Working Paper #07-31

September 2007

Vertical Separation vs. Independent Entry in the Spanish Electricity Network: An Experimental Approach

Aitor Ciarreta
Universitat de Pais Vasco

Enrique Fatas
Universitat de Valencia

Nikolaos Georgantzis
Universitat Jaume

Carlos Gutiérrez Hita
Universitas Miguel Hernadez

Vertical separation *vs.* independent downstream entry in the Spanish electricity network: An experimental approach[#]

Aitor Ciarreta

Dpt. of Economic Analysis, University of the Basque Country

Enrique Fatás

LINEEX & Applied Economics (I), University of Valencia

Nikolaos Georgantzís[*]

LEE/LINEEX Economics Dept., Universitat Jaume I and University of Cyprus

Carlos Gutiérrez-Hita

Dept. of Economic and Financial Studies, University Miguel Hernández.

Abstract

We present experimental results from a series of sessions organized using the *Power Market* simulator; a software designed to realistically replicate the Spanish Electricity Market. In the experiments reported here we compare the *status quo* to two alternative treatments which represent alternative market structures. In one of them, labeled as vertical separation, we assume that power generating firms and electricity distributors-end-suppliers belong to separate business groups. In the second, we study the effect of entry by independent end-suppliers. Both alternative scenarios dominate the *status quo* in terms of market efficiency, whereas the latter of them dominates the former.

Keywords: Experimental economics, Spanish Electricity Market, vertical relations.

JEL: C90, L43, L51, L53, L94

[#] We thank the NET Institute (www.NETinst.org) for financial support.

[*] Corresponding author: University of Cyprus, Faculty of Economics and Management, Economics Department, PO Box 20537, CY-1678 Nicosia, Cyprus. E-mail: nikosgeo@ucy.ac.cy

Introduction

The organization of the electricity market in Spain was transformed by the Royal Decree 54/1997. This law liberalized the market for electricity generation and introduced a spot market for electricity which started operations in January 1998.[1] Until 1996 there was no effective market to trade electricity and five companies possessed all the generation power, controlled transmission networks, and local distribution grids.[2] Since the early nineties demand has been rising above GDP increases. Furthermore, the requirements by the European Community to create and improve an effective electricity market in each member state forced the government to design a more competitive scenario for the electricity sector in Spain.

However, despite this liberalization process, there is still a high concentration in both the generation and distribution sectors. Besides, larger generators are also buyers in the pool. As a result, Spain's large electricity companies are active on both sides of the electricity spot market, selling electricity as generators and buying it from the spot market as retailers. Together with an inelastic demand, these features suggest that firms will use their market power to set prices above costs, We argue that the *status quo* in the Spanish electricity market (SEM, hereafter) is a vertically integrated structure, so that firms may exert an effective market power.

The main objective of the present study is to compare the *status quo* industry structure of the SEM described above with two alternative structures. One of the alternative structures involves entry by independent firms into the distribution sector. The other structure is the result of vertical separation between producers and distributors. Comparisons will be performed using the experimental data obtained from three implementations of the **PM** software

[1] This followed liberalization in the UK electricity market and was implemented simultaneoously with liberalization in Carlifornia.
[2] Two firms, Endesa (EN) and Iberdrola (IB) owned more than 70 percent of the total generation capacity.

corresponding to three alternative treatments: T1 (*status quo*), T2 (Vertical Separation) and T3 (Independent Entry). Our aim is to study the effects of vertical separation and independent entry not only on the market clearing price, but also on the following aspects of the market which have been neglected in all previous work so far:

- The ability of the sector to deal with demand- and supply-specific uncertainty with special emphasis to daily and seasonal variations.

and

- The frequency with which unfavorable demand or supply conditions lead to the interruption of electric energy provision.

Our results are interesting for similar regulatory measures implemented in an increasing number of countries aiming at a more competitive price formation mechanism.

Recently, several authors have studied the implications of the current conduct and performance of firms involved in the production and distribution of electric energy in Spain. Most of them warn us on the possibility that the market clearing mechanism used to determine electricity prices may facilitate collusion.[3] A somehow different approach is used by Ciarreta and Gutiérrez-Hita (2005, 2006), to reach a similar conclusion, according to which collusive outcomes are favored by the way in which firms submit their bids to the market.

In this paper, we explore a different way of improving the efficiency of the electric market in Spain, focusing on structural changes rather than studying collusion-facilitating aspects of firms' conduct. We propose and

[3] See for example the work by Fabra and co-authors (Fabra, 2003; Fabra et al., 2002; Fabra and Toro, 2006, Fabra et al., 2006), arguing that the auction used to clear the market may be responsible for the firms' increased ability to sustain prices which exceed those that would be in place if a more competitive mechanism were adopted.

study two alternative market structures in comparison to the *status quo*. The first of them concerns the result of breaking the vertical links between producers and distributors of electric energy. A similar suggestion emerges from the analysis by Gutiérrez-Hita (2006), although his approach is very different to ours. A second structural change proposed here is the result of entry by independent firms in the distribution of electric energy. Given the dynamic and complex nature of the market, none of these two types of changes is expected to cause results which can be trivially predictable from textbook Industrial Organization. Furthermore in all the studies mentioned so far, some important features of the industry have been systematically ignored. This has been the case, for example, with demand and supply dynamics, uncertainty due to weather and other external conditions, and asymmetries in firms' production plant configurations. For obvious methodological reasons, the resulting complexity regarding the combination of the aforementioned factors with the market clearing mechanism is also an underinvestigated question. Needless to say that none of the numerous recent studies on electricity markets has taken into account these important aspects in their recommendations for economic policy and (de)regulation. Furthermore, supplier asymmetries and vertical relations between producers and distributors, respectively selling to and buying from a pool are also neglected, although central to the case of an Electric network.

Without underestimating what can be understood on real world markets from abstract setups of reduced complexity, we claim that the experiment whose results are reported here accounts for important but greatly ignored details which are central in the case of an electricity market. Among them, daily and seasonal fluctuations affecting the demand and supply conditions seem to be the most important.

It should be noted that laboratory data have been broadly used to study resource and energy markets. However, most theoretical and experimental approaches have adopted simple abstract environments. In this paper we argue that if complexity, uncertainty and dynamic considerations are important for the functioning of such markets, our experimental design brings us as close as one can get to the market under study without the usual simplifying assumptions (symmetry, analytical tractability, etc.) which may not be as innocuous as is usually claimed or wished. Thus, apart from using the laboratory to address questions which are specific to this type of markets, an important novel feature of our approach is the realism of the software used to simulate the industry under study. With this, we do not argue that modelling real world markets though simpler abstract settings is not a useful strategy, but here we propose an alternative approach, allowing us to get closer to real world case under study at a reasonably low cost.

The Experimental Economics Laboratories of Valencia (LINEEX, http://www.uv.es/lineex) and Castellón (LEE, http://www.lee.uji.es) possess a unique experimental environment which was constructed, following engineering advice, to simulate the exact supply and demand conditions (including weather variations and daily and/or seasonal demand fluctuations) experienced by the producers and distributors of electric energy in Spain. At the same time, experimental subjects' interface has been developed in a way which reflects the productive structures, technological specifications, capacities and restrictions of each one of the producers of electric energy in Spain. The result of this effort has been materialized in the experimental software **PM** which is joint intellectual property of the two laboratories. The market-clearing mechanism implemented reproduces all the details of the auction adopted in the Spanish electricity pool.

A first set of sessions was run confirming the experimental subjects' ability to learn and behave in an economically meaningful way, which reproduces the current situation of the market. Daily demand fluctuations produce prices which follow the usual pattern: "Extreme Peak" prices are higher than "Peak" prices, the latter are higher than "Semi-valley" prices which are higher than "Valley" prices.

