Paper 4

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Utilities Policy 14 (2006) 196–207
UTILITIES POLICY
www.elsevier.com/locate/jup

Lessons from deregulation: Understanding electricity markets in South America☆

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Received 15 January 2005; accepted 19 February 2006

Abstract

South America has been the most progressive region in the developing world in terms of deregulating the electricity industry. In this paper we compare the evolution of deregulation, from initiation to the current state, in four South American countries: Argentina, Brazil, Chile, and Colombia. These four countries are similar in many dimensions, such as culture, language and macro-economic development. They are also all depending, to a large extent, on hydro-generated electricity. All four countries have implemented different deregulated systems, allowing a unique possibility to compare the performance of different implementations of deregulation on one continent. We describe the course undertaken by these countries and the results attained so far, and also compare and contrast the development of the different electricity industries. Finally, we discuss what can be learned from these countries and what they can learn from each other.

Keywords: Electricity markets; Deregulation; Latin American energy

1. Introduction

After two decades of electricity market deregulation in South America, we have accumulated broad experience of the process of deregulation, and it is important to codify some of these experiences. This is not only important for further development in South America but also relevant to other regions that are in the middle of liberalizing their electricity markets. While deregulation has already taken place in a variety of countries and regions it is interesting to compare countries in South America, which in some respects have many economic and demographic similarities but have chosen very different routes towards deregulation. Their institutional, and to some extent market, arrangements present significant differences. Furthermore, as deregulation has taken place at very different times during the last 20 years, it is fair to ask if the latecomers to deregulation have learned from the earlier experiences of neighboring countries. We believe that before assessing the impact of deregulation on a global scale we need to have a much better understanding of national and regional issues. The aim of this article is to contribute to the growing body of analysis of deregulation. By providing more case studies of the deregulation processes we improve our understanding of liberalization already underway, draw lessons from a comparison of experiences, and most importantly, make it possible to avoid repeating the failures while replicating the successes.

Electricity reform focuses on replacing monopolies with open and competitive markets. The underlying motivation

☆ An earlier version of this paper was presented at the 26th Annual Conference of the International Association for Energy Economics, Prague, June 4–6, 2003, with the name of "Past, Present and Future of the Latin-American Electricity Markets". This paper presents part of ongoing research that has been undertaken by the authors since early 2002.

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doi:10.1016/j.jup.2006.02.001

has been to provide electricity more efficiently, more reliably and with higher quality at a cheaper price (Armstrong et al., 1994; Bacon and Besant-Jones, 2001; Newbery, 2001). The changes in the electricity sector in South America have been actively promoted by international agencies such as the World Bank (World Bank, 1993) and the Inter-American Development Bank (Bacon and Besant-Jones, 2001; IDB, 2000).

The first country to deregulate in Latin America was Chile, which privatized and deregulated the state-owned electricity utilities. Argentina followed the Chilean model with some adjustments; other countries such as Ecuador, Peru, and Bolivia used a similar deregulation model. The adjustments to the Chilean model made in Argentina prevented some of the problems observed in Chile during the late 1990s, as discussed later in this paper, but not others that have emerged since the beginning of 2004. Despite some technological similarities with the Chilean electricity system, Colombia adapted the British model in the mid-1990s, while Brazil 10 years on is still trying to develop its own model.

In this paper, we will make comparisons among four countries in South America, to achieve a better understanding of how the different models of deregulation have shaped the evolution of their electricity systems since deregulation. We will compare and contrast Argentina, Brazil, Chile and Colombia. These four countries largely represent the different approaches to deregulation undertaken in South America. They are all developing nations with a very large hydroelectricity generation base, and they share some similarities with respect to culture, history, income distribution and institutional environment. This implies that comparisons should be meaningful. Mexico and Venezuela are not included in this analysis, as they have made very little or no progress in deregulating their electricity industries.

The paper is organized as follows. First, we present an introduction, which is followed by a section that discusses the general background of the chosen case studies. In the third section we present a detailed explanation of the market evolution of the four selected countries. The fourth section compares and contrasts the countries under discussion. We finish by drawing some general learning points in the conclusions.

2. Background and individual country developments

Table 1 shows an overview of the four selected countries in terms of macroeconomic indicators and basic information about their current state of the electricity systems. As mentioned in the introduction, there are many broad similarities between them. Although there are differences in size, population and GDP, they are relatively equal in terms of economic development and share the same social and cultural problems. As we want to understand the evolution of the deregulated market in these four countries, we need to establish how this is influenced by market structure, technology composition and/or economic performance.

We will follow the same structure in describing each of the four countries, before comparing them in later sections of the paper. For each country we provide the main information describing the reforms, market structure, major changes that took place and other significant events. The performance indicators chosen for assessing the electric systems' evolution included both efficiency and quality aspects. For efficiency purposes we present not only price, supply, and demand evolution but also a measure of market concentration in terms of the Herfindahl Hirschman Index (HHI).[1]

As for the quality aspects, we discuss the evolution of grid losses, and the frequency and intensity of interruption of the electricity services. In addition, more information is presented when required, to explain specific events that have had a significant impact on the corresponding system of the country where it occurred. The order of country presentation is alphabetical.

Table 1
Comparison of macro economic indicators and electricity industries in the four selected countries

	Argentina	Brazil	Chile	Colombia
Population (million)	37.928	174.485	15.579	43.745
GDP 2002 (billion US$)	102.19	452.39	64.15	82.19
Size (×1000 km^2)	3.761	8.512	757	1039
GDP per capita (×1000 US$/person)	2.69	2.59	4.12	1.88
Installed capacity (MW)				
Hydro	8857	62,121	4055	8810
Thermal	13,010	11,442	2682	4366
Others	1018	19,670	0	0
Total	22,884	75,530	6737	13,176
Technological composition (%)				
Hydro	39	82	60	67
Thermal	57	15	40	33
Others	4	3	0	0

World Bank (2003). Only the MEM, major subsystem with more than the 90% of the total electricity system in Argentine (Energía, 2002). Brazilian Energy Balance (BEB) 2002, MME. Only the SIC, major subsystem with more than 90% of the total demand in Chile. The total system in Chile has an installed capacity of 10,459 MW in December 2002 (CDEC-SIC, 2003; ISA, 2003; Espinasa, 2001).

