



FACOLTÀ DI
ECONOMIA
Università degli Studi di Verona

ZONAL PRICE ANALYSIS OF THE ITALIAN WHOLESALE ELECTRICITY MARKET

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Milan

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Contributions

Empirical investigation on **price dynamics** and **volatility facts** considering at the same time

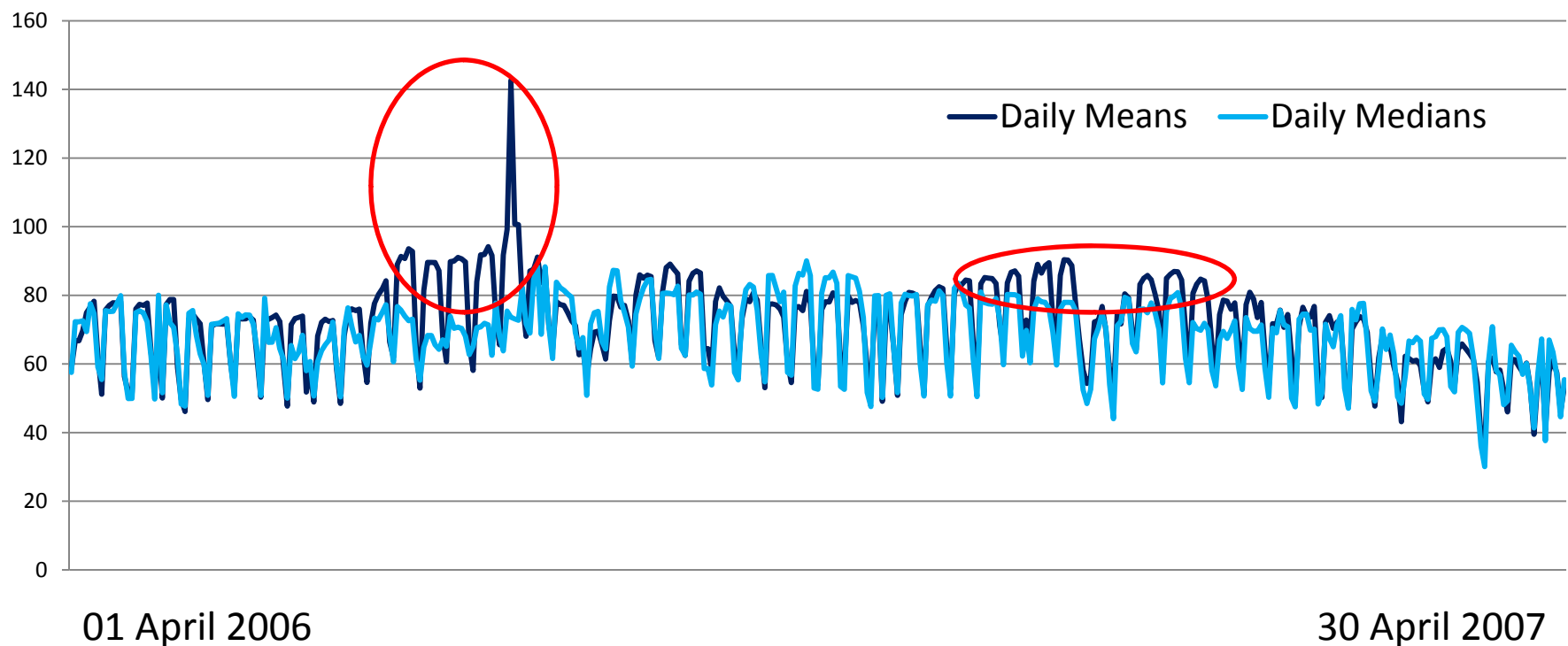
➤ Spiky behaviour

➤ Technology Mix and the Marginal Technology Index

➤ Congestion events

Spiky behaviour

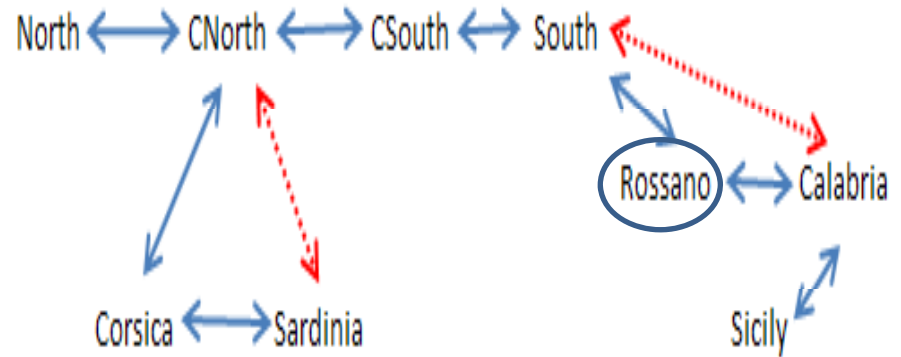
Instead of considering **simple arithmetic means** of 24 hourly prices, we have used the daily **medians** for each zone.