As mentioned above, in the study conducted here we aim at studying two alternative scenarios concerning the future of the industry. In the first alternative scenario (Treatment 2), we implement a market structure in which producers and distributors of electric energy are (vertically) independent entities. In the second alternative scenario (Treatment 3), we consider a more competitive distribution with a number of small but independent firms entering the downstream (distribution) market. Results from both alternative treatments will be compared to the benchmark case (Tretament 1) representing the status quo of the sector.

Hopefully, our results will contribute to fill the gap between theoretical results based mainly on simple, abstract, symmetric setups and a complex reality with asymmetric producers and distributors facing a complex and uncertain economic system.

2. Methodology and Experimental Design

The experiment proposed here is based on a three-treatment design. The first treatment (T1) is based on sessions which implement an industry structure which closely replicates the current status of the SEM. The two alternative treatments are inspired on the recommendations by several authors favoring either vertical separation of between producers and distributors (T2) or independent entry (T3) in the distribution market. In fact, the two scenarios have never been compared to each other so far. Furthermore, from a methodological point of view, it has been impossible so far to study these two alternatives in the presence of all the complexity governing the demand and supply conditions of the SEM.

In all our treatments we captured the essence of the market dynamics by focusing on the four common price auctions that generate power prices in Spain. Our main scope was to analyze the introduction of competition in the auction to analyze its effect on market prices. For this reason, while offers (bids) producers (sellers) were chosen by human subjects, the technological side of production was simulated in our servers using data coming from actual Spanish firms and final demand conditions were also simulated using data from the Spanish power market.

We ran three different treatments; every treatment simulated a different market condition. In the first one, every market included ten firms. Half of them sell electric power to the market, whereas the remaining five distribute power to final consumers.

Table 1 summarizes the main features of the other two treatments relative to our baseline:

	Treatment 1	Treatment 2	Treatment 3
# of producers	5	5	5
# of sellers	5	5	7
Vertical teams	Yes	No	Yes
# of markets	5	5	5
# of sessions	1	1	1

Table 1. Experimental Design

The main differences between treatments are the following. In the baseline condition (Treatment 1), all participants participated in teams made up of one producer and one seller. Earnings were equally divided among each team's members at the end of the experiment. In the other two experimental treatments, competition was introduced by breaking the vertical linkages between firms (in Treatment 2 subjects were paid on a purely individual basis), and increasing the number of independent sellers in the market (from 5 to 7 in Treatment 3).

We used a between-subject design, as each participant faced only one environment and one condition. Participants were assigned to one market side at random and played a finitely repeated (32 rounds) game with fixed roles. Rounds reproduced the seasonal conditions of demand and production by a sequence of seasons.

Sessions were run at the LINEEX computer lab of the University of Valencia. We aimed to gather data from fifty (sixty in treatment 3) firms for each treatment, grouped in five markets. Every treatment was run in a single session as the number of available computers in LINEEX's main room is 64. The number of firms varies across treatments due to the experimental design.

Subjects were recruited among the graduate and undergraduate student population of the University of Valencia and the graduate population at the Technical University of Valencia. In the former, we recruited among economics and business graduate and undergraduate students with at least intermediate knowledge of industrial organization. In the latter, only graduate students from the School of Industrial Engineers were allowed to participate in the experiment.

The recruitment procedures were the standard ones in Valencia. Students received an e-mail message announcing sessions. They then had to physically sign themselves in on a bulletin board. Subjects were only allowed to participate in a single session.

At the beginning of each session the experimenter read aloud the instructions and subjects asked as many questions as they wish. All questions were answered publicly by the experimenter. Before beginning to play, all subjects were asked to complete a short quiz about the payoffs and the rules of the experiment. The full text for the instructions and quiz are available from authors upon request.

Rather than using abstract terminology we employ a rather naturalistic corporate context. For example, firms were explicitly referred to as "producers" and "sellers". They were told to conduct a "firm" (or being part of a holding of firms in Treatment 2). We avoided the use of terms with what we considered strong connotations. For example, when being part of a team, subjects were not asked to cooperate (or fight) between them. They had no information about the rest of the treatments run in the experiment and we did our best to minimize contamination between subjects participating in different sessions, although we believe that this was not a major issue due to the complexity of our design.

The instructions stressed their individual roles in the experiment. As it can be seen in the instructions, the meaning of bids and offers was carefully explained to them, as well as the relevance of seasonality and production technologies. For experimenters who are used to worrying about repeated game effects, the use of fixed groups may seem like a strange design choice. However, the field settings that we are interested in simulating involve repeated interactions among the same agents. Repeated game effects and history dependence are presumably quite natural in these settings.

Subjects knew in advance that there would be a total of 32 rounds and that the demand condition would change depending on seasonal market conditions. The cost of a power supply interruption was also kwon in advance.

In each round all participants had to simultaneously submit their bids and offers for electric power. The screen on which subjects made their decisions displayed information about production costs (final demand) for producers (distributors). The PM software was developed from scratch using Java language. Figures 10, 11 and 12 are screenshots from this software. Both figures show the complex information available to subjects before and after they made their decisions and the intensity of their efforts doing their job.

Once their bids and offers were submitted, the software computed demand and supply functions and the four market prices. Firm’s payoffs were computed according to each firm buyer (seller) constraints. Figure 12 shows a sample output.

Separate windows on the feedback screen showed firms’ results for each market at the aggregate level. In all rounds subjects had full information about their own costs and profits, and market prices coming from each of the four common price auctions. Information about the profit level of all other participants remained unknown to them. Moreover, they had no information about other markets' performance in the same session.

At the end of the session, each subject was paid in cash for all rounds played plus a show-up fee of five euros. Payments took place on an individual and private basis. Recall that all payoffs are in "ECUs" (experimental currency units) which were converted to euros. The average total payoff was 95.29 € and the average session lasted about 150 minutes (another 60 minutes were used to explain the instructions and run the quiz). These earnings were sufficiently large to generate a good supply of subjects.

3. Results

In this section, we present the results obtained from 17 experimental markets: 6 under T1, 6 under T2 and 5 under T1. The discussion is based on the evolution of period averages of prices over 32 periods, plotted in Figures 2-8 and the number of supply interruption decisions in Figure 9. The first three of them are constructed to compare prices across the four different phases of demand during a day within each one of the treatments. These comparisons can be seen as a test of consistency for our experimental results, given that the price of electric energy in the "Valley" should be expected to be lower than the price in a "Semi-valley", which in its turn should be lower than the price on the "Peak" and this, lower than the price on the "Extreme Peak".

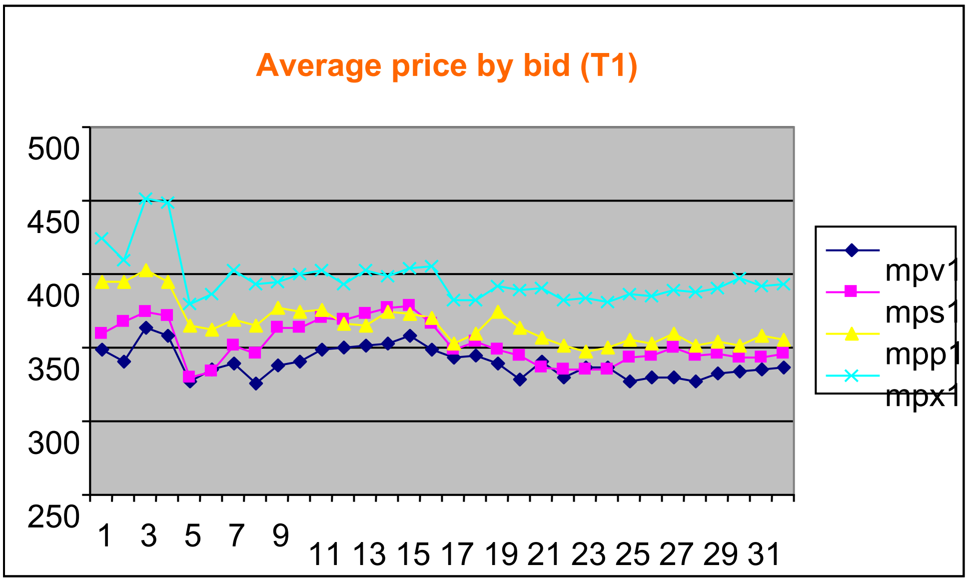

FIGURE 2: Evolution of price averages for the four daily phases in Treatment 1 (mpv1: Average price for "Valley", mps1: Average price for "Semi-Valley", mpp1: Average Price for "Peak", mpx1: Average Price for "Extreme Peak").

