REGULATORY GOVERNANCE AND CHILE'S 1998-1999 ELECTRICITY SHORTAGE

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Abstract

In the early eighties Chile completely reformed its electricity sector, introducing a regulatory framework that became extremely influential in the rest of the world. In 1998 and 1999, however, when the *La Niña* phenomenon brought one of the worst droughts on record, the price system collapsed. Random outages and three-hour long rotating electricity cuts occurred.

This paper studies the interaction between regulatory incentives and governance during the 1998-1999 electricity shortage. We present evidence showing that it was feasible to manage the supply restriction with no outages. The shortage can be blamed on the rigidity of the price system, which was unable to respond to large supply shocks, and on deficiencies in regulatory governance, which led to a weak regulator that proved unable to make the system work.

We show that the weakness of the regulator did not stem from lack of formal powers. The problems originate in the vulnerability to lobbies and lack of independence. Moreover, the regulator seems not to have fully understood the nature of the incentives in the price system during supply restrictions.

We conclude that the Chilean shortage shows the limitations during crisis of a rigid price system requiring heavy regulatory intervention. This suggests that countries where governance structures are ill suited to fill in loopholes left by the law should rely as much as possible on market rules that clearly allocate property rights ex ante and leave the terms of contracts to be freely negotiated by private parties.

Key words: electric regulation, hydrological risk, regulatory incentives, regulatory governance
JEL classification: L51, L94

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1. Introduction and background

Until 1980, electric regulation in Chile followed the usual pattern of contemporary electrical systems: state-owned firms that were vertically integrated and subject to rate of return regulation. The operation of electric generation companies (gencos) was inefficient, a consequence of the state not having an independent regulatory agency capable of regulating its own firms and of prices that were set in order to respond to short term political objectives. This structure was drastically reformed in the early eighties.[1] What was then a revolutionary price system was introduced, electric generation was decentralized and functionally separated from transmission and distribution, and incentive regulation was introduced in distribution. These massive changes in regulatory incentives were supplemented with the creation of a new regulatory agency with a ministerial rank, the *Comisión Nacional de Energía* (henceforth CNE), followed by the privatization of the industry in the late eighties.[2]

Chile's regulatory reforms have been quite successful. The regulatory incentives they introduced became a standard reference for reform in several countries.[3] Substantial new investments were made following privatization and operating efficiency increased significantly.[4] Despite this success, relations among the privatized firms, and between firms and the regulator, became increasingly adversarial, as inconsistencies and loopholes in the law began to surface.[5] These loopholes were unimportant while the industry was state-owned, but after privatization they became a source of wealth transfers between electric companies. Regulatory governance has proven inadequate to fill in these loopholes and the regulator's decisions are frequently disputed in court.

These problems became acute during the 1998-1999 energy supply restriction, when the *La Niña* phenomenon brought one of the worst droughts on record.[6] Disputes between gencos and the loopholes in the law caused the collapse of the price system and led to random power failures and energy rationing in November 1998. By April 1999, as water stored in reservoirs began to run out, electricity supply in Santiago was curtailed three hours a day, random power failures were frequent and experts were forecasting six-hour long electricity cuts. In response to the public outcry, the government introduced legal changes in June 1999. Unfortunately, some of these changes appear to be inconsistent with the current price system, which implies that future problems are in store. What

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[1] The key law is the DL N° 1 of 1982. It can be found in `http://www.cne.cl`.

[2] See Bernstein (1988) and Spiller and Viana (1996) for an overview of the restructuring process in the electrical sector.

[3] Here we follow Levi and Spiller's (1996, p.4) classification. They distinguish between "regulatory governance" and "regulatory incentives". The governance structure refers to the mechanisms that restrain the regulator's discretion and arbitrate conflicts that originate in these restraints. "Regulatory incentives" are the rules governing pricing, subsidies, competition, entry, interconnection and the like.

[4] For example, capacity increased from around 4,000 MW in 1990 to 6,000 MW in 1998.

[5] It stands to reason that there are opposed interests among firms and between firms and regulators. The problem in Chile is that many disputes end in the extremely slow and non-informed judicial system, where they escape the ordinary mechanisms of dispute resolution. For a discussion of conflicts in the electricity sector in Chile see Basañes, Saavedra and Soto (1999).

[6] By "supply restriction" we mean a fall of energy supply, which could be due to a drought or the failure of a power plant. By "shortage" we mean an excess demand for energy, which usually leads to outages.

are the explanations for the failure of Chile's supposedly modern system of regulatory governance?

In this paper we argue that the failure of regulatory governance and incentives has two main causes. First, the extreme rigidity of the price system. This inflexibility makes it unresponsive to the large variations in energy supply that are endemic due to the importance of hydroelectric (hydro) generation and the variability in hydrological conditions. Second, the only way in which the current price system can be made to work during periods of supply restrictions is through heavy and skillful regulatory intervention. The regulator must determine in advance the opportunity cost of energy when supplies are restricted, enforce the administrative measures needed to confront users with that cost and fill in the voids in the law's numerous loopholes by settling disputes between gencos.

A major problem is that the *ex ante* estimation of this opportunity cost represents a formidable informational requirement for the regulator. A second problem appears because of the deficiencies of regulatory governance. The executive, who is the nominal overseer of the regulator, is vulnerable to lobbying pressures and has shown little willingness to settle disputes which would result in large wealth transfers between companies or between companies and the public. For example, during the shortage the regulator did not act fast to settle disputes among gencos concerning the price of energy in the pool, despite being legally required to arbitrate in these conflicts. Moreover, the regulator has not been able to enforce the payment of compensations to consumers, which are essential to transmit them the opportunity cost of energy during a supply restriction. Another example of these failures was the tardiness in issuing a rationing decree, which forces gencos to allocate shortages among users and allows distributors to cut energy supply when necessary, without triggering penalties. The fear of the political repercussions of acknowledging that energy supplies were tight led to repeated postponements of the decree, thus allowing the use of the scant remaining reserves of stored water, worsening later outages. The unwillingness to resolve conflicts is occasionally broken by hasty measures designed to reduce the public outcry caused by outages.

The Chilean electricity shortage is a good case study of the interaction between regulatory incentives and governance. The price system fulfills its role of allocating energy production when there is sufficient capacity to meet demand at regulated, non contingent prices. However, it imposes rigid prices that do not allow automatic adjustments when supply restrictions make it physically impossible to meet demand at the regulated prices.[7] Rigid prices in a regulated market shift the burden of allocating resources to the regulator. The problem is that regulator is weak, being vulnerable to lobbying pressures, reluctant to assume political risks, and its rulings can be easily delayed in the legal system. Thus, the example of the Chilean energy shortages suggests that heavily regulated systems requiring the skilful intervention of the regulator have serious problems under weak governance structures. It also highlights the advantages of flexible price systems which transmit automatically the opportunity cost of energy to firms and users when governance is weak.

Before proceeding we call attention to three caveats. First, we focus on the short run response

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[7]The Chilean price system is even worse at handling situations in which the shortage is due to demand shocks. See Diaz, Galetovic and Soto (1999, p. 20; henceforth DGS).

to supply restrictions. We do not study the effects of regulatory governance and incentives on investment decisions, which obviously affect the magnitude and frequency of supply restrictions; see DGS (1999) for a formal long-run analysis. Second, our analysis is relevant for energy and not for power shortages. Energy shortages can last several months and are predictable. By contrast, power outages are sudden and seldom last more than a day.[8] Third, we concentrate on the power generation sector, as transmission and distribution played subsidiary roles in the crisis.

The rest of the paper proceeds as follows. In section 2 we describe the basics aspects of the regulatory governance and the price system in Chile. In section 3 we analyze the causes of the shortage and the role played by regulatory institutions. Section 4 discusses the conclusions.

2. Governance and prices in Chile

In this section we describe the institutions that regulate the electricity sector in Chile (regulatory governance) and the conceptual underpinnings of the price system in power generation. We also discuss one of the main structural features of the market, Chile's extreme hydrological variability.

2.1. Regulatory governance

There are four institutions that oversee the workings of the electricity market: the CNE, the Ministry of Economics, the Superintendency of Electricity and Fuels (henceforth SEC, its spanish acronym) and the Economic Load Dispatch Center (henceforth CDEC, its spanish acronym), the pool operator. We describe the role of each in turn.

The CNE   The CNE advises the government on energy policy. The head of the CNE has ministerial rank, but, somewhat inconsistently, the CNE is governed by a board that includes 5 additional ministers. This board reports directly to the President. An executive secretariat is in charge of operations. The CNE studies and proposes regulations, calculates regulated prices, provides technical advice to the government and is in charge of the technical oversight of the sector. Regulatory rule changes are usually prepared by the CNE. It is important to note that CNE regulates and advises the government, but it has no power to enforce compliance.

The CDEC   The pool regulator coordinates the operation of the generation-transmission system in central Chile and is responsible for system security.[9] The CDEC must inform gencos of current demand and supply conditions, coordinate power plant maintenance and verify compliance with the system's operational rules. Finally, the CDEC determines the spot price at which transfers of energy and power between gencos are valued (see below).

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[8]See Sanghvi (1983) for a discussion of the difference between energy and power shortages.

[9]There is a large independent system operating in the north of the country and two small systems operating in the extreme south.

Unfortunately, the 1982 electric law and its 1985 statute left the internal operations of the CDEC somewhat undefined. CDEC includes only power gencos with more than 2% of the installed capacity and transmission companies with at least 100 km of transmission lines.[10]

At the time of the shortage, it was composed by a board, an operations directorate and several working groups organized by area. The board governed the institution. Each member had one vote and the presidency rotated among all members. The pool operation was managed by an operations directorate which included a representative of each company. It was responsible for coordinating dispatch, verify the calculations and studies elaborated by the different working groups and ratify each month the balance of physical and pecuniary transfers between gencos made by the respective working groups.

An important weakness was that disputes within the operations directorate had to be referred to the board, which could only settle them by consensus. If the board was unable to reach the required consensus, the Economics Minister was responsible for issuing a decision within 120 days. This implied that unsettled issues could linger for a long time, and in the meantime decisions taken by the operations directorate on these issues were not legally binding on the companies.

The independence of the CDEC increased after the companies implemented in June 1999 the changes that had been introduced in the statute to the law which mandated an independent CDEC. While it is still governed by a board of company representatives, its operations are delegated to independent personnel. The procedures and models required to operate the system and model parameters are set by the independent operations directorate. A board member who disagrees with a decision made by the operations directorate can ask the board for a review. As before, the board needs a consensus to settle disputes, but if no unanimous decisions is reached, the conflict is referred to an expert commitee, which has 30 days to issue an opinion. If the decision is still not accepted unanimously by the board, it is referred to the economics minister, who has 60 days to settle the conflict. The most important change, however, is that the decision of the operations directorate is legally binding while a verdict is pending.

