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Examining the effect of quantities offered by hydraulic, renewable, non-renewable sources and thermal technologies on electricity prices in the MIBEL market through an ADRL approach

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Abstract

The objective of this article is to analyze and empirically validate the differential effects in the daily schedules of the induced electricity prices by selling bids for three different technologies, namely hydraulic, thermal and renewable energy sources (RES), in hourly values, by daily observations for the year 2018. To achieve this objective, we employ an autoregressive distributed lag (ARDL) model-bound testing approach The results of the ADRL-ECM method, which also reports the long-run analysis, show that (a) the renewable and thermal technologies positively and significantly affect the electricity price for Endesa and Hidroelétrica del Cantábrico generators and (b) the hydraulic technology impacts negatively the electricity price, both at a 1% level of significance. In addition, following a long-term perspective it must be highlighted that RES negatively impact the price of electricity with a 1% level of significance for the Iberdrola, E.ON Energy, Unión Fenosa and EDP Energy of Portugal generators. However based on a short-term perspective, the results report a positive effect between the quantities traded by hydraulic and thermal technologies on the electricity price for Endesa, Iberdrola, Hidroelétrica del Cantábrico and EDP Energy of Portugal, at a 1% level of significance.

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Keywords: Electricity price; Iberian electricity market; Hydraulic technology; Quantities offered; Renewable energy sources; Thermal technology

1. Introduction

The MIBEL electricity market is composed by certain important characteristics such as volatility and connection to seasonal cycles. For instance, the pricing behavior of the wholesale market is characterized by both non-constant volatility and a seasonal cycle in which jumps or spikes, i.e. large increases of price occur abruptly and are higher than a certain accepted threshold. As a result, the mean reversion level, which is connected to the seasonal cycle,

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is mainly affected by a process in which prices return to the initial seasonal level after some disturbances have occurred [1]. Currently, the electricity market price has become a crucial factor for all players in the energy sector, especially energy-producing companies. Taking this brief framework into account, we consider that it is a good opportunity for research to relate the electricity spot market prices and the quantities traded by players operating in the market so that the expected results can contribute to the rethinking of the rules of this market. On the other hand, traditional and new technology influences the offers in the wholesale market by electricity generators. As such, while hydroelectric production units can be considered as dynamic as they adapt their levels of outputs almost immediately, thermal production units can be considered as static, as they can hardly be immediately restarted or stopped, as opposed to what occurs with hydroelectric power units [2–4]. If the characteristics of the structured MIBEL market, where market players are supposed to interact and assess their dynamic strategic behavior among themselves, help players to immediately detect price divergences then, according Zalzar et al. [5], the low interconnection capacity in Spain and Portugal with the electricity markets of France and Germany may be responsible for the similarity of prices of electricity that one has occurred on the intraday and day-ahead markets. According to Macedo, Marques and Damatte [6], the penetration of renewable energy sources (RES) in the MIBEL market has resulted in a decrease in the equilibrium wholesale price. Several authors [7–9], among others, explain the behavior of the decreasing electricity prices, which can consequently create repercussions for generators of conventional hydraulic and thermal electricity power plants, while for stakeholders and investors in RES, this could reduce the price of electricity [10]. Moreover, this jeopardizes the use of renewable energy sources technologies, given that the merit order effect could hinder the proper integration of renewable energy sources in electricity markets [6]. The principal motivation for pursuing this analysis is based on the principal characteristics of the MIBEL market: (i) the great installed capacity of electricity players, which has an impact on the price of electricity of the wholesale market; (ii) the composition of companies (power plants) that generate electricity; and (iii) the offer pricing in the wholesale market, restricted in large measure by the diverse portfolio of technologies used by group of electricity generators that supply the electricity market with their huge installed capacity across different time periods. As such, the main purpose of this research is to scrutinize and validate the differential effects on the daily schedules of the induced electricity prices by selling bids for technology in the year of 2018. In other words, this paper analyzes how the technologies under special regime (RES) along with the traditional technologies (hydraulic and thermal) affect the wholesale electricity price in the MIBEL market. This hypothesis is based on the premise that in highly competitive electricity markets, the greater the penetration of renewable electricity, the lower the electricity price of in the wholesale markets will be, at least in the short-run perspective. This premise is also validated by some literature [6,11,12]. To validate the relationship between electricity price and quantities offered by hydraulic, thermal and renewable technologies, we used the autoregressive distributed lag (ARDL) approach. This econometric cointegration method captures the wholesale electricity market pricing dynamics making explicit the behavior of operators, and their strategic decision-making process, in the MIBEL market.