Geographical Structure



 Limited Production Poles



Two assumptions on **direct connections** between

- CNorth and Sardinia (no Corsica)
- South and Calabria (no Rossano)

Sample considered here is from 01/01/2005 to 31/12/2008

Technology Mix

Italian Electricity is produced by the following plants

1. Thermal power plants only with

- ✚ Coal
- ✚ Fuel oil
- ✚ Natural gas

2. Multi—fuel thermal power plants with

- ✚ Oil and coal
- ✚ Oil and natural gas

3. Combined cycle gas turbines

4. Hydro power plants with

- ✚ Pumped storage
- ✚ Run of the river (fluent)
- ✚ Reservoirs (modulation)

5. Gas turbine plants

6. Wind power plants

7. Other generation plants

The Marginal Technology Index (MTI)

In each individual zone, this index gives indications on the *technology fixing the price over that zone* and consequently we have associated a *fixing power* to every technology.

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Formally f_{rjt} is the frequency for the r -th technology over zone j on day t , for

$r = 1, \dots, 12,$

$j = 1, \dots, 7$ and

$t = 01 \text{ Jan } 2005 \text{ to } 31 \text{ Dec } 2008.$

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Secondly, we have constructed a set of dummies (one for each technology with the maximum frequency over the day) in the following way

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

The Marginal Technology Index (MTI)

	2005	2006	2007	2008
NORTH CCGT	25.75	26.51	34.57	41.97
Oil	9.94	5.24	3.65	2.08
Natural Gas	18.20	15.30	11.40	6.94
Oil & Coal	5.34	7.67	8.62	4.63
Oil & Gas	6.80	2.66	4.11	0.93
Coal	7.45	5.35	5.70	6.08
GT	0.02	0.13	0.00	0.00
Wind	0.00	0.00	0.00	0.00
Hydro Flu	3.15	1.97	4.16	3.64
Hydro Mod	22.47	15.06	11.31	6.30
Hydro Pum	0.43	18.66	13.60	9.49
Other	0.41	1.45	2.89	17.83

Percentages of MTI fixing the Zonal prices for individual years

	2006	2007	2008
CALB CCGT	14.26	25.27	37.53
Oil	10.00	5.01	3.03
Natural Gas	28.98	25.98	16.53
Oil & Coal	18.79	13.71	8.85
Oil & Gas	7.37	5.46	1.80
Coal	3.54	4.17	5.06
GT	0.31	0.10	0.03
Wind	0.00	0.00	0.00
Hydro Flu	0.58	1.24	1.78
Hydro Mod	6.04	5.54	3.43
Hydro Pum	9.14	12.65	7.74
Other	0.98	0.87	14.22

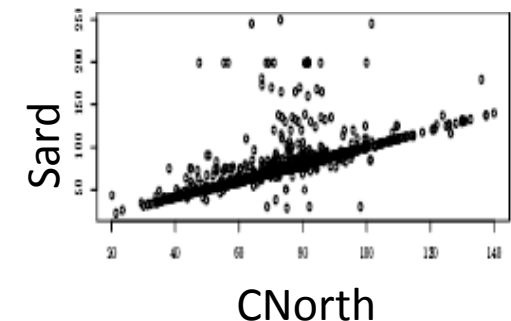
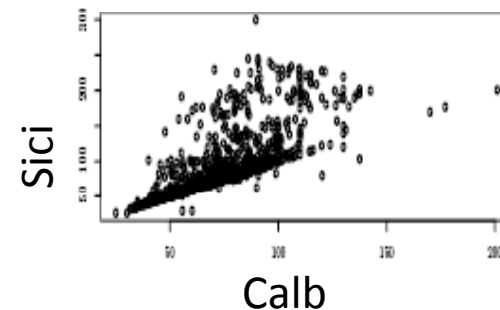
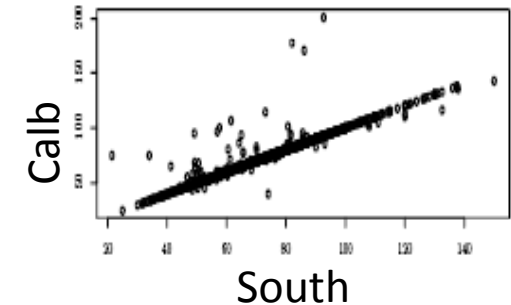
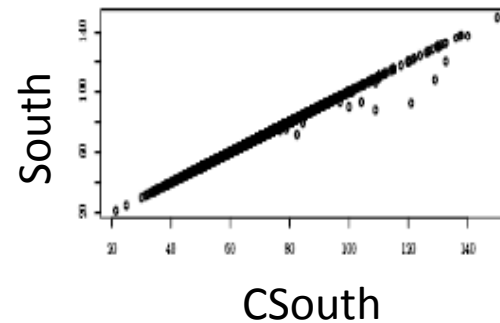
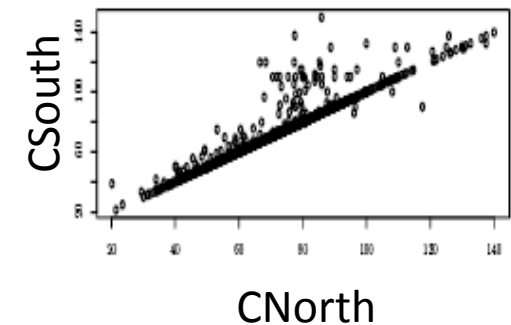
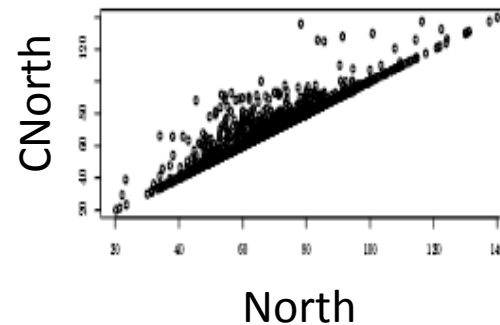
Congestions: the empirical evidence

