


# Scenario Forecasting of Italian Electricity Zonal Prices*

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***joint work with Luigi Grossi, Department of Economics, University of Verona**

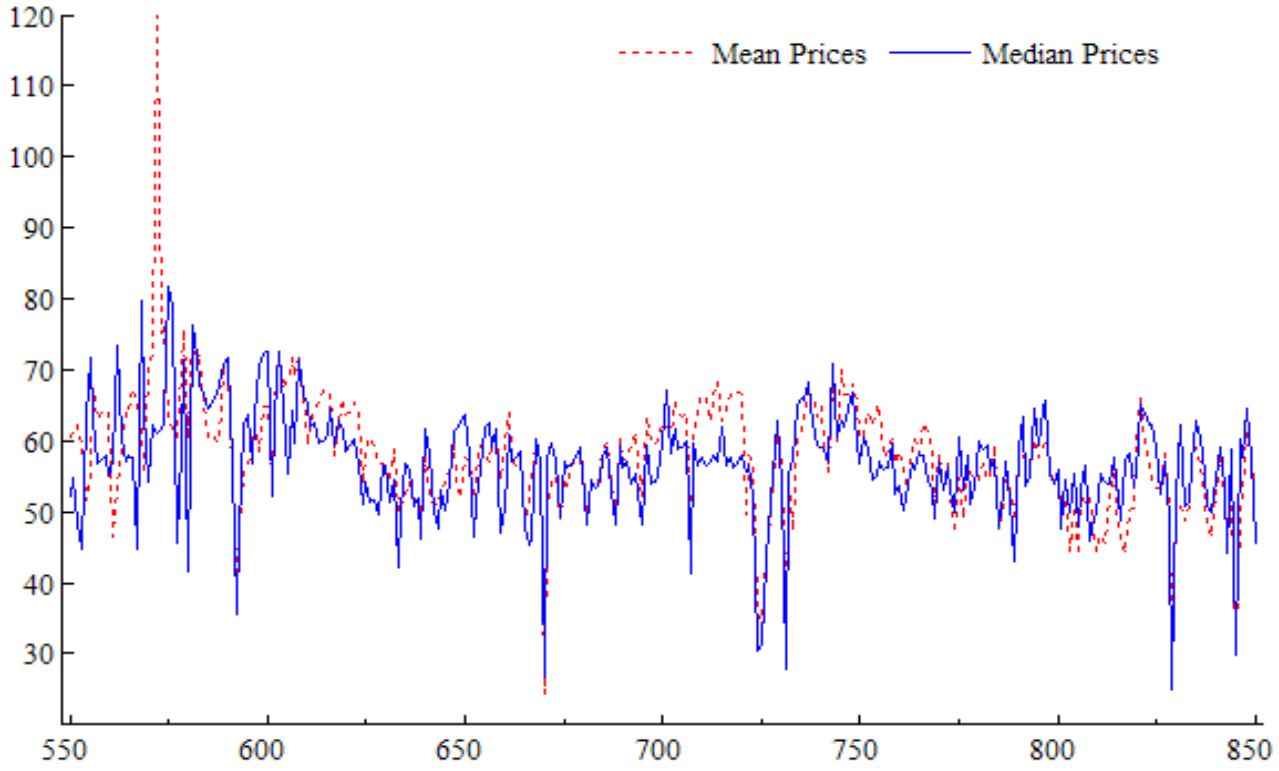
# Contributions

Empirical investigation on **zonal price dynamics** considering at the same time

1. Median filter
2. Technology Mix and the Marginal Technology Index
3. Market Power (TRSI)
4. Congestion events

# Median Filter

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



# Technology

## The Generation 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 (CCGT)
4. Hydro power plants with
   - Pumped storage
   - Run of the river (fluent)
   - Reservoirs (modulation)
5. Gas turbine plants (GT)
6. Wind power plants
7. Other generation plants

# Technology

## The Marginal Technology Index

The technology **fixing the price over one zone** is represented by the **Marginal Technology Index** (MTI).

Firstly, we have computed the frequency (number of hours) for every technology fixing the price over one zone.

Being $f_{rjt}$ the frequency for the $r$–th technology over zone $j$ on day t, for $r = 1, \ldots, 12$, $j = 1, \ldots, 7$ and $t$ from 01 Jan 2005 to 31 Dec 2008.

Secondly, we have constructed a set of 12 dummies (one for each technology with maximum frequency over the day) in the following way:

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

# Technology

## The Marginal Technology Index – Percentages

| | | 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 Marginal Technologies fixing the Norther Price

# Technology

## Clusters of Technologies

Then we have organized the previous technologies in six clusters

1. Coal: all multi–fuel and thermal power plants with coal
2. Thermal plants without coal (TNC)
3. Hydro: hydro modulation, fluent and pumped storage
4. Wind (or renewables)
5. Combined Cycles: CCGT and GT
6. Other: other plants not included in the previous ones

# Technology

## Clusters of Technologies – Frequencies

| | 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 |

Frequencies of Technologies fixing the price over individual zones.

