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Auction approaches of long-term contracts to ensure generation investment in electricity markets: Lessons from the Brazilian and Chilean experiences ☆

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ABSTRACT

The implementation of auctions of long-term electricity contracts is arising as an alternative to ensure generation investment and therefore achieve a reliable electricity supply. The aim is to reconcile generation adequacy with efficient energy purchase, correct risk allocation among investors and consumers, and the politico-economic environment of the country. In this paper, a generic proposal for a long-term electricity contracts approach is made, including practical design concepts for implementation. This proposal is empirically derived from the auctions implemented in Brazil and Chile during the last 6 years. The study is focused on practices and lessons which are especially useful for regulators and policy makers that want to facilitate the financing of new desirable power plants in risky environments and also efficiently allocate supply contracts among investors at competitive prices. Although this mechanism is generally seen as a significant improvement in market regulation, there are questions and concerns on auction performance that require careful design and which are identified in this paper. In addition, the experiences and proposal described can serve to derive further mechanisms in order to promote the entrance of particular generation technologies, e.g. renewables, in the developed world and therefore achieve a clean electricity supply.

1. Introduction

The need to ensure efficient generation adequacy forms the backbone of electricity markets. This includes the establishment of correct mechanisms and incentives to allow the entrance of new generation in order to meet load growth. This is particularly crucial in developing countries, where the primary challenge is to ensure sufficient capacity and investment to reliably serve their fast-growing economies.

The basis of competitive electricity markets is that, under system marginal pricing, short-term energy spot prices promote the efficient use of existing generation resources and provide signals to foster the interest of investors in building new capacity if needed (Schweppe et al., 1988). An imbalance between supply and demand because of demand growth, for instance, results in spot price increases and thus creates incentives for the construction of new plants. Moreover, the optimal amount of capacity can recover total costs, i.e. expected spot market revenues are enough to remunerate investment and cover operational costs. Despite this fact, different economic arguments regarding electricity pricing introduce additional explicit capacity remuneration methods or capacity requirements (or obligations) as needed mechanisms on electricity markets to incentivise investment and so ensure generation adequacy (Oren, 2000; Tezak, 2005).

This paper analyzes an alternative scheme for resource adequacy involving auctions of long-term energy contracts, reconciling efficient energy purchase, correct risk allocation among investors and the politico-economic environment of the market. The fundamentals of similar frameworks have been derived and analyzed earlier by a number of authors such as Bidwell (2005), Chao and Wilson (2004), Cramton (2006), Cramton and Stoft (2006), Oren (2005), Vazquez et al. (2002), among others. Therefore, the goal of this paper is to complement current knowledge by highlighting practical design and real implementation elements through lessons learned over 6 years of application of long-term contract auctions in Brazil and Chile. These two countries were selected because they have simultaneously implemented auction-based schemes to ensure generation adequacy, following the same conceptual basis but

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employing different procurement schemes. Note that this practical knowledge may be useful for regulators and policy makers not only in developing countries, but also in the developed world in which authorities have already shown interest for these mechanisms. As an example, a recent document published by Ofgem (2010) in the United Kingdom (UK) has identified auctions of long-term contracts as a tool to foster generation investment and therefore achieve targets for renewables.

This paper is organized as follows. Section 2 provides a summary of the fundamentals and international experience in energy market designs and resource adequacy requirements. Sections 3 and 4 discuss the specific challenges of developing countries, presenting an overview of the proposed solution to address resource adequacy. Section 5 describes the practical aspect of the auction mechanisms in Brazil and Chile and so allows us to understand the different ways in which the solution can be implemented. Section 6 compares practical aspects of their different designs and summarizes lessons learned. Section 7 narrows the proposed solution based on auctions of long-term contracts, including best practices. Section 8 concludes.

2. Market design and resource adequacy so far

2.1. The basic market philosophy

Early electricity market designs, pioneered by Chile and the UK, were centred on competition in the short-term energy spot market, which should provide all the ingredients for correct system operation and investment. Contracts to hedge spot price variability naturally arose. Consistency should have been assured because contracts could be priced in relation to the futures market, where the prices are in turn projected from spot prices and expectations of future changes in market conditions. Investment and operational generation costs could be recovered through a single energy price.

2.2. The difficulties and attempts for solutions

While the straight application of spot pricing theory may be conceptually efficient, international experience leaves room for doubt as to whether price spikes in an energy-only market create sufficient incentives for new investment. In addition, limited demand response and price caps to diffuse scarcity prices do not contribute to incentivize investment and spot price volatility creates challenges for project finance. In the case of developing countries, this is compounded by the observation that liquid futures markets are not available. Capacity payments or markets were established in some countries as mechanisms to provide fixed revenue streams to be compounded to the spot energy revenues and thus help the development of new generation. Economic conceptual support to these actions was based on early peak load pricing theory (Boiteux, 1949).

Hence, in the UK, an explicit "capacity adder" used to be included in the short term energy price in the form of an LOLP × VOLL uplift,[4] while a regulated capacity payment was introduced in Chile as a secondary product being supplied by generators. US markets such as PJM, NEISO and NYISO have also created market tools for that purpose. Argentina, Spain, Colombia, Peru, Italy and South Korea have also established regulated capacity payments at some stage. A good survey of the mechanisms adopted in developed countries can be found in Tezak (2005).

[4] VOLL = value of lost load; LOLP = loss of load probability.

Capacity payments have been opposed by some specialists, arguing that these distort the bidding signals, generation revenue and demand response, among others, in the energy spot market (Oren, 2003). However, other economic views argue for the need to have both energy and capacity products (Cramton, 2005).

More recently, a different solution based on forward contracts and call options has been proposed to support generation adequacy. Fundamentals of these proposals can be studied from Bidwell (2005), Chao and Wilson (2004), Cramton (2006), Cramton and Stoft (2006), Oren (2005) and Vazquez et al. (2002). Evaluating these proposals in practice becomes a difficult task as experience is not sufficient, however. Despite this, some qualitative and quantitative evaluations can be found in recent works such as Cramton (2006) regarding the New England case; Ausubel and Cramton (2010), Cramton and Stoft (2006), Harbord and Pagnozzi (2008) regarding the Colombian case; de Castro et al. (2008) regarding the Illinois experience; Loxley and Salant (2004) regarding the New Jersey BGS auctions; Barroso et al. (2006), Bezerra et al. (2006) and Cavaliere and Loureiro (2010) regarding the Brazilian case; Rudnick and Mocarquer (2006) regarding the Chilean case; Moreno et al. (2009) regarding the South American experience and finally Arellano and Serra (2010) in a more fundamental study on South American frameworks. All these studies evaluate the use of energy auctions as a positive reform to ensure adequacy through promoting investment and mitigating risks and market power. However, concerns about practical design elements and their impacts on final price and contract allocation are also exposed.

3. The challenge of developing economies

In the case of developing (or emerging) economies, Latin America provides a good example of failures in the early resource adequacy requirements and a later correction, with the adoption of improved mechanisms.

