Are Italian Electricity Zonal Prices affected by Technologies, Market Concentration and Congestions?

Angelica Gianfreda and Luigi Grossi[a]

[a] *DESI Department, University of Verona, Italy*

Abstract

In the last few years we have observed deregulation in electricity markets and an increasing interest of price dynamics has been developed especially to consider all stylized facts shown by spot prices. Only few papers, to the authors' knowledge, have considered the Italian Electricity Spot market since it has been deregulated recently. Therefore, this contribution is an investigation with emphasis on price dynamics accounting for technologies, market concentration and congestions as well as extreme spiky behavior. Most papers consider daily arithmetic mean of 24 hourly spot prices, but this produces a distortion because of the existence of spikes, therefore we have considered median values to correct for outliers. We aim to understand how technologies, concentration and congestions affect the zonal prices since these ones combine to bring about the single national price (*prezzo unico d'acquisto*, PUN). Hence, understanding its features is important for drawing policy indications referred to production planning and selection of generation sources, pricing and risk-hedging problems, monitoring of market power positions and finally to motivate investment strategies in new power plants and grid interconnections. Implementing Reg-ARFIMA models, we draw policy indications based on the empirical evidence that technologies, concentration and congestions affect Italian electricity prices.

Key words: Production technologies, Market power, Congestions

1. Introduction

Electricity prices display interesting features at daily level: mean–reversion, seasonality, time varying and clustered volatility, inverse leverage effect and extreme values called spikes or jumps, see for instance Escribano et.al. (2002), Knittel and Roberts (2005), Koopman et al. (2007) and Gianfreda and Bunn (2009) among others. While seasonality and clustered volatility are well–known features, the remaining stylized facts require to be better explained. Mean-reversion is the tendency that prices show tending to a long-run mean level. The inverse leverage effect, discovered by Knittel and Roberts (2005), is the inverse reaction to shocks: electricity price volatility tends to rise in presence of positive shocks more than in presence of negative ones. Extreme values or spikes are results of abnormally large variations in price caused by weather conditions, outages or transmission failures. The peculiarity is that the price does not stay on the new level to which it moves, but it tends generally to revert rapidly to the previous level. The influence of extreme observations is not generally considered in studying the generating processes of electricity time series, but the bias induced by outliers on model estimates is a very well–known problem, see Battaglia and Orfei (2005) and cited references. Modeling spikes is important and it is practice to distinguish between basically two different regimes: a normal one where the spot price is seasonal and mean–reverting and an abnormal one where the price jumps to high values reverting usually in short time to normal lower values, see among others Kanamura and Ohashi (2007). We instead propose to treat daily spikes with median daily prices and consider network congestions as proposed by Haldrup and Nielsen (2006) recalling that the Italian market is segmented showing characteristics as those of Nord Pool because the most congested links identify aggregations of zones. Hence this paper will contribute to and complete the first empirical analyses of the Italian Power Exchange as in Gianfreda and Grossi (2009), Petrella and Sapio (2009) and Bosco et.al. (2007) considering in addition outliers, technologies, market power and network congestions inducing a nonlinear dynamics. The procedure suggested in this paper is aimed to correctly identify the appropriate stochastic generating process for electricity prices which is important for several reasons. First of all, the price dynamics can be used to understand the deregulation process, verify the competition in this electricity market and give indications on spot and forward price definitions. Secondly, a good model identification leads to proper managing of network congestions for needs of continuous real time balancing. Thirdly, modeling is important for forecasting, for trading, for generation planning and plants availability, for risk management and hedging purposes in such market given the recent launch of the Forward

Electricity Market (MTE)[1] on 3 November 2008.

Summarizing our contribution, we propose a price dynamics which takes into account simultaneously long memory, production technologies, concentration and congestions. We also provide evidence that the special zonal structure of this market must be considered when modeling these prices since all series have weighted influence in determining the single national price.

It is well-known that electricity prices depend on prices of generation sources employed, however there is no evidence on the degree and sign of these influences. Moreover we control for exercise of market power from the generation side. Therefore we find answers on how generation sources, market power and congestions interact with the zonal price determination. Having a clear picture of these relationships, then it would be easy to obtain policy indications for future investments on an optimal technology mix, investments in additional capacity and in network interconnections.

The paper is structured as follows: Section 2 links our research to the existing literature. The Italian zonal structure is explained in Section 3, where technologies, market concentration and congestions are also introduced and defined. Model specifications and results are studied in Section 4, whereas policy indications are drawn in Section 5. Section 6 concludes.

2. Background and literature review

Earlier contributions proposed several specifications for the electricity price process, taking into account traded volume, as in Goto and Karolyi (2002), or price volatility, demand and margin as in Karakatsani and Bunn (2008) and again power consumption and water supply as in Koopman et al. (2007). Hence we have found precedents, but none of these has been employed in the first empirical investigations on the Italian market, to the authors' knowledge. In addition, considering recent data from 2005 to 2008, we detect important features of Italian spot prices implementing models with daily median prices accounting for spiky behavior, technologies determining zonal prices, indicators of market concentration and also congestions among contiguous zones. Following Haldrup and Nielsen (2006), we propose to consider possible congestions among zones, where a *congestion* is identified every time we observed different zonal prices. The technical factors underlying transmission network congestions may have a crucial influence over the behaviour

[1] All the abbreviations refer to the Italian definitions.

of generators resulting in the allocation of production and this may affect the final prices paid for electricity. Hence generation, congestions and market power are strongly interdependent factors as in Furió and Lucia (2009). Therefore as Zarnikau and Lam (1998) and Lisea et al. (2008) point out, the transmission capacity plays an important role in controlling congestions, reducing the impact of market power and improving market competitiveness.

In simple words, a generator has market power if it is able to raise the electricity price above marginal cost without experiencing a significant decline in demand. Previous studies focussed on this topic in the electricity generation sector relying on oligopoly theory, implementing simulation techniques to model the electricity generators' behaviour, see Green and Newbery (1992), Newbery (1998), and Wolfram (1998, 1999). Some others proposed empirical research as Wolak and Patrick (1997), Wolak (2000), and Borenstein et al. (2000), Helman, 2006, Bask and Widerberg (2009). For a survey on models to detect market power see Fridolfsson and Tangeras (2009). In addition, as Tamaschkea et al. (2005) suggest, it is important to distinguish between peak demand periods when there is the highest potential to exercise market power especially if there is a limited spare capacity available during these periods. And indeed a market can exhibit very little market power at certain times, but at other times when supply does not match demand, the market may show signs of market power. And this motivates our estimations according to calendar seasons, as it will be introduced further.

Traditionally, analysts and anti–trust regulators investigate market power issues using various measures of market concentration such as:

1. the popular *Hirschmann-Herfindahl* index (HHI), computed as the sum of the shares of the volumes sold in the market by market participants (see Murry and Zhu, 2008 and Blumsack et al., 2002 among others);
2. the *residual supply index* (RSI), which gives indications on the presence of residual market participants necessary to cover demand;
3. the *Lerner* index, computed as market price minus cost divided by price.

Since there is not a consensus on which measure is the best indicator of market power for the electricity markets, because there is a number of factors to account for (transmission constraints are an example), we have decided to consider two structural indexes (the HHI and the RSI) and to construct and compute what we called the *Zonal Lerner index* as suggested by Helman (2006).

3. The Italian Zonal Market Structure

The Italian wholesale electricity market started its operations in April 2004 but became an Exchange only in 2005 registering an increasing in traded volumes from 73 TWh in 2004 to 232 TWh in 2008. It is important to emphasize that since this market is comparatively young there are continuous structural changes as for instance the abolition of the Calabria zone and its inclusion in the Southern zone starting from the beginning of 2009[2]. As other electricity markets, the Italian spot market consists of the day–ahead market (*Mercato del Giorno Prima*, MGP), the adjustment market (*Mercato di Aggiustamento*, MA) and of the ancillary services market (*Mercato dei Servizi di Dispacciamento*, MSD).

The Italian independent system operator, Gestore del Mercato Elettrico (GME), operates on the day–ahead market (MGP) which is an auction market where participants start to submit their offers for sales and purchases nine days before and up to at 09:00 of the delivery day, when the MGP closes. Then according to the economic merit order criterion and to the capacity limits of the transmission lines between zones, offers and bids can be accepted. The accepted supply offers are evaluated at the clearing price of the zone. This price is the equilibrium price determined on hourly basis by the intersection of the demand and supply curves. Hence the *zonal market clearing prices* are those prices observed on several zones or areas, and they can differ across zones if a proportion of the grid becomes congested and so separated from the entire network (Weron, 2006). On the other hand, the accepted demand bids are evaluated at the single national price (*Prezzo Unico d'Acquisto*, PUN) which is the purchase price for end customers and it is computed as the average of the zonal prices weighted by zonal consumptions. On the adjustment market (MA) opening at 10.30 and closing at 14.00, participants can modify their positions resulting from the MGP market submitting additional supply offers and demand bids but now the zonal prices are used to evaluate the accepted purchase bids.