We have decided to exclude **Wind** and **Other**.

# Market Power

We have also considered indicators of market power as the *Hirschmann–Herfindahl Index* (HHI) and the *Residual Supply Index* (RSI).

The **HHI** is the commonly accepted measure of market concentration, calculated considering the market share of each competing firm.

The **RSI** measures the market supply capacity after subtracting supply capacity of one company (and then referred to the total demand).

# Market Power

## The *true* Residual Supply Index (TRSI)

$$TRSI_i(j,h) = \frac{\sum_{l=1,l\neq i}^{N} S_l(j,h) - S_i(j,h)}{V(j,h)} \qquad \text{where}$$

$l = 1, \ldots, N$ are market participants with $l \neq i$,

$S_{l,j}$ are quantities sold by other market participants and by the $i$–th participant respectively,

$V(j,h)$ are the total volumes sold on zone $j$ at hour $h$.

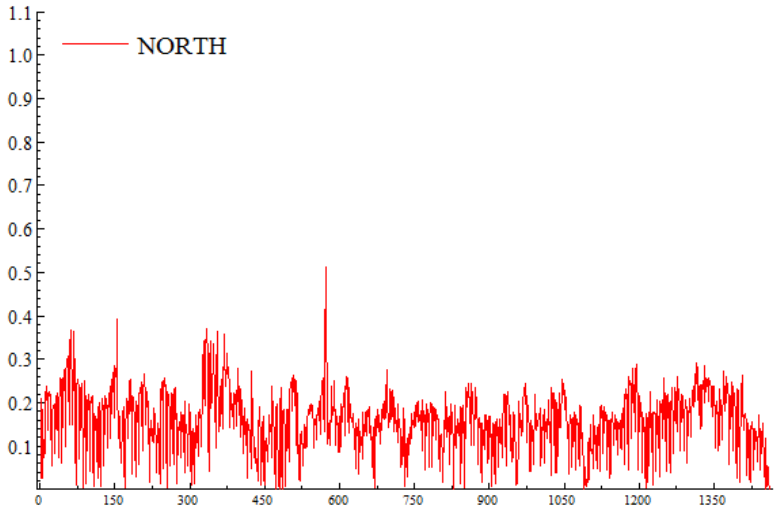
**Hence it is a measure of the presence of *residual market participants* necessary to cover the total demand.**

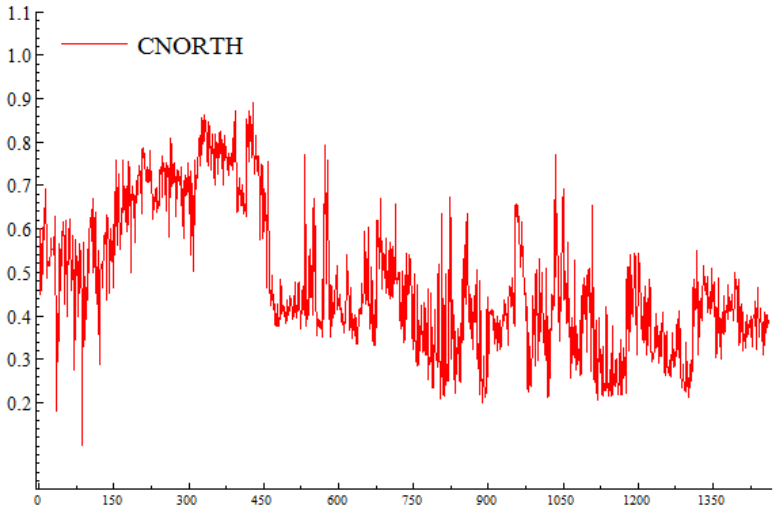
If **TRSI $< 1$**, then the $i$–th firm is **pivotal** or **necessary** to cover demand and she has **great market power**.

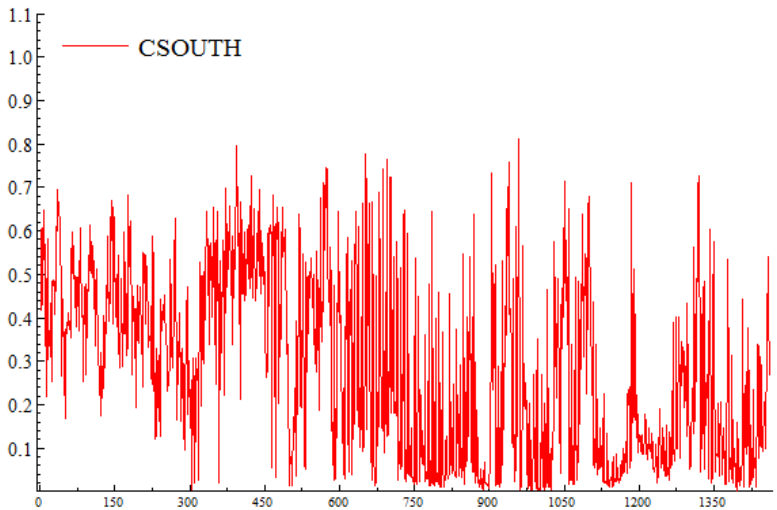
If **TRSI $\geq 1$**, then the $i$–th firm is **not necessary** and the market can be considered **competitive**.