The Ministry of Economics   The Ministry of Economics is responsible for setting tariffs following the proposals of the CNE.[11] In addition, it has two functions that are of particular importance during a supply restriction. First, as seen before, by law it must settle the disputes between gencos that emerge in the CDEC. Second, it is in charge of issuing rationing decrees. In both cases the law forces the Minister to ask for a technical report from CNE.

The SEC   The SEC is an independent supervisory agency that reports directly to the President. It is responsible for monitoring compliance with the law and its regulations. Among its duties are

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[10]There have been arguments pointing out that the lack of defined rules has been a major barrier to entry into generation. Moreover, the major generator (60% of capacity) owned the main transmission company.

[11]In this role, the Ministry acts as a fail-safe switch, by providing an additional stage at which incorrect prices can be vetoed.

verifying compliance with service quality standards and investigating the causes of outages. Until recently the fines that it could impose for noncompliance were very low: the maximum fine was about US\$ 26,000. Changes introduced in June 1999 increased the maximum fine to about US\$ 6 million. Moreover, the decisions of the SEC were usually delayed by companies appeals in court. The legislative changes introduced in June 1999 raised fines and determined that before going to court, the firm had to post 25% of the fine.

2.2. Regulatory incentives

In this subsection we describe Chile's hydrological variability which is the main structural feature that determines the effectiveness of regulatory governance and incentives. Last, we describe the main characteristics of the price system.

2.2.1. Hydrological variability in Chile

Figure 1 shows the amount of GWh that could have been generated each hydrological year using the current installed hydro capacity. Annual energy consumption in Chile is around 25,000 GWh. In a rainy year such as 1972-73 or 1992-93 nearly all the energy requirements can be supplied with hydro generation.[12] By contrast, during an extreme drought such as those of 1968-69 or 1998-99, hydro generation cannot supply more than 9,000 GWh (or 40%) of annual consumption. In an average year, about 80% of annual consumption can be supplied with hydro generation.

Despite this extreme hydrological variability, around 60% of consumers (by volume) pay regulated, non-contingent prices (see below), which leads to consumption patterns that are unrelated to energy availability. However, given the variability of supply, it is inefficient for consumption to remain constant in dry years.[13] Equivalently, it is inefficient to invest in enough thermal capacity to make up all of the energy shortfall during a drought. The problem thus becomes one of deciding the appropriate rules for allocating shortfalls. An efficient, automatic solution is to increase the price to reflect the higher opportunity cost of energy during droughts. This obvious solution was not deemed acceptable by the designers of the Chilean electric legislation, who believed consumers and gencos were too risk averse to accept the price variability implicit in the system. A second option is to suffer the recurrent random outages that characterized the 1998–99 hydrological year, which are costly and inefficient. Chile adopted what looked like a third alternative, under which consumers pay for the expected non-supplied energy during supply restrictions in their regular bill, in order to finance an incentive scheme that in principle reduces energy use efficiently during droughts (see

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[12] According to the electric legislation, the hydrological year begins in April and ends in March of the following year. The rainy season in central Chile runs from May through September. The thaw in the Andes mountains (where water is stored as snow) starts in October and ends in March. To avoid confusion, we adopt the following convention: 1998-99 refers to the hydrological year that began in April 1998 and ended in March 1999. 1998–1999 refers to the chronological period which includes calendar years 1998 and 1999.

[13] See Serra (1997) and DGS (1999) for a proof of these results.

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below).[14]

It is usually believed that large hydrological variability is responsible for the large transfers of energy between gencos specialized in different sources of energy. According to this belief gencos specialized in hydro generation will inevitably buy energy produced in thermal plants and, conversely gencos specialized in thermal generation will be on the buying side in wet years. As can be seen from table 1, most hydro capacity in Chile is owned by Endesa and Colbún. The third large genco, Gener, is mainly thermal.

While during the shortage buying and selling positions coincided with this belief—Colbún and Endesa where in deficit and Gener had energy surpluses—,this pattern is neither a structural feature of the system nor would it necessarily disappear had gencos a more balanced generation portfolio. The reason is that whether a genco is in surplus or deficit depends also and fundamentally on its commercial policy. A thermal generator whose contracts exceed its capacity will be on the buying side on a dry year, and, conversely, a hydro genco that follows a conservative commercial policy may be on the selling side even in a dry year. A central point of our analysis is that incentives during a supply restriction will depend on the net buying or selling position of a genco and not on its generation portfolio.

2.2.2. The price system

The preceding discussion shows that hydrological variability makes a well designed price system necessary both to ensure that users see the opportunity cost of energy and that exchanges between gencos occur smoothly. We now describe the Chilean price system, focusing on the mechanisms which are supposed to deal with large reductions in available energy. Since the generation market is structured around three prices—spot, node (or regulated) and free—each corresponding to one market. We describe them in turn.[15]

Exchanges between gencos The order in which generating plants operate is determined by the CDEC. Given current demand, dispatch is made according to strict merit order after accounting for transmission constraints. Gencos do not make bids; dispatch is made according to their marginal operating costs, which are fixed according to technical operation parameters and fuel costs.

By law dispatch is mandatory whenever the plant is available and the CDEC commands it to start operating. This implies that dispatch is independent of a genco's contracts. Gencos that sell more energy than they produce are required to buy the difference in the spot market at the spot price. Each month CDEC settles accounts between gencos. Unfortunately, neither the law nor the CDEC's 1985 statute indicated a specific procedure to settle accounts, a shortcoming that had important consequences during the shortage.

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[14]See Bernstein and Agurto (1992).

[15]There are regulated and free prices for transmission and distribution, but as they do not play a large part in the crisis of 1998-1999, we do not describe them.

The spot price always equals the opportunity cost of water stored in the Laja reservoir. When full, the Laja reservoir (Laja lake) holds enough water to generate about 7,000 GWh, around one-fourth of annual consumption. Since installed capacity on the Laja e- uents is limited to 2,500GWh, energy can be stored for succeeding years. The rate at which water in the Laja reservoir is used is governed by a stochastic dynamic programming model called OMSIC. The model trades off the benefit of using water today to generate power, thus displacing thermal generation, against the cost of not having water available in the future and thus having to use thermal generation or ration energy. OMSIC uses as data the current level of the Laja reservoir and estimates the probability of future hydrologies using a supposedly representative window of 40 years of past hydrologies (1940-41 through 1980-81 during the shortage). Each yearly hydrology is assumed equiprobable and statistically independent. The output of the model indicates the amount of water that should be drawn from the reservoir and the shadow price of the remaining water. This shadow price is the system's marginal cost or spot price, which is adjusted hourly.

Under normal conditions, the opportunity cost of water equals the operating cost of the most expensive thermal plant dispatched. By contrast, in all the hydrological scenarios in which the model predicts a shortage, energy transfers between power gencos are valued at the *outage cost*. This outage cost is the average cost to users of a shortage, estimated from user surveys which are conducted infrequently (only two surveys have ever been made, the last ten years ago; see CNE [1986] and Fierro and Serra [1993] and [1997]).[16] The value of the outage cost depends on the depth of the restriction. It was estimated at 139.7 mills/KWh for a restriction of less than 10% of current demand; 232.5 mills/KWh if the difference is between 10 and 20% and 330 mills/KWh if the restriction is larger.[17] Note that under normal conditions, the average spot price is about 30 mills/KWh (see figure 2).[18] Outage costs assume that restrictions are planned and announced well ahead of time so large users can adapt their processes or install generating capacity and residential users can adapt their behavior. The cost of unexpected energy cuts is obviously much higher.

The regulated market. The spot price is subject to extreme variations during the year and even during shorter periods (see figure 2). In May 1997, for example, just before the Niño current arrived in Chile, water in reservoirs was running out and the spot price rose to the outage cost. By contrast, in December of the same year reservoirs were spilling and the spot price was close to zero. When the law was introduced it was thought that such extreme variations in price were unacceptable to residential users and gencos, hence politically unfeasible. Hence the price at which distributors sell to residential and other small users with less than 2MW of installed capacity was

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[16]Surveyed users were asked to estimate the cost of reducing "normal" energy use by 10%, 20% and more than 20%. Users were told that these restrictions will be announced months in advance, given that energy (as opposed to power outages) can be predicted.

[17]A "mill" is a thousandth of a dollar, and the standard unit used in the industry.

[18]Beginning in July 1998 there was disagreement within CDEC on the spot price. For this reason, prices reported in the figure are not official during that period.

regulated.[19] Moreover, the law made it mandatory for gencos to sell at the regulated price to distributors.

The regulated price (*node price*) is calculated every six months by the CNE and corresponds to the expected marginal cost averaged over the next 24 to 48 months.[20] To fix this price the CNE runs a stochastic dynamic programming model called GOL (a coarser version of OMSIC) which, given a ten year projection of peak power and energy demand, minimizes the expected cost of generation and outage by optimally using the water in the Laja reservoir (note that the model explicitly accepts that outages may occur in the optimal solution). This model takes existing plants as given, but optimizes entry of future plants over the ten-year horizon. As in OMSIC, GOL estimates the probability of future hydrologies using a sample of 40 past hydrologies.

Within each six month period the node price remains fixed, independently of demand and supply conditions. Nevertheless, there is a mechanism to ration excess energy demand. When a shortage occurs the regulator issues a rationing decree. Under rationing, regulated consumers should be paid the difference between the outage cost and the node price (i.e., around 110 mills/KWh for a 10% restriction) for each undelivered KWh, i.e., energy that would have been consumed at the regulated price if it had been available. Of course, it is necessary to estimate non-delivered energy, since the regulator does not know how many KWh would have been consumed had the shortage not occurred. The legislation sets the amount to be paid to a regulated user is defined according to the following formula:

$$[(1 + g_t) \cdot (\text{supplied energy})_{t-1} - (\text{supplied energy})_t] \times [(\text{outage cost}) - p_N],$$

where t is the period when the shortage occurs, g_t is the rate of growth of aggregate energy demand between $t - 1$ and t projected in the previous calculation of the node price and p_N is the current node price.

It can be shown that under a set of stringent conditions this scheme of compensations replicates the allocation of energy under a free market for energy.[21] To see this, refer to figure 3. Assume that $x(t)$ KWh of energy are available, which is less than energy demanded at the node price p_N, $x^d(p_N)$. If the regulator sets the outage cost at $D^{-1}[x(t)]$ and $(1 + g_t) \cdot x(t - 1)$ is sufficiently large, then the opportunity cost of consuming an additional KWh equals the social opportunity cost—the price that would emerge in a spot market. However, there are several problems with this scheme: first, since the outage cost is determined *ex ante*, there is no guarantee that it is the right compensation, i.e. the one that equates demand to energy supply during the supply restriction. Proceeding to minuter details that have important consequences, the law does not specify how the period $t - 1$ is determined and its interpretation is determined by the regulator, but can

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[19] The designers of the law assumed that large consumers would be able to negotiate their contracts and were always capable of self-generating their power needs if unable to arrange a satisfactory contract.