3. Market evolution of the four selected countries

3.1. Argentina

Argentina deregulated its electricity industry in 1993. This was motivated by a crisis during the summer of 1988/1989, which was created as a result of mismanagement of the system operated by the Government (ENRE, 1998), as well as a general poor performance by the electricity companies (Pistonesi, 2002). The deregulation of electricity was part of a wider

[1] The HHI Index is usually used by regulators to measure market concentration. It is estimated as the sum of the squared market shares of participants. The US Department of Justice normally considers a market with an HHI less than 1000 as a competitive market, HHI between 1000 and 1800 as a moderately concentrated market, and an HHI of 1800 or greater as a highly-concentrated market For discussion about the properties of the Index, see Kwoka (1985). On the origin of the index, see Herfindahl (1950) and Hirschman (1964).

process in which the country opened up to capital markets, privatization, and deregulation of public services. Law 24065 of Argentina's Congress established the pillars for the Argentinian electricity market, and created ENRE (Ente Nacional Regulador de la Electricidad, National Regulator of the Electricity).

The wholesale market is organized in two parts: a spot market and a bilateral contract market. The spot price is the result of the optimal dispatch (short-term marginal costs). The distribution price is estimated for each trimester (8 h), and differentiates three load periods. A capacity payment mechanism was created and has been fixed at 10 US$/MWh. This is paid to generators with energy available during the 90 h of the weekly peak demand period (Montero and Rudnick, 2002).

On the supply side, the system was expanding up until 2002 at an average rate of 6% per year, not only in thermal capacity, but also in hydro capacity, reaching 22,884 MW of installed capacity for the main electricity market. On the demand side, the systems were expanding at a declining rate during the 5 years prior to 2002. In 2002 there was a fall in demand of 2% as shown in Fig. 1, resulting in a growing reserve margin and consequently a drop of prices. The system margin (calculated as the percentage difference between the installed capacity and the maximum demand, divided by maximum demand) has reached around 50% in 2003. It experienced a substantial increased in 2002, with a change of approximately 10% due to the combined effect of increases in the installed capacity and decreases in peak demand.

Consumers have to pay for other services that are included in its tariff, such as ancillary services and transport (CAMMESA, 2002). A relatively small part of the demand, 37%, is contracted, and the rest is traded in the spot market. The number of contracts for electricity has increased since the market started operations, from nine contracts signed in 1993 to more than 2000 in 2002 (CAMMESA, 2003).

Price reduction (see Fig. 2) can be partly explained by increasing competition. The number of generators increased

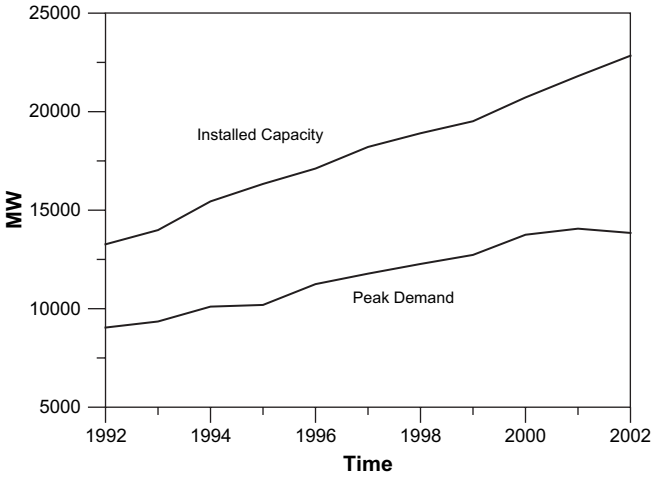

Fig. 1. Evolution of the Argentinean electricity market: installed capacity, peak demand. Source: CAMMESA (2003).

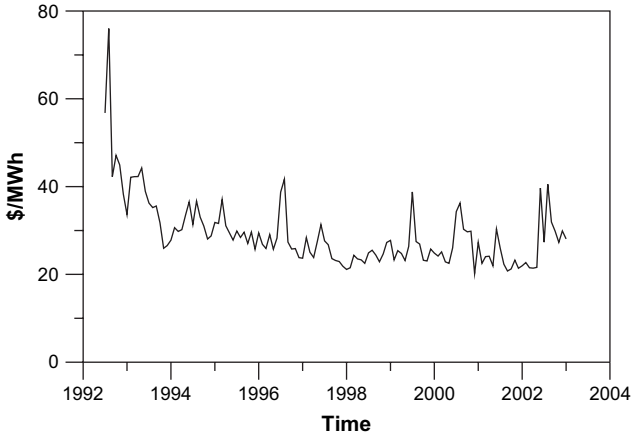

Fig. 2. Monomial average annual price in Argentina. Source: ENRE (2002).

from 13 in 1992 to 44 in 2002, competing in a market that trades around 2335 million Argentine pesos (in 2001) and where the largest five companies take about 43% of total sales (ENRE, 2002). According to 2001 data, 74% of the installed capacity is privately owned. There are 39 companies in the generation market, indicating significant competition (ENRE, 2002). The HHI was around 1500 for generation, close to 1250 for installed capacity, and less than 1400 for distribution in 2001 (ENRE, 2002), a relatively low HHI index for the business units. For market power analysis, it is important to recall that the electricity market in Argentina has a dispatch rule that is based on competition for the lowest costs, with price cap. Thus, market power can be considered moderate to low in the electricity market in Argentina.

There has been a significant increase in competition in generation and supply to large customers. The Argentinean system defines two kinds of large customer: *very large* and *large*, where very large customers consume in excess of 2 MW a year, and the large customer consume between 0.1 and 2 MW a year. The number of customers in the *very large* group has been stable at about 350, and the numbers in the *large group* have increased from 207 in 1995 to almost 2000 in the year 2002. The number of generators has stabilized at around 40, while there has been a considerable growth in transmission and distribution companies.

Argentina's market has also experienced a reduction in total grid losses. Immediately after deregulation, grid losses started dropping from around 10% to below 6% in 2002. The number of yearly interruptions was among the lowest in South America in 2001, 12 interruptions for a total of 12 h (Larsen et al., 2004).

Bacon and Besant-Jones (2001) assess the improvement in performance before and after privatization of Argentinean distribution companies. Companies exhibit significant improvements in both personnel indicators (number of employees, customers/employee)—in excess to 75%—and performance indicators (sales, reduction of losses, etc.)—above 60%. This is similar to what has been experienced elsewhere, such as in the UK where employment in generation decreased by 60% (Bunn, 1994). There can be little doubt that these

companies are much better run following deregulation and privatization.

