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Electricity Prices and Generation Costs in European Futures Markets with Implications for Spain

LUIS MARÍA ABADIE
*Basque Centre for Climate Change (BC3), ESPAÑA. E*mail: lm.abadie@bc3research.org
DAVID R. HERES
*Basque Centre for Climate Change (BC3), ESPAÑA. E*mail: david.heres@bc3research.org

ABSTRACT

This paper examines the influence of the cost of natural gas, coal and emission allowances on electricity prices. Quotes from the futures market are used rather than spot quotes, and panel data analysis is applied, with each futures contract being characterised by a given maturity. Data for the UK are used, and the conclusions provide insights for the Spanish case for which fewer quotes are available. The results show that the market prices imply an increasing role of natural gas and emission allowances in determining the price of electricity.

Keywords: Natural Gas, Power Plants, Electricity Price, Futures Markets.

Precios de la electricidad y costes de generación en los mercados de futuros europeos: Implicaciones para España

RESUMEN

Este estudio analiza la influencia de los costes del gas natural, del carbón y de los derechos de emisión en el precio de la electricidad. En vez de usar cotizaciones spot, se utilizan cotizaciones de los mercados de futuros realizando un análisis de datos de panel, en el que cada contrato de futuros está caracterizado por una determinada fecha de expiración. Se utilizan para ello cotizaciones de UK, obteniendose conclusiones de las que se extraen lecciones para el caso Español, donde existen menos cotizaciones disponibles. Los resultados muestran que los precios de mercado asignan un papel creciente al gas natural y a los derechos de emisión en la determinación del precio de la electricidad.

Palabras clave: Gas natural, plantas eléctricas, precio de la electricidad, mercados de futuros.

JEL Classification: O13, Q47, C23, L94

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1. INTRODUCTION

The development of natural gas markets in Europe has led to a growing link between these markets and a delinking from crude oil prices, to which they were initially linked. The development of gas pipelines and the construction of liquefied natural gas (LNG) plants have contributed to this interconnection of gas natural markets. Moreover, the increasing use of combined cycle gas turbines (CCGT) in generation facilities is in turn passing gas costs on to electricity costs, leading the latter to reflect the seasonality of gas prices.

This paper uses quotes from futures markets to analyse the impact of natural gas, coal, and carbon dioxide (CO_2) emission allowance prices on the price of electricity. These quotes should be taking into account the influence attributed by investors to variations over time in fuel and emission allowance prices, along with the performance of the generation mix in the setting of future electricity prices.

The statistical analysis is based on data from the United Kingdom (UK) and a few lessons are drawn for the case of Spain. The UK was chosen as a country where both the natural gas and electricity markets are highly developed.

Previous work has already highlighted the influence of natural gas prices on electricity prices. Analyzing UK historical time-series of quarter-ahead fuel and power prices from January 2001 to August 2005, Roques et al. (2008) find a correlation between natural gas prices and base electricity prices of 89 % (56 % for that between coal and electricity), which is in line with the fact that gas-fired power stations set the marginal price most of the time. In Germany, according to Sensfuβ et al. (2008), hard coal power plants only set prices in periods of low demand while gas-fired plants determine electricity prices during the majority of peak demand hours. As G. Federico and X. Vives (2008) point out, this has also been observed in Spain where "*CCGTs accounted for two thirds of the energy offered and accepted at 95% or more of the marginal price in each hour*". Contrarily, in the PJM market (United States), coal-fired plants still dominated in 2009, setting the marginal price 74 % of the time, while gas plants set it only 22% of the time[1]. At a more aggregate level, Yang and Blyth (2007) track quarterly electricity prices and gas prices across countries members of the Organisation for Economic, Co-operation and Development between 2003 and 2005. They find that electricity prices mirror gas prices, with a correlation coefficient of 0.763. Thus the price of electricity in the majority of developed

[1] Data from the Federal Energy regulation Commission at http://www.ferc.gov (accessed January 2011)

countries is mostly driven by the margin of this kind of technology, namely the clean spark spread[2].

Through the implementation of the Kalman Filter method, the convergence of the gas and electricity markets has been also confirmed in Abadie and Chamorro (2007) using spot prices in the UK and US.

Emery and Liu (2002) study the link between natural gas future prices and electricity futures contract prices in the California-Oregon Border and in Palo Verde. Their results suggest that many companies could be using natural gas as their marginal fuel for generating peak power.