[20] CNE chooses the exact length of the period. During the shortage the expected marginal cost was averaged over the next 48 months.

[21] For formal proofs see Serra (1997) and DGS (1999).

be contested in court. For example, the relevant period may be the same month or week during the previous year; or the regulator may decide that compensations have to be paid for the whole time the rationing decree is in force, or only during those hours when restrictions occurred. The choice between these alternatives will affect gencos and consumers, since large amounts of money are involved.

Note that compensations have been pre-paid by users (in expected value), because the GOL model (which determines node prices) admits scenarios in which energy shortages occur, in which case energy is valued at the outage cost. Hence, the fact that gencos pay compensations for non-provision of electricity in a drought does not imply that they will lose money in expected value, provided that the node price is an unbiased predictor of marginal costs. However, this compensations mechanism was weakened by the addition of a codicil (the notorious article 99*bis*) that limited compensations in the case of extremely severe droughts.[22] The reason for introducing the codicil was that the worst hydrological year included in the GOL forecasts of future hydrologies was 1968-69. This, it was argued, was needed to prevent gencos from losing money, since users were not insuring themselves against years that were drier than the driest considered when calculating node prices.[23] It can be shown that this limitation is ineffective and unnecessary to prevent losses in a steady state.[24] However, the biggest problem caused by article 99*bis* during the 1998-1999 shortage was that it did not define *any* price-setting rules under conditions worse than 1968-69. This meant that the opportunity cost of energy for regulated users was still the node price, since they were not compensated for undelivered energy.

The free market. The *free* clients, those with installed power of more than 2 MW, face a much simpler price system. These users negotiate energy contracts directly with gencos. These contracts establish supply conditions, reliability and prices. While a significant fraction of these contracts are closed at prices which reflect supply conditions only in the long-run, contracts can be freely renegotiated during a supply restriction. If the spot price of energy climbs above the user's valuation of energy, it seems natural to expect that the genco and the user will undertake a mutually advantageous renegotiation.

By their nature, the regulator has no power over the contracts signed by free agents with their energy providers, and this stated in the electric legislation.[25] In April 1999, however, the regulator imposed proportional rationing on all users, in violation of the law.

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[22]There is no clear explanation for the continued existence of article 99 *bis*. It was introduced just before the military government handed power to a democratic government. At that time, many laws were modified by last minute clauses which were not analyzed carefully. Afterwards firms were strongly opposed to any changes in the law, under the perception that any attempt at small corrections would lead to widespread and perhaps populist changes to the electric legislation.

[23]See Bernstein and Agurto (1992).

[24]DGS (1999) show this formally. Note that the long run equilibrium without article 99*bis* involves a mix of power plants that has a greater thermal component.

[25]Article 91° of the law.

2.2.3. The price system during supply restrictions

As we have mentioned before, when energy supplies are restricted the spot price should rise to the outage cost and (if the regulator issues a rationing decree) gencos will pay regulated users the difference between the outage cost and the node price for non-delivered energy. This means that all market participants see the opportunity cost of energy at the margin, and no shortage occurs:

- Gencos who are net buyers in the spot market pay the outage cost for each KWh. Moreover, they are indifferent between supplying additional energy to regulated users and paying the compensation, because in both cases they pay (outage cost $- p_N$), where p_N is the regulated or node price.

- Gencos who are net sellers in the spot market receive the outage cost for the energy they sell.

- A regulated user receives (outage cost $- p_N$) for each non-consumed KWh. Hence, the opportunity cost of consuming an additional KWh is $(p_N + \text{outage cost} - p_N) = \text{outage cost}$.

- Gencos (both net sellers and net buyers)[26] have incentives to bargain with free clients who value marginal energy at less than outage cost. Assuming low transactions costs, Coase's theorem implies that bargaining between gencos and free clients should lead to reductions in energy consumption up to the point where the value of energy at the margin equals the outage cost.

In theory, therefore, the law defined prices that were able to allocate energy efficiently during periods of supply restrictions. In the next section we analyze why the system failed during 1998 and 1999.

3. Regulatory incentives and governance during the 1998-1999 shortage

In this section we argue that there were three reasons for the 1998–1999 shortage: first, available energy was low from May 1998 onwards, partly because reservoir water had been used aggressively, partly because there was little rainfall during the rainy season that followed and partly because the combined-cycle gas plant Nehuenco failed to enter. Second, the price system was incomplete i.e., there were conditions (years with less rainfall than 1968-69) when the regulated price was not far from the equilibrium price. Third, regulatory governance proved inadequate to respond to these two problems. We begin the section with a description of the fundamental reason for the shortage (the "material" causes). Next we show that the rigidity and loopholes embedded in the price system made it unsuitable to manage a severe supply restriction. Finally, we examine the failures of the regulatory institutions during the shortage. In the appendix we provide a short cronology of the shortage.

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[26] At any given time a genco can be a net seller or a net buyer, given the contracts that it has signed and the ownership of the power plants that are operating.

3.1. The shortage's material causes

Even though reserves became very tight from July 1998 onwards, deficits and outages occurred only during November 1998 and between April and June 1999. According to the CNE, the aggregate deficit over these months was about 450 GWh.[27] To get a feeling of the order of magnitude of this figure, recall that annual consumption in Chile is about 25,000 GWh, and daily consumption in a normal day is about 80 GWh.

Low initial level of reservoirs As can be seen from figure 4, the reserves of energy kept in reservoirs were initially low, fell dramatically during 1998 and remained low until mid 1999. Energy in reservoirs as of January 1, 1998 was about 3,650 GWh.

As mentioned before, the Laja lake is by far the largest reservoir. The amount of water in it is measured by it height above sea level, or *cota*. When full the level of the Laja lake stands at 1,368 m. By contrast, the lake is almost empty at *cota* 1,310m. As can be seen from figure 5, water almost ran out in 1997. The 1997 winter was very rainy due to *El Niño*, but that was enough to fill just a third of the reservoir. Consequently, at the beginning of 1998 its level was at 1,330 m.

Excessive use of water in reservoirs As can be seen from figure 5 the level of the Laja reservoir fell quickly during the first half of 1998, as the *El Toro* and *Antuco* power plants were run at close to capacity from mid-February on. The lake's level reached 1,316 m in June.

In addition, the government, represented by the Ministry of Public works, sold Endesa, the main hydro-power genco, additional water in the Laja lake equivalent to 316 GWh of energy. This water was used during July and August, so by September, the *cota* reached 1,310 m. Also, Endesa was granted the equivalent of 200 GWh of water from the Maule reservoir.

Severe drought and protracted failure of the Nehuenco combined-cycle gas plant The 1998-99 winter was one of the driest on record, and worse than the 1968-69 hydrological year. For example, as can be seen from table 2, during the 1998-99 hydrological year a- uents into the Laja reservoir carried 65% less water than in a normal year and 35% less than 1968-69. This meant less energy available because hydro plants generated less. It also meant less accumulation of snow in the Andes, which implied that there would be less water available during the thaw (October through March) so reservoirs would remain almost empty until the new rainy season. Hence, by August 1998 it seemed very likely that there would be supply restrictions until at least mid-1999.

In addition, the Nehuenco 370MW combined-cycle plant, an experimental prototype designed to generate 2,600 GWh/year at full capacity, was unable to run normally until December 1998. It broke down again in late March 1999, requiring extensive repairs. To get an idea of how important this protracted failure was, note that had Nehuenco run normally after November 1998, it would

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[27]See *Generación bruta mensual SIC-SING* at http://www.cne.cl/cnenew/electricidad/electric.htm. The size of the shortage was 76 GWh in November, 160 GWh in April, 134 GWh in May and 79 GWh in June.

have produced about 8 GWh a day. Hence the 81 days of deficit would have been reduced to just 26.[28] Moreover, this is an underestimate, since reservoir water could have been saved had entry occurred at any moment during the first half of 1998, as Colbún repeatedly announced.[29]

3.2. The fundamental rigidity of the Chilean price system

The preceding subsection suggests that the material causes of the supply restriction were the drought and the protracted breakdown of the Nehuenco combined-cycle plant. However, as discussed before, the price system is theoretically designed to accommodate a supply restriction without suffering shortages. The problem is that there are fundamental limitations that prevent this mechanism from achieving an efficient allocation of energy. Compensations to regulated users are supposed to play a key role in transmitting the opportunity cost of energy to regulated users during periods of supply restrictions. Efficiency requires that the outage cost equals the marginal value of energy during a supply restriction, $D^{-1}[x(t)]$ on Figure 3, but this requires that the regulator must know *ex ante* both the demand curve and the amount of energy that will be available during the supply restriction. But, since $D^{-1}[x(t)]$ is by definition contingent, the regulator uses a coarse approximation to $D^{-1}[x(t)]$. Thus, it is unlikely that the outage cost will reflect the opportunity cost of energy during a supply restriction.

While the outage cost might be an approximation, one might argue that it sends the correct signals to the regulated market, since its value is several times the normal cost of energy. Unfortunately, compensations of any significance have never been paid, thus providing the wrong signals to gencos and users. During the 1998-1999 shortage, gencos that could not fulfill their contracts at the regulated price (i.e., with distribution companies) argued that the hydrology was drier than the driest year included in the regulated price calculations (see below). In the previous shortage of 1989 and 1990, the main genco (Endesa) challenged the obligation of compensations by arguing that the law was passed after contracts with distribution companies had been signed. This argument was successful in court. Thus, it seems reasonable to expect that users and gencos will not face higher opportunity costs of energy during supply restrictions. In that case, the market will have no forces making it converge to equilibrium:

- Since there is no obligation to compensate users for undelivered energy, gencos that are net buyers in the spot market prefer not to supply regulated users, while continuing to supply free clients under contract.[30] If they supply regulated users, they have to pay the outage cost for energy in order to resell it at the node price p_N, leading to a net loss of $(p_N - \text{outage cost})$ per KWh.

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[28] To obtain these figures we added Nehuenco's energy production to daily deficits and subtracted 8 GWh, Nehuenco's normal daily output when it runs without failures.

[29] A chronology of Nehuenco's problems up to December 1998 appears in Cámara de Diputados (1999, pp. 83-94).

[30] This behavior is equivalent to an insurance company not paying a policy in case of accident. Normally, it is automatically regulated by the potential loss of reputation of the insurance company. This is not the case for the legislated "insurance" enmeshed in Chilean electric prices.

- The opportunity cost of energy for a regulated user is still the node price, p_N (see figure 3). Hence, they do not change their demand for energy.