Currently, Argentina's electricity network is interconnected with Uruguay, Paraguay, and Brazil, and is planning to develop a bilateral market with Chile to take advantage of their potential electricity complementarities. The interconnection with Brazil has a capacity of 2100 MW, where 1050 MW were built during 2002 (CAMMESA, 2003).

Questions have been raised in connection with price structure and lack of incentives for new investment. The system margin has dropped because of the recovery of the economy and lack of incentives to investors. In these circumstances, companies have underinvested in generation and they have been unable to deliver the energy demanded. Second, the market has yet to face extreme weather conditions, as the temperature of the country and inflows to the reservoirs have been within the normal yearly variation, far from the severe conditions of the summer of 1988/1989. Third, the transmission sector is currently experiencing lack of investments, which could lead to problems in the operation of the system in the future (Pistonesi, 2002), further escalating the 2004 crisis.

3.2. Brazil

Privatization started in 1993 in Brazil, while deregulation began in 1998. The Brazilian electricity sector had the largest fraction of hydroelectric generation of the four countries. Complex chains of reservoirs require particular care to be able take advantage of coordination efficiencies. This system, if uncoordinated, could decrease energy production by 20% (Millán, 2001). However, instead of restricting deregulation, this structure calls for innovative solutions (Pereira, 1999). The adopted market in Brazil includes long term contracts, together with a market clearance mechanism for the remaining energy.

The reform initially promoted regulated bilateral contracts, but after the creation of a market for bilateral contracts, agents now negotiate contracts freely. The quantities traded in contracts have been reduced since 2003, inducing trading of more electricity in the spot market. Today, approximately 85% of electricity is traded through contracts and the remainder on the spot market (MAE, 2003a,b). The MAE (Mercado Atacaista de Energía Eléctrica, Electric Energy Wholesale Market) registers all contracts. Information about quantities traded in contracts is publicly available but contract prices are commercially confidential. MAE also determines the spot-market price by using an optimization model.

Considerable investments, close to R$18 billions, were made up to 1996 (ANEEL, 2003a,b): approximately US$5 billions in generation and about US$1.4 billion in transmission. In total 12,159 MW of new generation capacity was built and 8017 km of new transmission lines were constructed. ANEEL (2003a,b) reports from a survey on investor satisfaction: 21% were very unsatisfied, 35% reasonably satisfied and 44% very satisfied. Fig. 3 shows the electricity price evolution since 1999. Droughts contributed to the extremely high prices observed during 2001.

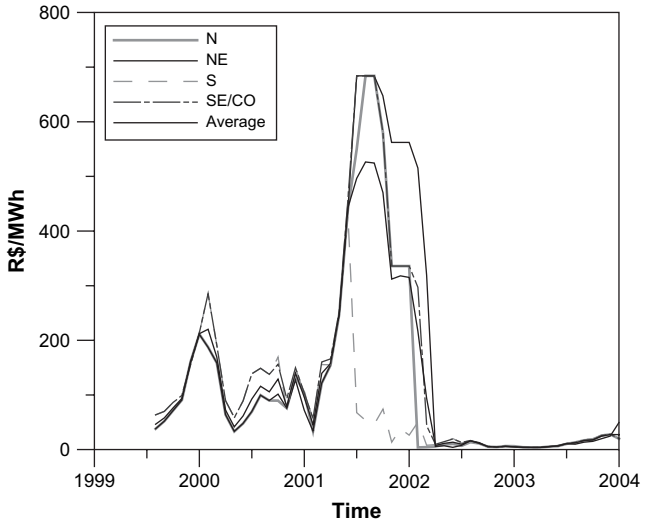

Fig. 3. Electricity prices in Brazil, monthly overall average from the four submarkets (own estimation, data from MAE, 2003a,b).

In terms of market power, there are some problems in Brazil. This might not be very clear at the national level, where the HHI index looks reasonable. However, one should look at the sub-market level where there is obvious market power in some regions. For instance, in the North East region, CHESF Hydro Electric Company of São Francisco, and ELETRONORTE Electric Centrals of the North of Brazil, have 43.7% and 39.2% of the installed capacity respectively (ANNEL, 2003b), and the HHI estimated for the installed capacity is around 3500. In this sense, the sub-market works as a duopoly rather than a competitive market.

The non-technical losses in Brazil have not changed significantly after deregulation. The non-technical losses have always been between 9% and 10% (MAE, 2003a,b). The quality of the service in Brazil, measured by the two indicators DEC and FEC, is shown in Fig. 4. The DEC (Duração Equivalente de Interrupção por Unidade Consumidora) represents average duration of interruptions in a year, while the FEC

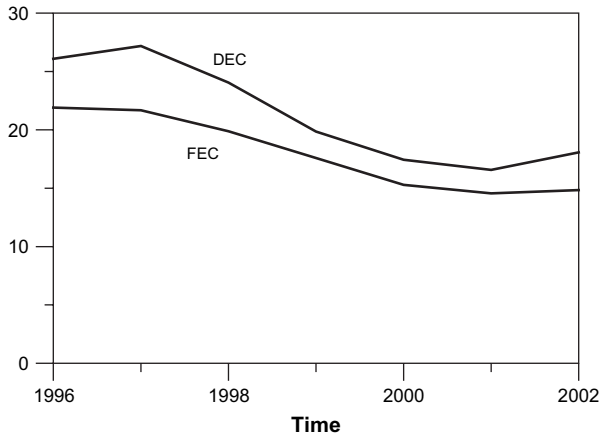

Fig. 4. Quality indicators' development: DEC (duration of interruption per consumption unit) and FEC (frequency of interruption per consumption unit). Source: MAE (2003a,b).

(Freqüência Equivalente de Interrupção por Unidade Consumidora) is the average hours of interruptions in a year. Both indexes have decreased after initiation of the market reform, with an improvement of approximately 30% (ANEEL, 2003a,b). Another index is IASC (Índice Aneel de Satisfação do Consumidor) which is the general perception of costumer satisfaction, and there has been no improvement of this since deregulation. The index is somewhere between Regular and Good, which implies that the residential users see some problems with the quality of the service, value, overall satisfaction, and trust in the system (ANEEL, 2003a,b).

