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Forward Price, Renewables and the Electricity Price: The Case of Italy

Valeria Di Cosmo*

Abstract: This paper investigates the determinants of the Italian electricity price (PUN) in order to determine the major challenges this market is currently facing. The results suggest that the policy maker should be aware that the importance of market expectations is increasing (captured in the model by the forward electricity price) and this may be used to understand and forecast the dynamics of spot prices. Second, the positive link between fuel prices and the Italian electricity price may lead to a greater exposure of the Italian electricity price to fluctuations in the international fuel markets. However the results show that the risks associated with higher fuel prices are partially mitigated by the presence of wind generation installed in the system.

Keywords: Electricity price, forward market, gas price

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1 Introduction

The analysis of the linkage between forward market, renewables and the electricity price is very important to understand the current development of the European markets. This paper will focus on the Italian market as this market both has a significant penetration of renewables (both solar and wind) and a well establish forward market. The results of this work may be useful to better understand the underlying dynamics between forward and renewables, which may be useful to address some relevant questions also for other European markets, like the Irish ISEM.

Italy depends on imported fuel for about 85 percent of its needs, as stated in the National Energy Agency report for 2010.¹ These imports mainly consist of oil and natural gas, while some electricity is also imported from abroad.²

In recent years, the Italian electricity sector has been subject to a wide reorganization, following the implementation of EC Directive 96/92, which set minimum goals for opening the national market to competition. The reform aimed to achieve harmonization among the legislation of the Member States required for the creation of an integrated European electricity market.

Further, Legislative Decree n.79 of March 16, 1999 (Bersani Decree) liberalised the activities of electricity production, import, export, purchases and sales and set an antitrust ceiling on the market share of the dominant operator implementing a series of measures meant to enhance competition. The partial success of the Bersani Decree can be seen by the substantial increase in the number of electricity operators (both generators and suppliers). Following this, various electricity companies have split their operations, moving away from vertical integration and establishing separate production entities. In a small number of cases companies have merged or have incorporated smaller enterprises.

As a consequence of all these regulatory changes, the Italian power market has seen a strong increase in the number of participants and in the liquidity, defined as the market share not owned by the former monopolist, see Table 1.

Moreover, recent changes on international fuel markets have affected the Italian electricity

¹See ENEA (2012).

²A brief description of the Italian fuel dependency up to 2012 may be found here: http://ec.europa.eu/energy/sites/ener/files/documents/2014_countryreports_italy.pdf.

price. First, both the European spot and forward gas markets (ICE) have dramatically increased their traded volumes since 2007. This, in turn, increased the linkage between gas and Brent price series. Second, the oil market underwent a huge crisis in 2008 when the price of the oil fell from 140 to 80 dollars per barrel.

Table 1: *Italian electricity market main indicators (2004-2012)*

Year	PUN (€/MWh)			Total Volumes (MWh)	Liquidity (%)	Participants (31 Dec)
	average	min	max			
2004	51.6	1.1	189.19	231572	29,1	73
2005	58.59	10.42	170.61	323185	62,8	91
2006	74.75	15.06	378.47	329790	59,6	103
2007	70.99	21.44	242.42	329949	67,1	127
2008	86.99	21.54	211.99	336961	69,0	151
2009	63.72	9.07	172.25	313425	68,0	167
2010	64.12	10	174.62	318562	62,6	198
2011	72.23	10	164.8	311494	57,9	181
2012	75.48	12.14	324.2	298669	59,8	192

Source: GME, 2013

Data for 2004 are from April to December

This paper analyses how the changes in the Italian electricity market and international fuel markets affected the determinants of the Italian electricity price, called "Prezzo Unico Nazionale" (PUN). Several papers estimate the fundamental determinants of the electricity prices in order to forecast them, and this paper partially follows this literature by estimating an ARMA-X model for the Italian PUN.³ There are some studies that examine the Italian market explicitly. Bosco et al. (2007) consider an autoregressive process to explain price dynamics for 2004. Gianfreda and Grossi (2012) estimate and forecast Italian zonal electricity prices from 2005 to 2008, focusing on the impact of market congestion and concentration. These authors find that indicators of market power and network congestion are good predictors of the Italian electricity prices at a zonal level. Finally, Gianfreda et al. (2015) analyse the impact of renewables on the Italian adjustment and balancing markets. The authors find that solar, wind and hydro power positively affect the price difference between the spot and the balancing price.