The region is characterized by high demand growth rates (over 5% yearly) and strong hydro share (about 60%). In the 1990s, the region introduced market reforms coupled to a privatization process in the electricity sector (Rudnick et al., 2005). Although differing in the implementation details, the first "generation" of power sector reforms was based on marginal pricing market mechanisms. In particular, the key driver for decisions was the spot price in the short-term market, coupled in some countries to regulated capacity payments as a secondary product.

While the accumulated reform experience has shown many positive aspects (Rudnick and Montero, 2002), some important difficulties appeared, in particular with respect to the adequacy of supply, e.g. power crises and rationings (Maurer et al., 2005). The first reason for these supply difficulties is that the economic signal provided by the energy spot market is too volatile and difficult to correctly indicate and stimulate the entrance of new capacity. This is especially true for countries with a strong hydro share, where the occurrence of conjuncture favourable hydro conditions can drive the spot prices downwards even if there are structural problems with supply. For example, Fig. 1 shows the sudden price spike experienced during the 9-month rationing in 2001 in Brazil. Note that, given the particular hydro conditions that occurred, the energy spot price did not reflect the scarcity of generation installed capacity, even just before the start of rationing. Similar trends have been observed in the Chilean electric system, in which spot prices are also very dependent on hydro conditions.

The second reason is the combination of strong demand growth and regional economic instability, creating uncertain

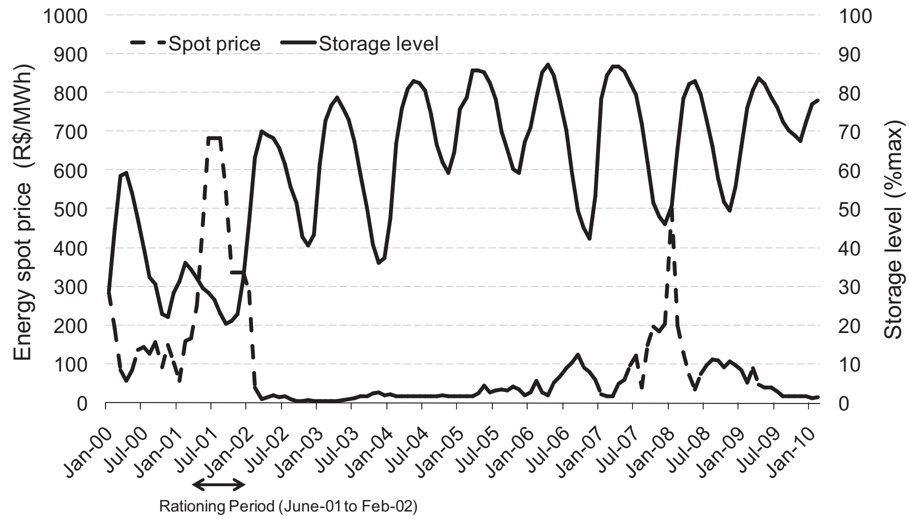

Fig. 1. Short-run marginal costs in R$/MWh and storage levels.

conditions for trading energy between neighbouring countries and impacting on energy price expectations. High demand growth in a country like Brazil, for instance, requires about 5 GW of new generation installed capacity every year (about 6 billion US$/annum) in order to maintain an adequate and secure supply to, in turn, achieve targeted levels of GDP growth (about 4%). In addition, international energy trading in an economically unstable environment has played a key role across the region, affecting not only prices but also demand security. Chile presents a good example regarding this matter: it has suffered a large gas import curtailment (from Argentina) from 2004 until now (2010). This has significantly reduced generation security margins and raised the annual energy spot price, especially during 2007 and 2008 when all available units were asked to be dispatched to supply some peak demand hours and monthly prices reached levels above 200 US$/MWh for some months.

All these make generation activity very risky, inhibit the closing of financing for new projects, increase the end-user generation price, demand time and make development of new generation more difficult on a constant basis. Capacity payments only represent a small part of the overall generator income and its role is very limited by the uncertainty of the energy spot market.

4. An alternative approach to ensure resource adequacy in electricity markets

4.1. Looking at Latin America

The usage of auction mechanisms, in which potential investors compete for long-term energy contracts for demand to be served for a number of years after the auction occurs, arose as an alternative in Latin America, led by Brazil in 2004 and Chile in 2005. Peru, Colombia and Panama also implemented auction based schemes during 2006–2009. Auctions foster the participation of many participants, ensure competition and tend to allow efficient price discovery. The product being auctioned – a supply contract – provides the revenue stability that is needed for financing and thus reduces risks for new comers.

The general proposal consists of calling energy auctions subject to terms and conditions as follows:

- winners should have enough time to develop their investment and a stable revenue guaranteed for a number of years;
- regulator or distribution companies should have a measure that allows the valuation of the different offers received so that it can be guaranteed that the winners are those who offer reliable capacity at efficient prices.

These auctions are fundamentally focused and justified by the willingness of the regulator to ensure generation investment in competitive conditions.

4.2. Formalizing the proposal of auction of long-term contracts

When analyzing the Brazilian and Chilean auction designs (Barroso et al., 2006; Rudnick and Mocarquer, 2006), some common fundamental concepts can be pointed out. From this comparison, it can be established that the core of the new scheme lies in three main rules:

(a) All consumers, both regulated and free (i.e. non-regulated large consumers), should contract 100% of their new generation requirements (demand growth, contract expiration with a decommissioning plant, etc.) in a long-term fashion;
(b) All contracts, which are financial instruments, should be covered by adequacy guarantees in the form of "firm energy" or "firm capacity" certificates or any other credible measure of adequacy. These should represent the maximum amount of capacity or energy that a project can deliver in adverse scenarios, e.g. when considering dry years for hydro plants. The adequacy guarantee of a generator is therefore a MWh or MW rating that reflects the generator's contribution to the overall system supply reliability. These can be calculated by the regulator following several methodologies such as in Batlle and Vázquez (2000), Booth (1972) and Faria et al. (2009).
(c) Regulated users must acquire their energy supply contracts through auctions. The process must be competitive and carried out in advance for meeting future demand. Free users can contract energy as they please, provided that they have evidence that they are 100% covered by contracts with adequacy guarantees.