In addition to being rigid in the short run, the price system is unresponsive to medium term changes in supply conditions (six months to a year). As we have seen in section 2, the node price equals the expected marginal cost averaged over the next 48 months. This implies that a severe current drought will enter the calculation of the node price only through the low current level of the Laja reservoir but its effect is diluted in the operation of the GOL model, where all possible hydrologies are included with equal probability and by the planned entry of new plants. Thus it was that by April 1998 the GOL simulations, which included several new combined-cycle gas plants that were presumed to enter in the future, made the node price drop by about 11%. In October 1998, when it was clear that the country was suffering a severe drought, the node price fell a further 8%, even though it obvious that there was very little snow in the Andes so the runoff would be one of the lowest on record. The node price dropped a further 5% in April 1999, just before random outages began. Thus, even though it was apparent that energy would be in short supply, node prices dropped by almost 25% during 1998 and the first half of 1999, which must have provided, to say the least, the wrong signals to consumers.[31]

Some analysts have argued that the demand for energy is not at all price responsive, so that the decline in the node price should have had no effect on energy consumption. Nevertheless, even a small elasticity of demand of the order of 0.2 would imply an increase of about 2% in the quantity demanded, a substantial amount given that the daily deficits during outages were about 8% of "normal" demand.[32,33]

Note that we have shown the existence of two sets of different problems. First, the fact that in practice electric companies have never paid compensations of any significance meant that the price system is not in equilibrium under severe droughts, a result of article 99*bis*. Second, the fact that regulated prices do not rise even when there is the certainty that energy will be in short supply leads users to be unresponsive to declines in supply.

3.3. Regulatory governance and the 1998–1999 shortage

In the previous subsection we have argued that the rules of the Chilean price system cannot accommodate large supply restrictions. As Williamson (1985 ch.1) has stressed, when transactions cannot be (or are not) organized under a price system, governance structures become the main de-

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[31] The methodology led to somewhat curious outcomes. Endesa installed about 450 MW of new capacity between February and April 1999 in response to the shortage. According to the rules, the CNE assumed that the new turbines would remain there at least two years, and that that made the node price drop even further.

[32] Berndt (1991, pp. 328–335) reviews the international evidence and concludes that the shor -run demand elasticity is between 0.1 and 0.2. More recent evidence is reviewed by Nesbakken (1999), suggests that estimates of the elasticity of the short-run residential demand for energy vary considerably across countries, between 0.2 and 0.6.

[33] The node price is about 40% of the representative residential bill. Hence, a fall of 25% of the node price implies approximately a 10% fall in the price paid by residential users.

terminant of resource allocation. We now examine the weaknesses of Chile's regulatory governance and its failure to prevent outages.

Why was water used so quickly? As we have mentioned, the use of reserves is theoretically dictated by the OMSIC model which values water at its intertemporal opportunity cost. In practice, however, the use of water in reservoirs has frequently been the result of haggling between gencos and there is evidence that it was used too quickly during the period preceding the outages.

To see the incentives at play consider the sequence of events as a severe drought unfolds. The spot price should gradually increase as water becomes scarce and more expensive thermal plants begin to operate. Moreover, since water can be stored for future use, a shortage that is predicted in the near future (say, two months ahead) will raise the present opportunity cost of water. As soon as the opportunity cost of water reaches the operating cost of the most expensive thermal genco all available thermal plants will be in operation into the system; water in reservoirs will only be used to prevent outages. Since the spot price can rise well above the node price as the energy restriction unfolds, gencos that are net buyers face an unpleasant situation.[34] These companies would benefit from more water being released from the reservoirs if (i) there is the possibility that they do not have to pay compensations in the event of an outage (shifting the cost to users), (ii) that it may rain, thus avoiding an outage at the last minute, as had happened in 1997, or (iii) that they might be able to avoid paying the spot price to gencos that are net sellers during the outage.

The fact that a genco bases its operations on speculations about the future rains is not necessarily inefficient, as long as the speculator is made to absorb the cost of bad outcomes onto other participants in the market, i.e., if it faces the right prices. On the other hand, if gencos that are net buyers in the spot market do not completely internalize the costs of a shortage, then they have incentives to use too much water from reservoirs.[35] Figure 6 shows the weekly average of the spot price during 1998.[36] The spot price remained close to 20 mills until mid-June, because hydro-power supplied a large fraction of demand, even though it was well known that the *La Niña* phenomenon was present and that reservoirs were at low levels. Recall that energy in reservoirs fell by 2,300 GWh between January and June. At the same time, at least 1,400 GWh of thermal energy was not dispatched during those months.[37]

As we have noted before, there have been claims that the repeated failure of the Nehuenco

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[34]Note that the node price is normally around 20 to 30 mills a KWh; the spot price is close to 60 mills per KWh when the most expensive thermal plant sets the price, and it can climb up to 330 mills a KWh during a severe shortage.

[35]This is an instance of moral hazard caused by the failure of regulatory governance.

[36]As mentioned before, beginning in July 1998 there was disagreement within CDEC on the spot price. For this reason, prices reported in the figure are not necessarily official.

[37] We compute this number as follows. First, we determined the number of days where an "inefficient" thermal plant (as defined by CNE; see *Generación bruta mensual SIC-SING* at http://www.cne.cl/cnenew/electricidad/electric.htm) was not dispatched at all. Then we multiplied this number by the daily average energy produced by the inefficient generator in November 1998, where thermal generators where run at almost full capacity (i.e. in this way we constructed a proxy of each plant's capacity). The estimate is conservative because we ignored days where plants were run at less than full capacity.

plant was responsible for the excessive use of water. Colbún, its owner, wanted to have Nehuenco on line as soon as possible, thus reducing its need to buy spot energy from more expensive thermal gencos and there is no reason to think that it willfully misrepresented information. However, as a net buyer it benefited from optimistic announcement, since that would lower the future (and hence present) spot price, thus allowing more water to be drawn from reserves. The third important player in the power generation market, the predominantly thermal genco Gener, was a net seller during this period and thus was in favor of higher spot prices. Gener proposed a methodology to account for the uncertain entry of Nehuenco, but its proposal was not adopted.[38]

The spot price climbed to 60 mills during the first week in July as energy consumption increased and the more expensive thermal plants where dispatched (see figure 6). In early July CDEC predicted a shortage of 85 GWh during the second half of July.[39] As we have mentioned before, the Ministry of Public Works used the risk of outages as an argument to sell Endesa the equivalent of 500 GWh of water from the Laja and Maule reservoirs which were originally earmarked for agricultural irrigation.[40,41,42] The terms of the agreement were not made public, but it appears that Endesa was given free hand to use the water, since it run its hydro plants at full capacity during July and August, displacing thermal generation while the water lasted. Indeed, water in the Laja reservoir was valued at a price of 0 for the purposes of dispatch.[43]

It can be easily shown with a simple model that whenever a shortage is imminent the opportunity cost of water equals the outage cost. As seen before, in that case all available thermal plants should be operating at full capacity. Thus, a simple indication of excessive use of water during July and August is that some available thermoelectric plants were not in operation. Clearly, a fraction of the water was needed to prevent outages, but a conservative estimate is that at least an additional 65 GWh could have been generated by thermal plants during July and August.[44] Consequently, the spot price fell as thermal generation was displaced and in addition, Endesa was able to stop being a net buyer of energy for a while.

It is hard to explain why the water provided to Endesa in July 1998 was not sold at "market"

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[38]See Cámara de Diputados (1999, p. 103).

[39]See Cámara de Diputados (1999, p. 116).

[40]This amount of energy, valued at the outage cost (140 mills per KWh) is worth about US$70 million; according to Cámara de Diputados (1999, p. 35), Endesa paid between US$2,2 and 2,4 million.

[41]Water in reservoirs can be used for electricity generation and for irrigation. Water from the Laja reservoir can be freely extracted for generation when its volume exceeds 500 million m^3. Below that level, however, extraction for generation cannot exceed 47 m^3/sec. Endesa argued that the minimum level of the lake was lower than previously estimated (in other words, the reservoir could hold more water than originally thought). Consequently, the *cota* at which the lake contained 500 million m^3 was not 1,316.93 m but 1,313.18 m (Cámara de Diputados [1999, p. 57]). Hence, Endesa argued that it could freely use that water. The Ministry of Public works apparently accepted that argument.

[42]The Maule reservoir has capacity for 1,500 million m^3. When the volume is larger than 670 million m^3 Colbún, a hydro generator, can use the water freely. When the level is lower than 170 million m^3, all water is reserved for agricultural irrigation. In the intermediate range use for generation requires authorization by the Ministry of Public Works.

[43]See Cámara de Diputados (1998, p. 21)

[44]This estimate was obtained using the procedure described in footnote 37.

prices, or subject to the condition that it should not substitute for thermoelectric generation. Note that the November 1998 outages were caused by energy deficits of 76 GWh, which were similar to the 65 GWh of thermal generation displaced by hydro generation during July and August. Endesa (supported by some members of the CNE) argued that it owned the water and therefore has the right to use it when it saw fit, which of course meant that merit order of operations did not apply, contrary to the spirit of the law and economic arguments.[45] Dispatch should be decided by OMSIC, regardless of the private interest of the owner of the plant.

The disputes among gencos and the non-optimal use of reservoir water were at least in part the result of the CDEC's governance structure. Until September 1998, decisions in CDEC required a consensus and all members had veto power. In practice, however, the two gencos that were in a net buying position were in powerful bargaining position. First, until May 1999 CDEC conducted operations in the headquarters of Transelec, Chile's main transco, which is fully owned by Endesa. Endesa was the agent with the best information about the state of the reservoirs and in practice ran the system. Second, disagreements within CDEC had to be referred to the Minister of Economics, who could take up to four months to issue a decision and was usually reluctant to intervene in conflicts between gencos. Moreover, the cost of ignoring the decision of the regulator does not seem to have been high, given good legal advice, because courts are slow and do not understand complex technical issues.

A third reason for the overuse of reserves was a gross overestimation of the amount of snow collected in the Andes, which would provide runoff to feed rivers and reservoirs from December to March. According to one regulator, it became known only in November that there would be much less water than in the worse previous drought of 1968-69.[46] Nevertheless, the consulting firm that predicts the amount of water available and advises CDEC, which was fully owned by Endesa at the time, made predictions that became steadily worse from September to November, even though there is little snowfall after mid-September. There is no reason to think that the consulting firm misrepresented information. Nevertheless, there were no independent checks on these predictions despite the obvious conflict of interest, since more optimistic announcements lead to the use of more reservoir water and to lower spot prices, which is profitable for a net buyer such as Endesa. The regulator did have independent information that the there was less snow available from late August, when the Ministry of Public Works reported that its measurement stations showed snow levels were far below normal, but it did not react to this information.[47]

As we have mentioned before, the legal changes introduced by the statute of the law have made the CDEC far more independent (though some analysts question this fact). This should help in case of a future drought. However, it is an open question whether the newly independent CDEC is strong enough to withstand the pressures of gencos and the regulator. As suggested by the experience of 1998-1999, net buyers of power have strong incentives and the ability to lobby for

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[45] See Cámara de Diputados (1999, p. 19 and 61).