My work differs from the previous analysis in many aspects. First, this paper analyses the impact of the Brent and gas crisis of mid 2008 and early 2009 on the Italian electricity

³See among others, Conejo et al. (2005), Weron (2006) and Schmutz and Elkuch (2004).

prices. Second, this paper tests the relation between electricity prices and the PUN forward market, the investment in wind generation, the demand and the fuel prices from the start of the market until the end of 2012. My results show that there is a structural break in the PUN series at the beginning of 2009, due to the fall in fuel prices. Before 2009, the main determinants of the Italian electricity price were demand and Brent oil price. After the break, the determinants of the PUN were demand, gas price, PUN forward and wind generation. This result is due to the investment in wind generation, as well as to the development of the Italian forward market (which took place in 2008). Finally, the significant effect of the gas price is probably linked to the development of liquid financial gas markets which allows generators to hedge their gas formula directly with gas instead of signing long-term contracts indexed to the Brent price. The outline of the paper is as follows. Section 2 describes the Italian market, Section 3 describes the data, Section 4 presents the model. The results of the estimation are presented in Section 5. Section 6 presents some robustness checks and Section 7 concludes.

2 The Italian electricity market

The Italian wholesale electricity market (IPEX) was established in 2004, rising the liquidity of the market as shown in Table 1 above. However, the number of eligible demand bids was kept quite low until the full opening of the market in 2007.

There are two electricity markets: the spot (MPE) and the forward (MTE) market. In the Italian electricity spot market, the electricity is traded one day-ahead in hourly blocks. The market is divided into six different geographic zones, and participants in each zone submit their offers (bids) in which they specify the quantity and the minimum/maximum price at which they are willing to sell/purchase electricity. The system operator accepts the bids/offers following the merit-order criterion and taking into account transmission capacity limits between zones.

As a result, in each hour there are six zonal marginal clearing prices. The Italian electricity price used in my analysis is calculated as the average of these prices, weighted for the quantities purchased in each zone. When system constraints prevent the flow of electricity between different zones, the zonal pricing will be paid to the sellers by the system operator,

and the buyers will get the PUN.

There are two other markets in addition to the day ahead market, the MI (intraday market) and the MSD (balancing market). The MI takes place in four different sessions: MI1 and MI2 both open at 10.45 and close at 12.30 and at 14.00 respectively on the day $T - 1$. MI3 and MI4 also open in $T - 1$ at 16.00 but close at 7.30 and 11.45 on the day in which the market is realised. In the intra-day markets the demand bids are evaluated at the zonal price, and they are aimed to allow the market participants to modify the schedules defined in the day-ahead market by submitting additional supply offers or demand bids. The participation in both the day-ahead and the MIs markets is voluntary.

There are two balancing markets: the ex-ante MSD and the balancing market (MB), which take place in multiple session.⁴ Participation in the balancing markets is compulsory, as these markets allow Terna S.p.A (the transmission system operator) to procure the resources required for managing, operating, and controlling the power system.

The forward market has been operative since November 2008 and is a regulated market where the independent system operator (GME) acts as the central counterparty clearing-house; participants can trade standardized forward electricity contracts, both base-load and peak-load, with delivery and withdrawal obligation, every working day from Monday to Friday, from 09:00 to 17:30.⁵ All the electricity market participants are admitted to this market.

The forward market is completed by the bilateral contract market (PCE), also regulated and managed by the GME. The following Table shows the volumes traded on the spot and the forward markets

Table 2: *Volumes traded in the spot and forward markets, TWh, 2008-2102*

	MPE	MTE	PCE
2008	337.0	0.1	152.4
2009	313.4	0.1	173
2010	318.6	6.3	236.2
2011	311.5	33.4	296.1
2012	298.7	55	307.6

Data source: GME annual report, various years.

⁴A detailed explanation of the MSD market is provided here: <https://www.mercatoelettrico.org/En/Mercati/MercatoElettrico/MPE.aspx>.

⁵See <http://www.mercatoelettrico.org/En/Mercati/MercatoElettrico/MTE.aspx> for more details on the operating time.

3 Data description

Information on hourly loads and spot electricity prices come from the market operator's website (<http://www.mercatoelettrico.org/En/Default.aspx>), as well as daily data on the forward electricity price established in the MTE. Prices of the bilateral contracts registered on the PCE are not available.

The forward price reflects 1-month-ahead expectations on the spot price. The expectations change on a daily basis, but the referring period is always the next month considered as a whole. Therefore, it is impossible to disentangle the expectation made in October 2009 by the market operators for the spot price on two specific days (e.g. the 16th and 22nd of November 2009), as the forward contracts are signed for the full month of November 2009. Thus, in order to capture the expectations of the month ahead the market realization, I took the average of the daily forward prices for the period before the considered spot price and kept it constant for the whole month. As a result, the PUN realized on the 16th and the 22nd November 2009 has the same forward price as a regressor.

As the scope of the present paper is to understand the determinants of the National electricity price, and all the regressors considered in this analysis are at daily or monthly level, first I calculated the hourly mean of the zonal prices weighted by the respective loads, and then I took the daily averages. For the loads, I simply took the daily averages.