Thus, these three main rules should interact as follows: (i) all new generation requirements from the entire system demand need

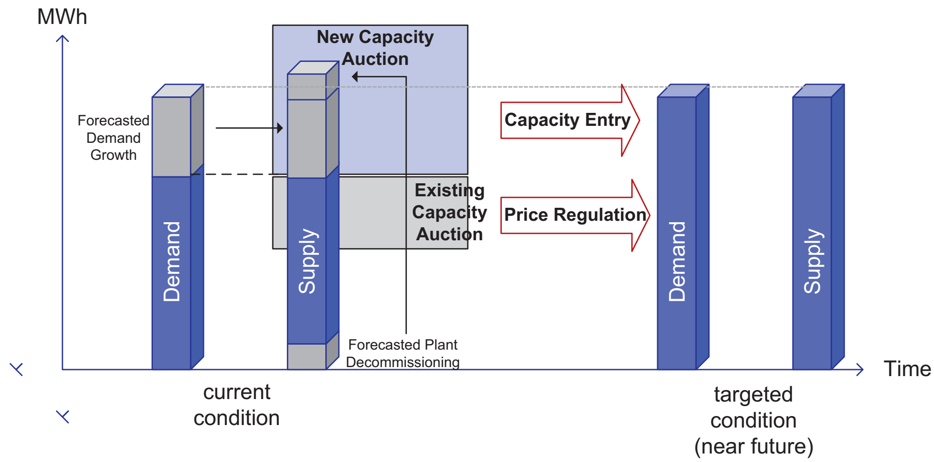

Fig. 2. Long-term and mid/short-term contract auctions' philosophies.

a contract to be supplied (rule a) and (ii) each bidder (generator) of the auction must ensure resource adequacy by means of firm energy/capacity certificate or any other credible means (rule b). While rules (a) and (b) ensure the security of supply, rule (c) ensures a competitive procurement. New investors must demonstrate that they qualify (technically and economically) to build the new plant in time by signing special performance agreements. Consequently, the needed capacities to supply the energy requirements are ensured based on a competitive methodology to clear the purchase prices so that the expected spot price signal is not crucial anymore to access the market.

Depending on market arrangements, short and mid-term contracts can be also auctioned to existing generation in the same manner. In this case, the objective is different: provide price regulation which minimizes the need for administrative definitions of regulated contract prices. Indeed, Brazil and Chile have adopted this scheme, replacing the old regulated contract price calculation based on spot price averages and long-run marginal cost estimations, respectively.

Fig. 2 illustrates how this mechanism functions. This also shows the scope of long and, potentially existing, short/mid-term contract auctions.

This proposal is narrowed further in Section 7 after empirically analyzing the positive and negative aspects, respectively, of the two aforementioned experiences.

At this point, it is worthwhile to notice that this proposal addresses issues about fundamental market design and so a new focus arises: competition for the market. The proposed mechanism can be applied on any electricity market in order to ensure resource adequacy or generation investment. However, this is strongly recommended for those markets that present: high volatility of spot prices; strong demand growth; the need to have long-term contracts for project financing for new generation; and the need to have a market benchmark to define prices for the energy contracts that distributors buy on behalf of regulated users.

5. Implementations: Brazil and Chile

Brazil and Chile show two clear examples of the formulated scheme to ensure generation investment. Although the philosophy is the same in both cases, they differ in practical implementation aspects. This section describes implementation elements to inform policy makers, regulators and analysts of the on-going regulatory changes in Latin America, while the next one shows analyses and lessons. The main characteristics of their electric systems and markets are also described in order to facilitate comparisons and potential implementations for other regulators.

5.1. *The Brazilian case*

5.1.1. *Electric system and market description*

The Brazilian electric system is the largest in Latin America. It has a peak demand of 70 GW which is presented during summer and an energy consumption of 450 TWh/annum (2009), growing about 5% a year. Its generation installed capacity is circa 106 GW and composition is mainly driven by hydro resources (80%). Despite the fact that the system is totally unbundled, there is an important fraction of generation installed capacity owned by the Government (60%). In addition, the largest generation companies are Furnas and Chesf which together own about 20% of the system's installed capacity. On the demand side, private distribution companies supply about 80% of the country's consumption. Furthermore, the total number of (main) generation and distribution companies is about 30 and 63, respectively, and they are located within one (or more) of the four system's areas: South, Southeast/Midwest, North and Northeast. Energy trading between demand and generation must be set through supply contracts negotiated in advance.

5.1.2. *General auction framework*

As described in Barroso et al. (2006), the first rule in the Brazilian regulation is that all consumers, both regulated and free, should be 100% contracted. Contract coverage is verified ex-post, comparing the cumulative MWh consumed in the targeted (previous) year with the cumulative MWh contracted. If the contracted energy is smaller than the consumed energy, the user pays a penalty related to the cost of building new generation. Regulated users are also allowed to be over contracted by up to 3%. In addition, total energy can be reduced in contracts, at the distributors' discretion, up to 4% in each year in order to take account of cases in which captive consumers become free ones.

The second rule states that all contracts, which are financial instruments, should be covered by Firm Energy Certificates (FEC); e.g. in order to sign a contract for 1000 aMW,[5] the generator or trader must show that it possesses firm energy certificates that add to the same amount. FECs are tradable and can, along the duration of the contract, be replaced by other certificates. The only requirement is that the total amount of FEC adds up to the contracted energy.

[5] aMW = average MW = GWh/#hours over a year. For example, 438 GWh = 50 aMW.

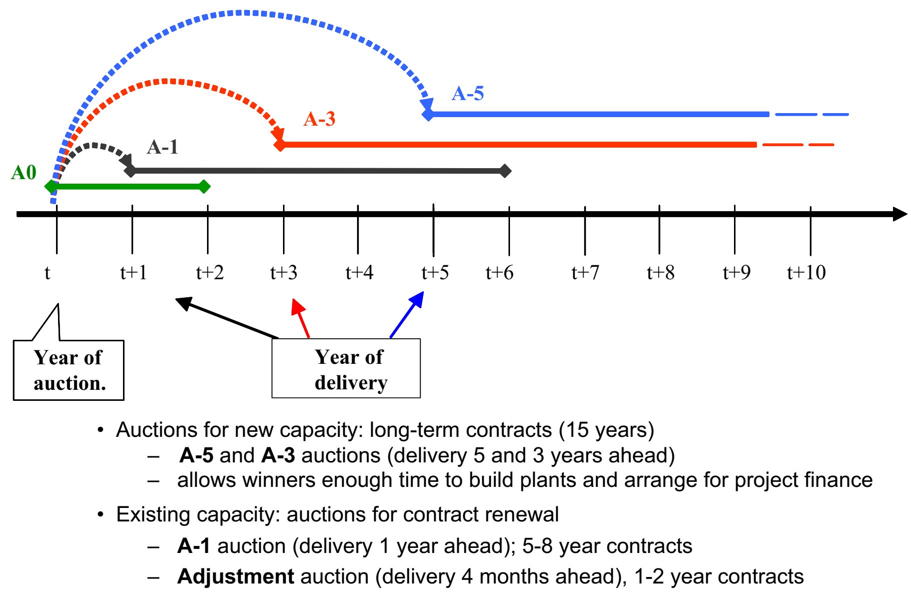

Fig. 3. Auctions for new generation in Brazil.

FECs are issued by the regulator for each generator in the system, are rated in MWh/year and reflect its secured energy production capability. For hydro plants, for example, the FEC corresponds to their (firm) energy production capability in dry years. For thermal plants, the FEC is given by the average availability (discounting average maintenance and forced outage rates), adjusted by a "derating" factor that depends on the variable operating cost.[6]

The joint requirement of 100% coverage of loads by contracts and 100% coverage of contracts by firm energy certificates creates a link between demand growth and entrance of new capacity.