Through Granger instantaneous-causality tests, Woo et al. (2006) find a two-way relationship in the electricity and natural gas prices, based on similar effects of demand in the California markets for electricity and natural gas.

In the European Union, the role of natural gas prices in setting electricity prices is becoming more predominant to the extent that the market share of coal in electricity generation under carbon constraints is decreasing (e.g. under the EU LCPD[3]). The actual situation, however, varies across countries and periods.

In Spain, there has been a change in recent years in the percentage of time in which each technology sets the price on the Spanish daily electricity market. Figure 1, based on information provided by the Spanish electricity grid Red Eléctrica Española (REE) in its mothly reports, shows an initial increase in the percentage of time for which CCGT technology sets the market price, followed by a decrease and a final upturn in the share of hydro-electric and pumped technologies[4].

It must be taken into account that the opportunity cost of using hydro-electric and pumped technologies is determined by the cost of the thermal plant that they displace. This means that the prices of fossil fuels (mainly natural gas and coal) and the corresponding CO_2 emission allowances are affecting electricity prices indirectly at those times when hydro-electric and pumped technologies are setting the marginal price. This is reflected in the fact that although there are times when CCGT technology does not set the marginal price, the difference between its quoted price and the marginal price on the market is often less than 5%.

The proportion of cases in which CCGT technology sets the marginal price in the Spanish daily market and the influence that it has on the prices set by hydro-electric and pumped technologies reflect a significant dependence on

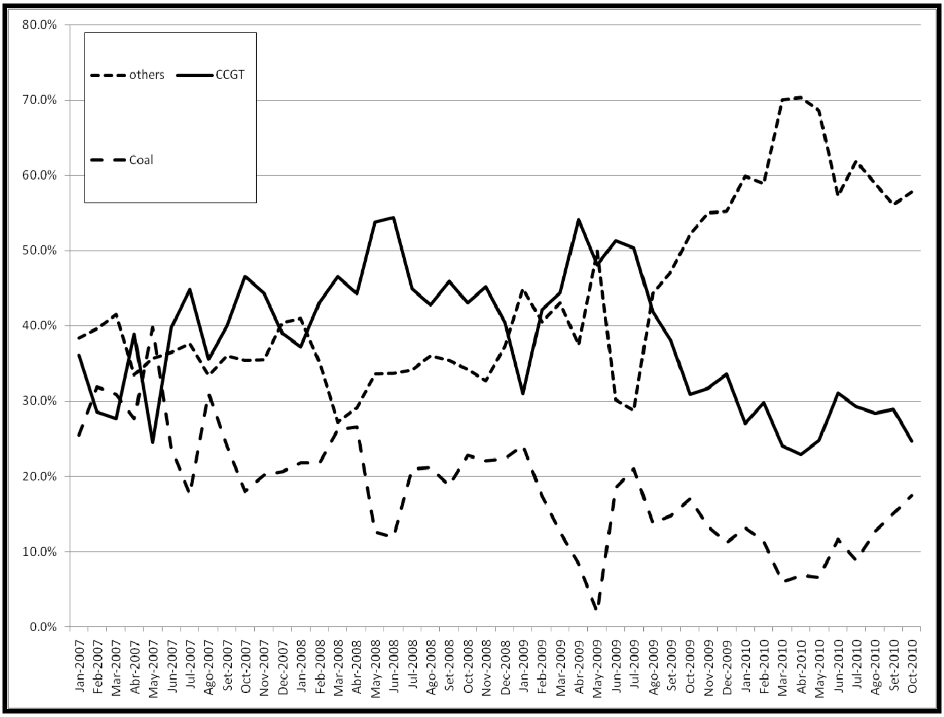
[2] The Clean Spark Spread (CSS) is the revenue from selling power net of the costs of natural gas and the required carbon allowances.

[3] Large Combustion Plant Directive 2001/80/EC.

[4] Pumped technology is used to pump water to greater heights, especially in trough hours when electricity demand is lower, so that electricity can then be produced at times of greater demand.

international prices for natural gas when electricity prices are set. This paper seeks to quantify that influence from a forward-looking viewpoint, checking whether the markets believe that this dependence will hold in future years, and if so to what extent.

Figure 1
Percentage of marginal price setting in Spain by technology



Source: Own computations; Raw data from Red Eléctrica Española (REE).