At 14.30 the transmission system operator, Terna S.p.A., starts its operations on the ancillary services market (MSD) and until 16.00 manages and controls the power system, cross zonal congestions and real-time balancing.

[2]Hence investigations refer only to a time period going from January 2005 to the end of 2008.

3.1. Technologies

Italian electricity is produced by the following plants: thermal power plants only with coal, or with fuel oil or with natural gas; as well as multifuel thermal power plants with oil and coal or with oil and natural gas; combined cycle gas turbines (CCGT); hydro power plants with pumped storage, with run of the river (fluent) or with reservoirs (modulation); gas turbine plants (GT); wind power plants and finally other generation plants not included in the previous ones. These twelve technologies have been used in a previous investigation of Italian zonal price dynamics (Gianfreda and Grossi, 2009) to detect influences of generation sources on price and volatility dynamics[3]. Contrary to what done by the GME[4], we have decided to cluster all previous technologies into the following six types of the MTI index for a better representation of zonal generations and distinguishing between oil, gas and coal producing plants[5]: *Coal* (all multifuel and thermal power plants with coal), *Thermal* (plants without coal), *Hydro*, *Wind* (renewables), *CC* that is combined cycles (CCGT and GT) and finally *Other* plants not included in the previous ones. As proposed by Gianfreda and Grossi (2009), we compute for every group of technology the number of hours (frequency) in which it has fixed the price over the corresponding zone and we built a set of 6 dummies, one for each group, and we attributed one to the group with the maximum frequency over the day and zero to the others. Formally, let f_{rjt} the number of hour for the r-th technology group used in zone j on day t. The dummy variable for the r-th group in zone j is then defined as

$$\begin{aligned} d_{rjt} &= 1 \text{ if } f_{rjt} = max_r(f_{rjt}) \\ d_{rjt} &= 0 \text{ otherwise.} \end{aligned}$$

From the summary reported in table 1, it is possible to exclude two technologies, *Wind* and *Other* in all zones, from our analysis since they have a low influence compared to the other sources.

[3]They firstly used the *marginal technology index* (MTI) which gives indications on the technology fixing the price over one zone.

[4]In the annual report GME, 2008b the following groups of technologies have been considered yearly and so at the national level: other, pumped storage, modulation, fluent, CCGT, thermal conventional, see page 99.

[5]It is well documented that oil and gas have similar and correlated dynamics whereas coal has a dissimilar behavior.

	Coal	CC	Thermal	Wind	Hydro	Other
North	73	632	366	0	449	40
CNorth	122	462	702	0	218	26
CSouth	143	362	817	0	183	26
South	151	356	815	0	185	25
Calabria	188	351	810	0	156	28
Sicily	18	325	1106	0	59	1
Sardinia	296	274	700	0	251	20

Table 1: Frequencies (number of days) of Technologies fixing the price over individual zones

3.2. Market Concentration

The number of operators has increased progressively through years growing from 66 and 76 of the sale side bidding and of the demand side bidding respectively on May 2005 to 98 and 95 sales and purchases operators on December 2008. These numbers refer to participants of both exchange and bilateral markets (GME, 2008a). Participants registered on the IPEX market increased from 51 in 2005 to 151 in 2008[6] (GME, 2008b). It could be possible to consider the number of market participants because as this number increases the market becomes more competitive and the price should decrease. Hence we expect to observe a reduction of zonal prices with the progressive increasing of competition. However this information refers to a national level without indications for individual zones, hence we have simply decided to consider the popular *Hirschmann–Herfindahl* index (HHI) as initial screening[7], the *Residual Supply* index (RSI) and finally an index that we have constructed and called the *Zonal Lerner* index (ZLI).

3.2.1. The Hirschmann–Herfindahl Index (HHI)

The HHI measures the degree of concentration and dispersion of volumes sold (and/or offered[8]) by market participants for each hour and each zone.

[6]Data for 2009 are not available yet.

[7]It is well–known that the HHI is a traditional structural index which measures static concentration and it represents just one of major sign of market power, see Hellmer and Warell (2009).

[8]The shares are defined by considering the volumes sold and/or offered (including those covered by Bilateral Contracts) by individual market participants aggregated on the basis

It is the sum of the shares of the volumes sold in the market by market participants as indicated in the following equation

$$HHI(j,h) = \sum_{i=1}^{N} [Q_i(j,h) * 100]^2 \tag{1}$$

with

$$Q_i(j,h) = \frac{V_i(j,h)}{\sum_{i=1}^{N} V_i(j,h)} \tag{2}$$

where $i = 1, \ldots, N$ are market participants, j represents the individual zones, h is the considered hour and finally V_i are volumes sold by the i–th participant.

The range values of this index are 0 when there is *perfect competition* and 10,000 points when there is *monopoly*. It is common practice to distinguish among the following intervals: if $HHI \leq 1000$ then the market is said to be *unconcentrated* equivalent to N firms with equal market shares, if $1000 < HHI < 1800$ then the market is said to be *moderately concentrated* and finally if $HHI \geq 1800$ then the market is *highly concentrated* or *poorly competitive* which is equivalent to have between 50% or 60% of N firms with equal market shares.

From a preliminary analysis of the Italian zonal HHI provided by GME (table 2), it is possible to state that in all Italian zones (apart from North) there is a poor competition on the generation side producing expectations on a direct relation between price and HHI, since when the latter increases then the price should increase as an effect of market concentration (or market power).

Looking at time series of certain hours belonging to delivery periods off–peak 1, off–peak 2 and peak[9], it is possible to see that there is a sensible shift in level in the HHI hourly series during the entire month of November 2008 (see figure 1). In that period we observed a shift in the HHI dynamics but similar behaviors can be seen neither in the quantities sold nor in the

of the group to which they belong.

[9]The delivery periods for the Italian market refer to the following groups of hours: *off peak 1* from 00.00 to 06.00 until the end of 2005 then from 2006 to 07.00; *peak* is from 07.00 (08.00 from 2006) to 22.00 (to 20.00 from 2006); *off peak 2* from 23.00 (or 21.00 from 2006) to 24.00.

	Unconcentration $HHI \leq 1000$	Moderate Concentration $1000 < HHI < 1800$	Concentration $HHI \geq 1800$
North	1,06	90,49	8,45
CNorth	1,08	0,97	97,95
CSouth	1,93	0,11	97,96
South	2,01	2,57	95,42
Calabria	2,05	0,00	97,95
Sicily	2,03	1,02	96,95
Sardinia	2,05	0,00	97,95

Table 2: Percentages of HHI levels with respect to the employed sample of 35064 hours

Residual Supply Index (RSI)[10]. Therefore when testing the exercise of market power using this index, we have considered also this event.

3.2.2. The Residual Supply Index (RSI)

The Residual Supply Index measures the presence of residual market participants necessary to cover the total demand, thus the index measures the ex-post residuality. The hourly zonal RSI published by GME has the following formulation

$$RSI_i(j,h) = \sum_{l=1, l \neq i}^{N} S_l(j,h) - V_i(j,h) \tag{3}$$

where $l, i = 1, \ldots, N$ are market participants, j represents the individual zones, h is the considered hour and finally V_i are volumes sold by the i–th participant. This difference between the total supply and the sum of ith sellers' supply (or in other words the quantity offered by other market participants) represents the *non-contestable volumes*. Hence dividing this quantity by the total quantities sold in one zone at one particular hour, we determined the hourly and daily aggregated RSI_i. If the index is less than 1, then the ith firm is necessary to cover the demand and so it is a *pivotal* supplier in the market; if the index is greater or equal to 1, then the ith firm is not necessary and the market can be considered competitive, see Manuhutu

[10] In the last quarter of 2008 across all zones and groups of hours, there has been observed a drop on sold volumes determined by the principal operator in favor of all other competitors, for details see GME, 2008b page 96.

and Owen (2009) and Rahimi and Sheffrin (2003). The index dynamics is reported in figure 2.

