheme was replaced by a centralized auction following the Brazilian approach, but there is no experience so far with this new design.

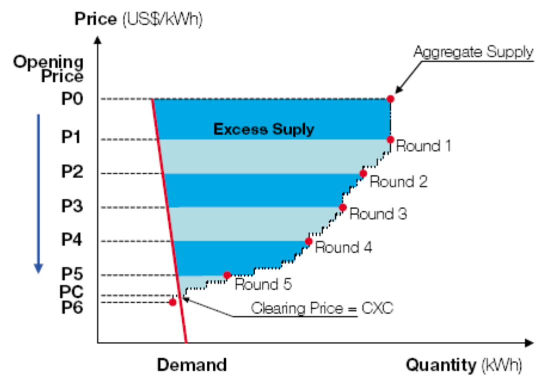
D. The Colombian Case

Colombia implemented a supply adequacy scheme based on Firm Energy Obligations (OEF), which is an option product designed to guarantee the reliability of energy supply in the long-run at efficient prices. In the Colombian system, generation units receive a Reliability Charge, CC, as payment for a commitment to deliver a given amount of energy, physically backed, at the *scarcity price*, set by the regulator, whenever the spot price surpasses this value. The option premium, CC, and the selection of new generators that will receive it, is made in a centrally held auction for FEO to be delivered in the 3^{th} years after the allocation process.

The allocation of the OEF among different generators and investors is done through a dynamic auction. In this transaction in the wholesale energy market, generators and investors participate actively, while the electricity demand of end-users connected to the system is represented by a price-quantity function previously established by the regulator (CREG). For this purpose, an auction to allocate the OEFs is undertaken three years before the firm energy obligation can be called. The Auction for the allocation of OEF is a one sided process. This means that only generators and potential investors, who have met all the requirements necessary to participate in the auction, can actively bid. The demand of end-users connected to the system is represented by an aggregate demand curve that is previously established by CREG and made public before the auction is conducted.

The mechanism utilized is a descending clock auction and is carried out as follows:

- The auctioneer opens the process at a price equivalent to two times the Cost of Entrant; a value calculated by CREG and made known to the bidders (generators and investors) before the auction. Likewise, the auctioneer announces the floor price at which this first round will close.
- Between these two prices the bidders draw their firm energy supply curve and then this information is sent to the auction administrator. Figure 4 describes the auction methodology.



Source: CREG, 2007.

Figure 4- Descending price-clock auction with intra-round bids in Colombia

To sum up, the unit price ($/kWh) paid for each kWh of firm energy allocated, as well as the firm energy allocated to each generator, are the result of a "descending clock auction" with an elastic demand curve (Figure 4), that takes place three years before the regulator estimates that the firm energy will be required, or when the Regulator so decides. The price obtained as a result of this auction is guaranteed to new investors for a period of up to 20 years, to help them in firming up their cash flow and thus to facilitate project finance.

IV. Theoretical Key-Aspect Analysis of the Current Designs

To analyze the current designs, various variables can be taken into consideration such as type of product auctioned (contract/options – standardized/different contracts), price location (zonal or nodal prices), market pricing (energy/capacity contracts) and auction types (sealed/open, pay-as-bid/uniform, etc.), among others. Therefore, the study shown in this section is focused on only some of these aspects which are pointed as fundamental for properly understanding auction design.

A. The Revenue Equivalence Principle (REP)

REP establishes that any type of standard[2] auctions delivers the same expected revenue to the auctioneer.

[2] An auction is standard if the rules of the auction dictates that the winners correspond to the bidders whose bids are the cheapest ones

Noticing that REP is not valid for auctions of contracts and options in electricity markets is straightforward when considering the key assumptions underlying the principle [6]:

1) Independence: the generation cost among the bidders should be independently distributed
2) Symmetry: the generation cost among the bidders should be distributed according to the same distribution function
3) Risk neutrality: all bidders should seek to maximize their expected profits

According to classical auction theory, each bidder knows only its own cost but not the cost of the remaining participants. Nevertheless, the latter costs are partially known by assuming a distribution function. So, in an electricity market where producers: (i) can generate by using different fuel types or generation technologies (no symmetry), (ii) have different risk profiles (no risk neutrality), (iii) and are not necessarily independent due to the presence of holdings and cooperative bidding strategies (no independence), REP is visibly not valid. For example, a theoretical assessment of differences between first and second-price auction under real market conditions, the Chilean electricity market, can be found in [5].

For this reason, designing issues are extremely important so as to deliver efficient prices and contract allocation. Different designs can deliver different results when considering the same market features.