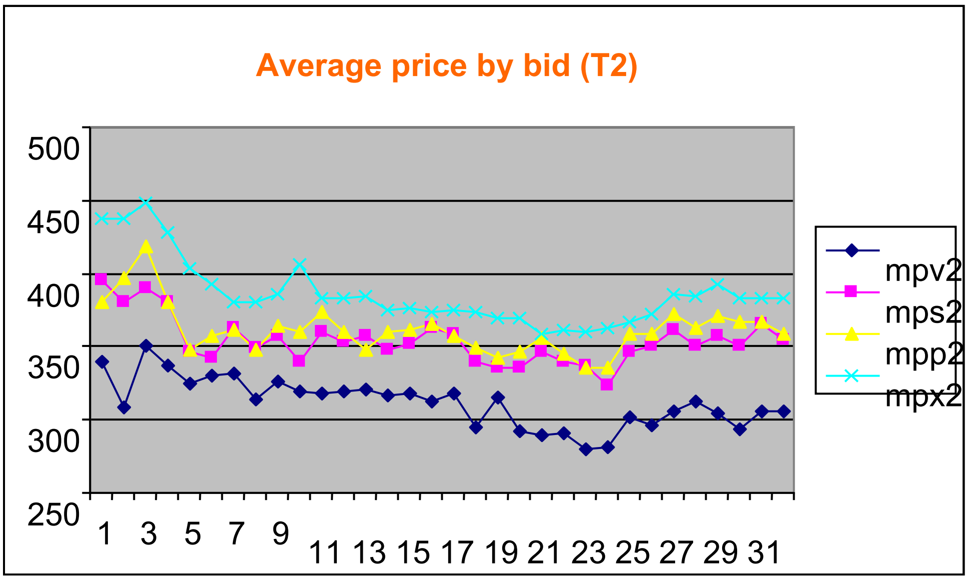

FIGURE 3: **Evolution of price averages for the four daily phases in Treatment 2 (mpv2: Average price for "Valley", mps2: Average price for "Semi-Valley", mpp2: Average Price for "Peak", mpx2: Average Price for "Extreme Peak").**

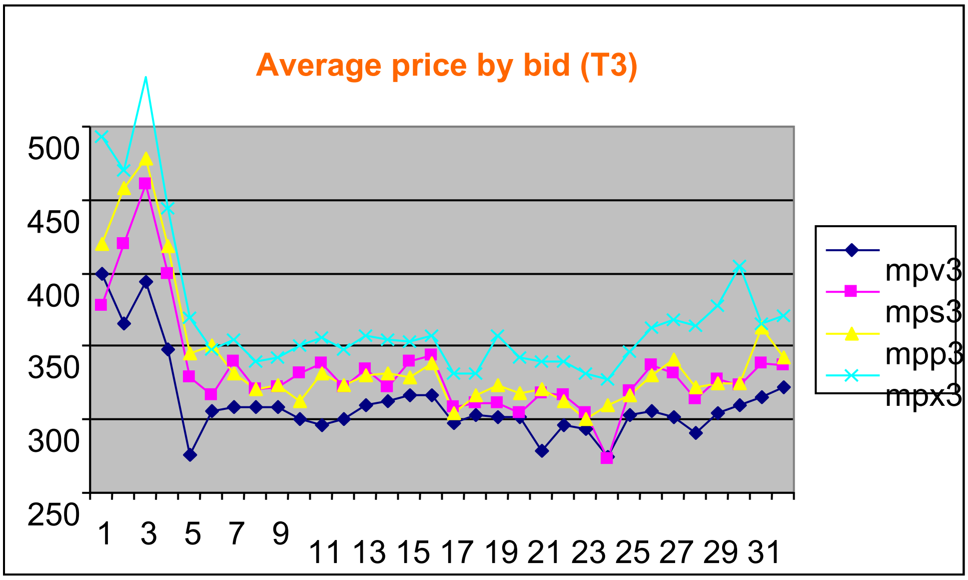

FIGURE 4: **Evolution of price averages for the four daily phases in Treatment 3 (mpv3: Average price for "Valley", mps3: Average price for "Semi-Valley", mpp3: Average Price for "Peak", mpx3: Average Price for "Extreme Peak").**

TABLE 2: Average prices by treatment and hour						
	Treatment 1		**Treatment 2**		**Treatment 3**	
	T1	***T1-stage***	***T2***	***T2-stage***	***T3***	***T3-stage***
pv	339.8 (51.3)	252.4 (39.5)	311.6 (51.4)	311 (58.3)	311.4 (57)	283.8 (31.7)
ps	353 (48.8)	291.4 (36)	353.9 (39.2)	351.7 (34.4)	334.2 (59.1)	325.9 (39.7)
pp	366 (57.4)	333.4 (25.9)	361.5 (37.5)	359.2 (33)	341 (63.5)	349.7 (33)
pep	397 (44.3)	341.4 (18.3)	386.2 (44.5)	394.6 (44.6)	369.5 (68.8)	375.3 (37.4)

Table 2 reports the average prices by treatment and hour. From the table, we see that on average, valley prices are the highest under treatment 1. There are not mean differences between semivalley and peak prices under treatments 1 and 2. Thus, introducing upstream-downstream competition does not seem to be the most efficient way of enhance competition. Results are changed when more independent distributors are allowed to operate in the market. Introducing upstream-downstream has a procompetitive effect only during valleys, whereas the entry of more independent distributors guarantees lower prices also during semivalleys, peaks and extreme peaks.

Generally speaking, both our working hypotheses receive some support by our data, as can be seen in each one of the Figures 2-4. However, if we concentrate on the differences between “Semi-Valley” and “Peak” prices, we see that the aforementioned general picture becomes less clear and the inverse ranking than that implied by our hypotheses is obtained in some cases. On the contrary, “Extreme Peak” and “Valley” prices are clearly the highest and the lowest in all periods of the experiment in all treatments, which implies a strong confirmation of the hypothesis that our design yields meaningful responses to the implemented daily fluctuations of demand.

Let us look now at graphs 5-8. On them, comparison of price averages across treatments provides a first approach to the main conclusions of this paper.