3.2.3. The Zonal Lerner Index (ZLI)

Helman (2006) focused on an alternative methodology for market power measurement, that is considering the difference between the electricity market price at one location and an estimate of the marginal cost of production and delivery to that location. The Lerner index is difficult to calculate accurately since production cost data is not always available in the electricity markets. But considering the Italian framework and referring to our groups of technologies determining the zonal prices, it is possible to estimate the market power exercised by a group of technologies determining the price over one zone. And indeed, given that we observe the marginal technology indexes and the zonal prices, we can also estimate marginal costs using the median prices of off–peak periods as proxy for zonal marginal costs (referred to that technology), since it is reasonable to think that generators produce electricity at a price such that it practically covers their costs when demand is low[11]. The Lerner index measures market power on a scale from a maximum of 1 (when a firm or technology has a greater market power) to a low of 0 (with negative values found for short time periods[12]) implying that a firm or technology has not market power (given that the market price is equal to the marginal cost). Formally we have defined and computed the *Zonal Lerner Index* (ZLI) for the group technology determining the price over zone j on day t as follows

$$ZLI(j,t) = \frac{(p_{jt} - c_{jt})}{p_{jt}}$$

where p_{jt} are the zonal daily median prices without seasonal adjustments, c_{jt} are the daily median marginal costs computed as $c_{jt} = median_h(p_{hjt})$ where h represents the off–peak hours on day t. Clearly, the price mark–up should be positive, since it is not reasonable to produce and sell electricity at a price lower than its production cost. But we observed that generally the estimated

[11]Clearly this is a limitation, due to the limited data availability, because this procedure can underestimate marginal costs.

[12]Sometimes this index is found to be negative, and this happens when prices of generation sources increase and there is no possibility to adjust the wholesale electricity price.

index lies in the interval [0.75; -0.5] as reported in figure 3[13].

[13]Practitioners observed that in off–peak hours zonal prices decrease below marginal costs, hence producing negative ZLI. As explored also simulation models of supply function equilibrium referred to generation mix produce negative mark–ups. Therefore the existence of negative mark–ups could be due to the inter–temporal nature of decisional processes of generation companies which accept loss in off–peak periods in return of high profits in peak hours.

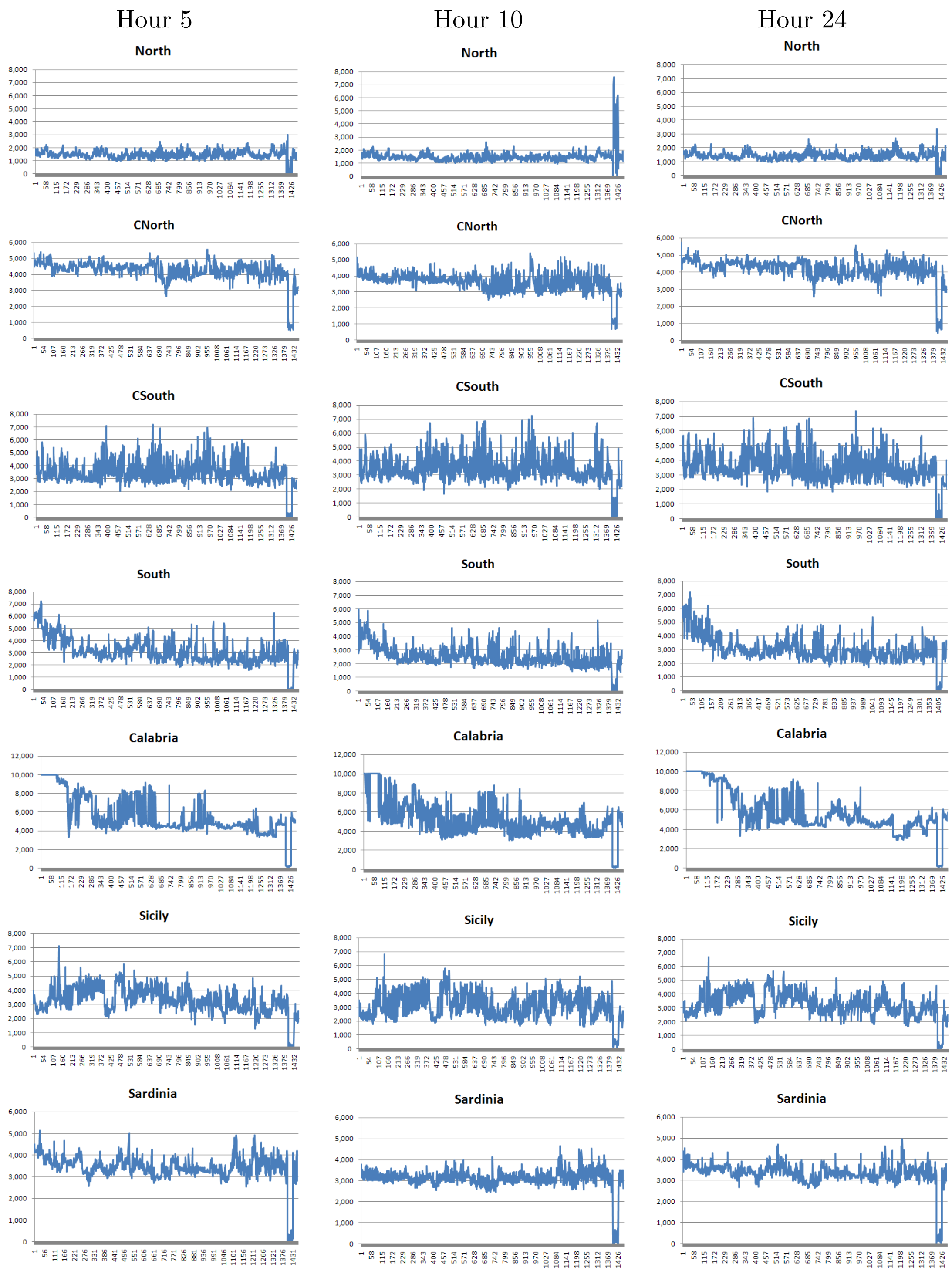

Figure 1: HHI time series of Hour 5 (Off–peak 1), Hour 10 (Peak) and Hour 24 (Off–peak 2) of all Italian Zones