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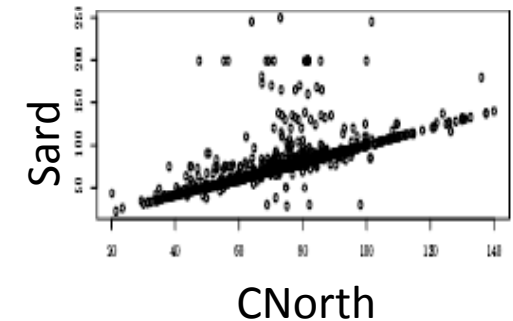
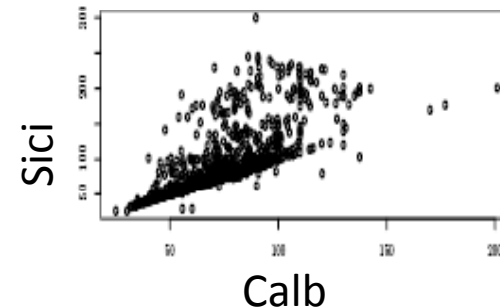
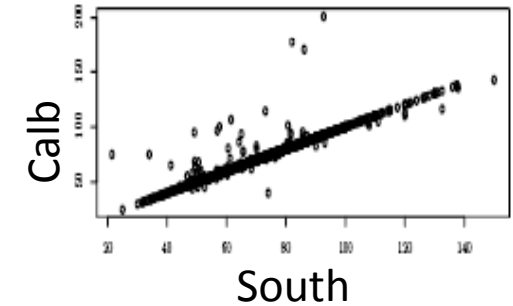
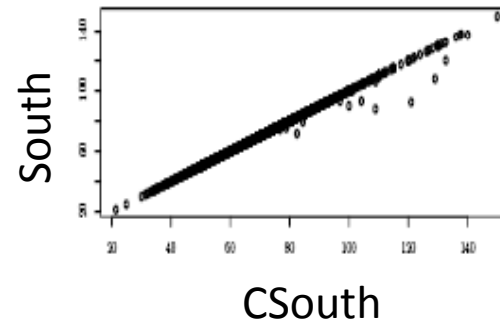
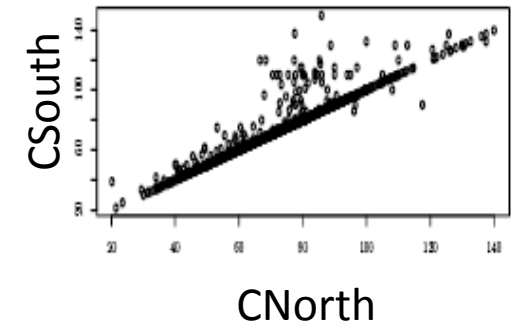
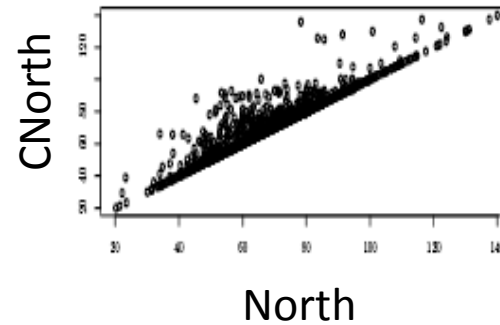
Hence looking at the scatter plots of daily median prices, the dispersion gives indications on congestions*.



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* Not only in Peak periods but also in Base and Off Peaks periods.

Congestions: the empirical evidence

Hours of congestions computed every time we observed different zonal prices among couples of zones.

		2005	2006	2007	2008	
North–CNorth	Off Peak 1	101	312	241	47	Off Peak 1 refers to hours 00.00 to 06.00 (until end of 2005) And to 07.00 (from 2006)
	Peak	1258	1997	2044	765	
	Off Peak 2	152	726	642	228	Peak refers to hours 07.00 to 22.00 (until end of 2005) 08.00 to 20.00 (from 2006)
	Base	1511	3035	2927	1040	
Calb–Sici	Off Peak 1	1150	1034	1036	1083	Off Peak 2 refers to hours 23.00 to 24.00 (until end of 2005) 21.00 to 24.00 (from 2006)
	Peak	2849	2070	2575	3518	
	Off Peak 2	342	822	982	1143	Base refers to all 24 hours
	Base	4341	3926	4593	5744	
CSouth–South	Off Peak 1	11	15	2	9	
	Peak	13	48	26	144	
	Off Peak 2	4	2	0	3	
	Base	28	65	28	156	

Congestions: Zonal Prices and the PUN

The **Zonal Price** is determined by the **marginal technology** fixing the price over the zone and it is the clearing price at which **accepted supply offers** are evaluated.