2. Methodology and data

To achieve the main objective of this analysis, we employ an ARDL approach. As such, initially the unit roots test was employed, since this analysis allows us to disclose the integration order of the dependent and the explanatory variables [13,14]. In order to use the ARDL analysis, we tested the assumption that each variable used was integrated in order zero or order one, hereafter I(0) or I(1). Unlike other papers found in literature, this paper seeks to test for structural breaks when examining both the short- and long-term relationships between electricity wholesale price and quantities offered by hydraulic, thermal and renewable energy technology sources.

The estimations used the ARDL methodology because it provides consistent results for small samples, which is the case in this article. The limit test is also advantageous regardless of whether the restrained regressors are integrated in order zero, or order one, or mutually cointegrated [15]. It is possible to write the ARDL equation as follows:

$$\Omega\left(L, p\right) y_t = \alpha_0 + \sum_{i=1}^{k} \beta_i\left(L, q_i\right) x_{it} + \delta^{'w_t} + \mu_t \tag{1}$$

$$\Omega\left(L, p\right) = 1 - \Omega_1\delta_1 L^1 - \Omega_2\delta_2 L^2 - \cdots \Omega_p L^p, (2) \tag{2}$$

$$\beta_i\left(L, q_i\right) = \beta_{i0} + \beta_{i1} L + \beta_{i2} L^2 + \cdots \beta_{iqi} L^{iqi}, i = 1, 2, \ldots, k, \tag{3}$$

where y_t is the explained variable; α_0 is the intercept parameter; L is a lag operator such as $Ly_t = y_{t-1}$, and finally w_t is an $sx1$ vector of deterministic variables [15]. However, we followed the more recent empirical approach [16–18], as it allows the estimation of our ARDL models formulated in a time series context through the use of response surface regressions. This allows obtaining asymptotic critical values and approximate p-values, for all independent variables being purely integrated in order zero or order one (and not mutually cointegrated). The dependable variable is the electricity market price (€/MWh) in hourly values by daily observations for the year 2018. The price of wholesale electricity is regressed with the quantity of electricity traded (MWh) by technology (hydraulic, thermal and renewable) and by firm (Endesa, Iberdrola, Hidroeléctrica del Cantábrico, E.ON Energy, Energy Gas Natural Fenosa and EDP Energy of Portugal). The variables were obtained in the Iberian Market Operator database.

3. Empirical results

Table 1 shows the unitary root tests of Zivot–Andrews structural breaks. They support in confirming the stationary carried out for the six generators considered in the sample of the Iberian Electricity Market. Table 1 reveals the breaks for the several hourly time periods in 2018 occurring for the quantities offered by hydraulic, renewable and thermal sources, respectively.

Table 1. Zivot–Andrews structural break-point unit root test.

Energy generators	Endesa	Iberdrola	Hidroeléctrica del Cantábrico	E.ON energy	Gas Natural Fenosa	EDP, Energy PT
At level	T stat	T stat	T stat	T stat	T stat	T stat
Electricity price	−11.659***	−11.659***	−11.659***	−11.659***	−11.659***	−11.659***
Quantities hydraulic	−18.750***	−16.592***	−15.405***	−8.091	−15.365***	−13.319***
Quantities renewable	−55.472***	−12.872***	−10.280***	−11.084	−13.110***	−12.413***
Quantities thermal	−9.300***	−13.962***	−10.661***	−13.911	−8.865	−9.208***
	Time-break	Time-break	Time-break	Time-break	Time-break	Time-break
Electricity price	6321	6321	6321	6321	6321	6321
Quantities hydraulic	2433	6232	1870	1675	6656	1722
Quantities renewable	3994	1661	6731	4881	4835	4860
Quantities thermal	1945	2669	1981	2340	7446	1670
Energy generators	Endesa	Iberdrola	Hidroeléctrica del Cantábrico	E.ON Energy	Gas Natural Fenosa	EDP, Energy PT
At 1st difference	T stat	T stat	T stat	T stat	T stat	T stat
Electricity price	−39.492***	−39.492***	−39.492***	−39.492***	−39.492***	−39.492***
Quantities hydraulic	−48.012***	−48.012***	−41.161***	−49.127***	−48.614***	−47.681***
Quantities renewable	−35.991***	−35.991***	−33.746***	−30.243***	−33.112***	−33.490***
Quantities thermal	−40.208***	−40.248***	−47.939***	−34.101***	−37.847***	−39.327***
	Time-break	Time-break	Time-break	Time-break	Time-break	Time-break
Electricity price	1325	1325	1325	1325	1325	1325
Quantities hydraulic	3095	7376	1325	2808	2952	2947
Quantities renewable	2077	2443	1324	7407	7391	7388
Quantities thermal	1326	1399	1418	7446	5881	1324

Notes: *** denotes a 1% level of statistical significance; ** denotes 5%; and * denotes 10%. The critical value at 1% is 5.34; at 5% is 4.80; and at 10% is 4.58. The maximum lag order is 4. The unit root test has a structural break in the intercept.