For the electrical plants that set the marginal price of electricity, the margin between that price and the cost of the fuel needed to produce electricity must be high enough to include the cost of CO_2 emissions as regulations will require.

There is therefore a risk for less efficient technologies and for those that fail to pass on allowance costs to electricity prices. The margins of such plants may shrink as climate policies become more stringent, and they may even end up becoming back-up plants used to produce electricity mainly at times of peak demand or to cover for base plants off-line due to faults or maintenance work. As shown below, futures markets consider an increase over time in emission allowance prices to be the likeliest scenario.

The rest of the paper is structured as follows. Section 2 outlines the data used in the analysis. Section 3 is devoted to the econometric estimation of panel data and Section 4 concludes.

2. DATA

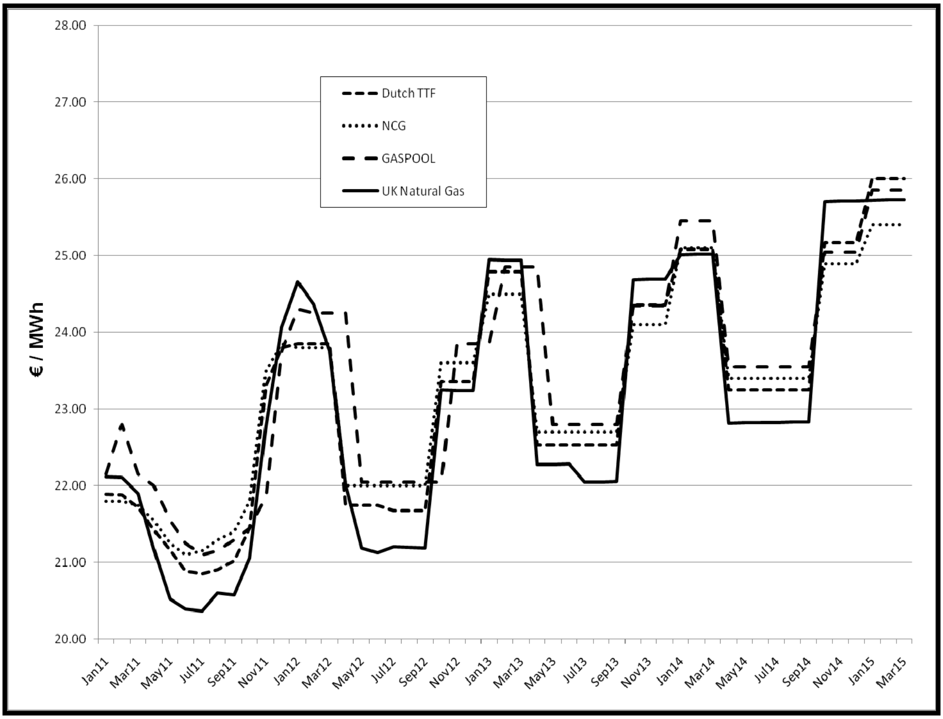
We collected data on futures markets covering all price quotes between 12/01/2009 and 11/30/2010, i.e. a period of exactly one year. All the quotes used are from the Intercontinental Exchange (ICE). More specifically, for natural gas we obtained quotes from ICE UK (pence/therm), ICE Dutch TTF, Netherlands (euros/MWh), ICE GASPOOL and ICE NCG, Germany (euros/MWh). In the case of electricity, data were collected from the ICE UK base electricity (pence/MWh). Coal future prices were available from the ICE Rotterdam, Netherlands (US dollars/tonne) and those for CO_2 emission allowances from ICE EUA European Union Emission Trading Scheme.

In order to homogenise data, the following conversions were made: 1) Therms were converted to MWh; 2) For coal €/tonne were converted to €/MWh considering 29.31 GJ/tonne and using the equivalence 1 GJ = 0.27777 MWh; 3) Quotes in US Dollars and pence were converted to euros as follows: zero coupon curves for each division were obtained for each day from inter-bank quotes and interest rate swaps. Term exchange rates were then calculated using the spot exchange rate and the zero coupon curve rates.

For natural gas, coal and UK electricity there are quotes with monthly maturities (i.e., expiry date) for a large number of periods, but no such quotes are available for emission allowances. Cubic splines were used to obtain quotes for intermediate periods in this case.