For the regulated users, the procurement of new capacity is carried out through two public auctions every year, for energy delivery 3 and 5 years ahead.[7] Separated auctions are carried out for existing and new capacities and all generation technologies compete together. For each auction type, distributors are required to inform the regulator of their load forecasts and a contract auction is carried out to meet the total load increase. Each winning generator signs separate (private) bilateral contracts with each of the distributors, in proportion to their forecasted loads. Demand uncertainty can be hedged by carrying out complementary auctions for existing energy once a year (for delivery during the next year) as well as adjustment auctions four times a year (for energy delivery 4 months ahead). For these, short/mid-term contracts are offered. Fig. 3 shows the general energy contract auction scheme.

The Brazilian regulation also allows the execution of separate auctions for renewables or for specific projects when applicable. These auctions are driven by policy decisions.

5.1.3. Contract types

In the case of auctions for new capacity, the country uses two contract types: standard financial forward contracts, where generators bid an energy price $/MWh for the firm energy (aMW) offered; and energy call options or "reliability options" as described in Vazquez et al. (2002). In the call option proposal, the consumer "rents" the plant from the investor, paying a monthly fixed amount $/MW (to allow investment and fixed cost recovery) for its availability and reimbursing the plant's owner on its declared variable operating costs ($/MWh) whenever the plant runs. The consumer is now responsible for any spot market transaction. Because spot prices tend to be low most of time (see Bezerra et al., 2006), the option contract is very attractive in Brazil.

Concerning option contracts, suppliers are allowed to bid not only on the option premium ($/MW) but also on the option strike price ($/MWh). Bids are compared on the basis of the expected benefit for consumers: the government, by means of a simulation procedure, calculates (i) the expected value of their fuel reimbursements (option exercise) (in $/year), and (ii) the expected value of the short-term transactions at the spot market (in $/year). This is described in detail in Bezerra et al. (2006). In other words, the government estimates the plant usage and provides expected operation cost and spot market transactions incurred by the consumer, which can be seen as "handicaps" for comparing options with different premium and strike prices. A single unit energy cost–benefit index in $/MWh of firm energy is then calculated for each technology. All contracts have full indexation to fuel prices and inflation.

Overall, from 2004 to 2010 Brazil has carried out 21 contract auctions involving the contracting of 42,000 aMW of firm energy including new capacity additions and contract renewals. These contracts involve different conditions (6 months, 1 – 30 years) and financial transactions of about 300 billion US$. In terms of new energy, more than 22,000 aMW of capacity was acquired.

A summary of the auction prices is depicted in Fig. 4.

5.1.4. Auction mechanism

In the Brazilian case, distributors add their demand in one process where every generator bids to obtain a certain amount of

[6] The philosophy is that an expensive plant, for example, diesel-fired, is only dispatched late in a drought situation, whereas a cheaper plant, for example combined cycle natural gas, is dispatched earlier. Consequently, the cheaper plant's contribution to the overall 'firm supply' is more significant than the contribution of a more expensive plant. Therefore, in the extreme case scenario, a thermal plant whose variable operating cost was equal to the rationing cost would have a firm energy certificate of zero aMW.

[7] The two-auction scheme is a mechanism that hedges against load growth uncertainty: it is risky to buy all load growth in just one auction and therefore a wait-and-see strategy is adopted, following a real options approach.

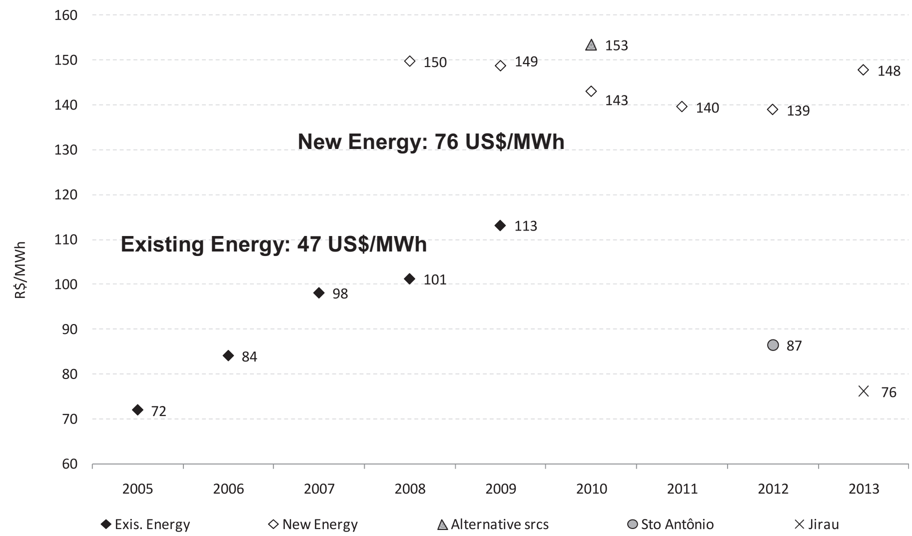

Fig. 4. Average contracted prices in Brazil in R$/MWh and US$/MWh.

MWh of a specific product[8] for future delivery. All generators and demand are matched simultaneously by means of a hybrid mechanism which is composed of a descending price clock auction with a final pay-as-bid round. The procedure works as follows:

(a) The auctioneer starts the auction with a very high energy price ($/MWh) and generators are asked to bid quantities (MWh) which they are willing to supply at this price. The starting price is set high enough to create excess supply.
(b) The clock auction is done in discrete rounds in which generators are asked to bid within a given period of time. In each round, the auctioneer announces just the round price and determines the total excess supply. While there is excess supply, the price decreases. This is done until the net amount of energy bid equalizes the (virtual)[9] auctioned demand. This is named the classification phase and the aim is to provide price discovery. Winners are selected to participate in the next phase, named final negotiation.
(c) In the final negotiation phase, generators bid in a multiunit sealed pay-as-bid format. The price of the bids cannot be higher than the price disclosed in the previous (classification) phase. Finally, the cheapest combination of bids defines the results of the auction.

5.2. The Chilean case

5.2.1. Electric system and market description

The Chilean electricity market was the first one in the world to be liberalized, in the early 1980s. It has a peak demand of about 8 GW for the two main interconnected systems (the northern and the central systems) which is presented during summer and an energy consumption of 57 TWh/annum (2009). The energy growth was affected by the world financial crisis, growing only 0.6% in 2009, instead of the 4.5 % projected before the crisis. Its generation installed capacity is circa 15 GW and contains an important penetration of hydro resources (about 40% in total and 50% in the central system). The system is mainly unbundled and a very small proportion of its generation capacity is owned by the government. In addition, the largest generation companies are Endesa, AES Gener and Colbun which own about (including subsidiaries) 35%, 18% and 17%, respectively. On the demand side, the largest distribution companies are CGE, Chilectra and Chilquinta Energia which feed about (including subsidiaries) 42%, 30% and 11% of the net country's population, respectively. Furthermore, the total number of generation and distribution companies is about 23 and 40, for the north and south systems, respectively. Energy trading between demand and generation within an interconnected system must be set through supply contracts negotiated in advance.