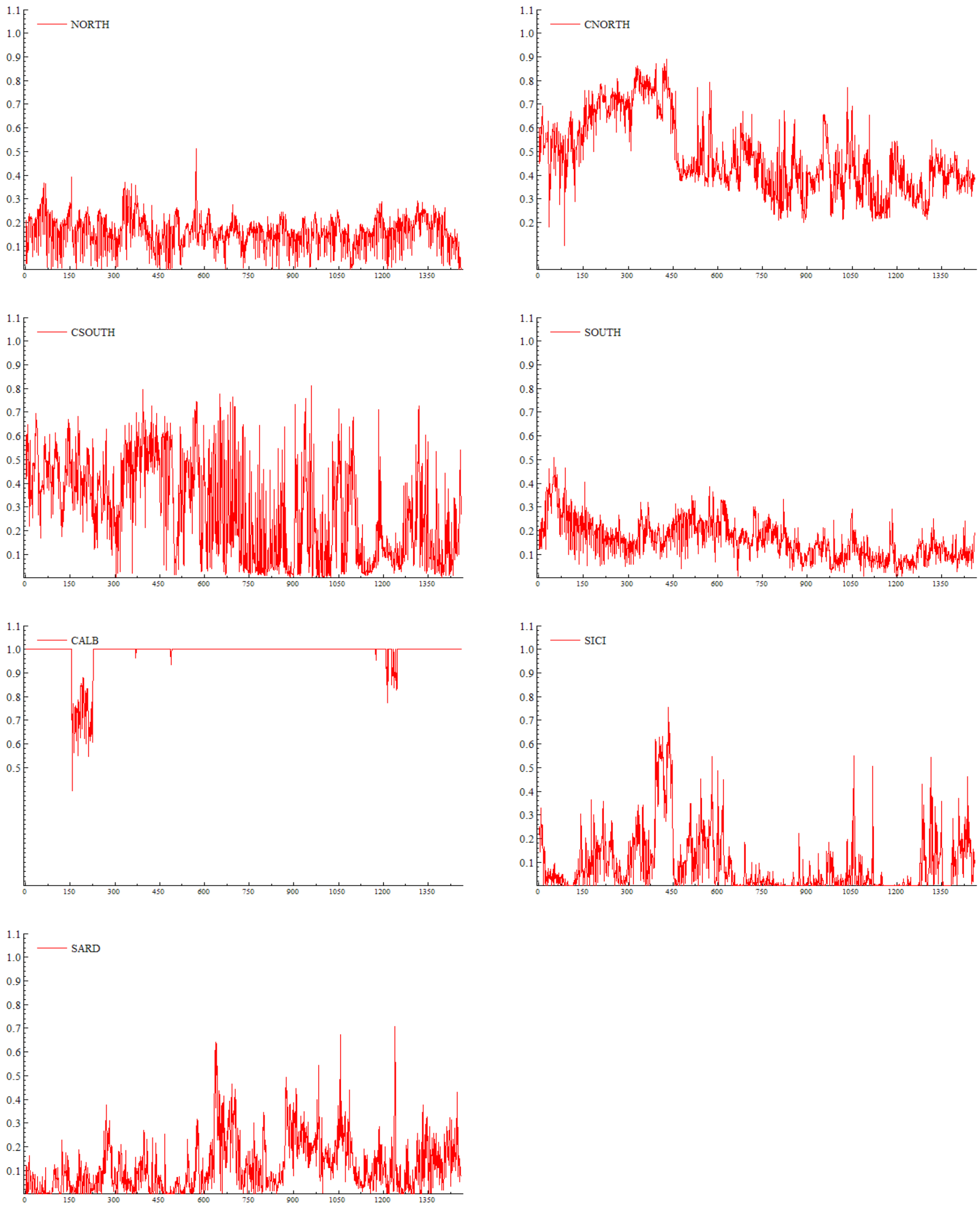

Figure 2: Residual Supply Indexes

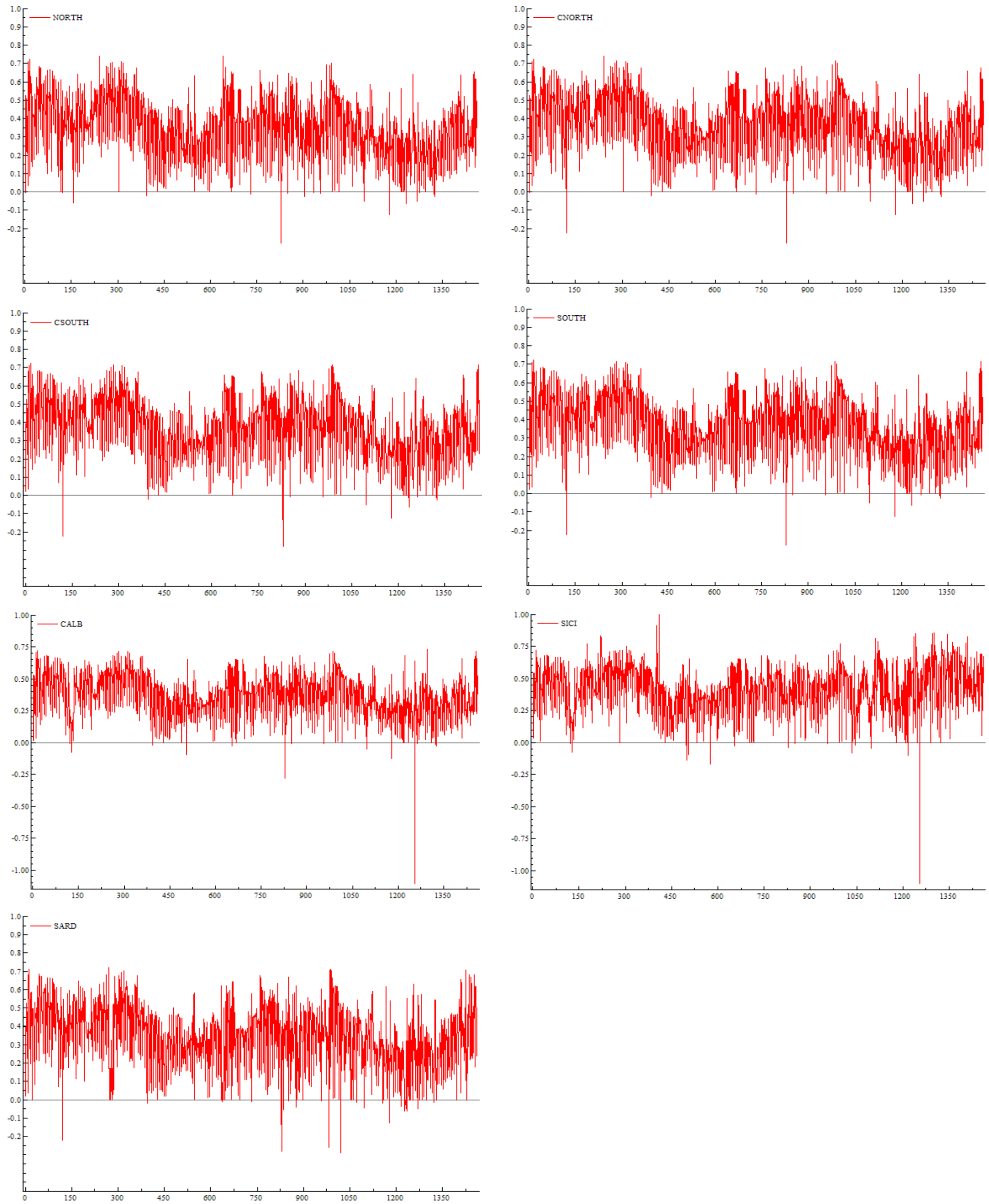

Figure 3: Zonal Lerner Indexes

3.3. Congestions

The Italian market has been then segmented into several zones as a consequence of congestions. In this paper we do not include into the analysis either the foreign virtual zones[14] or the limited production poles[15] but we only consider the physical national zones which are (from 2004 to the end of 2008) the following 7 regional zones: North, Central North (CNorth) which we assume[16] that is directly connected with Sardinia (Sard), Central South (CSouth), South, Calabria (Calb) directly connected with Sicily (Sici). Electricity flows in both directions[17], and so a congestion occurs every time the transmission capacity is exceeded. Figure 4 represents the Italian zonal market structure with circles indicating the limited production poles, blue arrows represent direct electricity flows whereas red ones are flows *assumed* as direct. Therefore transmission limits or, in addition, dissimilar suppliers behavior can cause differences between zonal marginal prices.

Preliminary investigations performed on couples of zonal daily median prices provided evidence on the importance of congestion state. Gianfreda and Grossi (2009) indeed defined the difference between zonal price and the single national price (PUN) as a marginal congestion cost and showed that the Italian market is inefficient since not all zonal prices are equal to the PUN prices. Instead of using congestions costs as defined in Hadsell and Shawky (2006) and implemented in Gianfreda and Grossi (2009), we identify and define daily time series of frequencies of congestions every time we observe different zonal prices among contiguous zonal couples which are are North–CNorth, CNorth–CSouth, South–Calb, Calb–Sici and finally CNorth–Sard. In addition, since one zone as CNorth is connected with North, CSouth and Sard, we have added frequencies of congestions at all borders adjusting for total hourly congestions[18]. Details on occurrences of these daily frequencies

[14]The *foreign virtual zones* ones are neighboring markets as Austria, Corsica, France, Greece, Slovenia and Switzerland.

[15]The *limited production poles* only inject electricity into the systems. We find Brindisi and Rossano among others.

[16]But CNorth is connected to Sardinia through Corsica.

[17]In addition to the previous assumption, we also consider a direct connection through South and Calabria even if it happens through Rossano, a limited production pole.

[18]For example, we have counted 46 congestions in one day in CNorth adding up observed frequencies of congestions at all three borders. Then we have divided the daily amounts by the daily total possible congestions for that zone, that is by 72 (accounting for 24 hours in a day and for 3 zones). Similarly for the other zones.

Figure 4: Italian market structure

referred to studied years are reported in table 3.

	2005	**2006**	**2007**	**2008**
North	1511	3035	2927	1040
CNorth	5296	5639	5552	4687
CSouth	1048	353	580	1438
South	704	2144	361	587
Calabria	5017	6005	4926	6175
Sicily	4341	3926	4593	5744
Sardinia	2765	2316	2073	2365

Table 3: Sum of daily frequencies of zonal congestions

4. Model Specifications and Empirical Results

Moving from the previous considerations, we proposed several models to try to understand which factors, among technologies (and therefore their costs), market concentration and congestions, affect zonal electricity prices.

4.1. Proposed Models

A preliminary empirical analysis of the Italian zonal market has been carried out using daily medians of prices and standard deviations in Gianfreda and Grossi (2009). They provide evidence of the presence of seasonality at daily and monthly levels and a long memory autocorrelation structure, hence we implement Reg–ARFIMA models with dummies for group of technologies, frequencies of congestions and the market concentration index to find empirical evidence supporting policy indications.