The main crisis in the Brazilian electricity sector occurred in 2001, when generation output declined substantially. Ever since 1996, water levels gradually decreased, and by 2001 an extreme dry season induced widespread blackouts. The main reasons for the crisis was the lack of investment in new generation capacity, unsatisfactory grid development, and incomplete and inadequate legislation, as well as lack of a flexible plan and delays in adjusting the rules before and during the crisis (Linhares et al., 2002; BNDES, 1996). The required new capacity did not emerge and the market-based mechanisms did not seem to provide the right incentives to correct the shortfall. The supply problems induced extremely high prices during 2001 (as shown in Fig. 3). This critical situation led to new reforms in the system.

There are questions related to the sustainability of the Brazilian market. This is far from complete and has already shown weaknesses regarding the required signal for expansion both in generation as well as in transmission.

3.3. Chile

In the early 1980s, Chile was the first country to liberalize electricity. It changed the industry from a state-owned monopoly to an open market, through the 1982 law of public service. Currently the electricity industry is almost totally private and the State is in charge of regulation. The market is composed of four separate systems: SIC (Interconnected Central System), SING (Norte Grande Interconnected System) and two smaller sub-systems. However, as the SIC includes 90% of the total demand, it will be the focus of our analysis. The market is controlled by the Economic Dispatch Load-Centre, CDEC, which is managed by the main generators and transmission companies. The CDEC operates the system based, by law, on reliability and minimum cost criteria.

The system was vertically and horizontally unbundled, and the CNE (Comisión Nacional de Energía) was created (CNE, 2002); this was followed by privatizations that took place in the middle of the 1980s (Fischer and Galetovic, 2000). The transformation process was initially successful in terms of increases in operational efficiency and substantial new investments. However, during the period 1998–1999 a major crisis emerged as the power industry could not supply the electricity that was demanded creating major blackouts in Chile.

The economic hourly dispatch is cost based; price and generation schedules are obtained from optimization models. There is a fixed capacity-payment to generators that contribute

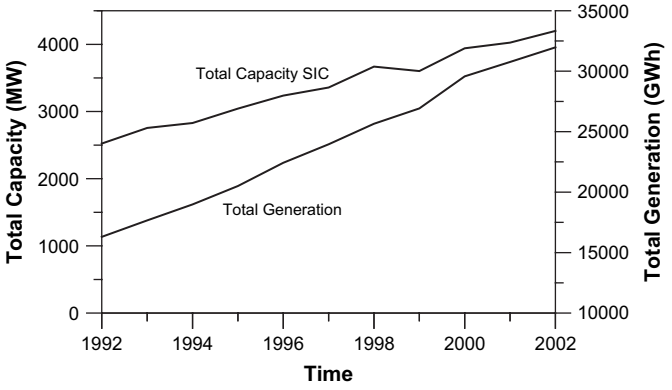

Fig. 5. Time series of the total generation and total capacity in the SIC. Source: CDEC-SIC (2002).

capacity in the yearly peak-demand period, which takes place from May to September (Montero and Rudnick, 2002).

Evolution of the total capacity at SIC, and the total generation, are shown in Fig. 5. The total generation takes into account not only demand (consumption), but also grid losses. Although the system in the early 1990s had a relatively large reserve margin, this was significantly reduced during the following years. In particular, we can observe an important reduction in capacity in 1999 that brought about the most significant electricity crisis registered in recent Chilean history.

The evolution of the spot price in Chile is shown in Fig. 6. The system is predominantly hydro-electric, and relies strongly on "Las Lajas" lake, the main reservoir in Chile, as illustrated by the second series in Fig. 6. There is a high correlation between the price and the level of water in the reservoir (50%, which is considered high in a complex system like this one). Thus, during the *La Niña* event of 1998/1999, as the water levels went down, both prices and variability increased significantly.

That the system in Chile is dominated by a very large company leads to a potential market power problem (ENGESA with 32% of the installed capacity in the SIC). However, the

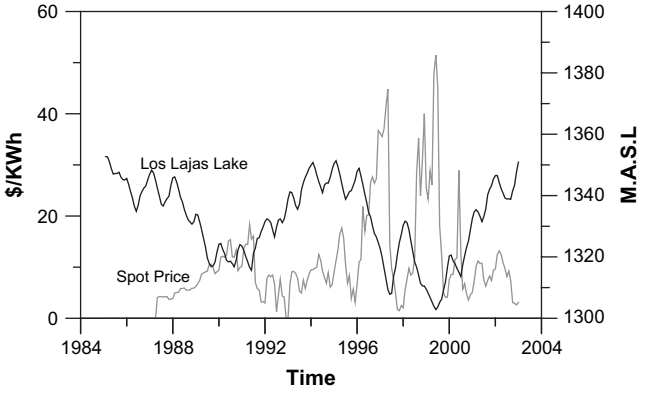

Fig. 6. Spot price (monthly average, December 2002) and level of "Las Lajas" lake. Note: the spot price in the Chilean electricity market does not include the aggregated value of distribution but it does include the transmission cost. Source: adapted from CDEC-SIC (2002).

situation has improved over the last 5 years, where the HHI has drop from more than 3000 (potential critical market power) to around 1500, which is still higher than most countries in Latin America.

Grid losses are very low compared with other countries in South America, around 5%. The system faced an average of 22 interruptions during 20 h in 2001 (Larsen et al., 2004).

The initial industry reform was successful, and incentives for new investment were also effective; new investments were made, and capacity increased from about 4000 MW in 1990 to 6000 MW in 1998 (Fischer and Galetovic, 2000). The structure of Chile's reformed industry was thought to be a regulatory system that could guarantee substantial independence from the political process (Spiller and Viana, 1996). However, problems started to emerge as the relationships among the privatized companies and the regulator turned increasingly adversarial, and fundamental governance problems became evident. Given this, along side the occurrence in 1998 and 1999 of a *La Niña*—a Pacific weather system that caused major droughts in Chile—a major supply crisis took place. The system faced not only random shortages but also, at the peak of the crisis, 3-h long rotating electricity cuts. Fischer and Galetovic (2000) and Rudnick and Montero (2002) argue that the Chilean blackout shows the limitations of the rigid price setting that has been imposed on the system, which requires major regulatory intervention.