[46] Cámara de Diputados (1999, p. 14)

[47] See Cámara de Diputados (1999, p. 117).

using reservoir water. This tends to aggravate the effects of the years with little rainfall.

The importance of small details: The spot market We have mentioned before that in early July, the more expensive thermoelectric units became active and the spot price climbed to 60 mills. Endesa claimed that this spot price was not acceptable arguing that the repeated failures of Nehuenco had forced Endesa to use its water reserves too quickly, so the spot price could not be calculated running the model.[48] The Minister eventually issued a veredict, but in december of the *following* year. Moreover, by early November, it had become clear that 1998-99 would be far drier than 1968-69, the driest year considered in the node price calculations. There was very little spare capacity because Nehuenco was still out of order. Thus, when a coal-fuelled thermoelectric plant was unexpectedly shut down for maintenance (Gener's Ventanas II) and Endesa's combined cycle gas plant San Isidro failed, a shortage occurred. Electricity was rationed via random and unannounced cuts. The spot price should have climbed to the outage cost, but additional disputes between gencos ensued. Endesa and Colbún claimed that there would have been no shortage with the hydrology of 1968-69. Given this claim these two gencos offered two different lines of argument to avoid paying the outage cost: Endesa argued that the limitations of compensations to users also applied to spot price transactions, and hence energy exchanges between gencos should be valued at the variable cost of the most expensive thermoelectric plant (about 60 mills per KWh). Colbún argued that the spot price should have been calculated simulating OMSIC under the 1968-69 hydrology, leading to lower spot prices (at most 60 mills according to Colbún).[49] Hence, for one reason or another there was no official spot price to value energy transfers since the second half of 1998 and until mid-1999.[50] Net sellers still had to supply energy because of mandatory dispatch regulations, even though they did not know at which price and when they would be paid.

The dispute was referred to the Economics Minister who requested an opinion from the head of the CNE (as required by the law). The CNE answered within five days that energy exchanges during a shortage should be valued at the outage cost.[51] Nevertheless, the minister took almost four months to reach a decision (March 26). The verdict agreed with the CNE, but its efficacy was weakened by adding that the CDEC should determine when shortages occurred in November 1998. This addition made the decision void of content, since any dispute within the CDEC would be blocked by the gencos that would lose by the decision.

While no details have been made public, it seems reasonable to think that the delays and the ambiguity in the verdict were caused by lobbying pressures. The Economics Minister could have settled the dispute by stating that shortages had occurred using the records of physical outages that were registered by CDEC. Moreover, he could have asked the SEC to investigate the reason for the inexistence of a spot price, an anomalous situation, and to fine gencos who had behaved negligently.

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[48] See Iglesias (1999).
[49] See Landerretche (1998).
[50] See the tables with spot prices in `http://www.cne.cl`.
[51] See Landerretche (1998).

Thus, the government gave an unambiguous signal that it would not intervene effectively to settle disputes.

The lack of a spot price had serious consequences. Given that net sellers of energy expect they will be paid a price for energy that is lower than the outage cost, they have fewer incentives to add additional capacity to ease the shortage, or to buy back energy from free clients and self–generators.[52] At the same time, net buyers of energy also face weaker incentives to help ease the shortage. Since no compensations are being paid, the cost of not supplying energy to regulated users is small and they feel little pressure to add capacity or to buy back energy from free clients and self generators. In fact net buyers did not allow self-generators to sell in the spot market, which meant that about 100 MW of power did not reach the market.[53] Of course, these incentives are moderated by the fear of political retribution: Endesa added around 450 MW of diesel turbines, even though the above arguments would indicate that it was not in its best interests. Unfortunately, these additions arrived only gradually between February and April 1999. In the meantime, between December and March an additional 400 GWh of energy stored in reservoirs was used.[54]

Demand-side management To reduce consumption the regulator implemented three measures. First, voltage was reduced by 7,5%. Second, public offices were instructed to reduce "unnecessary" consumptions. Third, the government launched an ineffective and lukewarm campaign asking the population to save energy. Nevertheless, the main regulatory instrument for managing a supply restriction is the *rationing decree*. It allows distributors to cut service without being fined and forces gencos to ration their clients and to compensate regulated users for the energy they do not supply, within the limitations of article 99*bis* of the law.[55]

Demand management under rationing follows a complex procedure. Each day, CDEC must determine whether projected demand exceeds available energy for the next day, in which case a 'restriction' is necessary. The deficit is analyzed as if it were an additional plant whose 'production' must be allocated among gencos. Each genco allocates her share of the deficit among its clients, either by agreeing to decreases in consumption or with outages if the agreements are not sufficient. The computation of the deficit is used to determine the compensations to be paid to regulated users, since they are based on undelivered energy.

The efficiency of the mechanism depends on two conditions. The first is the accuracy with which daily deficits are calculated. In principle, determining whether there is a deficit is simple, since it is an output of the OMSIC model. The problem is that residual water in reservoirs can almost always be used to match supply and demand for energy, so determining whether a restriction exists

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[52]Self generators are users who are connected to the system but who own their own power plants (e.g. paper mills, shopping malls, etc.).

[53]See Cámara de Diputados (1999, p. 108)

[54]CNE (1999) argues that this water had to be used anyway for irrigation purposes.

[55]This is the only situation in which a distributor can cut service without being legally liable for damages. In practice, however, distributors can usually avoid paying damages by claiming that service disruptions are caused at another level of the supply chain.

becomes a political issue, hence political pressures can be used. Moreover, the executive appears to have believed that the political cost of energy rationing was large, and tried to avoid announcing that rationing was needed for as long as possible.

The executive shied away from issuing a rationing decree in July 1998, when the CDEC predicted a shortage and chose instead to grant Endesa the use of additional water. In September the executive ignored a rationing recommendation of the CNE, and waited until outages in November made it inevitable. From December through March 1999, Nehuenco was operational and there were no outages, so the executive pressed the CDEC not to declare restrictions and hence there was no reduction in consumption during those months. This meant that the scant water in reservoirs was still being used after November, leaving the reservoirs almost empty by late March, when Nehuenco broke down for a long period, thus causing a new round of shortages.

The second key condition of the rationing mechanism is the existence of compensations to regulated users. The problem is that the electric law has loose ends that hamper the application of the compensations mechanism, so its effectiveness depends on the behavior of regulators, specially the SEC.

Since the compensation mechanism is complex and has never been applied, few if any users have any understanding of how it works.[56] Part of the reason is that compensations are calculated and then paid to users by distribution companies, who nevertheless act as simple conveyors of the payments, for the compensations are paid by gencos that are in deficit and unable to fulfill their contractual obligations. Hence, distribution companies, which interact with users, have no incentives to explain the mechanism to users because they do not benefit from the reduction in consumption. Moreover, provided that a rationing decree is in force, the law allows the distributor to administer shortages using power cuts, at no cost. Consequently, there are no agents with an incentive to push for compensations and hence little political pressure in favor of enforcing the compensations mechanism, while there is considerable pressure from gencos to avoid paying them.[57,58]

Moreover, the law is ambiguous about the precise conditions under which compensations are to be paid. Part of this ambiguity stems from the fact that the amounts to be compensated must be determined by running the OMSIC model. Hence, unless there is strong action on the part of the regulator, compensations will not be paid. For example, as soon as outages began in November and the rationing decree was dictated, gencos in deficit claimed that no compensations were due because with an hydrology like 1968-69 all contracts could have been fulfilled, so that the limitation

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[56]Even during the shortage few economists were aware of the existence of compensations. When the mechanism was explained in academic seminars it took participants some time to understand its intricacies.

[57]The difference between the outage cost and the node price is about 100 mills. Hence, each GWh that is not supplied to regulated users should originate about $100,000 in compensations. Since the aggregate deficit was about 450 GWh, and regulated users make about 60% of total consumption, paid compensations are estimated at about $25 million.

[58]During the latter part of the shortage some members of Congress and majors pressured for the mechanism to be applied.

of article 99*bis* applied. The SEC did not perform an independent evaluation of these claims and accepted them at face value, despite the evident conflicts of interest of the claimants.

During the next hydrological year that began in April 1999, the same gencos argued that forecasts indicated that *La Niña* would be in Chile at least until August, implying that no compensations were due since Article 99*bis* did not consider compensations when there were droughts for two years in a row. The winter of 1999-00, however, was normal, so that according to the law, compensations should have been paid for all the outages that occurred between April and June. Nevertheless the SEC did not enforce the payment of compensations even when all the required conditions concurred.[59]

The SEC attempted to enforce compensations only when the limitation in article 99*bis* was eliminated after the law was changed in June 1999. Then it claimed that compensations had to be paid during all of the period while a rationing decree was in force, even in those days when no deficit was predicted by CDEC. Gencos, by contrast, argued that compensations were due only in those days when an actual deficit was predicted by CDEC. A legal battle ensued which has yet to be resolved. In any case, the fact that SEC attempted to enforce compensations even after the shortage ended and on days were no deficit occurred suggests that it viewed them as fines but not as a price meant to transmit the opportunity cost of energy to users.

4. Conclusions

The Chilean electricity shortage is a good case study of the interaction of regulatory incentives and governance. Despite of the fact that the system received two large supply shocks (the protracted failure of Nehuenco and the driest year on record) there is compelling evidence suggesting that it was possible to run the system with no outages.[60] The total deficit was about 450 GWh; an efficient management of water in reservoirs during 1998, or a regulator willing to use its powers to enforce the price system, or an executive less worried about its image and less fearful of the political costs of decreeing rationing, would have been enough to release far more than 450 GWh of energy.

Too much water was used at two key instances: during the first half of 1998 due to excessively optimistic forecasts of Nehuenco's entry; and between July and September 1998, when the government postponed a rationing decree and granted additional water to Endesa without setting any conditions on its use. Failure to make the price system work made it worthwhile to postpone or avoid the installation of additional capacity. Endesa only began installing additional turbines in February 1999. Furthermore, self generators did not have any incentives to sell into the spot market and gencos did not have any incentive to negotiate reductions of consumption with their free clients.

The 1998-1999 shortage exposed fundamental limitations of the Chilean price system. First,

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[59] It has been pointed out to us that the limitation of compensations in article 99 bis could have been used nonetheless to challenge in court any attempt to enforce compensations, and that this may have discuraged the SEC to proceed.