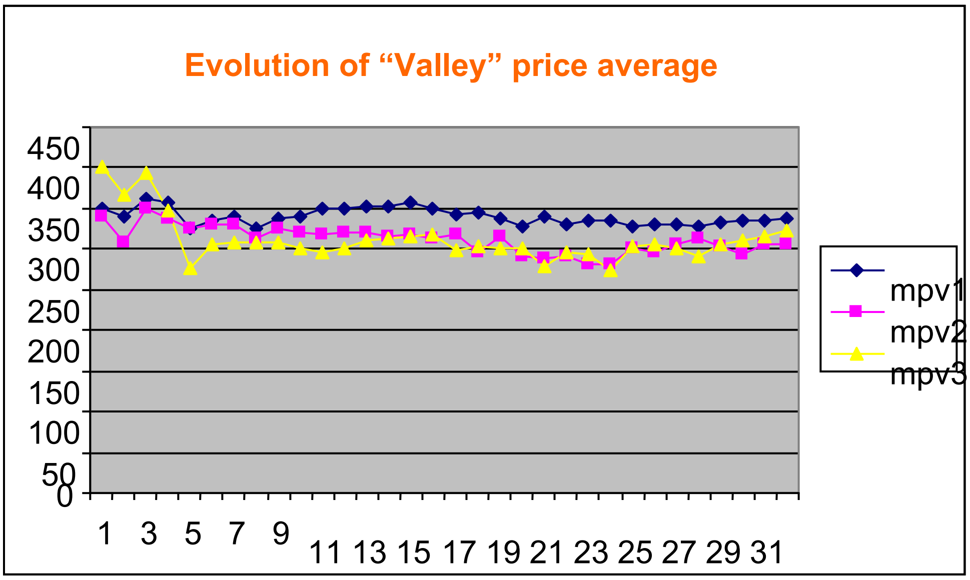

FIGURE 5: Evolution of "Valley" price averages for the three treatments (mpv1: Average price for "Valley" in treatment 1, mpv2: Average price for "Valley" in treatment 2, mpv3: Average price for "Valley" in treatment 3).

Figure 5 indicates that both vertical separation (T2) and independent entry (T3) in the market for electric energy distribution would reduce the prices of electricity as compared to the *status quo* (T1).

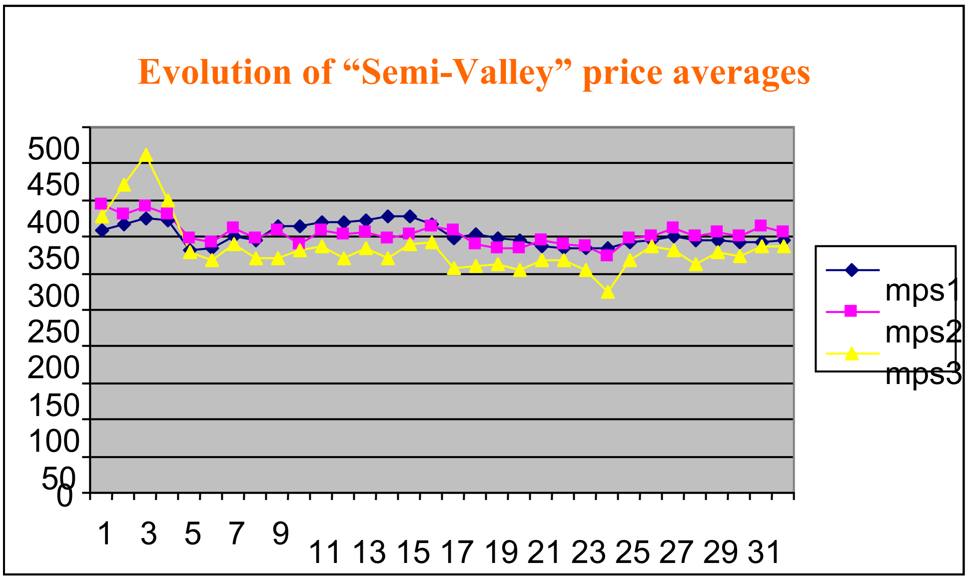

FIGURE 6: **Evolution of “Semi-Valley” price averages for the three treatments (mps1: Average price for “Semi-Valley” in treatment 1, mps2: Average price for “Semi-Valley” in treatment 2, mps3: Average price for “Semi-Valley” in treatment 3).**

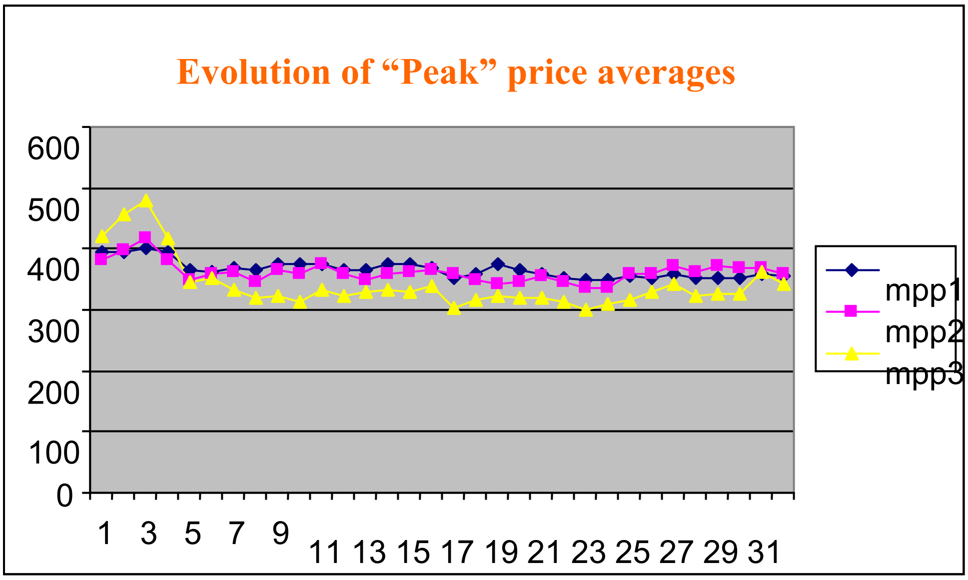

FIGURE 7: **Evolution of “Peak” price averages for the three treatments (mpp1: Average price for “Peak” in treatment 1, mpp2: Average price for “Peak” in treatment 2, mpp3: Average price for “Peak” in treatment 3).**

Regarding the prices of the “Semi-Valley” phase, Figure 6 suggests that the two alternative market structures studied here have a moderate effect on prices as compared to the baseline treatment (T1). More specifically, only the independent entry alternative seems to have a clear effect on prices, which are in this case systematically, although moderately, lower than in the other two treatments. On the contrary, vertical separation is not found to have any clear competition-enhancing effect on the prices of this demand phase.

Figure 7 indicates a similar pattern for “Peak” prices. Independent entry in the distribution of electric energy lowers prices, but less than in the case of what was found in the case of the “Semi-Valley” phase. Like in the previous case, vertical separation leads to prices which are not significantly different from those obtained in the baseline treatment for the same demand phase.

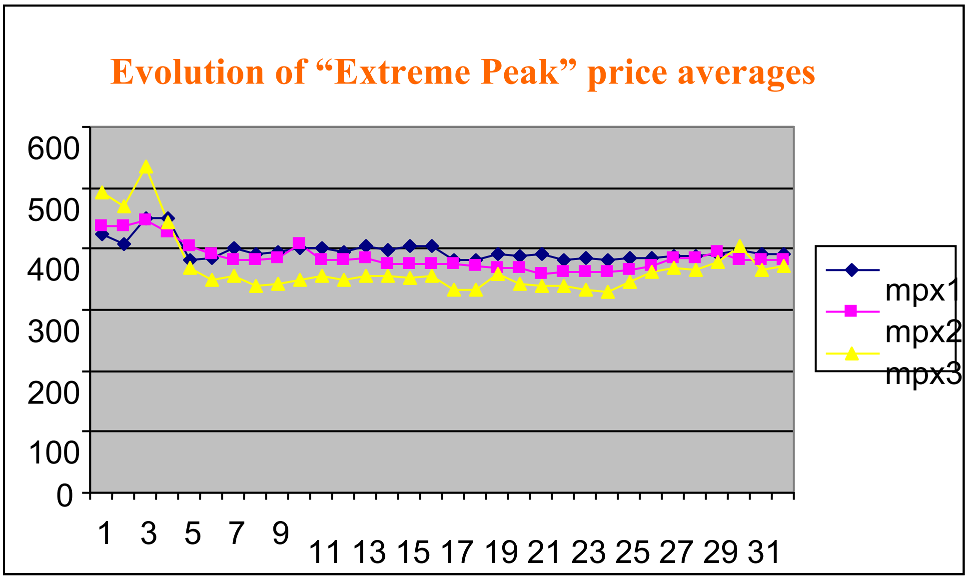

FIGURE 8: Evolution of “Extreme Peak” price averages for the three treatments (mpx1: Average price for “Extreme Peak” in treatment 1, mpx2: Average price for “Extreme Peak” in treatment 2, mpx3: Average price for “Extreme Peak” in treatment 3).