5.2.2. General auction framework

As described in Rudnick and Mocarquer (2006), a new regulatory model was implemented in the country by incorporating in consumer prices a real market signal through auction mechanisms in 2005. The old energy price calculation, driven by expected long-term spot prices, will fade out as auctions replace existing contracts. The aim is to reflect cost expectations of generators and investors, and promote the existence of an attractive market with high, but competitive yields. Specific characteristics of the Chilean electric auctions are as follows:

1. Distributors must be 100% contracted all the time, at least for the next 3 years.
2. Distributors must contract their energy through auctions.
3. Each distributor auctions its consumption requirements according to its own criteria (i.e. auction design is freely decided by each distributor).
4. A coordinated group of distributors are permitted to organize a process in order to simultaneously auction their net demand.
5. Distributors can auction contracts for up to 15 years at a fixed price (indexed according to changes in main variables).
6. Prior to the auction, the regulator sets a price cap for the auction which is publicly announced.
7. Prior to the auction, a capacity price is fixed by the regulator (indexed according to CPI) which is publicly announced.
8. The auction is cleared at a point which balances cost minimization and demand coverage maximization.

Given that distributors auction their demand at any time depending on their needs and also design their mechanisms and contracts depending on their own criteria, the current regulation dictates that all proposed mechanisms and contracts must be

[8] Brazilian product = a big market block of added demand with a specific period of supply. Demands from different distributors are standardized.

[9] A demand higher than the real demand is auctioned in the first phase.

revised and ultimately approved by the regulator before the auction occurs. An immediate consequence of this high degree of decentralization is that contracts cannot be standardized (i.e. contracts are not similar). This fact, in turn, allows generators to have many possibilities for which they can bid, i.e. generators can simultaneously present different bids (volume and price) for various types of contracts according to their preferences (risk, supply period, etc.).

Contracts with energy delivery at least 3 years ahead allow investors to obtain project finance and have sufficient time to build new plants. However, this requirement applies over all types of demand (baseline and demand growth) because new and existing generators participate in the same auction (i.e. there is no separation between new and existing generation auctions). This fact, in turn, permits large generation companies to use a mix of existing and new plants to justify their capacities. Additionally, generation capacities need to be justified by bidders providing sufficient and credible supports concerning existing and future projects. Evaluation of the aforementioned supports and decisions about their credibility are taken at distributors' discretion.

Although generators trade two products in the market, energy and capacity (or peak demand supply), competition is only set in terms of energy and so generators compete by offering an amount and price of energy. Nevertheless, the final contract includes volumes and prices of both energy and capacity. The latter is calculated according to pre-established load factors.

Furthermore, each distributor separates its demand into two groups: base energy blocks and variable energy blocks. The base energy block represents the fixed energy which will be consumed, while the variable energy block represents the energy increase which will be consumed due to demand growth. Both base and variable energy have different nature and conditions. Distributors can auction base and variable blocks separately in different contracts or combine base and variable energy into one contract since, as established by regulation, distributors are free to design their own contracts.

Overall, from October 2006 (first auction) to 2010, 3 auction processes have been carried out allocating an average demand of 28 TWh/annum to be served between 2010 and 2025. A summary of these results is shown in Table 1.

5.2.3. Auction mechanism

In the case of the Chilean first auction, distributors auction their demand in one single simultaneous, coordinated process, but without adding or mixing their contracts, i.e. generators could bid a price and volume of energy for each of the auctioned contracts. In addition, generators are allowed to bid for a net amount of energy higher than their capacities; however, each of them must specify its maximum capability to be contracted and the process can allocate energy, at most, up to this capability. All contracts are allocated by means of a multi-objective combinatorial sealed bid mechanism which seeks cost minimization and demand coverage maximization. The heuristic procedure to achieve the aforementioned multi-objective target is explained next:

(a) Generators bid a specific price ($/MWh) and energy amount (MWh—when specifying a monthly peak and off-peak supply) for each contract.
(b) For each contract, the price-quantity supply curve is drawn and intersected with the respective amount of demand (inelastic) as in a pay-as-bid auction. The generator capacities are not considered yet. Then, the clearing price of this auction is called the non-restricted mean price (NRMP).
(c) Now, constraining the allocation with generators' capacity limits, all feasible supply conditions are determined along with their respective clearing prices for each contract. Each clearing price is called the restricted mean price (RMP).
(d) For every feasible solution, the deviation between the NRMP and the RMP is computed for each contract:

$$\mathrm{DMP}_{b,c} = \frac{\mathrm{RMP}_{b,c}}{\mathrm{NRMP}_b} - 1 \tag{1}$$

where b is the block of contract's demand and c the feasible solution.
(e) For every feasible solution, the sum of squared deviations over all contracts is calculated as

$$\mathrm{SDMP}_c = \sum_{b=1}^{N} (\mathrm{DMP}_{b,c})^2 \tag{2}$$

(f) The final allocation of the auctions is given by the condition that presents the minimum sum of squared deviations.

Table 1
Contracted energy and prices per generator (up) and distributor (down). Summary from 2005 to 2010. Prices at Quillota 220 kV busbar and indexed 2009.

Generation company	Average price US$/MWh	Contracted energy GWh/annum
AES Gener	74.4	5419
Campanario	95.5	1750
Colbun	74.6	6782
Endesa	63.0	12,825
Guacolda	66.9	900
Emelda	95.0	200
EPSA	98.1	75
Monte Redondo	92.7	275
Distribution company	**Average price US$/MWh**	**Contracted energy GWh/annum**
Chilectra	58.7	12,000
Chilquinta	82.0	2567
EMEL	68.8	2007
CGE	90.1	7220
SAESA	65.9	4432

6. Discussion of critical elements in auction design and lessons learned

In this section, the goal is to study, mainly based on qualitative analysis, the critical characteristics of the presented auction mechanisms in Brazil and Chile as implemented, highlighting strengths and weaknesses in both jurisdictions.

Next, a discussion of critical implementation elements is offered when, at the same time, important lessons are pointed out. In turn, this analysis will serve, in Section 7, to narrow the high level proposal of long-term contract auction to ensure generation investment previously introduced in Section 4.

6.1. Price and efficiency performance should be major concerns in contract auction design

Final price (i.e. net payment) and efficiency are the basic criteria utilized to evaluate and compare auction performance. From the distributors' viewpoint, a natural criterion would be to design and select the best auction format which minimizes net payments. However, from the perspective of the society as a whole, efficiency (i.e. that the contract ends up in the hands of the generator who "values" it the most) may be more important (Krishna, 2002). As electricity supply is of the interest of not only the private sector but also the Government, both aforementioned characteristics should be considered when evaluating and determining the right design.