Using data on 51 futures quotes from the last day of the series (11/30/2010) for each location, the Figure 2 shows the high degree of correlation between the different natural gas markets, so it can be assumed that prices should be very similar across European markets.

Figure 2
Natural Gas Prices 11/30/2010



Source: Own computations; Raw quotes from Intercontinental Exchange (ICE).

The level of correlation in futures contract prices between base electricity and UK natural gas stood at 0.97 for the different contracts during the period analysed, while that between UK electricity and Rotterdam Coal was lower at 0.85.

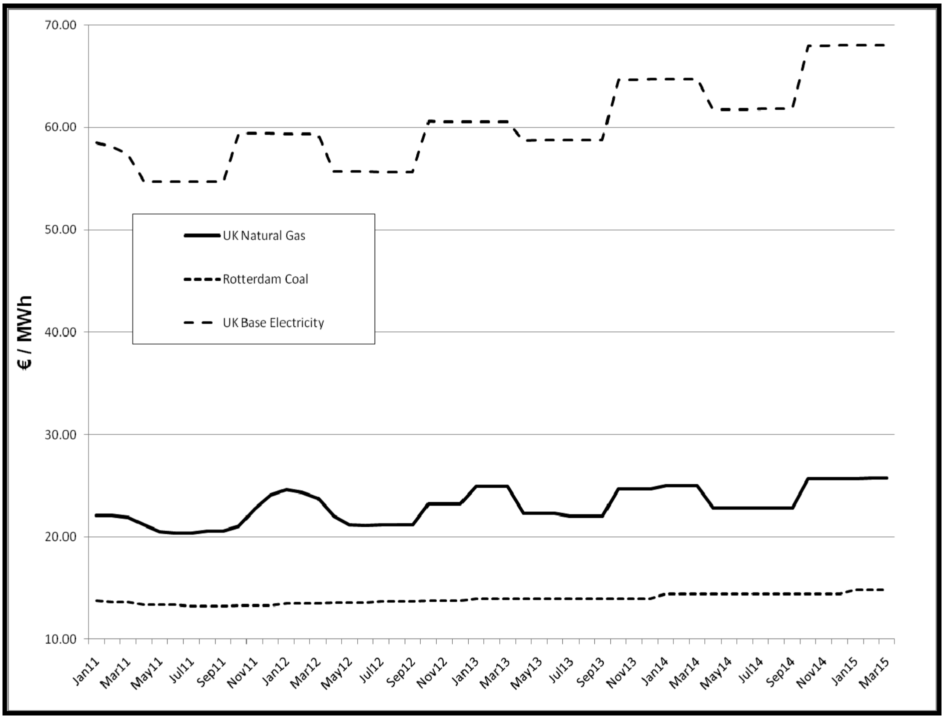
Seasonality is generally the result of higher demand for heating in winter and for air conditioning in summer. Figure 2 shows that there is a very similar pattern of behaviour across various European countries. Unfortunately, there is no organised hub market in Spain, though there is a project to create one. It is not therefore possible to determine the seasonality of gas in Spain, which might in principle make this a somewhat different case. However there is an increasing interconnection between countries via gas pipelines and LNG facilities, so any marked differences in seasonality would doubtless be the subject of arbitrage in the marketplace. On the other hand, the prices paid on the free market are usually linked to quotes on organised markets, and the market used in this study is one of those geographically closest.

Using quotes from 11/30/2010, Figure 3 shows that seasonality in natural gas prices is transferred to electricity futures contracts. This is the usual behaviour of quotes on all the days on the sample.

The few current futures contracts for electricity in Spain are heterogeneous in terms of their delivery periods. There are currently three weekly contracts, 3-5 monthly contracts, 4-7 quarterly contracts and 1-2 annual contracts (for the next year and the following year). By contrast, in the UK there are monthly quotes available every day up to 2015, as shown in Figure 3.

The data are processed as follows: since there are quotes every day with different maturity periods for electricity, coal and natural gas, they are paired off taking the relevant prices for each day and each maturity period. However, such homogeneous series are not available for emission allowances, so it was decided to estimate quotes for monthly maturities for each day. Using daily spot and futures quotes for maturities in December from 2010 to 2020, a cubic spline was drawn up that was used to obtain intermediate quotes.