Table 2 presents the outputs of the Gregory–Hansen cointegration test. As it is known, it takes into account regime shifts. Table 2 shows the results of the cointegration analysis with shifts considering the variables for individual generators. The results confirm the long-term relationships, based on the critical values reported for both the F- and T-statistics, which validated the level of statistical significance.

The absence of cointegration corresponds to the null hypothesis for all tests carried out. So, for all six generators, cointegration is validated using break regime and trend.

From our results, it can also be noticed that the obtained time breaks differ for the electricity generating companies, according to the tests carried out. As a result, it is not possible to establish a common pattern.

Table 2. Cointegration analysis with regime shifts using the Gregory–Hansen test.

Endesa	Break regime		Break regime and trend	
	ADF stat	Time-break	ADF stat	Time-break
Electricity price, quantities hydraulic, quantities thermal and quantities renewable sources	−14.14***	2968	−14.29***	3178
Iberdrola	ADF stat	Time-break	ADF stat	Time-break
Electricity price, quantities hydraulic, quantities thermal and quantities renewable sources	−16.35***	5643	−17.36***	2075
Hidroeléctrica del Cantábrico	ADF stat	Time-break	ADF stat	Time-break
Electricity price, quantities hydraulic, quantities thermal and quantities renewable sources	−13.64***	3256	−13.61***	3257
E.ON Energy	ADF stat	Time-break	ADF stat	Time-break
Electricity price, quantities hydraulic, quantities thermal and quantities renewable sources	−12.76***	5034	−13.16***	2899
Energy Gas Natural Fenosa	ADF stat	Time-break	ADF stat	Time-break
Electricity price, quantities hydraulic, quantities thermal and quantities renewable sources	−14.22***	5022	−14.72***	5881
EDP, Energy Portugal	ADF stat	Time-break	ADF stat	Time-break
Electricity price, quantities hydraulic, quantities thermal and quantities renewable sources	−14.02***	4952	−14.44***	5897

Notes: *** denotes a 1% level of statistical significance; ** denotes 5%; and * denotes 10%. The critical value at 1% is 5.34; at 5% it is 4.80; and at 10% it is 4.58. The maximum lag order is 4. The cointegration test has a structural break in the intercept.

Table 3. Long-term equilibrium based on ADRL bounds test.

Energy generators	ARDL Specification	F-stat	K	Case	T-stat	Cointegration decision
Endesa	ARDL(4, 4, 4, 4)	87.162***	3	3	−16.981***	Yes
Iberdrola	ARDL(4, 4, 4, 4)	99.930***	3	3	−19.199***	Yes
Hidroeléctrica del Cantábrico	ARDL(4, 4, 3, 4)	93.517***	3	3	−18.867***	Yes
E.ON Energy	ARDL(4, 4, 2, 2)	123.683***	3	3	−20.317***	Yes
Energy Gas Natural Fenosa	ARDL(4, 4, 0, 4)	127.583***	3	3	−22.146***	Yes
EDP, Energy Portugal	ARDL(4, 4, 3, 2)	98.117***	3	3	−18.384***	Yes

Notes: For the bounds test, the asymptotic critical value bounds are based on Pesaran et al. [19], with unrestricted intercept and no trend with max lags k in the dependent variable and regressors equal to 4. * denotes 10% of level of statistical significance; ** denotes 5%; and *** denotes 1%.

Considering that the ADF-statistics reported are larger than the higher critical bounds, it is possible to claim there are of short-term and long-term relationships in all six electricity generators in the MIBEL market. It is possible to conclude, with a significance level of 1%, that all generators (Endesa, Iberdrola, Hidroeléctrica del Cantábrico, E.ON Energy, Energy Gas Natural Fenosa and EDP, Energy of Portugal) are cointegrated, based on the results of the ADRL tests shown in Table 3.

The results of the ADRL are also shown in Table 4, for Endesa, Iberdrola, Hidroelétrica del Cantábrico and EDP Generators, showing a positive effect at a 1% level of significance, between the quantities traded by hydraulic and thermal technologies on the electricity price, in the short run. On other side, the special regime technology (renewable sources) shows a negative impact on the electricity price, with a level of significance of 1%. However, when the E.ON Energy generator is considered, all three technologies evaluated show that the electricity price was positively affected. In the analysis of the long-term, the results for Endesa and Hidroelétrica del Cantábrico are mixed: renewable and thermal technologies exert a positive effect on the electricity price; whereas hydraulic technology shows a negative impact on the electricity price, both with a 1% level of significance. Other important results that must be highlighted in the long term perspective are the results reported by renewable technology for the companies Iberdrola, E.ON Energy, Unión Fenosa and EDP, which show a negative statistical impact on the electricity price with a level of significance of 1%. So, based on the ADRL test, for a level of significance of 1%,

Table 4. Results for the ADRL unrestricted ECM estimation.