A second round of reforms has been proposed but little progress has been made at the legislative level. Fischer and Galetovic (2000) argue that, under the political and regulatory circumstances in Chile, the country should rely as much as possible on market rules that clearly allocate property rights ex ante. They also argue that the system should be allowed set the terms of contracts freely through a negotiation among the participants.

3.4. Colombia

The deregulation of electricity in Colombia started in 1994, and the spot market initiated operations in July 1995, supported by Laws 142 and 143 (Congreso de la Republica de Colombia, 1994a,b). Despite the differences from the UK, Colombia adapted a version of the UK model. The main reasons for reforms included: two previous blackouts in 1983 and 1992–1993, the impossibility of the government financing the required expansion, and the desire to increase the efficiency of the sector (Larsen et al., 2004). The Colombian electricity market is the only one in the region where pool prices are settled in a bidding process (Millán, 2001). The system is price-based, rather than cost-based as in the rest of the subcontinent, companies submit daily bids of both energy and prices (from hourly bids it has now changed to block bids) to the CND (Centro Nacional de Despacho, the system operator). CND decides on dispatch according to merit order, taking into account system restrictions. There is a capacity payment mechanism in place, intended to provide investment incentives in generation. These incentives are allocated according to an "optimization-simulation-model" operated by the CND and regulated by the CREG (Comision de Regulacion de Energia y Gas, Energy and Gas Regulation Commission). It is fixed at 5.25 US$/kW per month.

The Colombian electricity industry is characterized by a large hydroelectricity component, close to 70%, and is considered to be one of the most open markets in the developing world (Larsen et al., 2004). The supply has been increasing in both hydro and thermo capacity from 11,596 MW in 1994 to 12,954 MW in 2004 (ISA, 2003). In 1998–1999, the country faced the worst recession in a century, reflected in a fall in demand, which has gradually recovered since then. The installed capacity and the maximum demand are shown in Fig. 7. The decrease in demand was unexpected and was due to an economic crisis in the late 1990s (UPME, 2000, 1999).

At the end of 1997 and beginning of 1998 the El Niña South Oscillation occurred, which led to a reduction in the water supply to the hydro based electricity system, and therefore a reduction in the water available for the market. As can be seen in Fig. 8, prices rose sharply in the spot market but had little effect on the average contract price. It is important to observe, however, that blackouts did not take place during this period as the system was capable of producing sufficient electricity to satisfy demand. Compared with 1992, when Colombia faced the same macro climatic phenomenon with serious consequences in terms of shortage and blackouts, what happened during 1998 "proved", to many, that deregulation had important benefits, as the system could successfully confront a Niño of such intensity. However, it is not clear whether the system will deliver the necessary increase in capacity now that the economy is back in growth mode and the system is showing weaknesses, especially regarding the capacity payment mechanism (Larsen et al., 2004).

Monthly HHI has been estimated since 1995. As expected, HHI shows more variability for generation than for capacity or power availability. For capacity, according to the HHI, concentration has declined from about 1400 in 1994, to below 1200 in 2003. Note that at this level, HHI indicates that there is moderate concentration, which might seem unproblematic; but

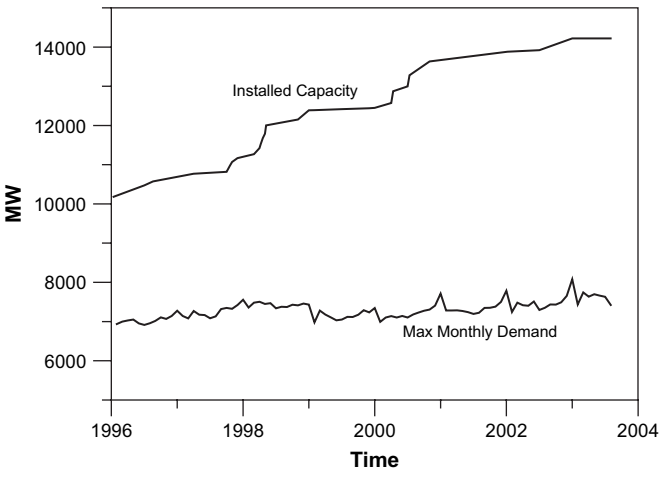

Fig. 7. Installed capacity and monthly maximum power demand in Colombia. Source: calculated with data from ISA (2002).

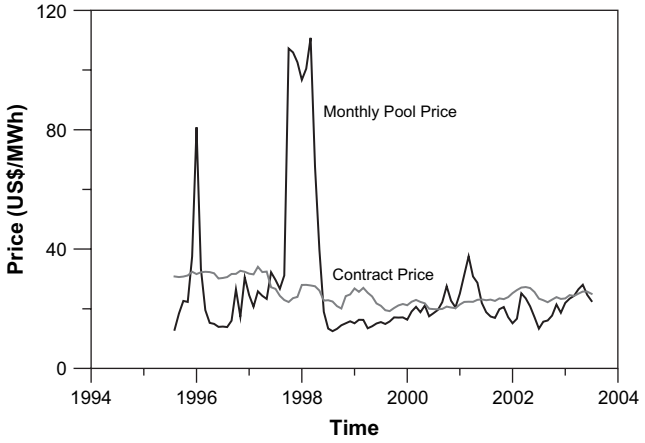

Fig. 8. The evolution of pool and contract electricity prices in Colombia from 1995 to 2002. Source: ISA (2002).

when examined seasonally and locally, the HHI for generation shows values closer to 1800 because of grid restrictions or hydro-power unavailability.

Losses in the Colombian electricity market are considered moderately high compared with other countries in the developing world (Larsen et al., 2004). The Grid Company, ISA, reported 21% losses in 1994. After deregulation, losses fell to around 15% in 2000, with important differences between regions.

There are limited network interconnections between Colombia and its neighbors. Some electricity transactions are taking place through TIEs (International Energy Transactions), with Ecuador, Peru, and Venezuela. These countries conform to what is called ''Mercado Eléctrico Andino''. This is an important step toward integrating the region, which may take advantage from the complementarities that exist, including: hydrological difference between Ecuador and Colombia, and technological and time differences between Venezuela and Colombia.