The proposed models can be formalized as follows:

$$(1-L)^d(y_t-\mu_t)=\varepsilon_t \qquad \varepsilon_t|I_{t-1}\sim NID(0,\sigma^2) \tag{4}$$

for $t=1,...,T$ where y_t is the zonal median electricity price, adjusted for seasonality, at time t, L is the lag operator defined by $Ly_t = y_{t-1}$ and $\mu_t = E(y_t|I_{t-1})$ is the mean equation conditioned to the set of information available at time $t-1$. Four different specifications have been considered for the conditional mean function, that is ARFIMA$_{tech}$ defined in eq. 5, ARFIMA$_{mp}$ in eq. 6, ARFIMA$_{cong}$ in eq. 7 and ARFIMA$_{all}$ in eq. 8 respectively:

$$\mu_t = \phi_1 y_{t-1} + \ldots + \phi_p y_{t-p} + \lambda_1 Tech_t \tag{5}$$

$$\mu_t = \phi_1 y_{t-1} + \ldots + \phi_p y_{t-p} + \lambda_2 MarPow_t \tag{6}$$

$$\mu_t = \phi_1 y_{t-1} + \ldots + \phi_p y_{t-p} + \lambda_3 Cong_t + \lambda_4 Cong_{t-1} \tag{7}$$

$$\begin{aligned}\mu_t = \phi_1 y_{t-1} + \ldots + \phi_p y_{t-p} &+ \lambda_1 Tech_t + \lambda_2 MarPow_t + \lambda_3 Cong_t \\ &+ \lambda_4 Cong_{t-1}\end{aligned} \tag{8}$$

where the $\phi_i y_{t-i}$ terms represent the autoregressive component of the price dynamics for $t = p+1,...,T$, with coefficients ϕ_i for $i=1,...,p$. *Tech*, *MarPow* and *Cong* are respectively the dummy variables indicating the *technology group* determining the price, the index of *market power* and finally the adjusted daily frequencies of *congestion* events, λs are regression coefficients.

4.2. Empirical Results and Preliminary Comments

Tables 4 – 8 show the maximum likelihood estimates of Reg– ARFIMA parameters applied to seasonal adjusted time series of daily median prices. We have considered the same order of the model for all zones, ARFIMA(7,1,0), as in our previous work to obtain white noise residuals. Looking at Reg–ARFIMA estimates, we can draw the following conclusions:

1. *Fractionally integration* is an important and salient feature to take into account since estimates of d are always significant and less than 0.5 for all proposed models and zones, as found previously in Gianfreda and Grossi (2009). Hence we confirm that these price processes have long memory.
2. The *autoregressive structure* (that is the AR terms) is found to be important to capture stylized facts of these electricity zonal prices.
3. The employed *groups of technologies* determining the zonal prices are generally significant across zones and models. In details looking at tables 4 and (5), *Coal* and *Combined Cycles*, (CC), always reduce electricity zonal prices, whereas *Thermal*, (TNC), power increases them. Finally *Hydro* is never found to be significant on the entire sample.
4. *Concentration* (or market power) is analyzed in table 6 considering three indexes. The HHI is found to have a controversial impact[19], since it should always have a positive sign (when the HHI increases then the price increases as result of exercise of market power) but it sometimes assumes negative values indicating that market power is beneficial to price reductions. The RSI indicates competitive markets when it approaches one, hence it should reduce the zonal prices but instead we always observe a positive sign. On the contrary, when the ZLI increases (to one or more) the market becomes less competitive producing a rise in prices and indeed we always observe this direct relation in positive signs assumed by the estimated parameters, even for calendar seasons. Moreover, looking at the Akaike information criterion (AIC), the best model accounting for market power is found to be that one with the *zonal Lerner index* so we have used this index in the following analysis independently of delivery periods of high and low demand, since we always observed exercise of market power (according to the ZLI).
5. *Congestions* are important in North, CNorth, CSouth, Sicily and Sardinia where raise zonal prices, and indeed all parameter estimates have positive signs apart for the Northern zone. Here we find that when the

[19]Looking at the entire sample, it is significant (with a negative sign) in CNorth, South and Sicily and it turns to be insignificant in the North, as it was expected looking at the percentages of the HHI index in table (2), and surprisingly also in Calabria and Sardinia, two zones with high market concentration. The same controversial results are found controlling for calendar seasons.

number of congestions approaches the maxima hourly values then the zonal price is reduced maybe as effect of imports from foreign markets. Interestingly and not surprisingly, South and Calabria are not influenced by congestions because there are limited production poles which only inject electricity into the system then providing the necessary supply (Brindisi in the Southern zone and Rossano in Calabria). See table 7 for insights.

Comparing the performance of suggested models we can conclude that the better specifications across zones are the following:

a) In the Northern, Central Northern and Central Southern zones, two groups of technologies, market power and congestions are found to be significant. Therefore all three studied factors affect these zonal prices.

b) In the Southern zone, the better model will be with two groups of technologies and market power only affecting zonal prices, since congestions are not significant.

c) Similarly in Calabria, where zonal prices are influenced only by one group of technologies and market power.

d) We have found the empirical evidence that one group of technologies, market power, and congestions influence zonal prices in Sicily and Sardinia.

	NORTH									
	All Sample		Autumn		Spring		Summer		Winter	
d	0.461	(0.000)	0.486	(0.000)	0.493	(0.000)	0.400	(0.000)	0.213	(0.017)
AR-1	-0.039	(0.466)	-0.047	(0.147)	-0.099	(0.001)	0.025	(0.660)	0.213	(0.016)
AR-2	-0.064	(0.086)	-0.111	(0.000)	-0.125	(0.000)	-0.026	(0.464)	0.089	(0.012)
AR-3	-0.038	(0.262)	-0.091	(0.001)	-0.132	(0.000)	0.014	(0.674)	0.107	(0.000)
AR-4	-0.083	(0.009)	0.006	(0.819)	-0.064	(0.018)	-0.057	(0.052)	-0.174	(0.000)
AR-5	-0.058	(0.070)	-0.013	(0.614)	-0.098	(0.000)	-0.068	(0.022)	-0.008	(0.808)
AR-6	0.037	(0.248)	-0.057	(0.026)	0.117	(0.000)	0.058	(0.053)	0.118	(0.000)
AR-7	0.186	(0.000)	0.220	(0.000)	0.035	(0.189)	0.248	(0.000)	0.273	(0.000)
Constant	62.157	(0.000)	24.493	(0.794)	120.513	(0.351)	82.430	(0.000)	57.594	(0.000)
COAL	-3.426	(0.003)	-10.327	(0.000)	-0.972	(0.292)	-0.637	(0.603)	1.836	(0.218)
CC	-2.039	(0.007)	-6.635	(0.000)	1.462	(0.050)	-2.635	(0.000)	1.691	(0.111)
TNC	2.466	(0.003)	-0.741	(0.263)	3.528	(0.000)	3.392	(0.000)	5.757	(0.000)
HYDRO	0.478	(0.536)	-1.422	(0.027)	1.264	(0.104)	1.283	(0.068)	1.784	(0.083)
AIC	10371.837		8075.286		8023.998		8242.892		8663.420	

	CNORTH									
	All Sample		Autumn		Spring		Summer		Winter	
d	0.439	(0.000)	0.494	(0.000)	0.492	(0.000)			0.245	(0.006)
AR-1	-0.012	(0.857)	-0.130	(0.000)	-0.081	(0.006)			0.194	(0.029)
AR-2	-0.051	(0.229)	-0.186	(0.000)	-0.129	(0.000)			0.073	(0.046)
AR-3	-0.020	(0.589)	-0.108	(0.000)	-0.158	(0.000)			0.081	(0.008)
AR-4	-0.061	(0.070)	-0.044	(0.099)	-0.066	(0.025)			-0.146	(0.000)
AR-5	-0.066	(0.050)	-0.037	(0.157)	-0.104	(0.000)			-0.042	(0.218)
AR-6	0.078	(0.022)	-0.050	(0.049)	0.108	(0.000)			0.116	(0.000)
AR-7	0.198	(0.000)	0.200	(0.000)	0.063	(0.021)			0.283	(0.000)
Constant	60.781	(0.000)	76.656	(0.669)	134.255	(0.376)			57.067	(0.000)
COAL	-3.019	(0.003)	-6.812	(0.000)	-3.210	(0.000)			0.226	(0.844)
CC	-1.973	(0.028)	-5.763	(0.000)	-1.642	(0.057)			1.302	(0.221)
TNC	1.834	(0.047)	1.683	(0.024)	-0.299	(0.731)			3.699	(0.000)
HYDRO	-0.213	(0.814)	0.447	(0.599)	-1.682	(0.051)			1.076	(0.269)
AIC	10343.533		7962.747		8032.190				8625.716	