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The **Single National Price** (Prezzo Unico d' Acquisto, **PUN**) is the **average of the zonal prices weighted by the zonal consumptions**. **Accepted demand bids** are evaluated at this price hence it represents the purchase price for final customers.

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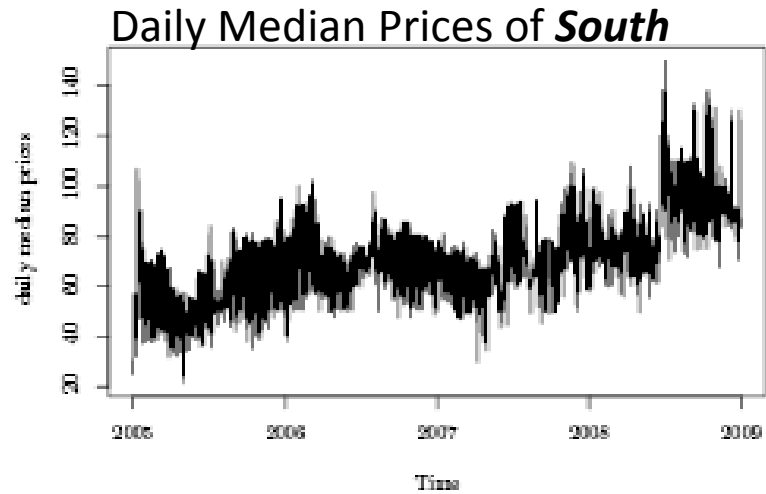
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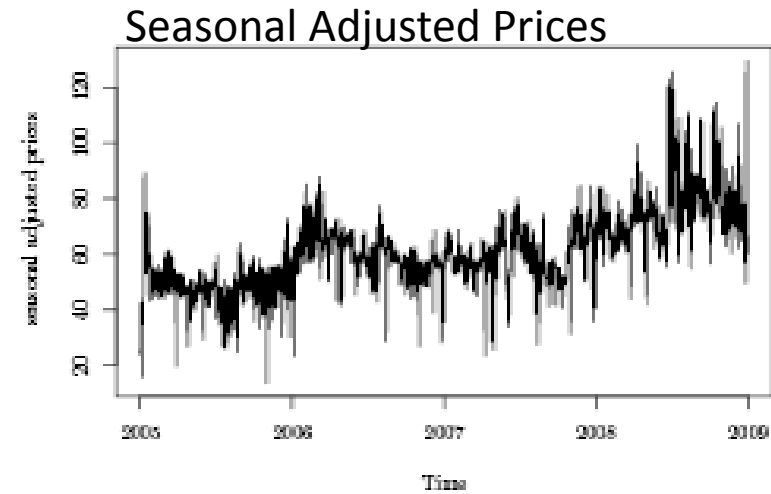
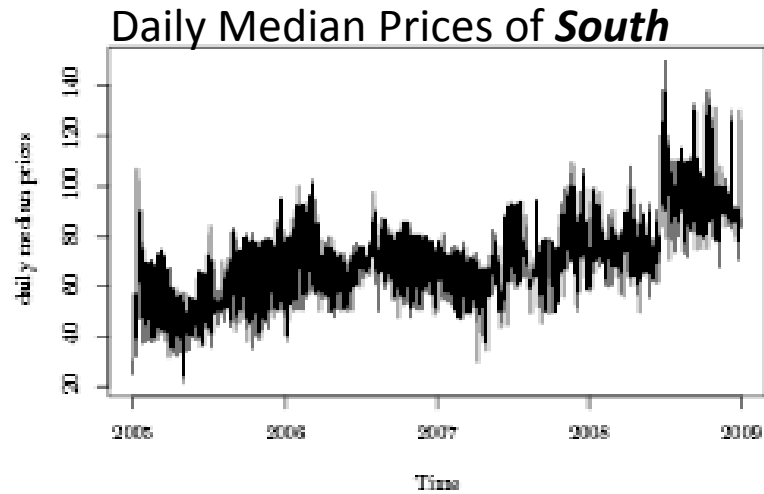
$$cc_{jt} = \text{median}_h \left(y_{jht} - \bar{y}_{ht} \right)$$

where y_{jht} is the j -th **zonal price** for hour h and day t
and \bar{y}_{ht} is the **pun price** for hour h and day t