Figure 3
UK Base Electricity, UK Natural Gas and Rotterdam Coal 11/30/2010



Source: Own computations; Raw quotes from Intercontinental Exchange (ICE).

3. ECONOMETRIC ESTIMATION

This section estimates an econometric model explaining the price of electricity. The general model is the following:

$$lpe_{it} = \alpha_i + X'_{it}\beta + u_{it} \tag{1}$$

where α_i are specific contract time-invariant effects, X_{it} is a vector of explanatory variables and β is the vector with the corresponding coefficients. The different future contracts (represented by their expiry date) are indexed by *i*, while the quote days in the period analysed are represented by *t*. The error term is:

$$u_{it} = \rho_i u_{i,t-1} + \varepsilon_{it} \tag{2}$$

where ε_{it} is not correlated over time but is allowed to be correlated over *i*.

Table 1 describes the dependent variable and the variables included in the vector of independent variables X_{it}. The price variables explaining *lpe* are also interacted with a variable representing the remaining life of the contract given its expiry date and the quote date (*life*). A trend variable and indicative variables for the different months for which we have observations are also included in X_{it}. The individual effects (α_i) may absorb contract-specific characteristics such as different levels of volatility and risk premium that depend on the time remaining for maturity.

Table 1
Description of Variables

Variable	Description
lpe	Natural logarithm of the price of electricity per MWh
lpg	Natural logarithm of the price of natural gas per MWh
lpc	Natural logarithm of the price of coal per MWh
lpa	Natural logarithm of the price of emission allowances per ton of CO_2
dec09-nov10	Seasonal dummy variables for the months in the period analyzed (e.g., dec09 equals 1 if price quote is from December of 2009 and 0 otherwise)
day	Trend variable with a range of 1 to 252 (days with price quotes in the period analyzed)
life	Ordinal variable equal to 1 if the number of months between the date of the price quote and the expiry date of the contract is less than or equal to 12. Equal to 2 if it is between 13 and 24 months, 3 if between 25 and 36, 4 if between 37 and 48, and 5 if greater than 48.

Source: Own computations.

Table 2 shows the mean and standard deviation for selected variables. The standard deviation is also reported accounting only for time variability *within* each contract series, and for cross sectional variability *between* contracts on a given day. Two set of results stand out from this table: 1) Prices of natural gas and coal show volatility that is much higher than that of the price of electricity (from the coefficient of variation for each series). The price of emission allowances is the one experiencing the highest variability of all series during this period; 2) Except for the price of emission allowances, a large portion of the variability in prices is due to differences in price quotes for different contracts in a given point in time (between variation), rather than differences across the period analyzed for a given contract (within variation).

Table 2
Summary Statistics

Variable	Mean	Std. Dev. (overall)	Std. Dev. (between)	Std. Dev. (within)
lpe	3.9914	0.1498	0.1417	0.0607
lpg	2.9824	0.2222	0.2078	0.0822
lpc	2.4948	0.1842	0.1830	0.0862
lpa	4.4698	0.5557	0.4253	0.4135

Source: Own computations.

Table 3 reports coefficients and panel-corrected standard errors for the fixed-effects estimation. Two pieces of evidence support the presence of individual effects (α_i). First, an ordinary least squares regression including dummy variables for each contract shows strong overall and individual significance of these variables[5]. Second, both fixed-effects and random-effects models show that the variance portion due to the individual-specific component of the error (α_i) is larger than that from the idiosyncratic error (u_{it}). Furthermore, our preferred estimates are those from the fixed-effects estimation not only because they are consistent (although not efficient) even if the true model is one with random effects but also because a Hausman (1978) test leads to rejection of the random effects model (i.e., correlation between X_{it} and α_I is different from zero which

[5] This least squares dummy variable regression is equivalent to a fixed effects specification without further adjustments to the error structure. The F-statistic (61, 6163) for joint significance of the contract-specific dummy variables is 177.88 (p-value=0.00), and only 10 out of 61 of such dummies are not statistically significant when tested individually.

could result in endogeneity bias and therefore a fixed-effects estimator is necessary for consistent estimation of coefficients)[6].