Data on the cooling and heating degree days are available for the following locations: Milan, Rome, Naples and Palermo from 2008 on the website www.degreedays.net. I took the average between these values as a proxy of the national weather. Cooling degree days are defined as the number of degrees that a day's average temperature is above 65 Fahrenheit (18 Celsius) and people start to use air conditioning to cool their buildings. In the same way, heating degree days are the number of degrees that a day's average temperature falls below 15.5 degree Celsius.

The gas price used by Italian generators is traded on the Virtual Exchange Point (PSV) platform and the price series were kindly provided by ENEL. As there are some missing data in the gas PSV series before January 2009, I interpolate them with the NBP data. Data on gas price at the UK Net Balancing Point (NBP), and the euro/pound exchange rate are from the Thompson-Reuters database.

Data on the CO_2 price were taken from Bloomberg (code MO1:COM). All information on fuel prices is on a daily basis. Since fuels are traded Monday through Friday, whereas electricity is traded on weekends as well, I set the weekend fuel prices equal to those of the previous Friday.

Data on solar generation are available on monthly basis on the Energy Regulator website (GSE) for the years 2010, 2011 and 2013 and on annual basis for the other years. I use daily data on solar irradiation from the European Climate Assessment Database (<http://www.ecad.eu/dailydata/index.php>) to calculate the daily solar generation for the years in my sample, as shown in the Appendix.

Data on wind generation are available on annual basis from ISTAT. Data on wind speed are available on a daily basis from the website: <http://www.wunderground.com>. I then calculate the wind generation from the wind speed data. The methodology used to approximate the wind generation series is described in the Appendix. Unfortunately, data on hydro power are available for the Italian system only on an annual basis and for that reason I didn't include them in my analysis.

Table 3 summarises the data for the electricity price (both spot and forward) and the main explanatory variables used in my analysis.

Table 3: *Summary statistics (2004-2012), €/MWh*

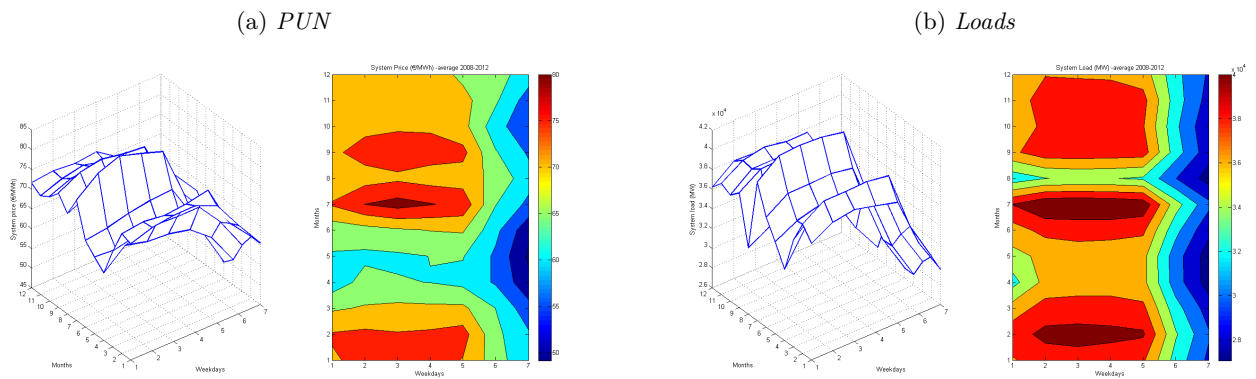
Variable	Obs	Mean	Std. Dev.	Min	Max
<i>PUN(€/MWh)</i>	3197	69.211	15.499	1.210	142.596
<i>Loads (MWh)</i>	3197	35852	4677	23075	46311
<i>Wind Generation GWh</i>	1645	24.922	13.867	0	70.612
<i>Solar Generation GWh</i>	1283	25.032	28.217	0.060	188.533
<i>Brent (€/MWh)</i>	2899	36.024	11.961	14.648	63.774
<i>Wind Speed (m/s)</i>	1644	5.449	1.588	2.286	14.056
<i>Gas (€/MWh)</i>	3166	21.272	8.263	3.392	87.494
<i>HDD</i>	1648	2.958	3.711	0	16.074
<i>CDD</i>	1648	2.289	2.982	0	10.382
<i>PUN forward (€/MWh)</i>	1645	72.050	11.360	49.753	108.000
<i>CO2 Price (€/tonn)</i>	1887	11.836	6.570	0.010	24.950

3.1 PUN and loads

The Italian electricity price tends to be above its average level both during the winter (January/February) due to the increase in the use of electric light, and in the summer, (July/August) due to the use of air conditioning. Traditionally, August is the month in

which both the industrial and the commercial sectors close for holidays, which explains why the price of electricity decreases during that month compared to the peak of July. Accordingly to Weron (2006), the pattern followed by the electricity price is related both to loads and international fuel prices. In particular, the Italian electricity price tends to be higher when loads are higher and lower when loads are lower, as shown by the following Figure:

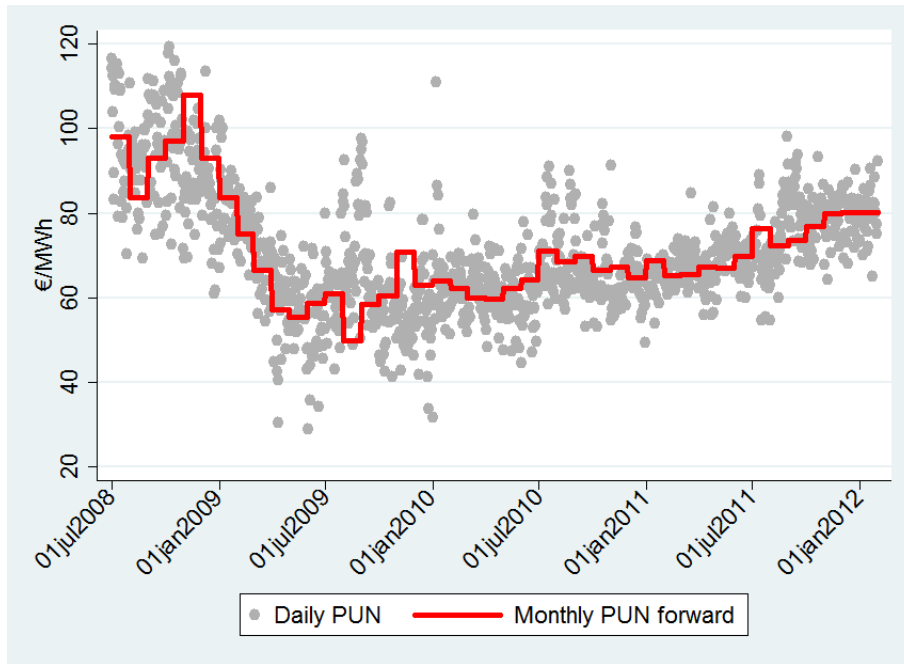
Figure 1: *PUN and loads distributions, average 2008-2012*



3.2 PUN and PUN forward

As shown in Table 2, forward contracts traded both in the MTE markets and bilaterally have rapidly grown in recent years. Unfortunately, data on bilateral contracts are not available and the MTE market data (considered here) are available only from July 2008. However, the one-month ahead forward price used in my analysis is closely related to the daily PUN, as shown by Figure 2.

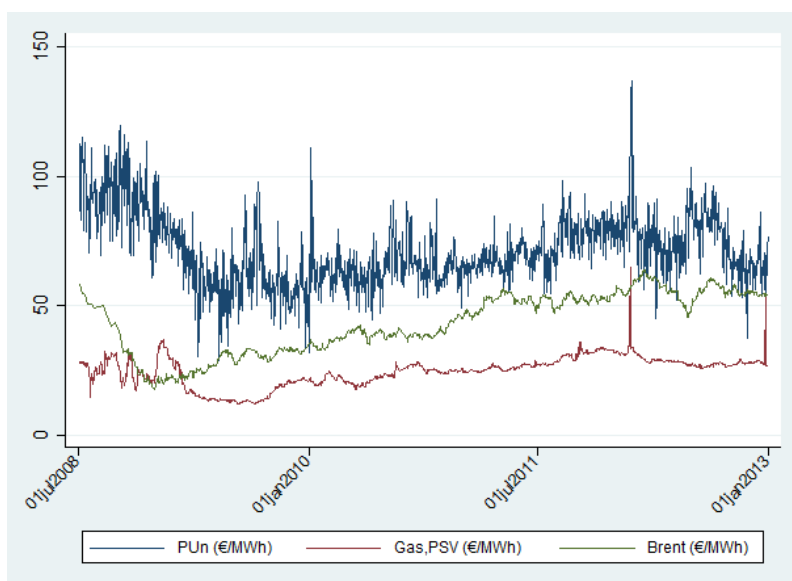
Figure 2: *PUN: daily spot and monthly forward (2008-2012), €/ MWh*



3.3 PUN and fuel prices

The recent increased liquidity of international natural gas markets has given more opportunities to generators to hedge the costs of their power plants on the international fuel markets. However, the financial crisis started in 2008 has potentially affected the determinants of the Italian electricity price in irreversible ways. Fig.(3) shows the dynamics of the Italian electricity price and of the main fuels used in the generation process from 2004 to 2012.

Figure 3: *PUN, gas (NPV) and brent (2008-2012) €/ MWh*



The Italian electricity price follows the gas and the oil prices quite closely. Thus the PUN decreases quite abruptly in the first quarter of 2009, reacting to the brent crisis of June 2008 and the consequent fall of the gas prices at the end of 2008 and beginning of 2009. The likelihood of a structural break of the PUN series during that time is tested in the following section.