[60] In fact, similar restrictions were managed in 1989 and in 1990 without outages.

it is rigid and unable to adapt to large supply (and demand) shocks that are endemic to Chile's energy conditions. For example, the node price, which is paid by regulated users, fell by more than 25% between April 1998 and April 1999, while the country was experiencing the worst drought on record. Compensations to regulated users are supposed to transmit the opportunity cost of energy to users during shortage. Nevertheless, the law contained a fundamental inconsistency, the limitation of compensations in article 99*bis*. This limitation created an incomplete price system and made it easier for gencos that were net buyers to claim that no compensations were due. Even without the limitation, it is unlikely that the compensations mechanism would have worked. It is cumbersome to apply, few if any users are aware of it (much less understand its workings) and it had been successfully challenged in court in the past.

Second, a fundamental moral hazard problem is embedded in the Chilean system. Gencos that are net buyers have strong incentives to press for the release of water in reservoirs, because it reduces current spot prices while the cost of future shortages is partly shifted to users and other gencos. Finally, in order for it to work, the current price system requires a skillful regulator who can enforce the payment of compensations to regulated users and settle disputes among gencos. On all these counts the regulator did poorly.

The governance of CDEC was inadequate during the shortage. CDEC was not independent and gencos had veto power on the legal validity of its operational decisions. It is remarkable that neither the law nor the complementary statutes contemplated provisions to expedite payments for energy transfers in the spot market. This loophole probably stems from the fact that the law was designed when the electricity sector was state owned, in which case wealth transfers among different firms due to regulatory mistakes are not very relevant. This situation has improved somewhat since the establishment of an independent operations directorate whose operational decisions are legally binding.

A careful analysis of the role of regulators during the shortage shows that their behavior did not stem from lack of powers. While it is true that fines were very small until the law was changed in June 1999 and that regulatory decisions can be contested in court, the regulator had several unused powers. First, the Economics Minister did not settle disputes between gencos effectively, which was key for the price system to work and failed to investigate the breakdown of the spot market. Second, the Ministry of Public Works sold water reserves at prices far below their opportunity cost without setting conditions on their use. Third, the Ministry of Economics repeatedly failed to issue and enforce a rationing decree until it was forced to do it by outages. Fourth, the SEC did not enforce the payment of compensations and did not show a clear understanding of how and under which circumstances they should be paid. When it suddenly changed its behavior and tried to make gencos pay, it interpreted compensations as a fine but not as a price whose role was to transmit the opportunity cost of energy to regulated users. Moreover, government officials did not seem aware that the article 99*bis* left an incomplete price system, thus failing to address the problem. We believe the weakness of the regulators stems from two sources: the vulnerability of the executive (which is the hierarchical superior of all regulators) to the concentrated lobbying power of genco's

without countervailing lobbies from disaggregated users; and from their limited understanding of the incentives underlying the price system under a supply restriction.

More broadly, the Chilean shortage shows the limitations of a price system requiring heavy intervention of the regulator under supply restrictions. Even the most detailed law designed to avoid discretion invariably leaves loose ends and loopholes. In countries where governance structures are ill suited to fill in the loopholes, these have unanticipated effects and disputes are eventually settled by haggling and lobbying. In our view these suggests that these countries should rely as much as possible on market rules that clearly allocate property rights *ex ante* and leave the terms of contracts to be freely negotiated between private parties. Enforcement of property rights and contracts is very strong in Chile so that it is feasible to follow this approach. It is noteworthy that the same gencos that disputed prices in the spot market had no problems in fulfilling to the letter the long-term contracts that ruled part of their energy transfers during the shortage.

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Appendix

A. Chronology

1. **January-June 1998**

   - 2,300 GWh of water in reservoirs is used.
   - Thermal plants are seldom run.
   - Plants at the Laja are run close to capacity; all water in Colbún reservoir is used.
   - Spot price remains low.
   - Protracted failure of Nehuenco to enter.

2. **July 1998**

   - Spot price climbs violently in early July as CDEC predicts shortage.
   - Endesa disputes dispatch price. Divergence goes to the Economics Minister. Verdict delayed until December.
   - Endesa receives additional water in Laja and Maule reservoirs. Estimated amount is about 500 GWh.

3. **July-August 1998**

   - Additional 500 GWh of energy stored in reservoirs is used.
   - Some thermal plants are not run, despite of the fact that additional water in reservoirs is given to Endesa to the specific purpose of prevent shortage
   - Nehuenco repeatedly fails to enter.

4. **September–October 1998**

   - Government decides not to decree rationing, despite a September report of CNE advising it.
   - Some rain eases restriction and delays shortage.
   - Nehuenco repeatedly fails to enter.
   - Energy stored in reservoirs falls an additional 110 GWh in September and 34 GWh in October, bringing reserves to only 718 GWh by the end of October.

5. **November 1998**

   - Endesa reports that thaw is far worse than expected.
   - Ventanas II plant (about 5 GWh of daily production) goes into unplanned maintenance on November 5.
   - Random outages begin on November 11 through November 26. Government decrees rationing on November 11. Estimated unserved energy is about 76 GWh; daily deficit about 8 GWh.
   - Endesa and Colbún claim that draught is worse than 1968-69, that under that year's hidrology they would have fulfilled all their contracts, and thus, that no compensations to regulated users are due.
   - Endesa and Colbún claim that the draught is *force majeure* and that spot price cannot be the outage cost. Divergence goes to the Minister of Economics.
   - Nehuenco enters on November 24, easing the shortage.
   - Energy stored in reservoirs falls an additional 43 GWh bringing reserves to only 575 GWh at the end of the month.

6. **December 1998**

   - Energy stored in reservoirs falls an additional 110 GWh bringing reserves to only 460 GWh at the end of the month.
   - Rationing decree is not renewed when current expires on December 31.
   - Restriction is lifted.

7. **January 1999**

   - Energy stored in reservoirs falls an additional 100 GWh bringing reserves to only 360 GWh at the end of the month.

8. **February 1999**

   - Energy stored in reservoirs falls an additional 100 GWh bringing reserves to only 250 GWh at the end of the month.
   - Endesa's San Antonio 150MW plant enters in full capacity.

9. **March 1998**

   - Energy stored in reservoirs falls an additional 114 GWh bringing reserves to only 136 GWh at the end of the month.
   - Endesa's Cabreros turbines (170 MW) enter.

10. **April 1999**

    - Nehuenco brakes down, and outages return.
    - An additional 90 GWh in Endesa's Cabreros central enter.
    - 24 days of deficit with 160 GWh of unserved energy.
    - Endesa's Cabreros Turbines (170 MW) enter.
    - Endesa's Antilhue turbines (50 MW) enter.
    - Endesa's Antilhue turbines (73 MW) enter.
    - A new rationing decree is dictated on April 30. Proportional rationing is imposed.

11. **May 1999**

    - Nehueneco briefly returns, but is unable to run at full capacity except for a couple of days.
    - 25 days of deficit with 134 GWh of unserved energy.

12. **June 1999**

    - Nehuenco breaks down again.
    - 17 days of deficit with 79 GWh of unserved energy.
    - Rationing ends June 22, as rains ease the shortage.

Table 1
Installed capacity in 1998

Group	Thermo	Hydro	Total
Endesa	599	2,692.7	3,291.7
Colbún	370	697	1,067
Gener	1,194.5	2,44.9	1,439.4
Others	187.3	885	1,072.3
Total	2,350.8	3,891.6	6,242.4

Source: CDEC

Table 2
Affluents to reservoirs
(normal year = 100)

(a) Whole hydrological year

Reservoirs	Normal	1968-69	1998-99
Rapel	100	15	24
Invernada	100	42	63
Colbún	100	35	37
Laja	100	52	34
Chapo	100	106	71
Melado	100	37	39

Source: CDEC

(b) November through March

Reservoir	Normal	1968-69	1998-99
Rapel	100	6	11
Invernada	100	28	36
Colbún	100	34	22
Laja	100	58	29
Chapo	100	138	64
Melado	100	35	26

Source: CDEC

Table 3
Number of idle days, inefficient plants
January 1998-March 1999

Plant	Diego de Almagro	Huasco TG	Huasco TV	Indio	Laguna Verde	Renca
January-June	144	113	155	143	155	155
July-August	12	8	9	11	10	20
September-March	11	8	10	6	20	14
Total	167	131	174	160	185	189
Capacity (in MW)	678	1,088	208	224	871	1,830

Source: CNE

**Figure 1: Hydro energy available
1957-58 through 1996-97**
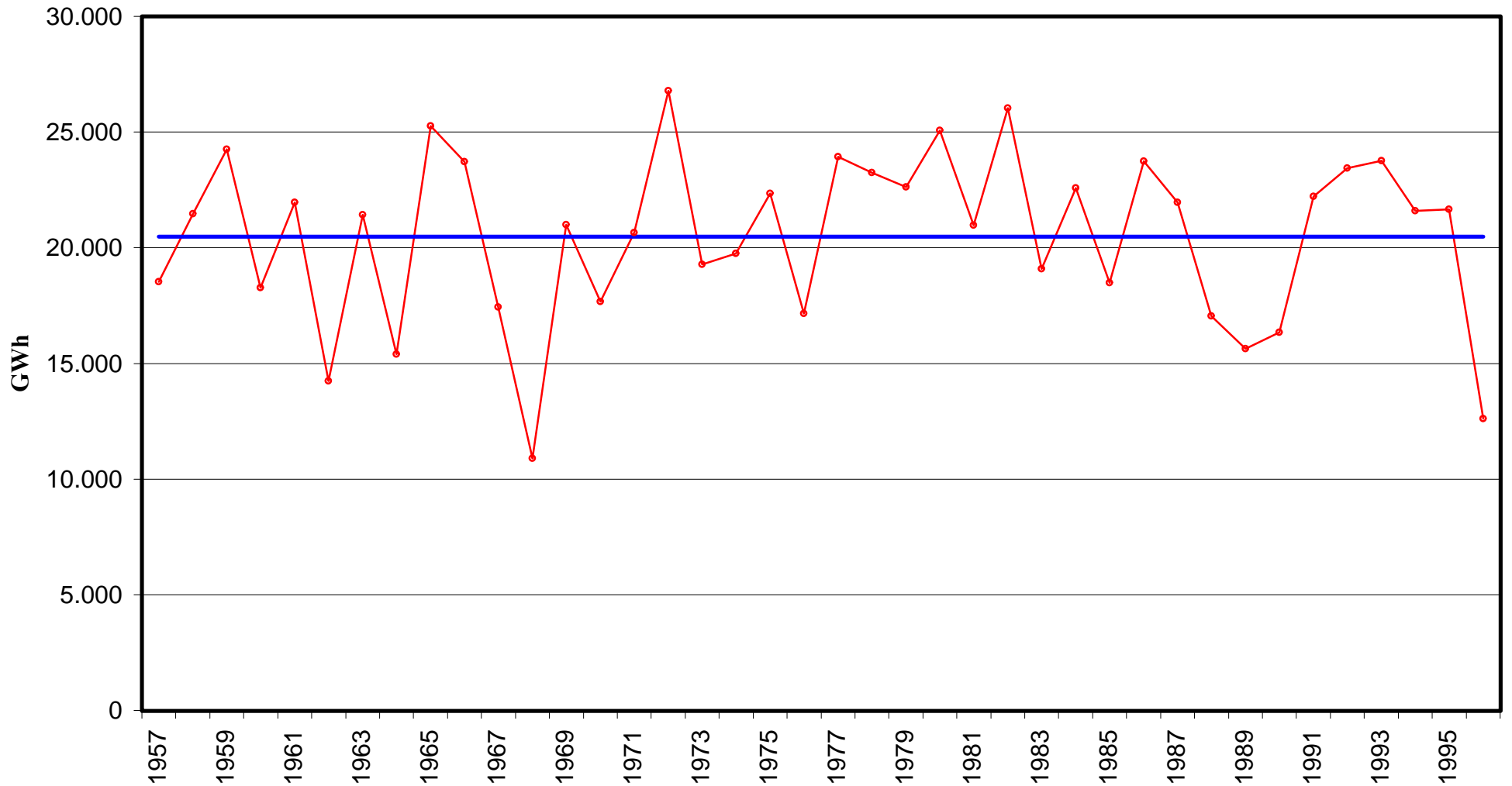
Source: Bernstein (1999)