Table 3
Fixed-effects regression

Dependent variable *lpg*		
lpg	0.5489***	(0.0169)
*lpg*life*	0.0622***	(0.0064)
lpc	0.1441***	(0.0341)
*lpc*life*	-0.1224***	(0.0136)
lpa	0.0736***	(0.0218)
*lpa*life*	0.0265***	(0.0046)
jan10	-0.0056	(0.0044)
feb10	-0.2016***	(0.0348)
mar10	-0.2028***	(0.0349)
apr10	-0.1982***	(0.0353)
may10	-0.1885***	(0.0357)
jun10	-0.1900***	(0.0359)
jul10	-0.1980***	(0.0361)
aug10	-0.1921***	(0.0366)
sep10	-0.1943***	(0.0369)
oct10	-0.1986***	(0.0372)
nov10	-0.1936***	(0.0375)
day	-0.0001*	(0.0001)
constant	1.8624***	(0.0435)
N	6243	
R^2	0.9988	
Panel-corrected standard errors in parentheses		

*p<0.05, ** p<0.01, *** p<0.001*
Source: Own computations.

[6] The Chi-square statistic for the Hausman test is 138.97 (18 degrees of freedom and p-value=0.00).

The fixed-effects estimates reported in Table 3 were obtained through the inclusion of dummy variables for each contract series rather than through implementation of the within estimator. The coefficients for these contract-specific dummy variables are available from the authors upon request. A first order autocorrelation structure as in equation (2) was imposed while the covariance matrix is also robust to heteroskedasticity and correlation over i. The autocorrelation parameters specific to each panel (ρ_i) are all positive with an average of 0.8251.

The R^2 is close to unity in both specifications indicating an extremely good fit of the data to the model. This, however, could be indicative of the problem of spurious regression which is associated with the non-stationarity of time-series (Granger and Newbold, 1974). Due to these concerns, separate unit root and cointegration tests were performed for each contract series[7]. Based on our results, all the series are integrated of order 1 which could cast doubt on any estimates obtained from this dataset. However, cointegration analysis showed that only 8 out of 69 sets of contracts series are not cointegrated, mainly due to the small number of observations (e.g., contracts expiring in January and February of 2010, and those contracts expiring in the months April to September of 2015 which were first traded in October of 2010). When the residuals from a regression based on non-stationary series are stationary, the series are said to be cointegrated and are free from the spurious regression problem (Engle and Granger, 1987). The results presented in Table 3 are based on the 62 contracts series that passed the cointegration tests, however, estimations with the full sample are practically identical.

Importantly, all the coefficients are significant and show the expected signs. They are also in line with our hypothesis that the price of gas plays a larger role than the price of coal in determining the price of electricity. The full impact of price changes varies with the magnitude of the remaining life of the contract (*life*). Given that all of our observations fall within one year period finishing in November of 2010, the sign of the coefficients for *life* reflect market expectations regarding the role of the different prices in determining the price of electricity. That is, a negative (positive) sign would suggest a decreasing (increasing) role of the corresponding price. Considering the coefficients for *lpg* and *lpg*life* the two models in Table 3 predict that a 10% increase in natural gas prices causes a roughly 5.5% increase in electricity prices in 2010, but about

[7] Augmented Dickey-Fuller tests with up to 4 lags were implemented. Other tests that are appropriate for balanced panel data have higher statistical power, however, our panel is highly unbalanced due to the different first and last date of trading of each contract series. Results from these tests are available from the authors upon request.

8.6% by 2015[8]. The coefficients for other price variables show that the futures markets expect an increasing (decreasing) role of gas and emission allowances (coal) prices in the years ahead when permit caps will be more stringent and coal-based utilities become less competitive[9]. The seasonal dummies (monthly) show that in the period analyzed, everything else equal, electricity prices were higher in December of 2009 and January of 2010 than in any other month of 2010. The magnitudes of the coefficients for February to November of 2010 are almost the same, indicating a stable price of electricity for those months, once the price of fuels and emission permits are taken into account.

Future research could explicitly incorporate dynamic features of price formation into the model, and explore the alternative causality paths of the price variables analyzed here. The latter has been analysed in Woo et al. (2006) where a two-way causality was established between electricity and natural gas prices in California. It would be interesting to investigate if the effect of electricity demand on natural gas prices is also as strong in the different European futures markets.

4. CONCLUSIONS

Electricity prices are determined by the variable costs of the marginal plants setting prices in wholesale markets. The availability of future markets for electricity and fuels used to generate it allows calculation of price margins and even hedging them as long as liquidity of the power plants permits. The quotes in these markets would be reflecting the expectations about the type of technologies that will be setting the electricity price in the future. This study analyzed panel data in which a time-series is available for each contract with a given maturity month. These series support the strong linkage that exists between natural gas and electricity which show a very similar seasonality.