4 Methodology

The most popular test for the presence of structural breaks is the one introduced by Chow (1960). However, this test is exogenously determined, as the researcher has to choose a plausible date for the structural break, then check for the presence of differences between the series before and after the break.

The Clemente and Rao test chooses the structural break point endogenously and detects the presence of a structural break in the shadow price series on the 8th of February 2009, whereas the Zivot test finds a break on the 12th of the same month. All the tests suggest a structural break in a similar period in February 2009; however tests by Zivot and Andrews (1992) and Baum (2001) reject the hypothesis of the presence of a unit root in the series.

The same tests on the gas price series shows that the presence of structural break cannot

be rejected at the 5% level for the end of December 2008. ⁶

Following the results of the previous tests, I look for the presence of structural breaks on the 12th of February 2009. The Chow test rejects the null hypothesis of absence of structural breaks with an F statistic equal to 130.66.

The existing lag between the fall in the brent price that occurred in June 2008 and the PUN reaction in February 2009 has two possible explanations. First, the gas contracts for thermal generators up to 2009 were linked to brent through a formula, and not directly. Before the development of financial and physical gas markets, the Italian Combined Cycle Gas Turbines (which were often the marginal plants) were buying gas through long-term contracts, usually hedged against an index based on brent products, called IT-REMIX. As the IT-REMIX included (among other brent products) 9-month lagged brent, it was falling with a 9-month lag with respect to the brent prices. As a consequence, the PUN shows a downturn about 9 months later than the brent prices.

Second, in 2009 some European financial markets for gas (such as TTF) start to increase their liquidity. As a consequence, it is possible that some generators hedged their gas contracts directly on the gas market. As shown by Figure 3, gas prices fell around February 2009, which explains the subsequent fall in the Italian electricity price.

In order to take the structural break into account, I estimate the model for two different periods. The first model considers the period from July 2008 (from which data on PUN forward and gas prices are available) to the identified structural break (12 February 2009). The second model is estimated from the 13th of February 2009, until the end of 2012. The model is estimated by using the ARMA specification, with lagged residuals. This captures the impact of fuel prices and loads on the electricity price and models the electricity price dynamics correctly.

Following Gianfreda and Grossi (2012) I tested for GARCH residuals, but the GARCH component is not statistically significant. In order to get the appropriate lag order and the correct specification for the residuals I estimate several models. The one chosen has the highest AIC test associated, equal to 7638 and includes 1 period and 7 period lags.

⁶The Clemente and Rao test statistic for pun rejects the hypothesis of the presence of a unit root in the electricity price series at the 5% level. The Augmented Dickey-Fuller test (ADF) test rejects the presence of unit root test both before and after the structural break. The ADF associated to the period before the structural break is -15.036, with a test statistic equal to -3.430. After the break, the test statistic is equal to -14.601.

Results on the other models are shown in the Table below:

Table 4: *AIC specification test 12 Feb.2009 - 31 Dec.2012*

AR(1/7)	7604
AR(1/5) AR(7)	7614
AR(1/4) AR(7)	7615
AR(1/3) AR(7)	7616
AR(1/2) AR(7)	7630
AR(1)AR(7)	7638

I then estimate the follow equation:

$$\begin{aligned}
 PUN_t = & \alpha + \beta_1 L_t + \beta_2 Gas_{t-1} + \beta_3 Brent_{t-1} \\
 & + \beta_4 PUN_{fwd}^t + \beta_5 PC_t + \beta_6 Wind_t + \beta_7 Solar_t + \sum \kappa^s D_t^s + \epsilon_t
 \end{aligned} \tag{1}$$

where $\epsilon_t = \rho_0 \epsilon_{t-1} + \rho_1 \epsilon_{t-7}$, PUN_t is the daily electricity price, L_t are the daily loads, Gas_{t-1} and $Brent_{t-1}$ are the gas and the brent day ahead prices, PUN_{fwd}^t is the forward of the PUN calculated one-month ahead of the delivery. PC is the price of carbon, $Wind$ and $Solar$ are the generation quantities by wind and solar power calculated as described in the Appendix and D is a set of dummies which account for yearly, weekly and monthly seasonality. My specification captures the impact of fuel prices, wind, financial markets and loads on the electricity price and models the electricity price dynamics.

The variables are estimated in levels and not in logs to take into account the presence of zeroes in the $Wind$ variable. In order to take the potential non-linear relation between the electricity prices, loads and wind, I include the square of loads and wind in Equation 1. However, neither the coefficient of the square of L_t or $Wind$ were significant at the 1% statistical level.

5 Results

As shown by Table (5a), before the brent crisis the loads are positively related to the spot price, which is intuitive given that when demand is larger, more expensive plants are called to generate. The positive between loads and PUN is also shown in Figure 1b.

The price of CO_2 is positively related to the electricity price as it is simply passed by the generators to the final consumers. As shown in Table 8 in the Appendix, before 2009 the investment in wind generation was not huge; this may explain why wind is not significant at this stage of the analysis.