B. Allowing Unlimited Number of Participants: Collusion, Holdings, Barriers to Entry

As in many competitive processes, the higher the number of competitors, the lower the cleared prices. But, because of the inapplicability of REP, different auction designs will be differently affected by this variable. Although, analyzing the real effects of the number of participants on the final equilibrium can be very hard to do, a small example based on a simplified case is shown for assessing this effect as follows. Assume a first-price auction with: (i) n+1 participants, (ii) one indivisible demand block offered for new investment, (iii) net cost of generation uniformly distributed between 50 and 100 US$/MWh among participants, (iv) and a reserve (cap) price of 100 US$/MWh. Given this framework, it is straightforward to see that the first order condition for optimum bidding under symmetric behavior is:

$$Max\{(b-x)\cdot(1-G_{(1)}(\beta^{-1}(b)))\},\ b=\beta(x)\Rightarrow \quad (1)$$

$$\beta'(x)\cdot(1-G_{(1)}(x))-\beta(x)\cdot g_{(1)}(x)=-x\cdot g_{(1)}(x) \quad (2)$$

$$with\quad \beta(x=100)=100 \quad (3)$$

Where β(x) is the bidding strategy in function of the generation cost x, b is the bid price, $G_{(1)}(\ )$ and $g_{(1)}(\ )$ are the probability and distribution function of first order statistic[3] for n independent uniform variables, respectively. These are shown below:

$$G_{(1)}(x)=1-(1-G(x))^{n} \quad (4)$$

$$with\quad G(x)=\frac{x}{50}-1\ \ \forall x\in[50,100] \quad (5)$$

[3] First order statistic refers to the minimum value of a set of n random variables

Now, when different number of participants, for instance, n+1=2 and n+1=11, compete in the auction, we have:

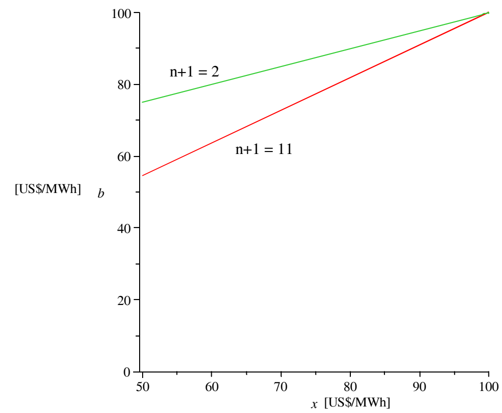


Figure 5- Bidding functions for n+1=2 and n+1=11

The larger the number of bidders, the lower the bid price for a given generation cost. For example, when only 2 competitors are in the auction with generation cost of 50 US$/MWh, they bid at 75 US$/MWh, in contrast, this bid decreases at 55 US/MWh if the number of competitors increases up to 11.

In fact, the number of competitors is a very important variable in an auction and therefore mechanisms must be designed in order to avoid collusion and/or barriers to entry. Also, designs must take advantage of the number of competitors in the market in order to obtain efficient prices. Although this conclusion seems to be obvious, there are mechanisms that do not pay attention of this variable as illustrated next. The Chilean auction presents a good counterexample in this respect when dividing the offered demand into several contracts or products and allowing generators to bid for their preferred products (for details see III.A). This fact delivers very low prices for the very overbid products and vice versa. What is more, in some extreme cases various products are unbid when, on the other hand, preferred products are bid at a very low price in the same process. This mechanism not only leads to an asymmetric price situation for Discos but also to price differentials which may not properly reflect losses and congestion in the transmission system. In Brazil, this phenomenon is avoided when all demand is added in a single market block and contracts are standardized, so agents compete for the same products leading to more competitive final prices.

Finally, the timetable of the process plays a very important role in terms of barriers to entry. When international investors analyze the market and carry out access arrangements in order to participate in an auction, they face numerous barriers that may not be fast to solve if the time window is short.

C. Reserve prices

Although according to classical theory reserve prices have a small impact on bidding behavior and final prices [6], different mechanism can increase the effects of this variable on the optimum equilibrium.

If we consider the theoretical example explained earlier, the bid price for a generator with cost of 70 US$/MWh when 6 agents compete is equal to 75 US$/MWh. But, if the reserve price is dropped to 80 US$/MWh, then the bid price decreases only up to 74.56 US$/MWh. This is explained because of the boundary condition, i.e., a lower reserve price highly affects the bid of the agents whose generation costs are in the neighborhood of the reserve price. For the rest of the bidders, the reserve price does not significantly impact on their strategies.