The main finding of this study is that, beyond the patterns observed in the short-run for specific days, markets are incorporating the increasing role that the prices of natural gas and emission allowances will have in determining the price of electricity in the future, at the same time that the influence of the price of coal is reduced. The confirmation of these expectations will imply tougher conditions faced by the more polluting plants such as those using coal. This would happen through two channels: 1) higher prices of emissions allowances will more adversely impact the costs of these plants compared to those based on

[8] Note that since *lpg* appears also interacted with *life*, the partial derivative of *lpe* with respect to *lpg* is the coefficient corresponding to *lpg* plus the coefficient corresponding to *lpg*life* multiplied by the value of life. The latter respectively being 1 and 5 for the years 2010 and 2015.

[9] See Abadie et al.(2011).

cleaner technologies; 2) these plants will set the price in a lower percentage of the trading hours, thus reducing their operation time and revenues whenever electricity prices are below their generation costs.

Although the study is based on UK data given the small number of quotes available for the Spanish electricity market, its conclusions should also be relevant in Spain due to the electricity and natural gas price convergence across European countries, and the single price for emissions allowances prevailing in Europe. It is important to note that even though coal could be subsidized in Spain in the short-run due to social and economic reasons, the impact of this intervention on the points here raised would not be large in the future.

Given the increasing convergence of natural gas markets in Europe[10], as well as the increasing role of the price of natural gas in determining the price of electricity, it could be expected that electricity prices across European countries will likewise tend to convergence. This convergence of electricity prices could be reinforced in the future with increased electrical connection capacity between European countries. This tendency will be further reinforced as contracts are increasingly being negotiated at market-referenced prices.

If information on futures quotes for natural gas in Spain becomes available and more iformation is available on futures for electricity, future research could determine more accurately the impact of natural gas prices on electricity there.

REFERENCES

ABADIE, L.M.; CHAMORRO, J.M. and GONZÁLEZ-EGUINO, M. (2011): "Optimal abandonment of EU coal-fired stations" in *The Energy Jounal*, 32(3): pp 175-207.

ABADIE, L.M. and CHAMORRO, J.M. (2007): "Un análisis cuantitativo de la convergencia entre el gas y la electricidad" in *Economía Industrial*, 365: pp 35-48.

EMERY, G.W. and LIU, Q. (2002): "An analysis of the relationship between electricity and natural-gas futures prices" in *The Journal of Futures Markets*, 22(2): pp 95-122.

ENGLE, R.F. and GRANGER, C.W.J. (1987): "Cointegration and error correction: Representation, estimation, and testing" in *Econometrica*, 55: pp 251-276.

[10] This convergence is linked to the development of markets, the building of new networks of gas pipelines and Liquefied Natural Gas (LNG) Plants.

FEDERICO, G. and VIVES, X. (2008): *Competencia y Regulación en los Mercados Españoles del Gas y la Electricidad,* pp. 168, Barcelona: IESE Orkestra.

GRANGER, C.W.J. and NEWBOLD, P. (1974): "Spurious regressions in econometrics" in *Journal of Econometrics*, 2: pp 111-120.

HAUSMAN, J. (1978), "Specification tests in Econometrics", in *Econometrica* 46(6), pp.

1251-1272.

ROQUES, F.A.; NEWBERY, D.M. and NUTTALL, W.J. (2008): "Fuel mix diversification incentives in liberalized electricity markets: A Mean-Variance Portfolio theory approach" in *Energy Economics*, 30(4): pp 1831-1849.

SENSFUβ, F.; RAGWITZ, M. and GENOESE, M. (2008): "The merit order effect: A detailed analysis of the price effect of renewable energy generation on spot market prices in Germany" in *Energy Policy*, 36: pp 3086-3094.

WOO, C.; OLSON, A.; HOROWITZ, I and LUK S. (2006): "Bi-directional causality in California's electricity and natural-gas markets" in *Energy Policy*, 34: pp 2060-2070.

YANG, M. and BLYTH, W. (2007): "Modeling investment risks and uncertainties with Real Options approach" in *IEA Working Paper Series*. LTO/2007/WP01.