Therefore, our results indicate that both structural changes considered here would lead to lower prices for electric energy. However, independent entry into the market of electric energy distribution is found to be systematically more effective than vertical separation in lowering prices.

Another interesting feature of our results concerns an aspect which has not been studied so far, but constitutes a central concern of policy makers regarding the function of the market for electric energy. The data contains information on seasonality, hydroelectruic resources, temperature and availability of new technologies. The effects of these variables on prices is tested.

If the weather is dry, hydroelectric generation cannot be used to cover baseload demand because the opportunity cost of water useage is very high. Therefore, generation comes from fossil fuels, which have a higher variable cost. Table 3 computes average prices under the different treatments depending on water reserves and for the four different types of hours.

Table 4 presents the results under three different scenarios of weather forecast. Interestingly, cold waves are more price rocketing than heat waves. The shape of the demand curve may be the reason of this behavior. We may observe more electricity is consumed during cold waves (heating) than during heat waves (cooling). Once again learning makes a difference during extreme peak hours under treatment 2 and cold waves.

Table 5 summarizes the results by season, treatment and time of the day, showing that, generally speaking, the aforementioned results concerning treatment effects are robust to demand and supply effects of the seasonal variations implemented here.

TABLE 3: Average prices by water reserves, treatment and hour							
		Treatment 1		Treatment 2		Treatment 3	
		T1	T1-stage	T2	T2-stage	T3	T3-stage
Dry	pv	342.6 (48.9)	255.7 (39.5)	315.5 (50.8)	311.8 (59.3)	321.4 (59.1)	285.9 (33.8)
	ps	359.8 (45.9)	297 (35.4)	360.6 (36.2)	352.4 (35.5)	347.6 (62)	326.9 (40.8)
	pp	369.7 (58.8)	334.8 (26.5)	369.3 (35.1)	357.6 (35.3)	353.5 (70.5)	350.7 (33.4)
	pep	402.8 (41.4)	343.4 (16)	393.4 (47.2)	396.3 (49.4)	386.3 (73.9)	376.2 (39)
Humid	pv	335.2 (55.1)	245.3 (39.5)	305 (52.1)	309.6 (57.1)	295.5 (49.6)	280.4 (28)
	ps	341.5 (51.6)	278.9 (35.2)	342.7 (41.6)	350.6 (33)	312.8 (47)	324.2 (38.1)
	pp	359.8 (54.8)	330.4 (24.9)	348.5 (38)	361.7 (29.1)	321 (44)	348.1 (32.7)
	pep	387.1 (47.4)	337.1 (22.5)	374 (36.8)	391.9 (35.9)	342.7 (49.4)	373.8 (34.9)

TABLE 4 Average prices by temperature, treatment and hour							
		Treatment 1		Treatment 2		Treatment 3	
		T1	T1-stage	T2	T2-stage	T3	T3-stage
Normal	pv	339.1 (52.1)	250.9 (39.4)	310 (51.5)	310 (58.3)	309.7 (55.2)	282.9 (31.4)
	ps	351.8 (49.1)	289.5 (35.6)	352.8 (39.1)	351.5 (34.7)	330.3 (53)	325.4 (39.5)
	pp	364.4 (57.1)	332.9 (25.8)	359.4 (36.2)	358.6 (33.7)	337 (57.9)	348.7 (31.9)
	pep	395.3 (43.6)	339.9 (17.4)	384.6 (42.7)	393.3 (43.8)	364.4 (61.9)	374.6 (36.8)
Heat Wave	pv	339.3 (51)	251.4 (49.1)	312.2 (49.7)	311 (70.1)	298.5 (39.7)	282 (33)
	ps	360.2 (49.2)	297.5 (38.6)	360.5 (31.5)	348.4 (41)	334.6 (38.5)	327.3 (44.7)
	pp	367.2 (54.8)	335 (31.1)	373 (28.3)	358 (30)	336 (49.2)	349 (33.6)
	pep	395.7 (34.5)	346.2 (7.5)	384.5 (46)	384.9 (36.1)	362.3 (40.8)	374.3 (35)
Cold Wave	pv	350.8 (42.8)	274.5 (35.4)	332.5 (52.8)	322.9 (54.5)	348 (83)	298.1 (35.5)
	ps	361.5 (47.7)	311.5 (43)	362.5 (48.9)	357 (28.7)	386.3 (115.2)	331.6 (42.9)
	pp	388 (65.5)	340 (28.3)	380 (57)	367 (28.2)	401 (111.6)	364.9 (47.8)
	pep	421.6 (57.3)	358.8 (31.2)	409 (63.7)	420.4 (56.7)	446 (123.6)	385.4 (50.2)

TABLE 5 Average prices by season, treatment and hour							
		Treatment 1		Treatment 2		Treatment 3	
		T1	T1-stage	T2	T2-stage	T3	T3-stage
Winter	pv	345.5(45.2)	260.2(32.4)	319.5(55.9)	315.7(52)	339.1(69.6)	296.5(31.5)
	ps	358.6(45.5)	291.9(35.6)	364.1(45)	354.7(30.2)	361.7(87.4)	328.9(38.8)
	pp	379.2/64.1)	341.1(29.8)	371.4(43.1)	364.6(33)	379.6(89.5)	358.2(38.6)
	pep	409.9(55.4)	341.9(24.4)	404.7(52)	418.4(58.4)	412.9(101)	384.5(48.3)
Autumn	pv	343.8(53.8)	248.2(42.2)	309.4(44.1)	312.8(65.2)	313.6(47.9)	279.7(30.7)
	ps	359.2(48)	295.3(38.8)	356(34.9)	356.1(35.1)	333.4(38.7)	325.5(40.5)
	pp	362.6(56.2)	329(21)	362.5(34.7)	355.6(30.4)	334.9(44.2)	345.4(29.2)
	pep	398.1(36.1)	345.1(6.4)	381.4(37.7)	379.8(32.3)	366.3(55)	368.5(31.4)
Spring	pv	333.5(57.3)	252.9(40.4)	305(55.1)	306.1(54)	292.6(46.3)	278.9(31.4)
	ps	337.9(49.3)	286.2(35.9)	343.1(43)	349.3(34.6)	314.8(44.9)	322.4(38.5)
	pp	358.5(49.7)	330.7(25.9)	348.3(40)	362.1(32)	323.7(47)	346.6(31.8)
	pep	387.5(46.7)	335(24.3)	375.1(39.3)	392.5(36.5)	343.8(40.8)	374.6(34.6)
Summer	pv	336.4(49)	248.4(44.7)	312.3(50.6)	308.8(64.4)	300.6(50.6)	280.2(31.2)
	ps	356.2(50.7)	292.2(36.7)	352.5(30.5)	346.4(38.9)	326.8(40.6)	326.7(42.5)
	pp	363.7(58.5)	332.9(26.9)	363.9(28.1)	353.5(36.6)	325.2(43.9)	348.6(31.8)
	pep	392.4(33.9)	344.8(9.7)	383.4(43.6)	384.5(34.4)	354.7(38.1)	373.4(32.7)

Finally, in Figure 9, we can observe a phenomenon which has not been reported so far. Note that the entry of new firms in the market for electric market distribution increases the incentives of both downstream and upstream agents to use supply interruptions as a strategic weapon signaling their bargaining strength. However, interestingly, the vertical separation treatment (in which producers and distributors of electricity are independent from each other) yields the lowest number of supply interruptions, which indicates that it is the presence of vertical relations among incumbents that triggers the "interruption wars" reported here.