Historically, regulators have used public reserve price (or price cap mechanism) to keep under control, generally by pushing down, the equilibrium price in an auction. However, theoretical material proves that the use of this tool is not necessarily beneficial from the consumers' point of view (auctioneer) as agents can use it as a reference point to bid and so the result of the auction can be affected in various ways depending on the design as indicated in [7]. The Chilean process provides a good example of public reserve prices which may increase iteratively after every unbid auction and ultimately affect the net auctioneer's revenue (Discos' payments). In this framework, agents can take consideration of the aforementioned price cap increase in every round and so bid higher prices. This scheme also allows competitors to bid under a step-by-step strategy where the new increased price cap fixes the new reference.

D. *The Effects of the Winner's Curse and Indexing Formulas*

This general auction scheme proposed for generation adequacy allows generators to ensure future cash flows by fixing their revenues through contracts and so stimulates investment. However, high levels of competition may drive prices close to the net generation cost and therefore, given the fact that this is not a well known value for the entire contract period, lead to generation bank rote. Theoretically, this can be understood as a winner's course phenomenon as illustrated next. If 5 future power coal plants are competing in an auction in which only 2 bidders can win, then, the winners will be those with the 2 cheapest bid prices. Now, if the 5 competitors assessed the future cost of building and operating a coal power plant and bid in the same process, why do they bid different prices? The answer to this question is that they may have different expectation about the future coal price and therefore, the winners are those with the most optimistic projections. By definition the lowest projection is below the market price[4] and the second lowest may be below it, so under extreme competition when prices go close to the expected generation cost, the risk of bank rote arises.

The winner's curse effect can be mitigated by the agents by bidding reasonably. In addition, indexing formulas can be included in the process with the intention of avoiding this phenomenon by updating contract prices according to fuel prices variance. However, it is important to highlight that including indexation forces the auctioneer to take a position with respect to future fuel prices and so a possibility of wrongly allocation may take place.

In the Chilean mechanism, indexing formulas are proposed by each bidder together with its supply offer. The mentioned formula must be built according to the power source of the bidder. However, it is important to highlight that, according to the designers (Discos), due to the unpredictability of fuel prices, these formulas are not taken into account by the auctioneer during the auction process. This fact has caused several discussions in the Chilean electricity market because contract allocation can dramatically change if price projections are incorporated into the mechanism.

E. *Pay-as-Bid vs Uniform Price Auctions*

Whilst REP can be applied, pay-as-bid and uniform price auctions deliver the same equilibrium. But, due to the inapplicability of REP in auctions of contracts in electricity markets, variations arise and therefore regulators need carefully analyze which is the most suitable design for their particular market conditions.

Uniform price auctions are slightly more preferred in academia as this can be easily linked with classical microeconomic theory as shown below.

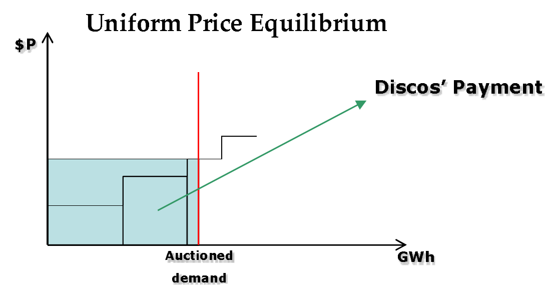


Figure 6- Equilibrium in a uniform price auction

Under this scheme, price is cleared by the marginal bidder and so the bidding strategy used by each participant is fully cost reflective.

On the other hand, pay-as-bid auctions drive participants to hide real costs and inflate their bids as each bid ultimately fixes the final payment. This fact forces bidders to speculate and so all bid prices are similar as shown next.

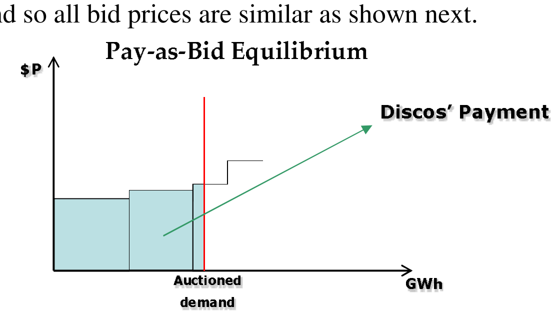


Figure 7- Equilibrium in a pay-as-bid auction

Although uniform price auctions are preferred from a theoretical point of view under perfect market conditions, there are evidences that these facilitate collusion more than pay-as-bid auctions [8]. For example, this argument was used in the regulatory reform carried out in the electricity market in Great Britain during the beginning of this decade.