It is worth noting that the price of gas is not related to the price of electricity before 2009. This is mainly due to the fact that before the brent crisis in 2008 generators were hedging their production against brent, through long term contracts negotiated with their suppliers.

Table (5b) shows the result of the same regression after the structural break of 12 February 2009.

After the structural break of February 2009 both loads and the gas price are significantly related to the Italian electricity price. Brent turns out to be not significant after the 2008 crisis.⁷

As mentioned above, the structural break in the PUN series is mainly the result of the fall in the brent prices in the summer of 2008. In Italy, the gas contracts signed by power generators were usually long term contracts (i.e. more than 30 years) indicised to brent in order to hedge the power plants from the risk of abrupt price changes. The instability of the brent price jointly with the high liquidity in the gas market combined to reduce the explicative power of brent on the Italian electricity price series.

⁷As the data on PUN forward are available only from July 2008 on, yearly and monthly dummies have been dropped from the regression before the structural breaks. Moreover, the 7th autoregressive lag was not significant at the 10% level and it was removed from the specification.

Table 5: *Estimation results: PUN, 2008-2012*

(a) 03 Jul. 2008 - 12 Feb. 2009		(b) 12 Feb. 2009-31 Dec. 2012	
<i>Loads(GWh)</i>	1.64** (0.622)	<i>Loads(GWh)</i>	1.61*** (0.193)
<i>Gast_{t-1} (€/MWh)</i>	-0.104 (0.298)	<i>Gast_{t-1} (€/MWh)</i>	0.164* (0.0728)
<i>Brent_{t-1}(€/MWh)</i>	0.555*** (0.149)	<i>Brent_{t-1} (€/MWh)</i>	-0.162 (0.155)
<i>PUN_{fwd}^t (€/MWh)</i>	-0.0359 (0.145)	<i>PUN_{fwd}^t</i>	0.327* (0.137)
<i>PriceCO₂ (€/ton)</i>	0.389 (0.218)	<i>Wind(GWh)</i>	-0.0582** (0.0197)
<i>Wind(GWh)</i>	-0.179 (0.119)	<i>Solar(GWh)</i>	0.0167 (0.0205)
<i>WorkingDays</i>	yes**	<i>PriceCO₂ (€/ton)</i>	-0.536 (0.279)
<i>Monthly and year dummies</i>	not significant	<i>Years</i>	yes*
<i>AR₁</i>	0.527*** (0.0917)	<i>Months</i>	yes***
<i>Obs</i>	110	<i>WorkingDays</i>	yes***
		<i>AR₁</i>	0.541*** (0.0176)
		<i>AR₇</i>	0.0943*** (0.0253)
		<i>Obs</i>	1160

Data on solar generation are available from January 2009

The wind coefficient is equal to -0.058, which can be interpreted as saying that every 1MW increase in wind generation (equal to about 25% of the average wind generation in my sample) will lead to a decrease of the electricity price equal to -0.06 €/MWh, or about 0.3% of its average value in my sample.

The solar coefficient is not statistically significant. There are two possible explanations for this. First, the increase in solar generation happened mainly in 2012-2013, as shown in Table 9 in the Appendix. As my analysis focuses on the period before 2013, the effects of solar generation on the Italian electricity price are probably not fully captured by my sample. Second, the daily data captures the average effect of solar during the day. Solar power is more effective during the central hours of the day, and it is likely to reduce the electricity price only during specific hours. My analysis shows that, before 2013, the solar power did not change the Italian electricity price at daily level significantly.

The coefficient of the emission permit price is not significant in this specification. However

the low levels of the Emission Trading Scheme (ETS) price between 2009 and 2012, may partially explain this result.

Results in Table 5b show that the one month ahead forward price is positive and significant; this means that higher market expectations are verified in the spot market. Before the PUN structural break the forward price was not statistically significant. This may be explained considering that data on forward price are available only from June 2008, and the market was not very liquid in the first months of activity. As a result, during this period, the link between the forward price and the spot price was not really strong.

Finally, as loads and prices are determined simultaneously in the electricity market, I have to take into account the possible endogeneity of the volumes traded in my specification. In order to take this into account, I re-estimate the previous model in two step. First I regress loads on cooling and heating degree days. Then I use the estimated loads as regressor in Equation 1.

6 Robustness check

In order to control for the potential endogeneity of the loads, I control for the different sources of seasonality. Following Lotufo and Minussi (1999), Juberias et al. (1999), Ling et al. (2003) and Liu et al. (1996), I use data available from the following site: <http://www.degree-days.net/>, which are available from mid 2008. Cooling and heating degrees days have been calculated as the average between values of several Italian locations, as described in Section 3.

As shown by Table 3, weather data have some missing values; as a result, estimated loads have 19 missing observations, leading to a total of 1648 observations. No structural breaks were detected for the loads, so I estimate the load model across the complete period, from 2008 to 2012.