Market evolution has been satisfactory in terms of investment, competition, efficiency and reduction in electricity losses. Market prices have remained low but tariffs and subsidies are still a major issue. This has created problems for an important number of distribution companies that seem non-viable not only are customers incapable of paying for electricity, but also subsidies are insufficient and losses are high. A detailed account of the Colombian electricity markets is presented by Larsen et al. (2004). Possible reforms are now under review. CREG (the regulator) has taken under considerations a variety of studies (TERA, 2001; COMILLAS, 2000; and UN-COLCIENCIAS-ISA, 2000) in order to reform the market. However, these studies were conducted in 2000 and there has been little or no progress since then.

4. Comparison of the evolution of the four electricity markets

We have briefly discussed the four case studies in order to provide an overview of the dominant electricity market structures in South America. The deregulation process is generally not well understood, and we need to examine the factors and conditions that determine the circumstances under which the alternative ''deregulation models'' are likely to succeed in South America. One way of building a better understanding is to compare and contrast countries that are similar in many dimensions (i.e. to hold one set of variables constant) and see how other sets of variables have affected the outcome. However, to obtain a broader insight we need to make more than a pure economic analysis. The South American countries discussed have some similarities, e.g. culture, geographic location, technology, economy, etc., but also have many differences in relation to the way they chose to deregulate, e.g. market framework, regulatory intervention and control, timing, etc. In this section we present a cross comparison among the countries, based on a number of factors from the previous section.

We focus on the common structural elements found in these markets, and believe that we will be able to learn important lessons from this comparison, that can inform not only countries in South America but also other countries which have recently deregulated or are about to deregulate. Table 2 summarizes the four cases. We use general qualitative and quantitative indicators for comparing these cases and also standard indicators from economics (Newbery, 2001; Hunt, 2002; Stoft, 2002) to highlight the performance of these markets in terms of efficiency and quality. Efficiency is reflected in market prices and depends largely on concentration; reliability is affected by volatility; and quality is measured by the frequency and intensity of interruptions of service and by service perception when data are available.

A qualitative summary of what we have observed is presented in Table 3. It shows a cross comparison of the four cases and the current state of their performance in a number of areas.

Both Brazil and Chile faced very small reserve margins that have led to electricity supply crises with considerable shortage of electricity and relatively high prices. The reason for this shortage is the lack of investment mainly in new generation capacity. On the other hand, Argentina and Colombia have enjoyed high reserve margins, which led to very low spot prices at the beginning of the new century. The underlying reason for the high reserve margins is, largely, the deep recessions in their respective economies. Note that data confirms a direct relationship between the economic behavior and electricity demand for Brazil (for the Colombian case, see e.g. Larsen et al. (2004)). Insufficient electricity generation capacity could constrain future economic growth. The natural question is then, do the current electricity markets, given their structure, provide the incentives for expansion to meet consumers' demand? In other words are these markets providing the right signals for investors to bring new capacity into place? We will discuss a possible answer to these questions, in two parts, below.

Deregulation does not mean that investors will instantaneous begin investing in additional capacity. Investment decisions take significant amounts of time. Decision-makers will

Table 2
Summary of development in four South American countries

	Argentina	Brazil	Chile	Colombia
Pre-restructuring. Political environment and ownership	Weak economic growth and unstable political institutions since the 1940s, however, they have strong provincial institutions. State owned industry until the recent privatization	One of the highest rates of growth in SA. In 1970s, Brazil moved towards full government ownership of the industry, probably due to lack of incentive for private investment, and political instability	Relatively stable before 1950s. Political problems in 1960s and 1970s, where the government took over close to 90% of the generation capacity	Until recent privatization, government owned almost the whole industry, with a continued political instability, up to the current date
Selected model	Adapted with improvements from Chile	Adapted from different countries with own innovations	Pioneer	Adapted from UK
Pool design	Cost based bidding	Cost based bidding	Cost based bidding	Bid based
No. firms[a]	38	14	4	26
Private sector participation (%)				
Generation	60	30	90	70
Transmission	100	10	90	10
Distribution	70	60	90	50
Market share of the three largest firms (%)				
Generation	30	40	50	50
Transmission	80	60	100	100
Distribution	50	40	50	60
Proceeds from sale of electricity distribution entities[a] (million US$)	763	1369		1681
Price setting mechanisms				
Generation	Cost	Cost	Cost	Price
Transmission	Price cap	Cost of service	Cost of service	Price cap
Distribution	Price cap	Price cap	Efficiency standard	Price cap
Average electricity prices in June 2001 (US cents/kWh)				
Residential	10.04	11.02	8.58	6.42
Commercial	15.25	10.09	8.19	7.78
Industrial	7.30	3.12	5.52	4.19
Quality of the service				
Average number of interruptions per year	12	17	22	60
Hours of interruptions per year	12	15	20	58
Electricity trade in contracts (%)	38	85	–	70

[a] Source: Bacon and Besant-Jones (2001).

be looking for the appropriate signals in order to start new generation projects. This often includes considerable time to establish the government's commitment to reforms and the regulator's determination to carry through deregulation. Brazil, for example, was expecting a capacity shortage since 1996 (BNDES, 1996), and had observed how water levels in reservoir were falling for years, until the situation finally became very serious in 2001 (MAE, 2003a,b). However, there was no reason to expect that the market should have attracted investors to build new capacity, especially given the very unclear market rules that existed in Brazil. A similar situation occurs when there has been a long period of excess capacity in a market (i.e. high reserve margin and low prices). As economic recovery takes place in Colombia and Argentina, it will most likely require a significant amount of time before

Table 3
Qualitative cross comparison of the electricity markets' performance in Argentina, Brazil, Chile, and Colombia

	Argentina	Brazil	Chile	Colombia
Reserve margin	High	Small	Small	High
Volatility	Low	Very high	High	High
Market power	Moderate	High local	High moderate	Moderate and Local
Losses	Low with improvements	Low	Low	High with Improvement
Interruptions	Improvements	Improvements	Improvements	Little improvements

investors will be committed. Investors need to be confident about the regulatory framework and also be sure of the demand-growth patterns before they commit to investment, a process likely to take a few years.

Another issue in South America, although equally relevant to other parts of the world, is that governments and market regulators should be aware of timing issues if they want to prevent blackouts. Markets should provide the appropriate signals for capacity investment, but if this is not the case then the rules governing markets need adjustment. An electricity crisis will slow down economic growth and can have a devastating effect on the future prospects of a country or region. Regulation is a learning activity that incorporates both innovations as well as successful experiences from other markets. However, we have observed several examples where major shortages have not been prevented, as in the widely cited case of California in 2000–2001 that cost that state billions of dollars (McNamara, 2002; Sweeney, 2002).