There is no agreement about which design is ultimately the best when considering different market conditions; whilst pay-as-bid seems to behave better under collusion problems and

[4] When the market price is given by the average of the five projection prices

repeated auctioning, speculation may distort the efficient equilibrium as explained next. In a uniform price auction the best strategy is biding just the generation cost and prices are cleared by the marginal bid. In a pay-as-bid auction the best strategy is bidding what each bidder believes will be the marginal bidder's bid. So, efficient generators can fail to do so and finally lose in the auction process.

In Chile, a pay-as-bid mechanism is used to allocate supply contracts among generators. Despite the fact of the inefficient allocation risk explained earlier, the cheapest generators are generally the winners[5] of the process as shown in Figure 8.

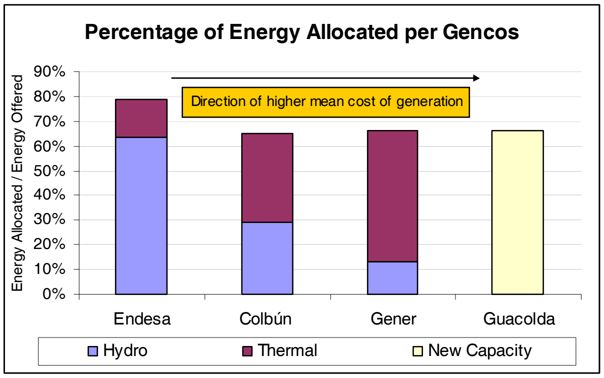


Figure 8- Percentage of energy allocated per Genco in the first Chilean auction

An interesting mechanism is the hybrid scheme that can be observed in the Brazilian process. Although the auction is a pay-as-bid scheme at its last stage, the classification part corresponds to a type of uniform auction (for details see III.B). This special design named simultaneous descending clock auction plus a pay as bid negotiation stage presents attractive characteristics for auctioning long-term contracts in electricity markets such as:

1) The pay-as-bid negotiation stage avoid collusion problems as the final price depend on each bid
2) The first stage allows the auctioneer to discover the market price and so set an efficient price cap for the negotiation stage
3) As winners are mostly selected in a uniform price scheme, the risk of inefficient allocation due to speculation is totally mitigated

To conclude, various standard mechanisms can be applied in this proposal and need to be review by regulators. These can be classified as follows:

1) Sealed bid auctions and open auctions
2) Uniform and pay-as-bid or discriminatory auctions
3) Single product and singe product
4) Homogeneous products and heterogeneous product
5) Allocation rule: English, Dutch, ascending or descending auction, etc.

V. Conclusions

Auctions of long-term energy contracts have emerged as an attractive option to ensure supply adequacy in many countries. Latin America provides a good example and other countries are now considering the introduction of auctions for long-term energy contracts, as their power systems evolve and this form of procurement gains momentum around the world. Spain has adopted the auction system. Other countries such as Turkey, South Africa and Romania also seem to be moving along these lines. In sum, there is a growing demand to "learn" more about how auctions should be designed and operated.

When introducing auction of contract and/or options for ensuring adequacy in electricity markets, selecting or designing the right mechanism to do so is extremely important. In electricity contract auctions, REP cannot be applied and so design must take care of efficiency in terms of price and allocation. A wrong mechanism may lead to inefficient allocation, lack of competition, presence of collusion and therefore a price increase for the end consumer. In the paper different real designs are presented by contrasting pros and cons in practice and then key theoretical aspect are analyze for stressing the importance of pure design in an auction process.

VI. Looking forward in the implementation of energy auctions

Despite the optimism surrounding energy auctions, implementation has not been an easy task, particularly in markets with few participants and limited competition. It has been a challenging, learning experience. This process requires extensive regulatory oversight. Results of the auctions developed so far have been mixed. On the positive side, they have established a transparent market mechanism for allocation and procurement of generation capacity. Also, they have avoided some of the pitfalls and abuses related to single sourcing or direct negotiation between the contracting parties, which reduces the demands on the regulatory oversight process. Prices resulting from the auctions have also provided an elegant solution to the regulatory challenge of what are the "prudent" costs of generation that should be passed on to final customers. An important factor to consider in the auction design process is how far in advance of delivery to run the auction to allow sufficient competition with existing firms to provide the energy. In addition, it is also important to keep the volume of energy auctioned small in each individual auction in order to prevent extreme market outcomes.