Figure 2: spot and node price (monthly averages)
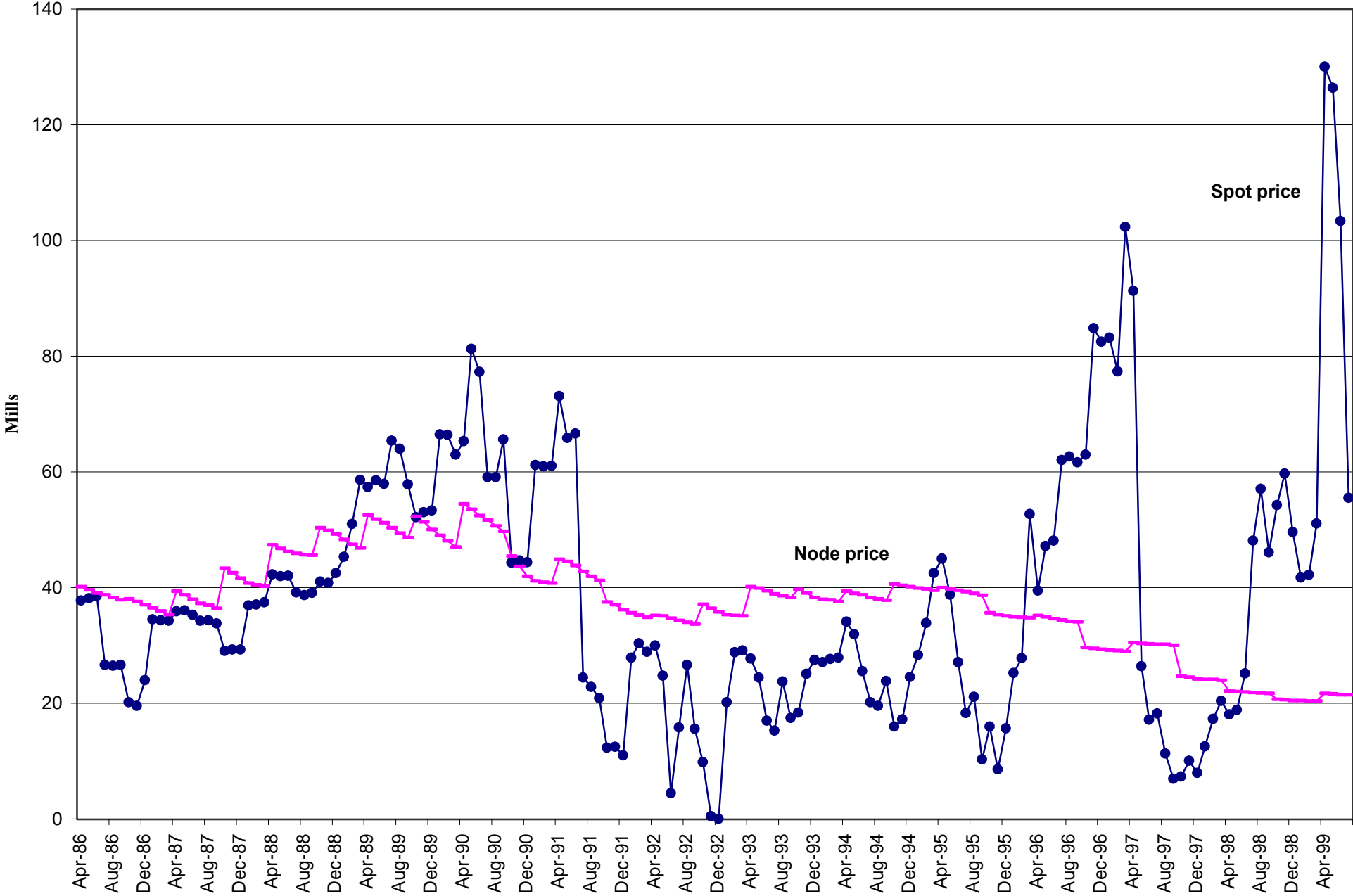
Source: CDEC and CNE
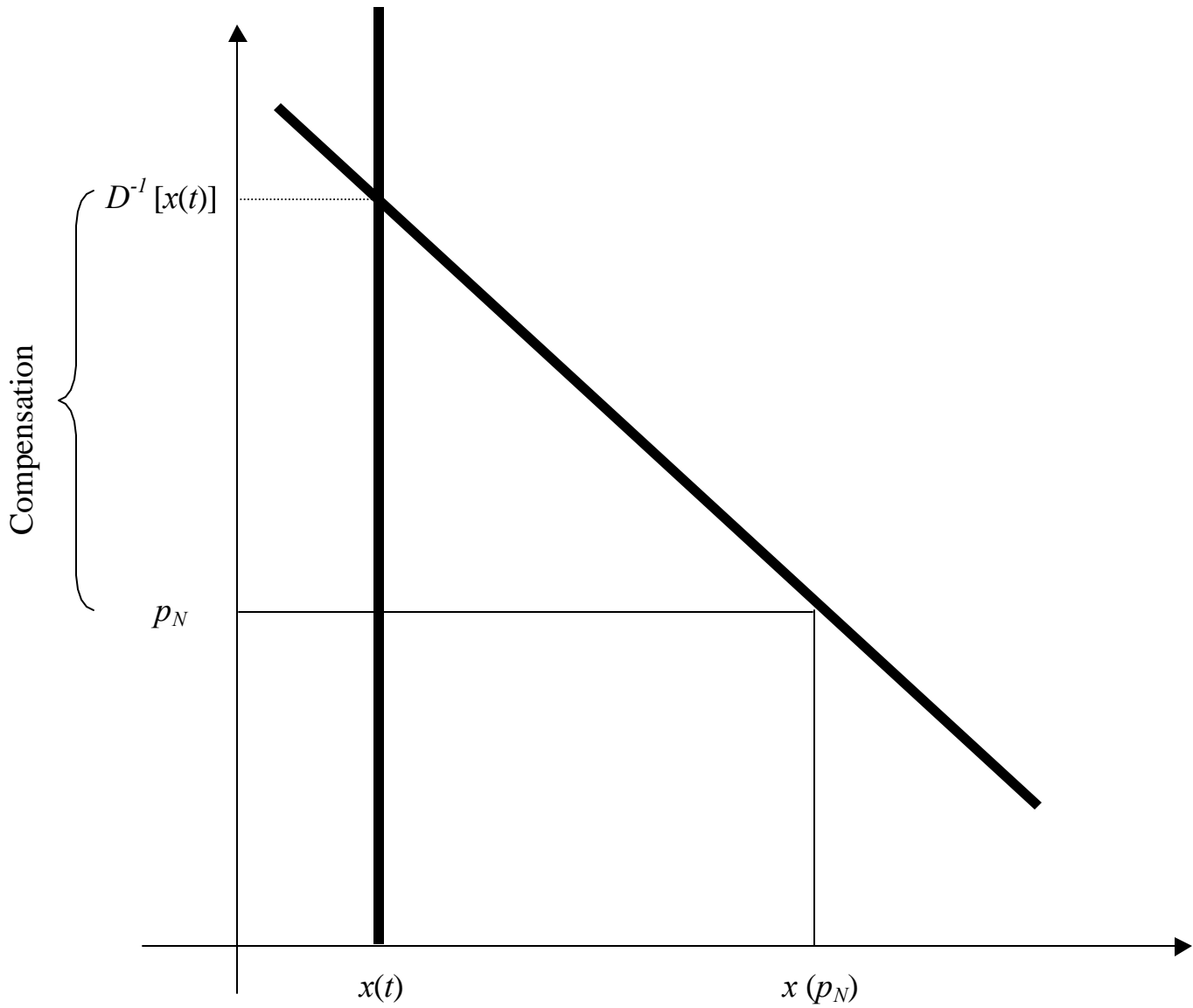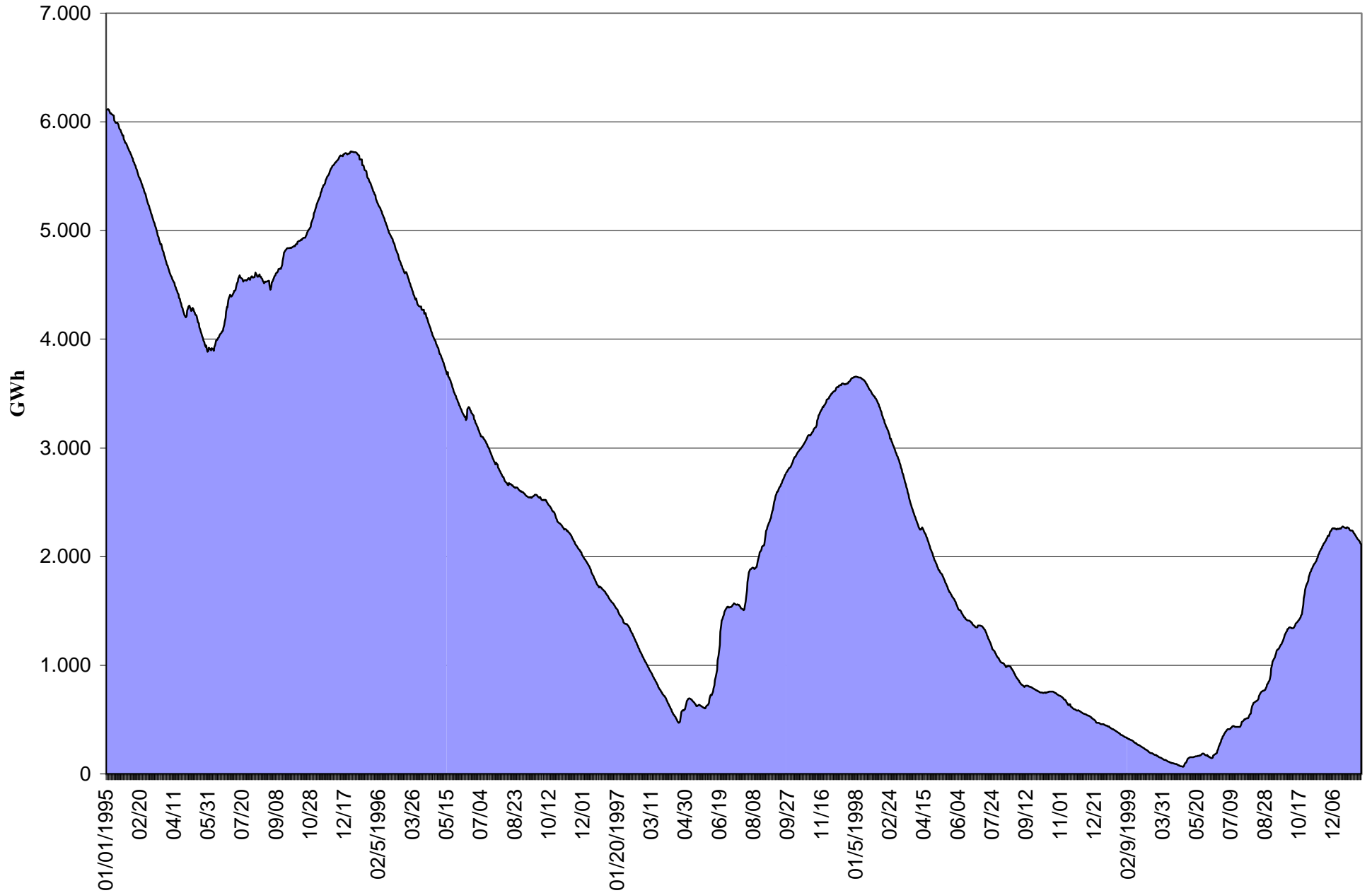
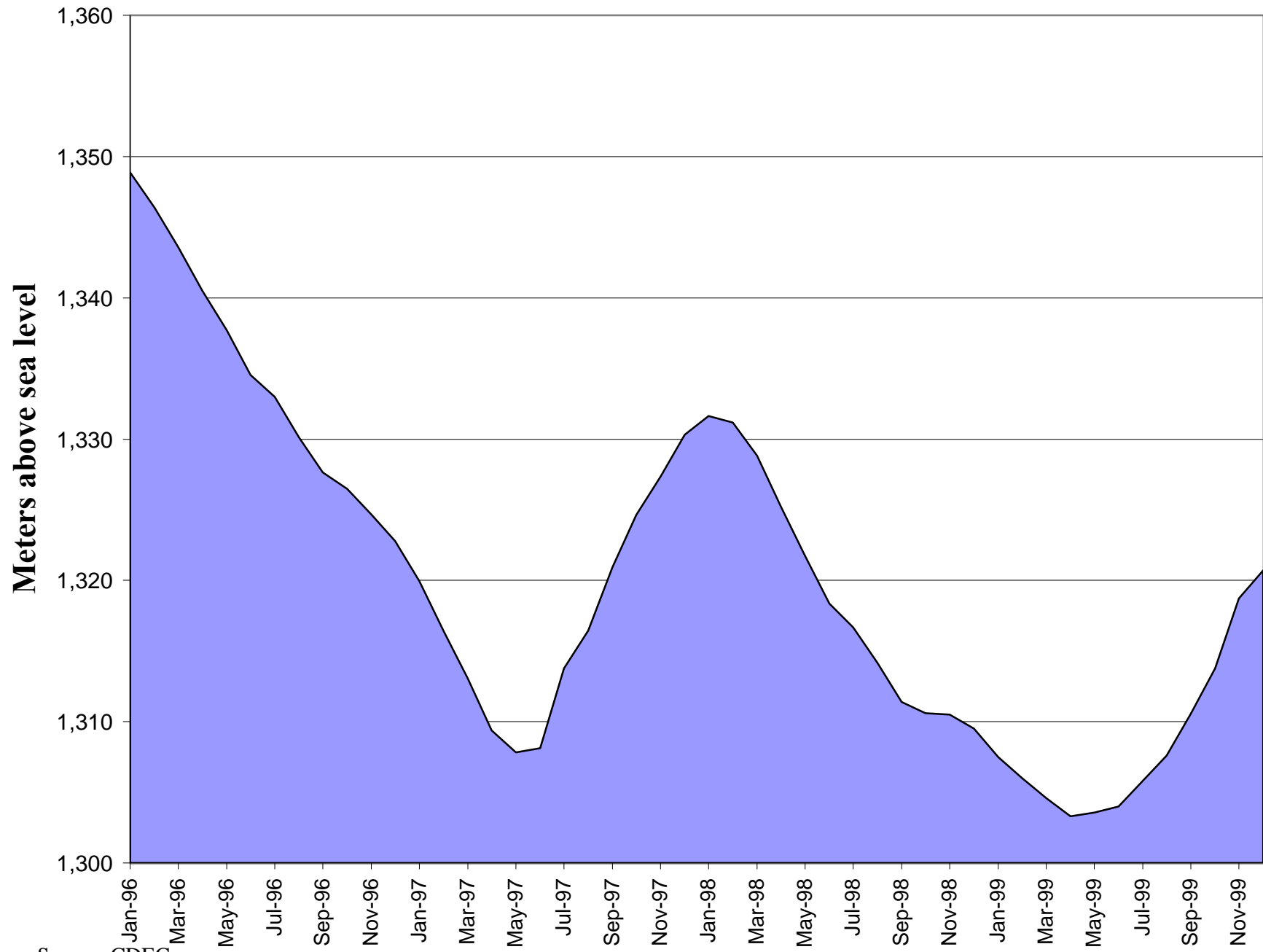**Figure 3**
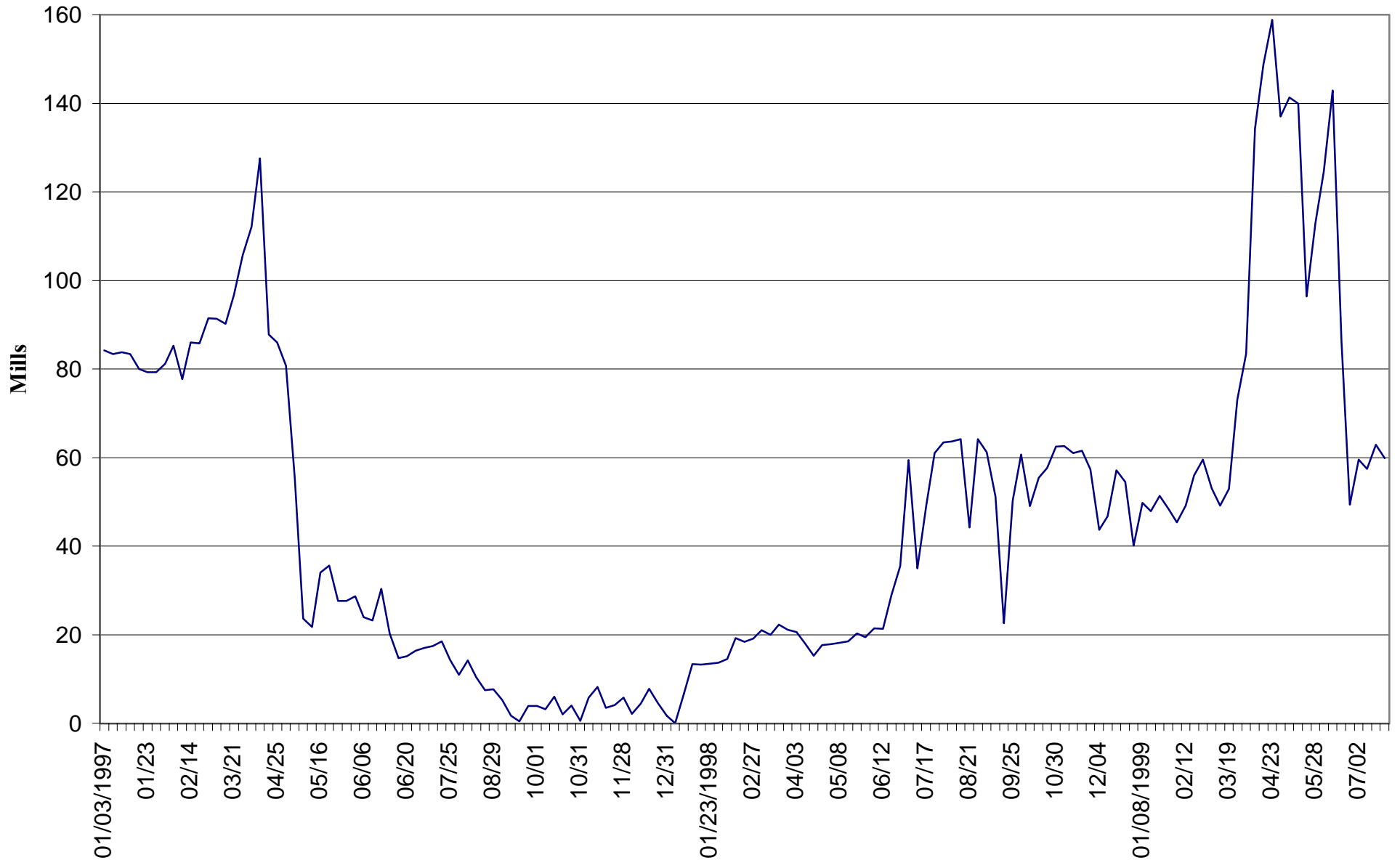**The compensation mechanism**

Figure 4: Energy in reservoirs 1995-1999

Figure 5: Level of Laja lake
1996-1999

Meters above sea level (y-axis, ranging from 1,300 to 1,360)

x-axis: Jan-96, Mar-96, May-96, Jul-96, Sep-96, Nov-96, Jan-97, Mar-97, May-97, Jul-97, Sep-97, Nov-97, Jan-98, Mar-98, May-98, Jul-98, Sep-98, Nov-98, Jan-99, Mar-99, May-99, Jul-99, Sep-99, Nov-99

Source: CDEC

**Figure 6: spot price
January 1997 - July 1999**

Source: CDEC and CNE