In the case of Chile, for instance, the mechanism was designed to reach low prices and high auctioned demand coverage. However, based on recent experiences, this has neither achieved low prices (the rise of high prices in the last Chilean auction has even allowed expensive wind turbines to enter the market when directly competing against conventional plants) nor large auctioned demand coverage (indeed, the same demand blocks were offered in various consecutive auctions since on average a single process was able to allocate only about 75% of the auctioned demand). Furthermore, it is very difficult for the auctioneer to define and manage the criterion or set of rules which tune and balance two different objective functions. This fact may produce a final outcome merely based on the auctioneer's (distributor) discretion.

Brazil, on the other hand, presents a more classical approach founded on a hybrid descending-clock and pay-as-bid auction which permits first price discovery and facilitates then price minimization by awarding the cheapest bids.

Regarding efficiency, it is a well-known fact that achieving efficient outcomes for most of the multi-unit auctions is very hard (Klemperer, 2004). Despite this, it is not difficult to observe that the Brazilian scheme is likely to be less inefficient than the Chilean one. Indeed, the complex and discretional set of allocation rules which follows a multi-objective criterion in the Chilean design may increase bidder uncertainty which, in turn, increases the likelihood of inefficient assignments (Cramton, 2001). In the same way, the fact that the assignment in the Brazilian auction is explicitly centred on price only rather than price and demand coverage would permit lower prices to be derived than in the Chilean approach.

Consequently, it is likely that the Brazilian mechanism presents a better behavior than the Chilean one regarding both price and efficiency performance.

6.2. Demand forecast should be determined by market agents

The amount of auctioned demand should be determined by distribution companies while the regulator establishes the right incentives and penalties for over/under predicting. This minimizes the intervention of the regulator and allows market participants to reflect real expectations. It also favours the existence of a timewise strategy in which distributors can determine when and how much to auction in order to minimize payments, e.g. take advantage of low fuel prices, and risks, e.g. hedge demand projection uncertainties. For example, distributors in Brazil usually auction their future demand in two rounds, e.g. 5 and 3 years ahead. This allows them to firstly auction a demand part which is very likely to be consumed and, after 2 years, auction the rest and more uncertain volumes of demand. This, in turn, has the extra benefit of facilitating the entrance of power generators that require more lasting construction periods. In a similar manner, an amount of auctioned demand driven by market agents allows them to take advantage of further considerations that may be outside of the range of concerns for regulators.

With some differences, Brazil and Chile follow this philosophy.

6.3. Contracts should be lasting and provide receivables for new investors

For new energy requirements, long-term contracts should be considered (up to 15–20 years) in order to ensure revenues and reduce risk to the investor, providing receivables for project-financing. Brazil and Chile follow this path.

6.4. Auction timing should allow construction of new plants

New energy requirements should be auctioned, at least, 3–5 years in advance in order to ensure the entrance of new generation. The number of years "in advance" is related to the time needed to build the marginal technology for the system's expansion when considering issues such as environmental license approvals, the need for operational tests, etc. Contract renewals can be auctioned in a shorter period prior to real delivery. Brazil and Chile follow this path.

6.5. The auction allocation mechanism should consider risk assessment of indexing formulas

Indexing formulas are used in contracts with the intention of hedging mid- and long-term risks. However, this in turn forces the auctioneer to take a risk position when allocating contracts. Therefore, assumptions on price projections may have critical effects on the allocation decision.

After carrying out several auctions without taking these formulas into account, in 2008, Brazil started using projections of the most relevant fuels for the allocation process, adopting a forward-looking approach. The projections should come from scenarios provided by a neutral entity, in this case, the International Energy Agency (IEA). In Chile, on the other hand, the auctioneer does not take into account indexing formulas when allocating, avoiding any type of risk assessment. This decision has had heated opposition from both costumers and generators since the consideration of the aforementioned formulas may decrease the level of prices within the commitment period and hedge risk in a better manner for the consumer and ultimately derive a different allocation for contracts among generators. No agreement has been reached in this jurisdiction.

6.6. Implementation of standardized contracts and a centralized auction process should be positively considered

The degree of centralization when aggregating demand (centralized auction of identical or standardized contracts and decentralized auction of non-identical contracts) produces several differences in both the design of the mechanism and the strategies of participants. For example, in the presence of identical contracts (as in Brazil) it is possible to add all demands in one large market block, without allowing generators to choose their counterparts. In contrast, in the presence of non-identical contracts (as in Chile) that have large differences in aspects such as period of supply, risks, supply conditions, etc., a generator can bid for a specific contract following its particular preferences. Therefore, while bids for preferred contracts may be very competitive, prices for others may end up much higher. These preferences may be justified because of the following:

- quality of the distributor as a payer;
- vertical integration between distributors and generators;
- credibility of the amount of auctioned demand (in Chile, distributors only pay for the consumed energy even if the contracted energy is higher) and
- different risk conditions of contracts, among others.

Hence, contracts in Brazil can be assumed to be perfect substitutes (i.e. any MWh in contract A is equal to another MWh in contract B), driving more homogeneous prices across the system (or sub-system). In contrast, different contracts in Chile can be assumed to be substitutes or complements depending on generators' preferences, driving potentially high price differences. This is so because generators in Chile can bundle their bids

Table 2
Contract prices per distributor in the first Chilean auction. Prices at bidding busbar and not indexed (2006).

Prices per Distributor US$/MWh						
Year	Chilectra	Saesa	Chilquinta	EMEL	CGE	Total
2010	53.6	50.7	52.2	55.6	53.5	52.7
2011	53.6	50.7	52.2	55.6	53.8	52.8
2012	53.6	50.7	52.2	55.6	54.1	52.8
2013	53.6	50.7	[illegible]	[illegible]	54.3	52.9
2014	53.6	50.7	[illegible]	[illegible]	53.1	52.6
2015	53.6	50.7	52.2	55.6	53.1	52.6
2016	53.6	50.7	52.2	55.6	53.1	52.6
2017	53.6	50.7	52.2	55.6	53.1	52.6
2018	53.6	50.7	52.2	55.6	53.1	52.6
2019	53.6	50.7	52.2	55.6	53.1	52.6
2020	53.6	0.0	[illegible]	0.0	53.1	53.3
2021	53.7	0.0	[illegible]	0.0	53.1	53.2
2022	53.7	0.0	52.2	0.0	0.0	53.3
2023	0.0	0.0	52.2	0.0	0.0	52.2
2024	0.0	0.0	52.2	0.0	0.0	52.2
					Average =	52.8

Same bidding busbar
≠
10% difference

Table 3
Contract prices per generator in the first Chilean auction. Prices at bidding busbar and not indexed (2006).