	CSOUTH									
	All Sample		Autumn		Spring		Summer		Winter	
d	0.463	(0.000)	0.491	(0.000)	0.493	(0.000)	0.477	(0.000)	0.322	(0.000)
AR-1	0.010	(0.850)	-0.092	(0.003)	-0.093	(0.001)	0.112	(0.003)	0.124	(0.176)
AR-2	-0.103	(0.003)	-0.158	(0.000)	-0.158	(0.000)	-0.149	(0.000)	0.000	(0.997)
AR-3	-0.046	(0.167)	-0.109	(0.000)	-0.118	(0.000)	-0.005	(0.853)	0.058	(0.114)
AR-4	-0.034	(0.278)	-0.060	(0.025)	-0.074	(0.007)	0.020	(0.456)	-0.132	(0.000)
AR-5	-0.049	(0.108)	-0.078	(0.004)	-0.094	(0.001)	0.019	(0.475)	-0.063	(0.094)
AR-6	0.048	(0.108)	-0.072	(0.006)	0.105	(0.000)	0.042	(0.101)	0.118	(0.001)
AR-7	0.219	(0.000)	0.264	(0.000)	0.056	(0.041)	0.247	(0.000)	0.296	(0.000)
Constant	60.889	(0.000)	214.861	(0.472)	147.834	(0.351)	108.989	(0.281)	56.544	(0.000)
COAL	-1.177	(0.231)	-5.184	(0.000)	-0.987	(0.268)	-0.432	(0.672)	2.824	(0.009)
CC	-2.640	(0.004)	-5.510	(0.000)	0.170	(0.846)	-6.146	(0.000)	1.511	(0.156)
TNC	2.838	(0.002)	1.475	(0.045)	0.993	(0.260)	4.802	(0.000)	4.098	(0.000)
HYDRO	0.511	(0.586)	0.153	(0.853)	0.231	(0.785)	0.620	(0.521)	0.291	(0.783)
AIC	10390.235		7882.460		7983.640		8492.830		8601.363	

	SOUTH									
	All Sample		Autumn		Spring		Summer		Winter	
d	0.458	(0.000)	0.486	(0.000)	0.492	(0.000)	0.480	(0.000)	0.327	(0.000)
AR-1	0.012	(0.826)	-0.069	(0.033)	-0.095	(0.001)	0.107	(0.002)	0.115	(0.204)
AR-2	-0.098	(0.005)	-0.160	(0.000)	-0.150	(0.000)	-0.147	(0.000)	-0.004	(0.930)
AR-3	-0.037	(0.275)	-0.054	(0.059)	-0.115	(0.000)	-0.006	(0.831)	0.049	(0.186)
AR-4	-0.030	(0.335)	-0.051	(0.063)	-0.072	(0.009)	0.020	(0.441)	-0.126	(0.000)
AR-5	-0.056	(0.069)	-0.097	(0.000)	-0.093	(0.001)	0.017	(0.505)	-0.064	(0.089)
AR-6	0.055	(0.070)	-0.058	(0.026)	0.113	(0.000)	0.045	(0.075)	0.114	(0.002)
AR-7	0.220	(0.000)	0.267	(0.000)	0.058	(0.034)	0.257	(0.000)	0.296	(0.000)
Constant	60.195	(0.000)	157.090	(0.310)	141.272	(0.340)	123.487	(0.305)	56.158	(0.000)
COAL	-0.240	(0.808)	-3.470	(0.000)	-0.432	(0.622)	-0.192	(0.849)	3.351	(0.002)
CC	-1.768	(0.054)	-3.240	(0.000)	0.043	(0.959)	-6.368	(0.000)	2.207	(0.035)
TNC	3.494	(0.000)	2.854	(0.000)	1.154	(0.182)	4.721	(0.000)	4.532	(0.000)
HYDRO	0.980	(0.297)	1.658	(0.057)	0.368	(0.660)	0.574	(0.550)	0.183	(0.862)
AIC	10388.485		7904.102		7961.128		8480.409		8614.912	

Table 4: Reg–ARFIMA$_{tech}$ estimates (with p–values in brackets) for technology effects on Italian Electricity Zonal Prices when convergence was achieved.

	CALABRIA									
	All Sample		Autumn		Spring		Summer		Winter	
d	0.454	(0.000)	0.484	(0.000)	0.465	(0.000)	0.481	(0.000)	0.255	(0.002)
AR-1	-0.003	(0.957)	-0.101	(0.004)	-0.102	(0.027)	0.128	(0.000)	0.198	(0.016)
AR-2	-0.102	(0.005)	-0.169	(0.000)	-0.069	(0.054)	-0.193	(0.000)	-0.002	(0.962)
AR-3	-0.039	(0.263)	-0.112	(0.000)	-0.084	(0.010)	0.025	(0.389)	0.072	(0.030)
AR-4	-0.047	(0.139)	-0.004	(0.894)	-0.118	(0.000)	-0.051	(0.060)	-0.099	(0.001)
AR-5	-0.034	(0.281)	-0.109	(0.000)	-0.014	(0.657)	0.073	(0.008)	-0.030	(0.371)
AR-6	0.048	(0.114)	-0.063	(0.022)	0.092	(0.002)	0.035	(0.161)	0.144	(0.000)
AR-7	0.218	(0.000)	0.292	(0.000)	0.064	(0.022)	0.272	(0.000)	0.278	(0.000)
Constant	60.181	(0.000)	149.265	(0.303)	55.800	(0.009)	178.061	(0.373)	57.774	(0.000)
COAL	-0.480	(0.647)	-3.037	(0.001)	0.654	(0.549)	-2.809	(0.008)	0.777	(0.472)
CC	-1.614	(0.093)	-3.157	(0.000)	1.921	(0.064)	-8.219	(0.000)	0.415	(0.686)
TNC	4.140	(0.000)	3.148	(0.000)	4.121	(0.000)	2.136	(0.066)	3.810	(0.000)
HYDRO	1.457	(0.168)	0.932	(0.284)	2.826	(0.008)	-1.444	(0.193)	-0.320	(0.797)
AIC	10557.753		8079.374		8534.682		8392.876		8737.193	

	SICILY									
	All Sample		Autumn		Spring		Summer		Winter	
d	0.485	(0.000)	0.411	(0.000)			0.482	(0.000)	0.102	(0.041)
AR-1	-0.143	(0.000)	-0.078	(0.069)			-0.085	(0.021)	0.216	(0.000)
AR-2	-0.040	(0.181)	-0.022	(0.489)			0.055	(0.079)	0.078	(0.012)
AR-3	0.009	(0.762)	0.104	(0.000)			0.007	(0.801)	0.056	(0.045)
AR-4	0.034	(0.217)	-0.011	(0.665)			0.093	(0.001)	0.064	(0.019)
AR-5	-0.050	(0.063)	-0.067	(0.009)			-0.053	(0.052)	0.015	(0.592)
AR-6	-0.019	(0.480)	-0.114	(0.000)			-0.007	(0.810)	0.038	(0.185)
AR-7	0.035	(0.190)	0.056	(0.035)			0.027	(0.313)	0.136	(0.000)
Constant	74.359	(0.139)	102.248	(0.000)			66.666	(0.724)	72.165	(0.000)
COAL	-4.985	(0.304)	-5.331	(0.587)			-2.479	(0.7119	2.181	(0.586)
CC	-10.899	(0.000)	-13.977	(0.000)			-11.383	(0.005)	-5.537	(0.042)
TNC	1.225	(0.667)	-3.195	(0.207)			-0.412	(0.922)	1.770	(0.516)
HYDRO	-3.974	(0.249)	-4.090	(0.189)			-4.963	(0.330)	-6.813	(0.055)
AIC	12967.502		11078.604				11281.130		10525.508	

	SARDINIA									
	All Sample		Autumn		Spring		Summer		Winter	
d	0.308	(0.000)	0.211	(0.002)	0.489	(0.000)			0.136	(0.081)
AR-1	0.241	(0.005)	0.335	(0.000)	0.069	(0.026)			0.330	(0.000)
AR-2	0.068	(0.052)	0.090	(0.003)	0.194	(0.000)			0.037	(0.211)
AR-3	0.039	(0.190)	0.105	(0.000)	-0.025	(0.367)			0.087	(0.003)
AR-4	0.000	(0.995)	0.106	(0.000)	-0.146	(0.000)			-0.096	(0.000)
AR-5	-0.018	(0.528)	-0.036	(0.221)	-0.125	(0.000)			0.036	(0.224)
AR-6	0.027	(0.356)	-0.003	(0.910)	-0.037	(0.207)			0.107	(0.000)
AR-7	0.082	(0.003)	0.024	(0.376)	0.176	(0.000)			0.214	(0.000)
Constant	60.364	(0.000)	60.626	(0.000)	60.191	(0.809)			60.537	(0.000)
COAL	-1.751	(0.258)	-3.286	(0.050)	-0.161	(0.932)			-0.520	(0.614)
CC	-1.337	(0.390)	0.702	(0.661)	2.202	(0.217)			-1.565	(0.139)
TNC	3.648	(0.021)	3.951	(0.017)	8.019	(0.000)			1.899	(0.061)
HYDRO	0.851	(0.571)	1.654	(0.337)	3.588	(0.047)			0.592	(0.544)
AIC	12068.514		10500.862		10201.519				8780.158	

Table 5: Reg–ARFIMA$_{tech}$ estimates (with p–values in brackets) for technology effects on Italian Electricity Zonal Prices when convergence was achieved (continued).