On the other hand, policy makers and investors have raised concerns about auction mechanisms. Investors tend to complain about the lack of transparency of the auctions, and that the government's desire to introduce some elements in the auction process to increase competitiveness may in fact decrease market efficiency. Resolving this tension between energy policy requirements of the government and a desire for transparency and economic efficiency is extremely difficult, and certain countries have been more successful than others. Furthermore, energy auctions may drive new capacity expansion in a certain direction, resulting in solutions different from the ones that policy makers or least-cost planners originally envisioned. For example, developers may

[5] The more the hydro share, the cheaper the cost as Andeans rivers in Chile allow investors to produce at a very cheap cost when big reservoirs are used

prefer bidding for smaller, less risky projects, possibly to the detriment of large hydro plants. Contrary to energy policy makers, developers are less concerned about diversification of supply sources, energy security, location, and other energy policy considerations.

Furthermore, little activity has been seen in terms of participation of demand resources in the auction design process. Some recent initiatives in developed countries have proved the potential of treating supply and demand resources on a level-playing-field basis, thus participating in the same auction processes. For example, New England (NE-ISO) has included demand resources in the Forward Capacity Market in 2007. Energy efficiency and other demand resources were able to compete with generation to meet system reliability. It is expected that demand resources may represent 15% of market needs in the future. Auctions are now being considered for the ancillary services (NE-ISO) and for energy efficiency per se (PJM).

The jury is still out in terms of the effectiveness of the auction mechanisms to attract least cost green-field generation (or demand resources) and price it efficiently; particularly in places where policy makers still want to have a strong voice as far as energy policies are concerned. The major factors to be studied are: (1) the type product to be auctioned — energy, capacity or some hybrid product, (2) how far in advance of delivery to run the auction, (3) how much volume to auction and how frequently to run the auctions, and (4) how to efficiently allocate and clear prices; auction designed.

VII. References

[1] Vickrey, W., "Counterspeculation, Auctions, and Competitive Sealed Tenders", The Journal of Finance, Vol. 16, No. 1. (1961), pp. 8-37.

[2] Fabra, N., von der Fehr, N.H., and Harbord, D. (2002) Modelling Electricity Auctions, Electricity Journal, Septiembre, Vol. 15, No. 7, pp. 72-81.

[3] von der Fehr, N.H. and Harbord, D. (1997) Competition in Electricity Spot Markets: Economic Theory and International Experience, Memorandum, University of Oslo.

[4] Barroso, L, Rudnick, H., Moreno, R., Bezerra, B., "Ensuring Resource Adequacy with Auctions of Options and Forward Contracts", paper 07GM1368, IEEE Power Engineering Society 2007 General Meeting, Tampa, Florida, June 2007

[5] Moreno, R., Rudnick, H. and Barroso, L., "First Price and Second Price Auction Modelling for Energy Contracts in Latin American Electricity Markets", 16th Power Systems Computation Conference, July, 2008, Glasgow, Scotland

[6] Krishna, V., "Auction Theory", Academic Press, 2002

[7] S.Rosenkranz, P.W.Schmitz, "Reserve Prices in Auctions as Reference Points", The Economic Journal, 117 (April), 637–653.

[8] Fabra, N., "Tacit Collusion in Repeated Auctions: Uniform versus Discriminatory", Journal of Industrial Economics, Vol. L1, No. 3 (Sept.), pp. 271-293, 2003.

VIII. Biographies

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Luiz Augusto Barroso (S'00, M'06, SM'07) has a BSc in Mathematics and received in 2006 the PhD degree in operations research from COPPE/UFRJ, Brazil. He is a technical director at PSR, where he has been providing consulting services and researching on power systems economics, planning and operation, focusing on hydrothermal systems in Brazil and abroad. He has been a speaker on these subjects in Latin America, Europe and US/Canada

Sebastian Mocarquer, IEEE Member, graduated as Industrial Electrical Engineer from Pontificia Universidad Católica de Chile. He is presently the Development Manager at Systep Ingeniería y Diseños. He has directed several tariff studies in Chile and has made regulatory studies with utilities, regulators and investment banks in Chile and abroad.

Hugh Rudnick, IEEE Fellow, is a professor of electrical engineering at Pontificia Universidad Catolica de Chile. He graduated from University of Chile, later obtaining his M.Sc. and Ph.D. from Victoria University of Manchester, UK. His research and teaching activities focus on the economic operation, planning and regulation of electric power systems. He has been a consultant with utilities and regulators in Latin America, the United Nations and the World Bank.