I use daily data to estimate the following equation:

$$L_t = \alpha + \beta HeatDegree_t + \gamma CoolDegree_t + \theta HeatDegree_t * WD_t + \delta CoolDegree_t * WD_t + \eta WD_t + u_t \quad (2)$$

where $u_t = \rho_0 u_{t-1} + \rho_1 u_{t-7} + \theta \epsilon_{t-1}$, L_t are the daily load data in GWh, $HeatDegree_t$ indicates the number of heating degree days in day t , $CoolDegree_t$ is the one related to cooling degree days. WD_t is a dummy equal to 1 if t is a working day and 0 otherwise, which to help capture the use of electricity due to other causes than changes in the weather. I also include the two interaction terms between degree days and weekday dummies, as degree days may have a different effect on electricity used during work days and on weekends. Finally, u_{t-1} is the error term, which is lagged for one and seven days and has a moving average component.

Table 6: *Estimation results: loads, 2008-2012*

<i>HeatDays</i>	174.6** (53.57)
<i>CoolDays</i>	196.3* (86.54)
<i>WorkingDay</i>	yes***
<i>WorkingHeat</i>	yes***
<i>WorkingCool</i>	yes***
<i>AR</i> ₁	0.799*** (0.02)
<i>AR</i> ₇	0.0685*** (0.0175)
<i>MA</i> ₁	-0.0824** (0.0263)
Obs	1648

Both cooling and heating degree days are significant and positive in determining the system loads. As in Italy the main fuel used for heating is gas (and oil, in rural areas) the consumption of electricity reaches its peak during the summer, so cooling degree days are positive and significant in determining the shape of the loads. However, during the winter electricity usage for lighting reaches its peak during January/February (as shown in Figure 1b), making heating degrees positive and significant.

The fitted loads mimic actual load quite well, as they have the same mean (35294 MWh). The standard deviation associated to the fitted loads is 4199, where the same measure for loads is 4448.

I then use the loads predicted by Equation2 to estimate the PUN model described by Equation 1. Results of the second step estimation (both before and after the break) are reported in the following Tables:

Table 7: *Estimation results: PUN, 2008-2012*

(a) 03 Jul. 2008 - 12 Feb. 2009		(b) 12 Feb. 2009-31 Dec. 2012	
$Loads_{Predicted}(GWh)$	0.874*** (0.223)	$Loads_{Predicted}(GWh)$	0.831*** (0.0630)
$Gas_{t-1} (\text{€}/MWh)$	-0.0501 (0.286)	$Gas_{t-1} (\text{€}/MWh)$	0.140* (0.0637)
$Brent_{t-1} (\text{€}/MWh)$	0.591*** (0.126)	$Brent_{t-1} (\text{€}/MWh)$	0.116 (0.0772)
$PUN_{fwd}^t (\text{€}/MWh)$	0.0789 (0.139)	$PUN_{fwd}^t (\text{€}/MWh)$	0.392** (0.128)
$PriceCO_2 (\text{€}/\text{ton})$	0.362 (0.201)	$PriceCO_2 (\text{€}/\text{ton})$	-0.455* (0.203)
$Wind(GWh)$	-0.0819 (0.13)	$Wind(GWh)$	-0.0466* (0.0203)
AR_1	0.485*** (0.0930)	$Solar(GWh)$	0.031 (0.0204)
AR_7	-0.02 (0.0933)	$const$	12.04 (8.845)
Obs	106	AR_1	0.527*** (0.0175)
		AR_7	0.104*** (0.0254)
		Obs	1148

Data on solar generation are available from January 2009

The results of the model before the structural break are close to the one reported in Section 5. Brent and loads are the only determinants of the electricity price before the structural break of 2009. ⁸

The magnitude of the coefficients is only slightly different, as the Brent influences on the prices is a little higher in this model. Also loads have a lower coefficient in this model. Following the AIC criterion, this model has a lower predictive power than the previous one. ⁹

Also the results on the sample between the structural break of February 2009 and the end of 2012 are quite similar. In the two-step model, the determinants of the Italian electricity price are essentially the gas price, the loads, the PUN forward and the wind. However, in this model also the price of carbon is significant and negative.

⁸Again, for the estimation before February 2009, the 7th lag in the AR component was not significant.

⁹The two AIC statistics are equal to 741 for the two-step model and 766 for the previous model.

The fit of the two-step model after the series break is almost the same.¹⁰

7 Conclusions

This paper investigates the determinants of the Italian electricity price (PUN).

First, this work shows how the presence of the structural break at the beginning of 2009 changed the determinants of the PUN. Before the brent and gas crisis, the brent price was positively and significantly related to the PUN, due to the presence of long-term contracts in the supply of gas for the Italian generators, indexed to brent price. The role of the gas price was not significant during that period. After 2009, the volatility of brent jointly with the liquidity available on the gas markets increased the effect of natural gas prices as a determinant of the PUN. Variations in the brent price become statistically insignificant at this point.