	All Sample		Nov 08		Autumn		Spring		Summer		Winter	
						NORTH						
d	0.449	(0.000)	0.453	(0.000)	0.483	(0.000)	0.492	(0.000)	0.370	(0.000)	0.318	(0.002)
HHI	0.000	(0.855)	0.003	(0.125)	-0.002	(0.004)	0.002	(0.146)	0.011	(0.000)	0.001	(0.738)
AIC	10433.825		10405.179		8274.202		8055.978		8315.166		8707.384	
d	0.438	(0.000)			0.485	(0.000)	-0.113	(0.122)	0.355	(0.000)	0.153	(0.075)
RSI	72.166	(0.000)			79.586	(0.000)	65.397	(0.000)	52.485	(0.000)	84.971	(0.000)
AIC	10205.995				7951.929		7764.454		8265.411		8455.485	
d	0.421	(0.000)			0.456	(0.000)	0.481	(0.000)	0.408	(0.000)	0.097	(0.198)
ZLI	33.033	(0.000)			31.828	(0.000)	35.339	(0.000)	29.497	(0.000)	36.640	(0.000)
AIC	10049.406				7762.340		7553.653		8121.257		8325.345	
						CNORTH						
d	0.389	(0.000)	0.405	(0.000)	0.487	(0.000)	0.492	(0.000)	0.388	(0.000)	0.294	(0.002)
HHI	-0.002	(0.017)	-0.003	(0.002)	-0.001	(0.203)	-0.003	(0.000)	0.000	(0.679)	-0.001	(0.198)
AIC	10386.833		10347.211		8185.656		8040.485		8348.521		8646.310	
d	0.458	(0.000)			0.495	(0.000)			0.402	(0.000)	0.326	(0.000)
RSI	20.377	(0.000)			25.844	(0.000)			7.100	(0.040)	25.672	(0.000)
AIC	10364.914				8129.695				8349.028		8616.858	
d	0.371	(0.000)			0.483	(0.000)	0.131	(0.017)	0.425	(0.000)	0.140	(0.048)
ZLI	32.729	(0.000)			31.067	(0.000)	33.311	(0.000)	33.434	(0.000)	34.462	(0.000)
AIC	10025.841				7645.351		7636.073		8078.607		8321.741	
						CSOUTH						
d	0.450	(0.000)	0.448	(0.000)	0.485	(0.000)	0.493	(0.000)	0.443	(0.000)	0.336	(0.000)
HHI	0.001	(0.013)	0.001	(0.040)	0.000	(0.568)	0.002	(0.000)	0.003	(0.000)	0.000	(0.239)
AIC	10462.508		10431.066		8081.611		7965.755		8719.902		8626.994	
d	0.453	(0.000)			0.490	(0.000)	0.494	(0.000)	0.454	(0.000)	0.334	(0.000)
RSI	12.405	(0.000)			14.128	(0.000)	9.663	(0.000)	18.404	(0.000)	7.526	(0.000)
AIC	10428.002				7996.848		7957.181		8666.244		8631.765	
d	0.444	(0.000)			0.480	(0.000)	0.074	(0.154)			0.188	(0.008)
ZLI	31.545	(0.000)			29.654	(0.000)	31.945	(0.000)			36.503	(0.000)
AIC	10148.556				7614.577		7563.744				8285.126	
						SOUTH						
d	0.421	(0.000)	0.430	(0.000)	0.451	(0.000)	0.492	(0.000)	0.446	(0.000)	0.247	(0.000)
HHI	-0.001	(0.025)	-0.002	(0.010)	-0.001	(0.034)	0.000	(0.898)	0.001	(0.534)	-0.004	(0.000)
AIC	10454.118		10419.802		8043.164		7962.197		8758.521		8608.960	
d	0.449	(0.000)			0.477	(0.000)	0.490	(0.000)	0.451	(0.000)	0.399	(0.000)
RSI	33.225	(0.000)			42.531	(0.000)	25.210	(0.000)	36.066	(0.000)	18.680	(0.002)
AIC	10425.799				7979.709		7920.170		8727.739		8655.282	
d	0.443	(0.000)			0.471	(0.000)	0.099	(0.067)			0.184	(0.011)
ZLI	31.627	(0.000)			29.672	(0.000)	31.850	(0.000)			37.051	(0.000)
AIC	10134.552				7578.139		7540.873				8296.053	
						CALABRIA						
d	0.426	(0.000)	0.426	(0.000)	0.468	(0.000)	0.468	(0.000)	0.458	(0.000)	0.239	(0.000)
HHI	0.000	(0.358)	0.000	(0.490)	0.001	(0.034)	0.001	(0.038)	0.001	(0.018)	-0.001	(0.003)
AIC	10644.963		10617.339		8202.470		8555.496		8690.558		8765.026	
d	0.415	(0.000)					0.472	(0.000)			0.133	(0.234)
RSI	11.782	(0.167)					68.903	(0.000)			-262.018	(0.366)
AIC	10643.896						8516.903				8771.933	
d	0.437	(0.000)			0.466	(0.000)	0.433	(0.000)	0.470	(0.000)	0.116	(0.083)
ZLI	27.285	(0.000)			31.281	(0.000)	26.417	(0.000)	15.478	(0.000)	38.908	(0.000)
AIC	10380.283				7749.301		8328.791		8610.928		8380.106	
						SICILY						
d	0.481	(0.000)	0.486	(0.000)	0.401	(0.000)			0.481	(0.000)	0.452	(0.000)
HHI	-0.005	(0.000)	-0.007	(0.000)	-0.004	(0.000)			-0.002	(0.056)	-0.010	(0.000)
AIC	13006.730		12954.670		11108.528				11310.249		10515.831	
d	0.486	(0.000)			0.422	(0.000)			0.487	(0.000)	-0.303	(0.000)
RSI	86.838	(0.000)			95.051	(0.000)			109.038	(0.000)	86.051	(0.000)
AIC	12922.304				11010.951				11117.100		10405.430	
d	0.482	(0.000)			0.417	(0.000)	0.493	(0.000)	0.484	(0.000)	0.094	(0.128)
ZLI	45.434	(0.000)			42.428	(0.000)	42.165	(0.000)	49.215	(0.000)	49.923	(0.000)
AIC	12831.056				10964.582		10581.935		11092.550		10320.031	
						SARDINIA						
d	0.264	(0.002)	0.279	(0.001)	0.178	(0.014)	0.489	(0.000)	0.248	(0.000)	0.148	(0.049)
HHI	-0.003	(0.101)	-0.005	(0.012)	-0.001	(0.377)	-0.014	(0.000)	0.016	(0.000)	-0.002	(0.048)
AIC	12085.942		12044.759		10519.852		10212.455		9845.484		8796.153	
d	0.343	(0.000)			0.274	(0.000)	0.490	(0.000)	0.283	(0.000)	0.166	(0.003)
RSI	86.257	(0.000)			101.241	(0.000)	96.342	(0.000)	64.439	(0.000)	55.555	(0.000)
AIC	11876.394				10128.578		10068.352		9785.696		8651.346	
d	0.301	(0.000)			0.200	(0.004)	0.481	(0.000)	0.285	(0.000)	-0.105	(0.081)
ZLI	33.387	(0.000)			22.806	(0.000)	47.098	(0.000)	43.993	(0.000)	35.640	(0.000)
AIC	11909.641				10447.411		9878.505		9651.129		8420.176	

Table 6: Reg–ARFIMA$_{mp}$ estimates (with p–values in brackets) for market power effects on Italian Electricity Zonal Prices when convergence was achieved. Autoregressive estimates are omitted for sake of brevity (these results are available on request).