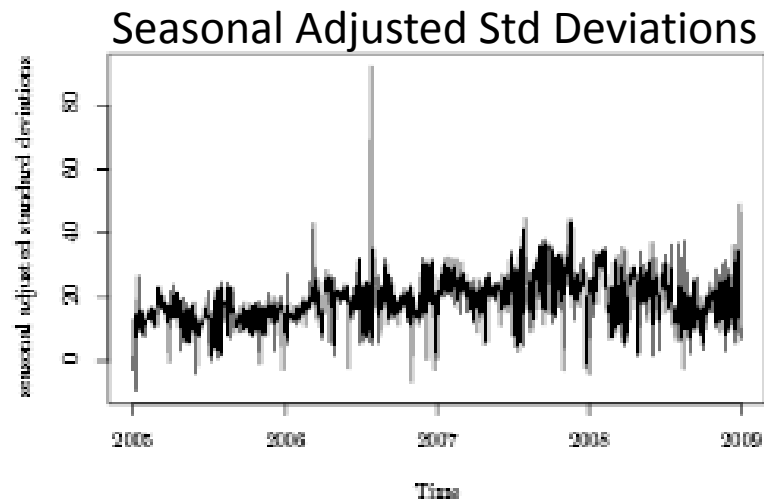
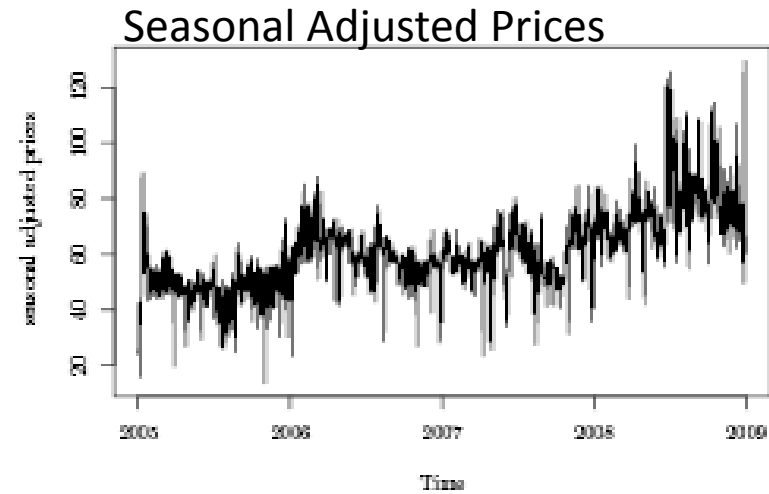
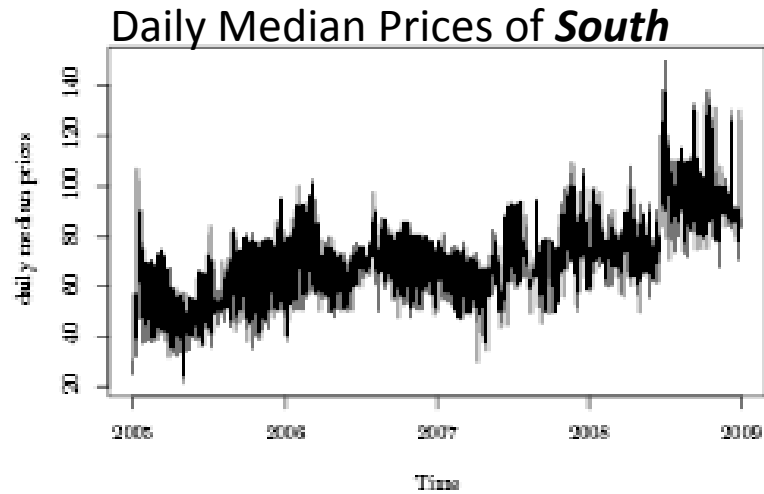
Preliminary Data Analysis



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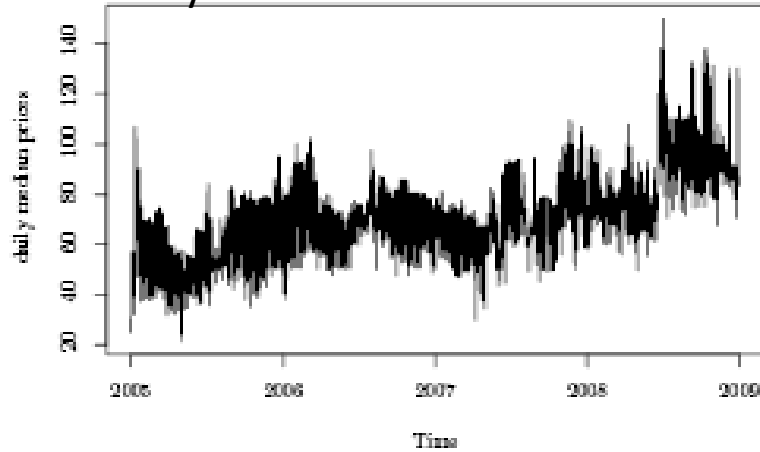