Second, this paper analyses the determinants of the Italian electricity price. The results of the work show that after 2009 the one month-ahead expectation of the PUN captured by the forward contract became significant in determining the spot prices. The increased importance of financial markets is consistent with the changes made to the Italian electricity market after 2007.

Finally, I investigate the impact of the high investment in renewable generation made after 2010. In particular, I focus my analysis of the effect of wind and solar generation. The results also show that, after the structural break of February 2009, wind generation is significantly and negatively related to the electricity price. My results show that raising the average wind generation in the system by 1MWh will lead to reduction in the PUN equal to 0.06 €/MWh. Solar generation is not significantly related to the Italian electricity price. The main reason for the lack of significance of this variable is that during the period analysed in this research, solar generation was not very high.

Robustness checks made to control for potential load endogeneity confirm the previous results.

¹⁰The AIC criterion is equal to 8525, instead of the 8529 associated to the previous results.

Appendix

7.1 Wind generation

As discussed by Traber and Kemfert (2011) and Knittel and Roberts (2005) the impact of wind generation on electricity prices has increased in recent years due to the massive investment in wind capacity. In Italy the installed wind capacity has risen sharply in recent years as stated by the Italian System Operator.¹¹

The data on wind speed are collected for the major Italian airports. As a result, the data on wind speed don't perfectly match the locations where the wind parks are located. I took data for Milan, Rome, Naples, Campobasso, Bari, Palermo and Alghero in order to capture the wind speed close to the biggest Italian wind parks.

I then calculated the wind power associated to the typical wind turbine for every city considered in my sample using the following equation:

$$P0_s = \pi((diam)^2/4) * AirDensity * WindSpeed_s^3 \quad (3)$$

where $P0$ is the wind power in KW, s is the considered station, $diam$ is the diameter of the windmill rotor, here assumed equal to 80mt. The air density is measured in kg/m^3 and is set equal to 1.225. I considered the same limits related to the wind speed as done in Mulder and Scholtens (2013), imposing a wind power equal to 0 when wind speed is higher than 24.5 m/s or lower than 1.6 m/s.

In order to calculate the wind generation derived from Equation 3 above, I assume that the wind speed is distributed as a Weibull distribution. To get a better approximation, I took the yearly distribution of the wind speed for every station. I then estimated the scale and the shape of the associated Weibull distribution and calculated the appropriate density function. The wind generation for each station is given by:

$$WindGen_s = Numb.Days * Q_s * P0_s \quad (4)$$

where $Numb.Days$ are the days of the considered year, Q_s is the wind speed density

¹¹Data on annual installed capacity by type of generation can be found here: http://www.terna.it/default/Home/SISTEMA_ELETTRICO/transparency_report/Generation/installed_gen_cap.aspx

associated to the s -th station and $P0_s$ is the wind power calculated in Equation 3. I then calculated the average of the wind generation across the different stations.

Finally, I compared the annual generation calculated with the annual data on wind generation released by ISTAT, and re-scaled the daily amount of wind generation calculated with the procedure described above in order to match the actual annual generation.¹²

Table 8: *Wind generation by year, MWh (2008-2012)*

Year	Wind Gen, (MWh)
2008	4861
2009	6543
2010	9126
2011	9856
2012	13407

7.2 Solar generation

Generation from solar power increased sharply from 2010, as shown in the following Table:

Table 9: *Solar generation by year, GWh (2007-2013)*

Year	Solar Gen, (GWh)
2007	87
2008	193
2009	677
2010	1906
2011	10795
2012	18862
2013	21589

Data source: GSE (2013)

As the variable generation costs associated to solar generation are almost equal to zero, high levels of solar generation may push the electricity price down; so I have included solar generation in my analysis. Data on solar generation are available from the GSE on monthly basis only for the years 2010, 2011 and 2013.¹³ For 2008, 2009 and 2012, data are available on annual basis. In order to build the daily series, I've taken data on solar irradiation from the website <http://www.ecad.eu/dailydata/index.php>. Data on solar irradiation are available for the following locations: Brindisi, Cagliari, Rome and Verona, which represent a good mix between northern and southern regions. I took the

¹²Data on annual wind generation are available here: www.istat.it.

¹³See GSE (2013).

average of the solar irradiation for these locations and used this new series to interpolate the monthly data on solar generation available from GSE. I used the proportion between sunshine hours and solar generation in 2013 to approximate the yearly generation for 2012. Finally, I interpolate the yearly generation for 2009. Even if the interpolation technique for 2009 is pretty poor, the solar generation at that date was quite low (677GWh) and its impact on the Italian electricity price at that date should not be strongly significant. As the amount of solar generation before 2008 is negligible I do not interpolate years before 2009 in my analysis.

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