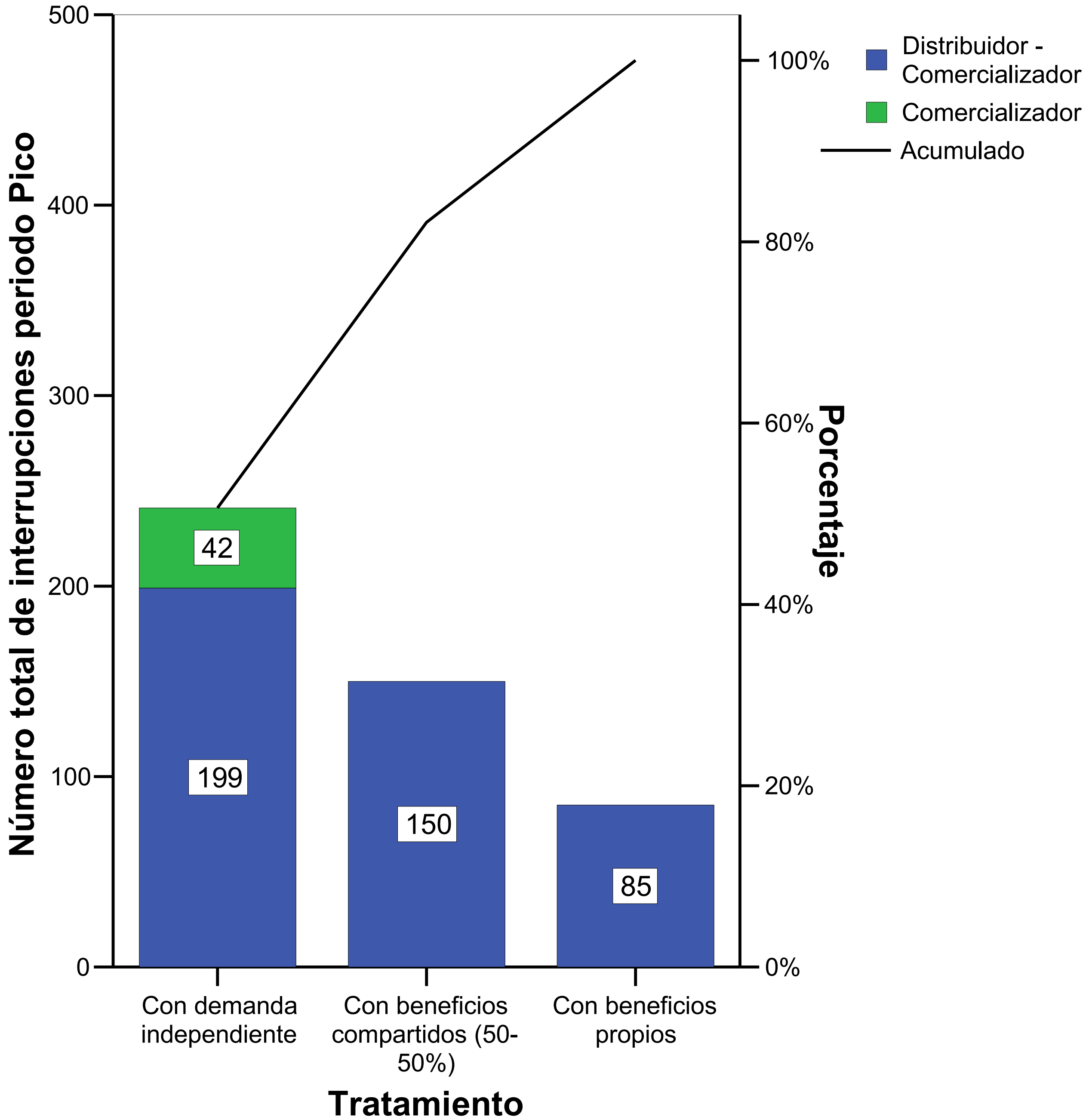

FIGURE 9: Total number of electric energy supply interruptions per treatment.

4. Econometric Results

We can now test several hypotheses on the effects of the treatments under different scenarios on valley, semivalley, peak and extreme-peak prices. We have bidders that have been working under a vertically-integrated market structure, individuals that bid under a vertically-separated market structure, and new entrants on the demand side of the market. Therefore, we have three different groups, which are affected by several exogenous characteristics summarized in Section 3.

We build binary dummay variables to account for discrete shifts of the prices and quantities under differences in exogenous conditions. We estimate models of the form:

$$p_i = \mu + \delta_1 winter_i + \delta_2 autumn_i + \delta_3 spring_i + \delta_4 humid_i + \delta_5 dry_i + \delta_6 heatwave_i + \delta_7 coldwave_i + \varepsilon_i$$

and

$$q_i = \mu + \delta_1 winter_i + \delta_2 autumn_i + \delta_3 spring_i + \delta_4 humid_i + \delta_5 dry_i + \delta_6 heatwave_i + \delta_7 coldwave_i + \varepsilon_i$$

where p_i denotes price at type of hour *i* and q_i denotes quantity at type of hour *i*, where *i* is valley, semi-valley, peak and extrreme peak. The dummies have the following interpretation; $autumn_i$ indicates whether or not the observation corresponds to that season, then it holds that, the expected price when $autumn_i=1$ is,

$$E[p_i \mid autumn_i = 1] = \mu + \delta_2$$
$$E[p_i \mid autumn_i = 0] = \mu$$

The estimated coefficients are interpreted as the difference between the expected price under different exogenous conditions for the market participants before bidding takes place. Thus, we are analyzing how ex-ante known variations affect bidding in the short-run. We take a summer normal day as the basic environment in which bidding takes place. Tables 6 and 7 present estimation results.

TABLE 6. Price model								
		All (785)	**T1 (164)**	**T2 (64)**	**T3 (160)**	**T4 Replic. T1 (117)**	**T5 Replic. T2 after T4 (156)**	**T6 Replic. T3 after T1 (128)**
Pv	Winter	3.1	15.1	-42.9*	17.1	7.4	60.5***	29.4***
	Autumn	-18.8**	8.3	-65.3**	-2.9	7.1	---	0.7
	Summer	-23.1**	---	-66.1**	---	2.4	-12.2	---
	Spring	---	11.8	---	21.3	---	54.7***	25.3**
	Humid	-26.7***	-13.8	-60.5***	-28.8*	0.5	-75.7***	-26**
	Normal	-10.6	-3.8	-19	0.2	-9.5	2.8	-2.1
	Heatwave	-9.3	---	-15	---	-6.63	---	0.2
	Coldwave	---	3.2	---	17.5	---	14.3	---
	Constant	337.3***	339.3***	332.6***	312.2***	315.1***	310.7***	281.7***
	R^2	0.03	0.01	0.13	0.03	0.01	0.21	0.09
Ps	Winter	0.3	12.6	-42.7**				
	Autumn	-20.7**	4.3	-46.7*				
	Summer	-26.6***	---	-51.6**				
	Spring		2.6	---				
	Humid	-33.8***	-19.6	-55.8***				
	Normal	-10.1	-5.3	-26.1				
	Heatwave	-3.6	---	-19.1				
	Coldwave	---	-1.5	---				
	Constant	373.1***	360.2***	368.1***				
	R^2	0.05	0.04	0.14				
Pp	Winter	-2.4						
	Autumn	-38.5***						
	Summer	-41.7***						
	Spring	---						
	Humid	-43.5***						
	Normal	-12.1*						
	Heatwave	-4.6						
	Coldwave	---						
	Constant	401.4***						
	R^2	0.09						
Pe	Winter	-3.6						
	Autumn	-52.7***						
	Summer	-55.5***						
	Humid	-58.9***						
	Normal	-15.5**						
	Heatwave	-11.8						
	Coldwave	---						
	Constant	444.9***						
	R^2	0.15						