	NORTH		CNORTH		CSOUTH		SOUTH	
d	0.444	(0.000)	0.414	(0.000)	0.442	(0.000)	0.437	(0.000)
AR-1	-0.011	(0.863)	0.026	(0.726)	0.032	(0.597)	0.042	(0.505)
AR-2	-0.065	(0.108)	-0.044	(0.315)	-0.091	(0.015)	-0.093	(0.014)
AR-3	-0.034	(0.342)	-0.001	(0.980)	-0.024	(0.503)	-0.017	(0.636)
AR-4	-0.076	(0.022)	-0.063	(0.064)	-0.053	(0.100)	-0.037	(0.252)
AR-5	-0.063	(0.060)	-0.058	(0.092)	-0.043	(0.182)	-0.041	(0.196)
AR-6	0.045	(0.179)	0.085	(0.014)	0.051	(0.109)	0.055	(0.083)
AR-7	0.183	(0.000)	0.202	(0.000)	0.208	(0.000)	0.209	(0.000)
Constant	62.899	(0.000)	59.687	(0.000)	60.373	(0.000)	61.428	(0.000)
Congestions_t	-6.701	(0.000)	0.136	(0.945)	16.388	(0.000)	3.326	(0.222)
Congestions_{t-1}	1.124	(0.306)	4.022	(0.040)	2.421	(0.411)	1.561	(0.566)
AIC	10399.097		10390.238		10440.382		10459.163	

	CALB		SICI		SARD			
d	0.423	(0.000)	0.481	(0.000)	0.323	(0.000)		
AR-1	0.034	(0.606)	-0.132	(0.000)	0.201	(0.016)		
AR-2	-0.087	(0.028)	-0.038	(0.222)	0.049	(0.182)		
AR-3	-0.020	(0.592)	-0.002	(0.941)	0.039	(0.213)		
AR-4	-0.041	(0.214)	0.038	(0.169)	-0.027	(0.353)		
AR-5	-0.021	(0.526)	-0.057	(0.037)	-0.006	(0.837)		
AR-6	0.054	(0.085)	-0.015	(0.577)	0.022	(0.452)		
AR-7	0.206	(0.000)	0.039	(0.149)	0.083	(0.003)		
Constant	63.150	(0.000)	61.351	(0.168)	56.482	(0.000)		
Congestions_t	-1.929	(0.308)	21.470	(0.000)	14.274	(0.000)		
Congestions_{t-1}	-1.740	(0.358)	-0.849	(0.713)	4.325	(0.014)		
AIC	10636.344		12950.186		12025.236			

Table 7: Reg–ARFIMA_{cong} estimates (with p–values in brackets) for congestions effects on Italian Electricity Zonal Prices.

	NORTH		CNORTH		CSOUTH		SOUTH	
d parameter	0.431	(0.000)	0.375	(0.000)	0.457	(0.000)	0.458	(0.000)
AR-1	0.060	(0.471)	0.109	(0.256)	0.059	(0.284)	0.059	(0.281)
AR-2	-0.051	(0.272)	-0.042	(0.364)	-0.098	(0.005)	-0.101	(0.003)
AR-3	0.008	(0.852)	0.043	(0.323)	-0.023	(0.509)	-0.026	(0.445)
AR-4	-0.075	(0.042)	-0.045	(0.206)	-0.037	(0.241)	-0.027	(0.395)
AR-5	-0.044	(0.255)	-0.032	(0.383)	-0.046	(0.137)	-0.046	(0.133)
AR-6	0.056	(0.142)	0.090	(0.015)	0.050	(0.107)	0.053	(0.084)
AR-7	0.300	(0.000)	0.343	(0.000)	0.312	(0.000)	0.313	(0.000)
Constant	51.350	(0.000)	47.447	(0.000)	47.984	(0.001)	48.579	(0.001)
COAL	-2.183	(0.027)	-1.658	(0.052)	-0.987	(0.242)	-0.416	(0.625)
CC	-0.828	(0.193)	-0.608	(0.420)	-1.565	(0.045)	-1.339	(0.088)
TNC	1.218	(0.081)	1.929	(0.013)	2.368	(0.003)	2.857	(0.000)
HYDRO	-0.134	(0.836)	-0.393	(0.605)	0.188	(0.815)	0.221	(0.785)
ZLI	31.723	(0.000)	32.112	(0.000)	30.538	(0.000)	30.775	(0.000)
Congestions_t	-5.590	(0.000)	-2.232	(0.187)	12.046	(0.000)	3.280	(0.156)
Congestions_{t-1}	1.725	(0.064)	4.993	(0.003)	5.178	(0.041)	0.916	(0.692)
AIC	9982.451		9982.126		10056.662		10068.469	

	CALB		SICI		SARD	
d parameter	0.461	(0.000)	0.485	(0.000)	0.386	(0.000)
AR-1	0.035	(0.497)	-0.119	(0.000)	0.175	(0.024)
AR-2	-0.106	(0.002)	-0.036	(0.222)	0.034	(0.355)
AR-3	-0.038	(0.257)	-0.009	(0.752)	0.031	(0.332)
AR-4	-0.039	(0.207)	0.037	(0.179)	-0.002	(0.958)
AR-5	-0.020	(0.517)	-0.079	(0.003)	-0.030	(0.304)
AR-6	0.045	(0.128)	-0.007	(0.783)	0.015	(0.611)
AR-7	0.277	(0.000)	0.084	(0.002)	0.089	(0.002)
Constant	50.379	(0.001)	46.690	(0.335)	41.719	(0.000)
COAL	-0.765	(0.420)	-1.248	(0.778)	-1.734	(0.219)
CC	-1.255	(0.142)	-9.380	(0.000)	1.513	(0.287)
TNC	3.500	(0.000)	-0.172	(0.947)	4.158	(0.004)
HYDRO	0.734	(0.435)	-4.055	(0.197)	-0.442	(0.746)
ZLI	26.301	(0.000)	40.903	(0.000)	33.877	(0.000)
Congestions_t	0.728	(0.670)	18.044	(0.000)	17.095	(0.000)
Congestions_{t-1}	-0.173	(0.917)	1.337	(0.528)	4.675	(0.004)
AIC	10309.063		12710.978		11799.053	

Table 8: Reg–ARFIMA$_{all}$ estimates (with p–values are in brackets) for all studied effects on Italian Electricity Zonal Prices.

5. Policy Indications

To the authors' knowledge, this is the first empirical study which provides evidence on influences (with signs) of generation sources, market concentration and congestions on Italian electricity zonal prices given the hourly and zonal data availability.

Looking at the preliminary comments and at the empirical evidence provided in this paper, we try to draw the following indications on appropriate modeling of these Italian zonal prices (see points 1 and 2) and policy indications referred to technologies (point 3), market power and congestions (points 4 and 5):

1. and 2. *Fractional integration* and the *autoregressive structure* are important facts to be taken into account since the former indicates that these price processes have long memory, whereas the latter captures stylized facts as day–of–the–week effect of these electricity zonal prices. Hence we confirm the first indication on the appropriate models to be used, as in Gianfreda and Grossi (2009).

3. Considering *technologies* determining zonal prices, we have that

   - *Other* or renewable generation sources are even not mentioned in this work since there were unimportant on the studied sample therefore demanding for huge investment efforts.
   - *Wind* has been excluded from the analysis since it never determined zonal prices, for the special nature of this generation source. It was found important in Calabria and Sicily only in 2005 with very low percentages[20] and to this aim again massive investments would be required especially in zones with interconnection problems.
   - Even if *hydro* determines zonal prices, interestingly here it is found to be non influential on all zonal price dynamics. Then it could be excluded in modeling problems, and on the other side this calls for further investigations.

[20]See Table 1 in Gianfreda and Grossi (2009) for details on the Marginal Technology Index through years.

- *Combined cycles*, as CCGT and GT, reduce electricity prices as well as *Coal* and this, when investing in new generation plants, gives a priority to the former technologies since the latter is highly polluting.
- Finally investments in *thermal* power plants without coal (TNC) should be discouraged because this technology seems to increase zonal prices.

4. and 5. *Concentration* and *congestions* are found to be significant. Considering market power, further analysis is called for deeper investigations of this phenomenon addressing issues such as the formulation of better indexes to account for most factors intrinsic in the electricity sector. Among ways to mitigate market power and congestions problems, one solution would be the expansion of generation capacity together with the simultaneous, or even better ex–ante, expansion of the transmission capacity accounting for the Italian practitioners' experience according to which the latter requires between 5 and 10 years for realization. Looking at foreign connections, also more efficient and capable extra–country interconnections can improve market competitiveness.

6. Conclusions

This paper is an analysis of effects of technologies, concentration and congestions on Italian Electricity zonal prices. According to the most recent contributions in the time series analysis applied to electricity prices for instance Haldrup and Nielsen (2006), Kanamura and Ohashi (2007), Karakatsani and Bunn (2008), we took into account the long memory feature of the generating stochastic process estimating a parameter of fractional integration, which turned out to lie very close to 0.5. A causal analysis in the framework of Reg–ARFIMA models confirmed the significant impact of production technologies, market concentration and congestions on these price dynamics. These results have been converted in tentative suggestions for policy indications to be followed when programming the medium–long term energy policy in Italy.

Concluding, we have provided firstly insights on relationships between zonal electricity spot prices, technologies, concentration and congestions and secondly policy indications on the future investment strategies with respect to the technology mix and the network grid. In addition we would like to emphasize that special attention should be spent on the construction of new transmission lines given that generators can serve only if there exists adequate transmission capacity, since the installation of new generating capacity is expected to produce even more and sudden bottleneck problems.

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