Short-term	Endesa	Iberdrola	Hidroeléctrica del Cantábrico	E.ON Energy	Gas Natural Fenosa	EDP, Energy PT
LD Price	0.290541***	0.33075***	0.3831***	0.33962***	0.37753***	0.224447***
LD2 Price	−0.006444	0.00853	0.01056	0.004127	0.031213***	−0.011083
LD3 Price	−0.05882***	−0.07754***	−0.07022***	−0.05029***	−0.080179***	−0.07702***
D1 Q. hydraulic	0.00713***	0.00227***	0.02187***	0.01555***	0.013365***	0.002687***
LD Q. hydraulic	0.00154***	−0.00033***	0.01592***	0.006296***	−0.001819***	0.000093
LD2 Q. hydraulic	0.000917***	0.00039***	0.01046***	0.003243***	0.001568***	0.000345***
LD3 Q. hydraulic	0.001744***	0.00039***	0.02522***	0.002695***	0.003499***	0.000493***
D1 Q. renewable	0.01202***	−0.00385***	−0.16742***	0.002161***		−0.000243***
LD Q. renewable	−0.01686***	−0.00062***	−0.17369***	0.003637***		0.000183
LD2 Q. renewable	−0.02531***	0.000236	−0.07472***			0.000482***
LD3 Q. renewable	0.008969***	0.000409***				
D1 Q. thermal	0.00296***	0.001462***	0.0057***	0.001459***	0.002699***	0.00666***
LD Q. thermal	0.001052***	0.000278	−0.00068***	0.00277***	−0.001453***	0.001155***
LD2 Q. thermal	−0.000169***	0.000741***	−0.00042	0.000741***	0.000459**	
LD3 Q. thermal	0.000183***	0.00038***	−0.00227***	0.00038***	0.000418**	
Constant	2.49326***	4.78677***	3.37402***	4.78677***	4.79108***	3.61220***
ECt−1	−0.051662***	−0.07056***	−0.05362***	−0.05652***	−0.0673***	−0.06312***
Long-term	Endesa	Iberdrola	Hidroelectrica del Cantábrico	E.ON Energy	Gas Natural Fenosa	EDP, Energy PT
Q. hydraulic	−0.01450***	0.00258***	−0.06163***	−0.0444***	−0.015626***	−0.001934***
Q. renewable	0.058136***	−0.0115***	0.25766**	−0.0205***	−0.03190***	−0.003068***
Q. thermal	0.0044467***	0.00046	0.01237***	0.008115***	0.003479***	0.008707***
R^2	0.4105	0.4104	0.3356	0.3758	0.3999	0.482
Adjust R^2	0.4092	0.409	0.3342	0.3748	0.3988	0.4811

* denotes 10% of level of statistical significance; ** denotes 5%; and *** denotes 1%. ECt-1: lagged error cointegration term.

it is possible to conclude they are cointegrated, with the expected sign, although not for all six generators. It is also possible to interpret the negative sign as a convergence towards the long-term equilibrium. Moreover, the statistical significance of the error correction mechanism indicates that the long-term equilibrium convergence speed will be relative high should the system be confronted with a shock. Just to give an example, in the two dominant players in MIBEL, Endesa and Iberdrola, the values of the term ECT_{t-1} for Endesa (−0.0516) and for Iberdrola (−0.0705), imply that the wholesale electricity price value is corrected by 5.16% and 7.05% hourly, respectively, as a result of the adjustment from the short-term to the long run equilibrium.

4. Conclusion

The aim of this paper was to analyze and quantitatively evaluate the relationship between offer of quantities by hydraulic, thermal and special regime with renewable technological sources in the MIBEL market, hourly during the day in 2018. As the quantities offered by hydraulic, renewable sources and thermal technologies and the wholesale electricity price series is stationary, it was possible to estimate the cointegration procedure. In this study of cointegration by generator company and by technologies it was found that the offer of quantities by these three technologies influences the wholesale price of electricity in the short-term as well as in the long-term. Based on the importance of our results using the ADRL techniques, and the expected signals and estimates for explaining the interrelations between the price and quantities offered by type of technologies in the MIBEL wholesale electricity, market, it is possible to understand how the integration of the special technologies such as renewable energy sources, in alignment with other traditional technologies such as hydraulic and thermal, affects the short-term and long-term price dynamics of these daily markets. For a more in-depth understanding of the results herewith presented, we recommend the consultation of the EU Directive 2009/28/EC regarding the possibility to promote the use of electricity to produce energy from sustainable sources.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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