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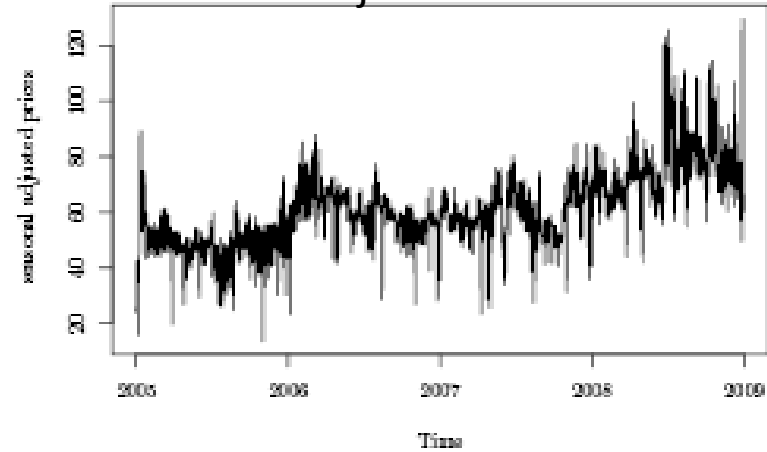


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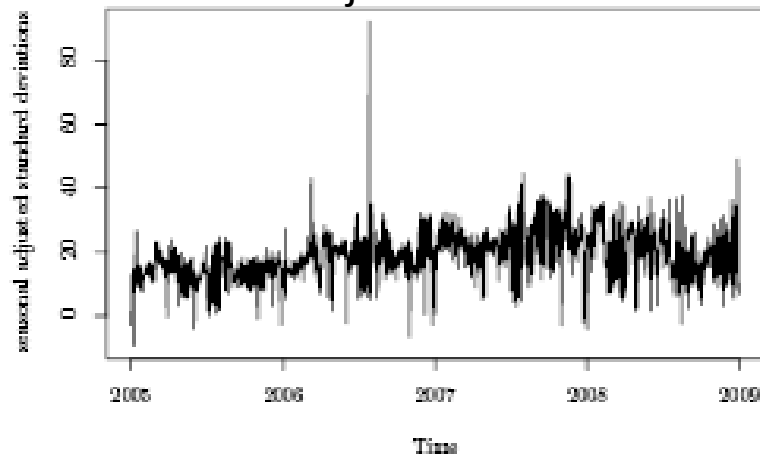
Daily Median Prices of *South*