Number of observations for each treatment in parenthesis

- Significant at 10% level
- ** Significant at 5% level
- *** Significant at 1% level

TABLE 7. Output model

	All (785)
	Valley output model
Winter	1547.4***
Autumn	2181.8***
Summer	1949.5***
Spring	---
Humid	1384.7***
Normal	-1843.6***
Heatwave	-475.4*
Coldwave	---
Constant	16486.5***
R^2	0.31
	Semivalley output model
Winter	2157***
Autumn	2347.4***
Summer	2368***
Spring	---
Humid	2247.9***
Normal	-1040.4***
Heatwave	-99.9
Coldwave	---
Constant	17166.2***
R^2	0.25
	Peak output model
Winter	2402.2***
Autumn	2799.1***
Summer	2636.7***
Spring	---
Humid	1989.4***
Normal	-1732.3***
Heatwave	-649.9*
Coldwave	---
Constant	18751***
R^2	0.28
	Extreme peak output model
Winter	1865.5***
Autumn	3405.5***
Summer	2990.7***
Spring	---
Humid	2324.5***
Normal	-1913.1***
Heatwave	-876.9**
Coldwave	---
Constant	20891.8***
R^2	0.18

Number of observations for each treatment in parenthesis

- Significant at 10% level
- ** Significant at 5% level
- *** Significant at 1% level

Generally speaking, these estimates provide a rigorous test confirming the findings reported in the previous section. Furthermore, it is confirmed that our experimental setting leads previously uninformed subjects to actions which induce quite realistic market outcomes reflecting what would have been expected to happen under each type of hour and each specific weather condition. An additional finding is that weather conditions have a stronger and statistically significant effect on output than prices.

Our main conclusions are summarized in the following section.

4. Conclusions

Many experts[4] have suggested restructuring the Spanish electricity market. However, textbook industrial organization tells us little on the direction that such restructuring should follow. More sophisticated theoretical models systematically fail to address a number of central features of the real world. Furthermore, given the fact that historical data cannot be used to infer anything on the effects of a given structural change, empirical research would also fail to address the issue of what we should expect to observe following a change in the current structure of the market.

We have reported here results from a series of experiments designed to address the effects of two alternative structural changes: vertical separation of corporations which are active on both sides of the market (generation and distribution) and independent entry of firms in the market of electric energy distribution.

Our results indicate that both measures would lead to lower prices, although independent entry in the distribution sector would yield more significant price decreases. However, this is achieved at some cost, as it would increase the number of supply interruptions. Breaking the vertical links between producers and distributors would lead to much more moderate price decreases, but this would be combined by a decrease in the number of supply interruptions.

Policy makers need to be assisted by research instruments and methodologies which are appropriate for addressing some central features of the real world market under study, like demand fluctuations, production and demand-side asymmetries and exercise of market power through implicit recognition of strategic interdependences. Such objectives are more likely to

[4] A recent example is Vives (2006).

be achieved by appropriately designed and conducted laboratory experiments, of which this is a first attempt.

APPENDIX: Software interface

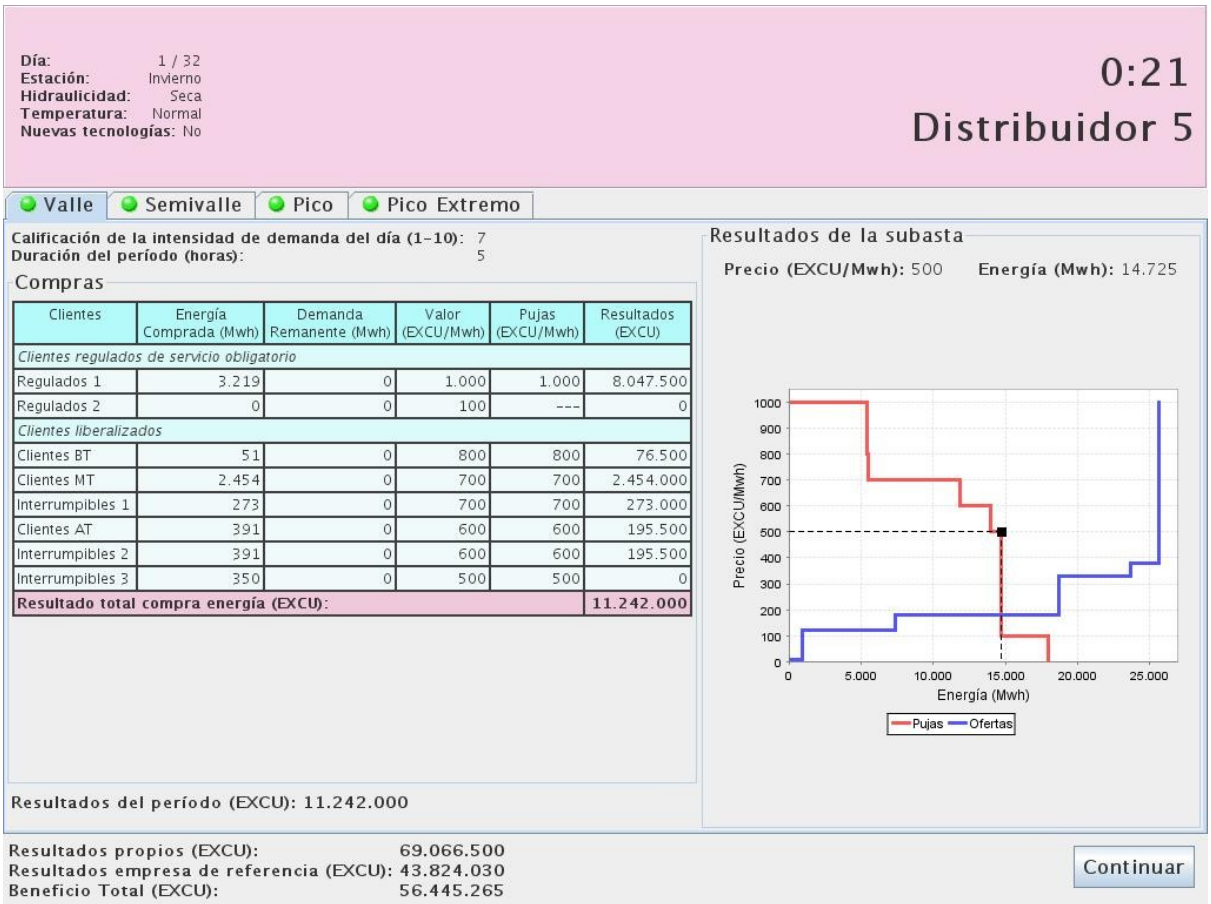

Figure 10: Strategy-submission and feedback interface for a distributor.