Electricity markets tend to induce cyclical behavior in reserve margin (Bunn and Larsen, 1992, 1999; Ford, 2001, 2002; Dyner et al., 2003; IEA, 1999). Even though there is not yet enough data to analyze this statistically, we might observe two phases of the cycles. While Brazil and Chile have gradually recovered from their crises and are beginning to decrease their reserve margins, Argentina and Colombia have been rapidly increasing their reserve margins since the turn of the century. It should be possible to take advantage of this situation as discussed below.

The spot electricity prices in Brazil, Chile, Colombia, and to lesser extent Argentina are driven strongly by rainfall, a situation that makes them vulnerable to extreme *El Niño/La Niña* events. These create excessive rain fall in some countries, while at the same time, droughts in other countries. Lack of rain leads to water scarcity, which increases prices and volatility while excess rain creates very low prices (making it difficult for non-hydro-based generators to run). In 1999, Chile faced a *La Niña* event that led to a reduction in the levels of the *Las Lajas* Lake, large rises in electricity prices and blackouts. Colombia has faced two events of this type since deregulation: the first in 1997–1998, which significantly increased prices but posed no serious threat to the electricity supply; and the second in 2002, which had no significant implications as it was much less intense and Colombia had a larger reserve margin compared with the previous event. In Brazil, a series of problems combining with an irregular dry season led to blackouts and a huge increment in prices. Meanwhile, Argentina that initially exhibited a decreasing trend in prices, during 2004 experienced shortfalls in electricity supply because of reductions in investment, scarcity of gas and low water levels in reservoirs. Fig. 9 summarizes the price evolution of the spot market price for these electricity markets. There is at least one obvious conclusion that one can draw from the figure, which is that several of the markets seem to be ''out of sync''. This could be exploited, as a way to stabilize some of the more extreme movements in price, across the region.

Regional markets will benefit countries because of the existing complementarities. Regional markets would be able to take advantage of the different impacts that weather systems such as El Niño have on countries, making the markets more efficient and lowering the volatility. Regional markets would also balance the generation technologies allowing for a more predictable price, similar to the effect NordPool has had on the Norwegian market.

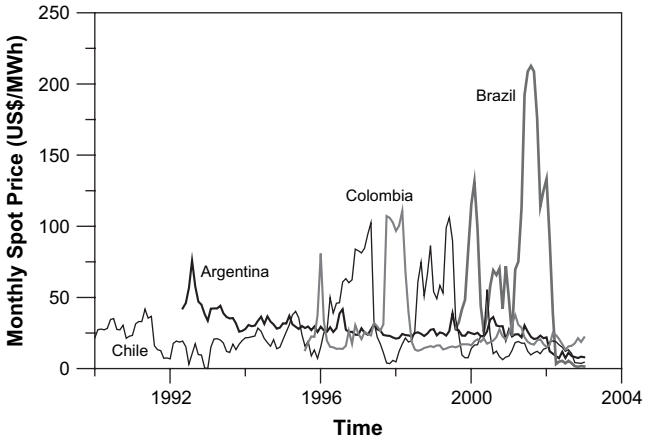

Fig. 9. Monthly spot price evolution of the main electricity markets models' in South America, standardized in US dollars per MWh (US$/MWh).

Another important aspect that can be observed is the partial decoupling of the wholesale and retail markets, especially with respect to prices, as these are not passed on directly from producers to consumers (except for large users). The way that changes in the wholesale market are transmitted is through a smoothing process that incorporates the price variation into the consumers' tariff (or price), with long time lags (Stoft, 2002). Table 2 shows the fraction of the electricity traded on contracts, in Brazil up to 85% compared with around 70% in Colombia. In other cases where the market is not fully deregulated, the domestic sector is still a monopoly and prices are only allowed to change very slowly (largely influenced by politics). To some degree, this was what happened in California, where retail tariffs did not reflect wholesale prices, in the end requiring government intervention to keep the electricity system afloat (see, among others, Sweeney (2002) and McNamara (2002) for a discussion of the Californian crises).

Fig. 10 shows the comparative volatility in the four countries. As we can observe, Argentina has had the lowest volatility by far during the period up to 2003, whereas volatility in Chile and Colombia has been of comparable magnitude, although the volatility dropped significantly in Colombia from 1999 onwards (after the Niño). The interesting point to observe is that Brazil has had very large and increasing volatility in electricity prices. On the other hand one reason for the reductions of volatility in Argentina, Chile and Colombia, apart from the weather, has been the increase in reserve margins during much of this period. Brazil has seen the opposite, a decrease of reserve margin, especially during the most recent years where it has struggled to get enough capacity in place.

Colombia and Argentina have shown that both price-bidding and cost-based models can produce acceptable results

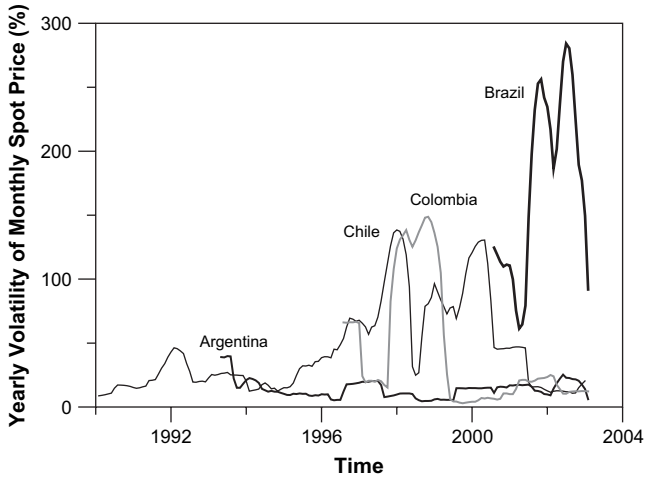

Fig. 10. Yearly volatility of the monthly spot prices of the main electricity markets models in South America, estimated from prices in US dollars per MWh.

in deregulated electricity systems. However, in the late 1990s and early this century both countries have had major recessions in their respective economies, which stopped or reversed any growth in demand. The real test of these regulatory systems will be in the years to come, where there will almost certainly be a strong need for investment in new capacity (Larsen et al., 2004). However, as discussed above, the effect of lags might prevent enough new capacity being in place when it is most needed (Fischer and Galetovic, 2000). To make the situation even more complex, the political instability in Latin America triggers debates on ownership of the electricity sector (public versus private) as well as prices, tariffs, cross-subsidies and the robustness and integrity of the regulatory institutions. All of these factors affect the perceived risk and uncertainty to foreign investors and might, in the end, have detrimental effects on the willingness of private investors to provide the necessary capital (Spiller and Viana, 1996).