Prices per Generator US$/MWh					
Year	Endesa	Gener	Colbun	Guacolda	Total
2010	50.8	57.9	[illegible]	55.1	52.7
2011	51.0	57.9	[illegible]	55.1	52.8
2012	51.1	57.9	53.8	55.1	52.8
2013	51.3	[illegible]	53.8	[illegible]	52.9
2014	50.7	[illegible]	53.8	[illegible]	52.6
2015	50.7	57.9	53.8	55.1	52.6
2016	50.7	57.9	53.8	55.1	52.6
2017	50.7	57.9	53.8	55.1	52.6
2018	50.7	57.9	53.8	55.1	52.6
2019	50.7	57.9	53.8	55.1	52.6
2020	50.9	57.9	55.5	55.1	53.3
2021	51.0	57.8	55.5	0.0	53.2
2022	50.8	57.8	0.0	0.0	53.3
2023	50.4	57.9	0.0	0.0	52.2
2024	50.4	57.9	0.0	0.0	52.2
				Average =	52.8

>
existing generation
new generation

according to their specific financial policies (risk aversion), i.e. generators can assess the value of a contract with respect to whether another particular contract is obtained or not (Krishna, 2002). Consequently, in Chile high price differences among contracts and, in turn, among distribution areas can be clearly observed. Furthermore, it can be proved that these differences are above the acceptable levels than can be justified because of the natural pay-as-bid price differences, network losses or/and congestion. To give two critical examples, the facts that (i) contracts at the same reference (bidding) busbar have resulted in different prices in the past (see Table 2), and (ii) some contracts have been totally unbid while others have been overbid show a clear bias towards some particular contracts.

Moreover, in Chile, this high degree of decentralization has permitted distributors to design and manage their own auctions. This fact has opened a discussion and leaves room for doubt about the (right and/or perverse) incentives of distributors to design a mechanism which obtains low final consumer prices.[10]

The discussed degree of centralization is also a critical variable if the auctioneer would like to mitigate market power effects. For example, it has been argued that simultaneous auctioning by all consumers in a coordinated and centralized fashion, as in Brazil, is required to achieve maximum market power mitigation (Arellano and Serra, 2010). Furthermore, if forward supply contracts are not awarded simultaneously, e.g. many smaller auctions are carried out at distributors' discretions as in Chile, collusive equilibria are more likely to appear and therefore a lesser market power mitigation effect from forward contract auctioning may be expected.

Finally, a centralized process that simultaneously auctions all needed requests, aggregating them in a large demand block, also presents the advantage of increasing the interest of more participants and permitting distributors to share the benefits of lower prices, in particular, among the smaller ones that are unlikely to call the attention of large international bidders.

6.7. Discriminating policies for existing and new generation should be positively considered and energy policy decisions incorporated

In the Brazilian case, existing and new generators are separated in different auction processes for two reasons: risk allocation and average price minimization. Concerning the former, it is argued that new and existing generation need to be contracted when considering different conditions. A new generator needs long-term contracts to ensure project financing. In contrast, if long-term contracts are given to existing plants as well, the contract portfolios of distribution companies would become inflexible and therefore difficult to adapt to load growth variations. Hence, existing plants are offered contracts of shorter duration (5 years, typically). Concerning price minimization, if new and existing generations are separated, then existing plants cannot take the higher prices cleared by new plants. Thus, existing and new generation achieve more cost-reflective contract prices (see results in Fig. 4).

In Chile, on the contrary, existing and new plants compete in one single process which equalizes bid and contract prices between new and existing generation. For example, Table 3 shows the case in which existing generation even obtained higher prices than new generation.

Although classical theory supports the existence of a combined new-existing capacity auction (as price clearance of a specific product – electrical energy – must be fixed by one – marginal – technology), the Brazilian mechanism proposes a new politically and technically viable alternative that, in practice, encourages new investment and lowers average prices to end customers. In addition, it must be mentioned that, as explained in Armstrong (2006), there is no justification for public policies that prohibit price discrimination in general since the welfare effects of allowing price discrimination are ambiguous and so this is not necessarily bad.

Brazil also allows technology-specific and project-specific auctions for energy policy purposes. For example, specific auctions have been carried out for renewables (cogeneration from sugarcane bagasse and wind power (Porrua et al., 2010)) and for large hydro developments in the Amazon region. This can be of special interest to regulators in the developed world which seek to promote investment in specific technologies, e.g. renewables.

6.8. Disclosure time of reserve prices may affect agents' behavior

In the Brazilian and the Chilean mechanism, the reserve price is revealed before the auction occurs and so it may be understood as a reference price or regulator's price tolerance by bidders. Although this effect can be mitigated by the contestability of the

[10] It is worthwhile to consider that contract prices are passed directly to the end consumers by means of a pass-through mechanism. Thus, distributors have a constant yield for their assets, regardless of the auction results.

market in new generation auctions, this can become a critical design element in the case of existing generation auctions.

6.9. Generators' adequacy guarantees can be either market or system based depending on rationing management policies

While the Chilean regulator has adopted a strong market-driven policy to ensure generation adequacy, the Brazilian market has assumed a more system-based viewpoint. In the latter, generators need to cover their bids by firm energy certificates issued by the regulators. This openly shows the willingness of the authority to guarantee a minimum security margin between demand and supply and therefore ensure resource adequacy. In contrast, in the case of Chile each distributor accepts (or not) the adequacy guarantees given by generators at its own discretion. This market-driven scheme implicitly forces distributors to assess their own adequacy risks and so may also force them to assume consequences if wrong decisions were taken, e.g. a distributor may be forced to shed its demand if there is lack of system capacity caused by its supplier. Indeed, if lack of capacity is assumed by those that have failed contracts, in principle, market-driven policies should deliver the efficient level of adequacy. However, as in most of the cases lack of supply adequacy during rationings is allocated according to political criteria, e.g. residential customers are usually the last ones to be shed, system-driven policies such as the one applied in Brazil may be a better scheme since incentives driving market-based policies are distorted.

6.10. Auction design should respect current network arrangements and propose solutions to problems derived from this linkage

A correct signaling of the transmission costs is of great importance to the selection of the most economical projects in the generation auctions (Barroso et al., 2007).

Therefore, when designing auctions of long-term contracts, this interaction of network and energy cost needs to be carefully analyzed. First, it needs to be considered that there are natural characteristics of the targeted market and, in particular, of its network arrangements that will condition the existence of particular rules in the auction mechanism.

A first example of this interaction and particular rules is the difference between the Brazilian and Chilean auction design in terms of the localization of the bidding process. In Chile, for instance, each bidding request (auction) must be explicitly referred to a "bidding busbars" on the system in order to incorporate network signaling (see Fig. 5). In contrast, in Brazil, contracts can be auctioned without defining a specific bidding location on the system since, by definition, there is only one energy price which is irrespective of location and locational signals are fully given by transmission charges (Barroso et al., 2007). Note that this difference is primarily driven by the nature of the transmission arrangements in these countries, i.e. Chile is a locational marginal price (LMP) based market whist Brazil is a zonal marginal price (ZMP) based one.

Furthermore, the link between energy and transmission arrangements can create additional issues that may have severe impacts on auction performance (price and efficiency) and so designers must seek solutions to these.