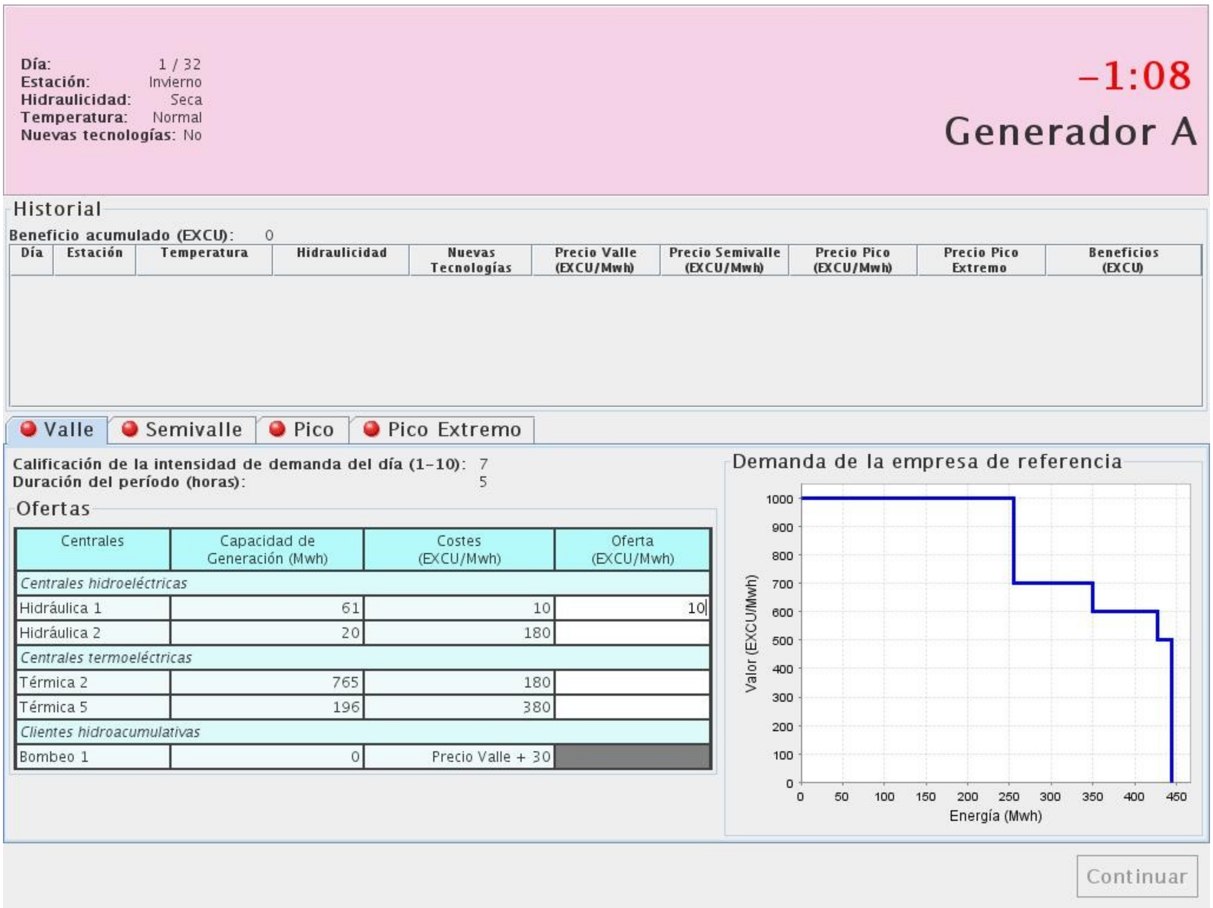

Figure 11: **Strategy-submission and feedback interface for a producer.**

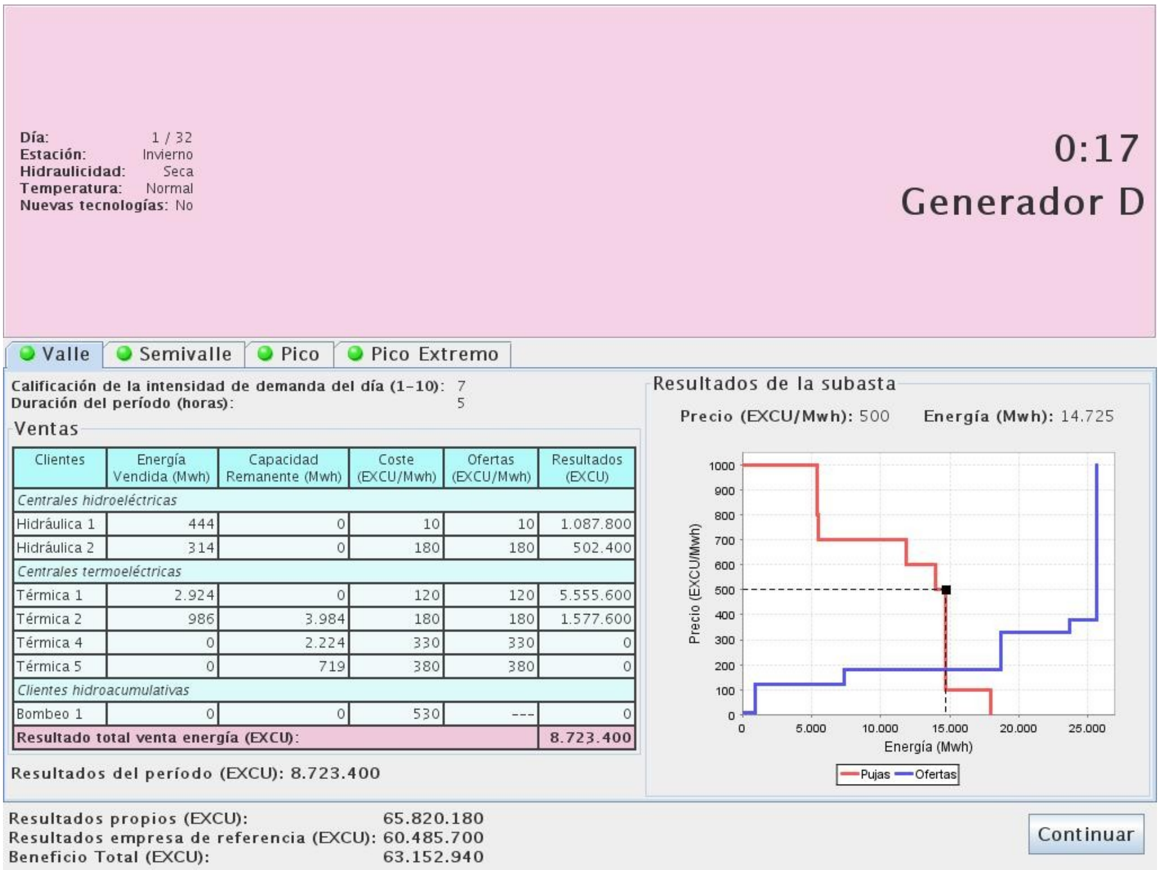

Figure 12: **Feedback screen of a producer after the clearing price has been determined for a given period.**

5. References

Ciarreta, A. and C. Gutiérrez-Hita (2005), "Strategic Behaviour and Collusion: The Spanish Electricity Market", REPEC 02/2005, DEFAEII Working Papers.

Ciarreta, A. and C. Gutiérrez-Hita (2006), "Supply Function vs Quantity Competition in Supergames", International Journal of Industrial Organization 24, 773-783.

Fabra, N. (2003) "Tacit Collusion in Repeated Auctions: Uniform versus Discriminatory Auctions", Journal of Industrial Economics 51, 271-293.

Fabra, N., N.-H. von der Fehr and D. Harbord (2002), "Modeling Electricity Auctions". The Electricity Journal 15, 72-81.

Fabra, N., N.-H. von der Fehr and D. Harbord (2006), "Designing Electricity Auctions", Rand Journal of Economics 37, 23-46.

Fabra, N. and J. Toro (2006), "Price Wars and Collusion in the Spanish Electricity Market" International Journal of Industrial Organization 23, 155-181.

Gutiérrez-Hita, C. (2006), "Liberalisation in the Spanish Electricity Market: A Model of Vertical Relations", Unpublished PhD Thesis, Universitat Jaume I, Castellón (Spain).

Vives, X. (2006), "La Reestructuración del Sector Eléctrico", Sector Público-Sector Privado, *El Mundo*, October 23, 2006.