In most—if not all—deregulation processes there is a gradual approach to opening up markets (in developing as well as developed countries). The first step is normally accomplished by creating the legal framework, which might include some privatization, and in all cases institutional reforms. When there is confidence that this initial limited opening is working and producing the intended results, reforms will continue allowing more consumers to participate in the market by lowering the consumption threshold for participation. As the participation in the market is increased, the last step is to allow the domestic market to participate (as is the case in, e.g. the UK and Norway) and we reach a fully competitive market (at least in theory). No developing country has yet moved to a fully competitive market (Bacon and Besant-Jones, 2001), and in the great majority of cases they are moving very slowly—if at all—toward the opening of the market for domestic customers. It is an open question whether one can stop the process and where the process should be stopped, i.e. what is the "optimal" threshold demand for customers to be allowed to participate in the market.

5. Discussion and conclusion

The first impression is that Latin America did well overall during the years after deregulation; however, when one takes a closer look the complete picture is more ambiguous. The adjustment processes of the frameworks have not been "maintained", creating potential major problems in the future. Leaving aside the initial determination to solve old problems, we have seen a reluctance to face the imperfections that emerged within the newly deregulated industries, which has led to a stalemate in the future development of the electricity industry. This said, one should not underestimate the successes that these systems have had over the last decade.

Here we have presented and compared four cases of national deregulation of electricity markets in Latin America. These ranges from the oldest in the region (and the world) Chile, to the youngest in the region, Brazil. The South American markets are not completely developed but provide a number of warnings to other countries. We have pointed out both some existing and potential problems. Chile came out of a critical situation in 1999 with extremely high prices and shortages; Brazil faced a supply crisis in 2001 with very high prices and shortages, and Argentina was experiencing a similar situation, with much lesser effects, during the year 2004; after a long recession Colombia is now facing a (dangerous) decline in reserve margin. There are, however, a large number of positive experiences. These include increases in private investments, better managed systems (lower losses), and potential (in some cases realized) lower prices. There are also a number of cases in which the systems managed to provide enough electricity to cover demand, where many people would have thought it not feasible. Another, important question to ask is whether the systems would have done better without deregulation. Of course, it is not possible to answer this question, but it is worth remembering that in many cases it was blackouts and bad management that led to the deregulation decision.

We have observed episodes in South America where Brazil and Chile have suffered from major blackouts and which have also occurred more recently in Argentina. In many cases these crises could, in retrospect, have been prevented, but they would have required regulators and politicians to take a long-term view about these issues and consider, at least:

- First, the need for detailed understanding of possible market developments 4–6 years ahead. This would allow the regulator to understand whether there is a possibility for electricity shortage and in which cases this might happen (for support tools, see e.g. Dyner and Larsen, 2001). An example of this is the realization already in Brazil, in 1996, that there might be problems in the future (BNDES, 1996).
- Second, regulators have to "face up to" the expected shortages of electricity. This includes sharing the concern with investors and consumers as well as with politicians; it also involves explaining the circumstances under which a shortage might happen (as well as the likelihood of it) and the consequences, in terms of interruptions as well as potential economic cost to the country.

- Third, politicians need to accept that changes have to be made. In most cases this will imply changes to the laws that govern the deregulated system or the power of the regulatory institutions. If changes are introduced well in advance, possible shortage may be prevented. However, regulators and politicians face the problem of explaining why they are ''fixing'' something that is not yet broken. One example of this might be the change, in England, from the original pool-based pricing to a system that is much closer to NordPool (known as NETA).

By means of these considerations, Colombia might still be able to prevent a possible crisis (Larsen et al., 2004), which Argentina, Brazil and Chile were not able to prevent. In this connection it should also be clear that not all situations can be prevented; but with foresight and determination it is likely that the majority of these situations could be prevented.

Since all the analyzed markets have experienced successes as well as difficulties, regulation must be reviewed and adjusted according to market requirements. Despite initially being pioneers worldwide, the South America countries almost ''froze'' the reforms and no substantial adjustments have been made to cope with the challenges that have emerged. Chile, Argentina, Brazil and Colombia are in unstable political environments that have delayed new rounds of reforms, being termed as ''Second Generation Reforms'' (Millán, 2001). It should be clear that deregulation is not a ''one-off'' event, but an ongoing process that will have to continue for at least as long as the systems' transition period, which can last decades (Dyner and Larsen, 2001).

Generally, productivity and efficiency have increased after the reforms, as a result of the introduction of competition. However, not enough of the productivity and efficiency gains have been passed on to consumers. Countries such as Argentina and Chile have faced the problem, because the regulators have avoided creating uncertainty for investors about revenues in the future by allowing for a relatively high price (Bacon and Besant-Jones, 2001). A similar situation occurs in Colombia (Larsen et al., 2004). This might make the situation better for the investors, but create another set of problems as the consumers see no benefit from the reforms.

The new round of reforms should take into account different aspects of the problem. First, they should consider an economic recovery of the region. Second, they may rely more on market institutions (for example, financial elements), which would create the appropriate incentives and tools for resources allocation and risk management. This would improve the industry performance and reliability. Third, the reforms should consider the *State of the Art* of electricity markets; particularly, they should include learning from areas with a similar technology mix, such as NordPool. Fourth, the future design should take into account the possibility of creating regional integration, again possibly looking at NordPool.

Expanding on the last point, we believe the next step for the South American electricity markets has to be the development of regional integration among neighboring countries. Although regional integration has slowly started, this needs to be one of the main areas of focus for Congress, regulators and transmission companies in the region. It will help markets to improve their performance, not so much because of the competition, but mainly because of the existing complementarities among the neighboring countries. Regional integration is feasible under the right political climate, but it requires both commitment and taking into account other experiences with similar topologies, such as the Scandinavian model. More research and analysis is needed in this direction.

Acknowledgments

The authors thank ISA-MEM, the electricity market manager in Colombia, for providing valuable information, and Erling Moxnes and Paul Ellis for their comments.

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