In this framework, a major element which needs to be considered is the risk associated with network uncertainties, e.g. network charges and network constraints. In Brazil and Chile, there are neither firm nor financial instruments to mitigate risks caused by networks when trading energy contracts. This, together with the fact that networks are centrally planned, may create strong incentives for bidders to increase bid prices in energy auctions in order to hedge network risks. This fact, in turn, may drive higher levels of inefficiencies from auctions' outcomes since, in general, bidder uncertainty increases the likelihood of inefficient or low-value assignments, makes bidding difficult, undermines confidence and can lead to defaults (Cramton, 2001).

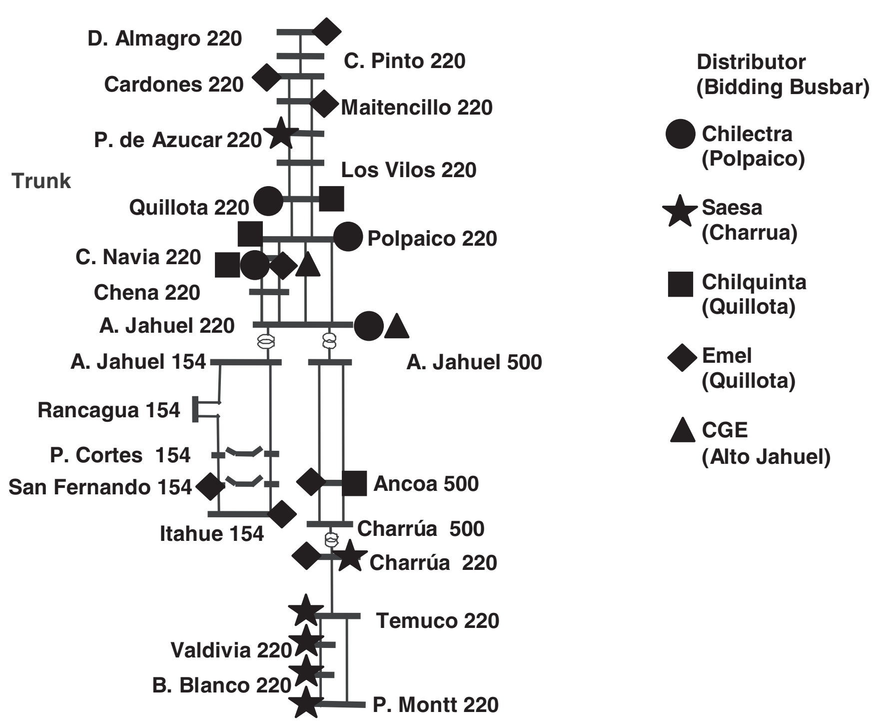

Fig. 5. Consumption (spot on the network) and bidding nodes (indicated on the legend) of distribution companies in the Chilean system. First auction.

Table 4
Comparison between Brazilian and Chilean auctions and final proposal.

Proposal	Chile	Brazil
Hybrid descending–clock and pay as bid auction mechanism. Design should privilege price and efficiency performance	Two targeted objectives are balanced to allocate contracts in a pay-as-bid fashion	Hybrid descending-clock and pay as bid auction mechanism. Existence of two phases: classification phase (uniform price mechanism) and negotiation phase (classic pay as bid mechanism)
New demand must be 100% contracted by auctions to ensure future generation adequacy. Possibility to implement all demand contracted (new and existing) at all time for tariff purposes	Distributors are 100% contracted at all time (new and existing)	Distributors are 100% contracted at all time (new and existing)
Auctioned demand should be foreseen by distributors	Auctioned demand is foreseen by distributors	Auctioned demand is foreseen by distributors
Contracts should be lasting and provide receivables for investors	Contracts are lasting and provide receivables for investors	Contracts are lasting and provide receivables for investors
Auction should be carried out ahead of time to permit investors to build new plants	Auction are carried out at least 3 years ahead to permit investors to build new plants	Auction are carried out 5 and 3 years ahead to permit investors to build new plants
The allocation mechanism should assess the effect of indexing formulas	The allocation mechanism does not assess the effect of indexing formulas	The allocation mechanism does assess the effect of indexing formulas
One large centralized process in order to auction demand from different distributors	Possibility that each distributor auctions its own demand independently	One large centralized process in order to auction demand from different distributors
Added demand	Demand is not added	Added demand
Standard contracts of demand	Each distributor designs its own contracts	Standard contracts of demand
Different auctions processes for existing and new generators	Existing and new generators compete in the same auction	Different auctions processes for existing and new generators
Reserve price disclosure should be done after the auction occurs	Reserve price disclosure before the auction occurs	Reserve price disclosure after the auction occurs
Generators should ensure adequacy through certificates (system viewpoint) or, alternatively, private companies can evaluate adequacy if they assume consequences	No certificates. Private evaluation of adequacy	Firm energy certificates issued by the regulator
In locational marginal price (LMP) based markets, the bidding process should be located at a specific node. No location needed for system or zonal marginal price (SMP/ZMP) based markets. Network risks should be properly hedged	Transmission constraints are considered by locating the bidding process at a specific node (LMP model). Network risks are not hedged	The process is not located at a node. Transmission constraints considered by means of transmission charges (ZMP model). Network risks are hedged

In Brazil, this issue has been resolved at the stage of the auction design by informing generators of their stream of annual transmission charges (for a number of years, usually, the entire contracted period) before the auction occurs. This calculation is based on a predefined 10-year plan for transmission and generation. Differences between actual network costs and the ones informed before the auction are absorbed by distributors. In the case of Chile, network costs are not informed and fixed in advance and therefore risks remain being faced by bidders.

7. Proposal of auction of long-term contracts

Based on the previous overall assessment of the Brazilian and Chilean actual experiences, a generic proposal for a long-term electricity contract auction approach is made, as summarized in Table 4. The main elements on auction performance that require careful design are identified and compared with the empirical applications in those two countries. The main core of the proposal is explained in Section 4.

8. Conclusions

Overall, the new contract auctions in Brazil and Chile have been of great interest to international investors looking to South America's electricity market: candidate suppliers include a wide variety of technologies, comprising new hydro projects, gas, coal and oil-fired plants, sugarcane biomass and international interconnections. These also have served as laboratory examples for third parties wanting to follow the same or similar path. The framework provides regulatory instruments to mitigate load growth uncertainty, energy spot price volatility, and the need for "project finance" from new generation investments.

Partially replacing the old market regulation based on spot price by an auction mechanism has incorporated a strong market signal to promote new investment. The whole process must be well designed in order to get efficient prices, to achieve the entrance of new investors, and to develop competition and demand coverage. Various key variables have been addressed across the paper so as to facilitate implementations, local improvements and international regulatory analysis.

Furthermore, components of these auctions of long-term contracts may be also the way forward to promote zero carbon technology investment. Many similarities arise between this proposal and some new pro-decarbonization market arrangements in terms of the need to push new investment in an environment without enough incentives from the short-term signals.

Finally, it is clear that to achieve good auction performance, the auction approach must be carefully designed. Therefore, every market design must be tailor-made for the country's conditions and environment. There is no one size that fits all.

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