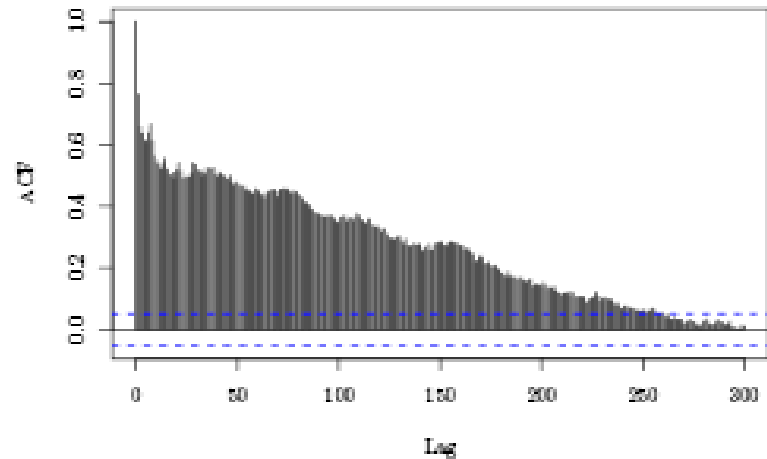
Seasonal Adjusted Prices



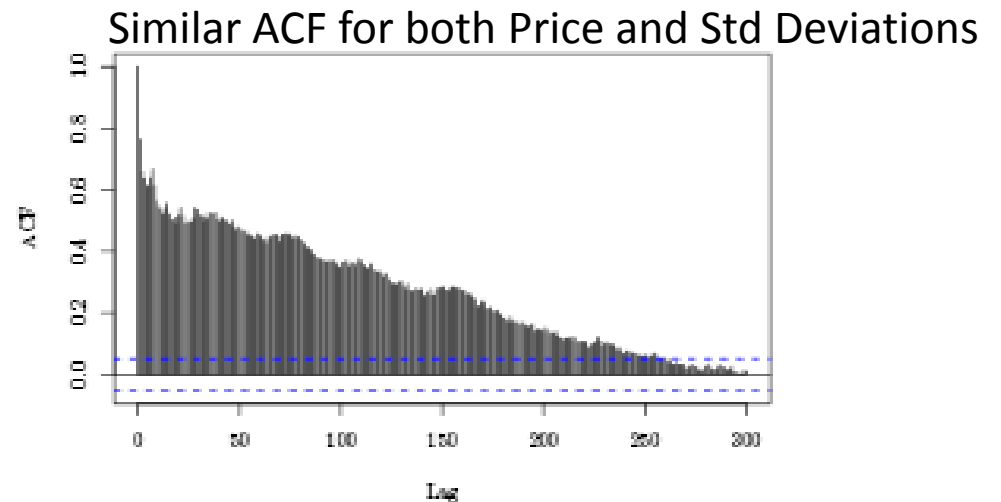
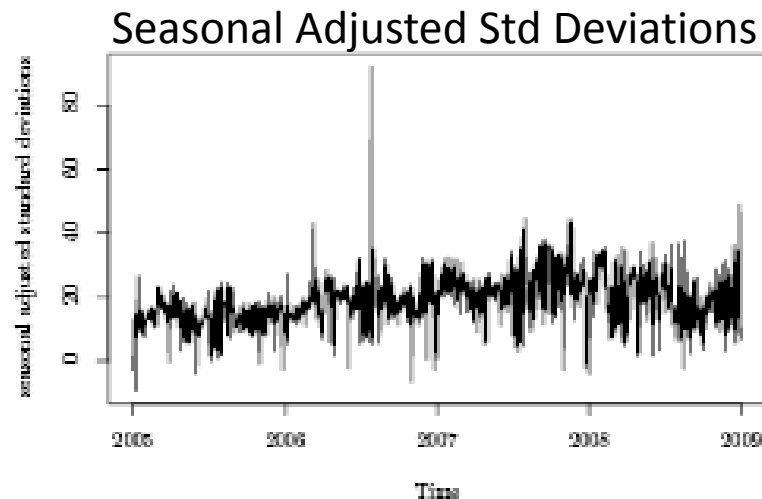
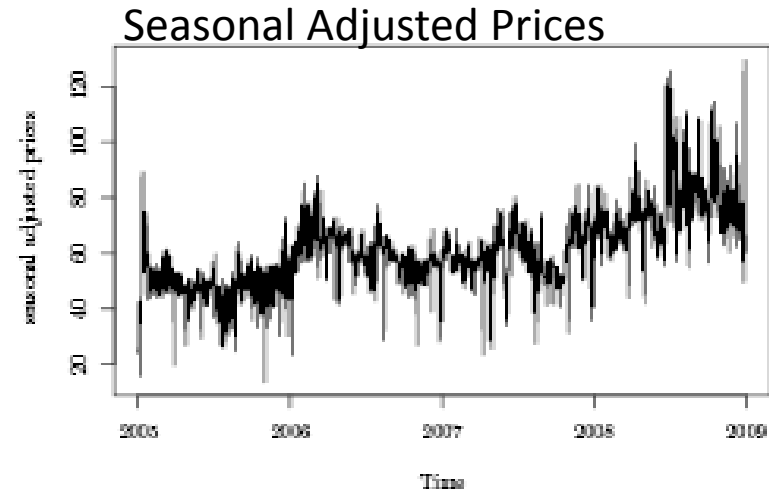
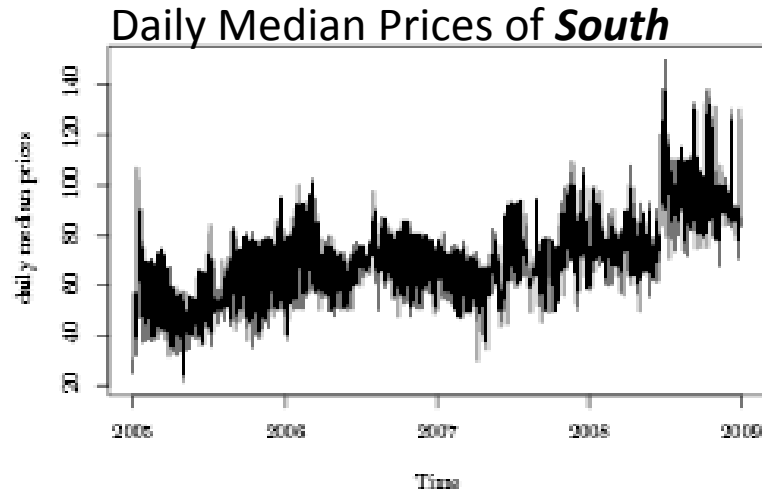
Seasonal Adjusted Std Deviations



Similar ACF for both Price and Std Deviations



Preliminary Data Analysis



Stationarity (KPSS) and Unit Roots (PP) Tests confirm **long memory**, hence we have used **Reg—ARFIMA** models.

Model Specification

ARFIMA Models to capture long—range correlations, that is

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

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Regression Models for the conditional mean function (μ_t) to account for short—range properties

$$\mu_t = \phi_1 y_{t-1} + \cdots + \phi_p y_{t-p} + \sum_{m=1}^M (\lambda_{m0} x_{mt} + \cdots + \lambda_{ms} x_{m,t-s})$$

for $t = p+1, \dots, T$ where ϕ_i for $i = 1, \dots, p$ and λ_{im} for $m = 1, \dots, M$ and $i = 1, \dots, s$ are regression coefficients and x_{mt} are the covariates built previously.

Model Selection and Estimates

To obtain white noise residuals, the selected order of the model is an ARFIMA (7,1,0) for all zonal series of seasonal adjusted daily median prices and standard deviations.

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	CNORTH	CALB	NORTH	SARDINIA		CNORTH	CALB	NORTH	SARDINIA
d	0.445 (***)	0.452 (***)	0.471 (***)	0.462 (***)	d	0.326 (***)	0.292 (***)	0.248 (***)	0.292 (***)
Constant	61.0 (***)	62.5 (***)	62.9 (***)	59.1 (***)	Constant	18.7 (***)	18.2 (***)	17.8 (***)	21.6 (***)
CCGT	-0.172	-0.026	-0.9	0.338	CCGT	0.873	0.039	1.585 (**)	-0.709
Oil	1.656 (*)	1.542 (*)	3.533 (***)	1.257	Oil	0.997 (*)	3.353 (***)	2.735 (***)	1.094
Natural Gas	1.453 (**)	1.039	1.753 (***)	0.604	Natural Gas	-0.158	0.77	0.468	-0.727
Oil & Coal	-1.544 (**)	-3.058 (***)	-1.508 (**)	-1.597	Oil & Coal	-1.072 (**)	-0.726	-0.967 (*)	-1.015
Oil & Natural Gas	0.73	-0.382	-0.608	0.791	Oil & Natural Gas	-0.209	0.904	0.296	0.534
Coal	-2.824 (***)	-2.656 (**)	-1.498 (*)	-1.286	Coal	-1.742 (***)	-1.405	-0.526	-1.335 (**)
Hydro Flu	-6.54 (**)	-7.588 (*)	-1.743	-0.796	Hydro Flu	0.069	-2.656	-1.889 (*)	0.764
Hydro Mod	0.337	-0.66	0.433	0.334	Hydro Mod	-0.757	0.226	-0.046	-1.017
Hydro Pum	-1.182 (*)	-2.183 (***)	-0.231	-0.654	Hydro Pum	-0.96 (**)	-0.294	1.655 (***)	0.214
Other	-2.091 (**)	-3.649 (***)	-1.798 (**)	-1.348	Other	-1.188 (*)	-0.674	-1.462 (**)	-1.748 (*)
Congestion Costs	0.68 (***)	0.543 (***)	0.875 (***)	1.105 (***)	Congestion Costs	0.249 (***)	0.233 (***)	0.517 (***)	0.175 (***)

ARFIMA Model Estimates for DAILY MEDIAN PRICES

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	SICILY	CSOUTH	SOUTH		SICILY	CSOUTH	SOUTH
d	0.001	0.456 (***)	0.452 (***)	d	0.479 (***)	0.318 (***)	0.319 (***)
Constant	57.1 (***)	62.0 (***)	62.0 (***)	Constant	23.0 (*)	18.4 (***)	18.3 (***)
CCGT	-1.484	0.196	0.352	CCGT	-0.452	0.195	0.126
Oil	1.74	1.182	1.195	Oil	2.982 (***)	0.74	0.885
Natural Gas	1.109	1.024	1.105 (*)	Natural Gas	-0.34	0.174	0.306
Oil & Coal	-0.06	-3.157 (***)	-3.104 (***)	Oil & Coal	-0.228	-0.638	-0.51
Oil & Natural Gas	-0.733	0.394	0.569	Oil & Natural Gas	-0.917	0.782	0.771
Coal	-6.272 (*)	-2.64 (**)	-2.358 (**)	Coal	-2.899	-1.435 (*)	-1.388
Hydro Flu	-5.061	-13.418 (***)	-7.738 (*)	Hydro Flu	1.834	-1.87	-2.21
Hydro Mod	2.189	-0.467	-0.112	Hydro Mod	-0.173	-0.653	-0.31
Hydro Pum	-1.939	-1.939 (***)	-1.783 (**)	Hydro Pum	-1.224	-0.386	-0.303
Other	1.198	-3.146 (***)	-2.858 (***)	Other	-5.645 (***)	-1.153	-0.952
Congestion Costs	1.06 (***)	0.931 (***)	0.917 (***)	Congestion Costs	0.197 (***)	0.14 (**)	0.114 (**)

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Comments and Policy Indications (1/2)

- 1) Congestion costs are significant at 1% confidence level again for both zonal prices and volatilities. On one hand they have a positive sign indicating, by their definitions, a raising in prices because grid congestions obstacle electricity flows from one zone to another one.

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Hence these considerations give the **first indication on more** (when possible) investment strategies to develop the network grid across zones (and between national zones and foreign markets).

Comments and Policy Indications (2/2)

2) Moving to the **Generation Sources**, we have the following remarks among others:

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b) We provide evidence on how **other sources** and **hydro generation** reduce both prices and volatilities. So let be the **third indication** on how renewable power is better than power coming from oil based plants.

c) Specific comments are required for **wind** which determined (through years) the price only in Calabria and Sicily with very low percentages.

Consequently, this could give the **final indication** on investing in wind plants especially in zone with bottlenecks problems.

Conclusions

We have firstly provided insights on the **significant impact** of **congestions** and **production technologies** on **price and volatility dynamics**, in the framework of Reg-ARFIMA models.

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Secondly these results have been converted in **tentative policy indications** on the **future medium-long term investment strategies** with respect to the **grid** and the **technology mix** of the Italian Market.

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