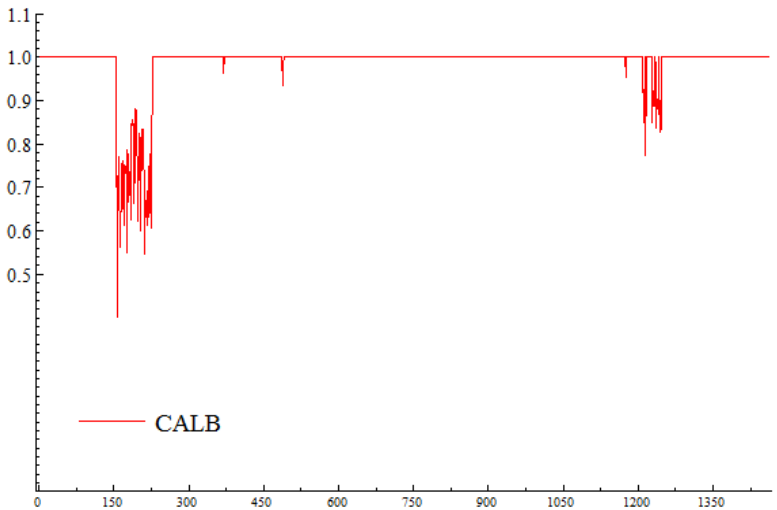
# Market Power

## TRSI zonal dynamics



# Congestion Events

## Definitions

We identify and define

**daily time series of frequencies of congestions**

every time we observe

**different zonal prices among contiguous couples of zones**.

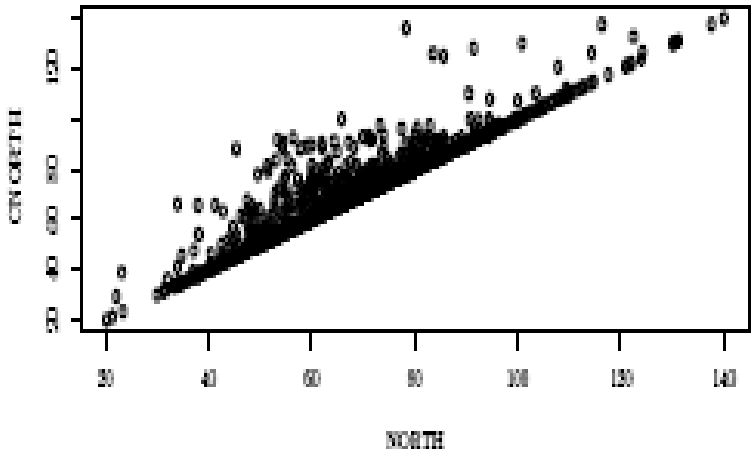
In addition, since one zone as CNorth is connected with North, CSouth and Sard, we have added frequencies of congestions at all borders adjusting for total hourly congestions.

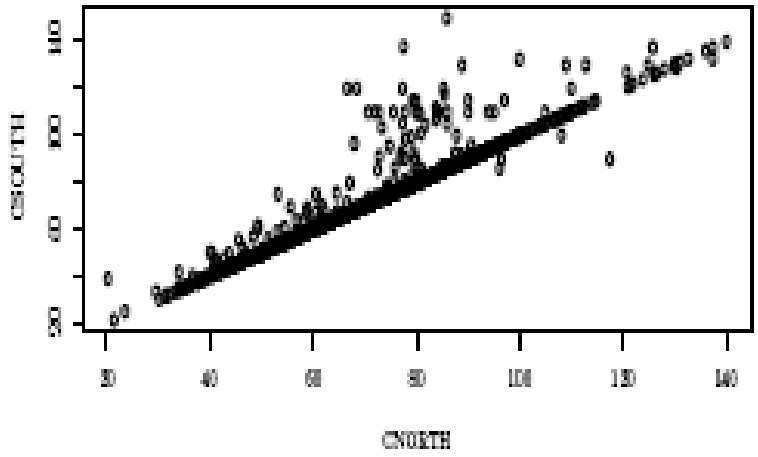
# Italian Market Structure

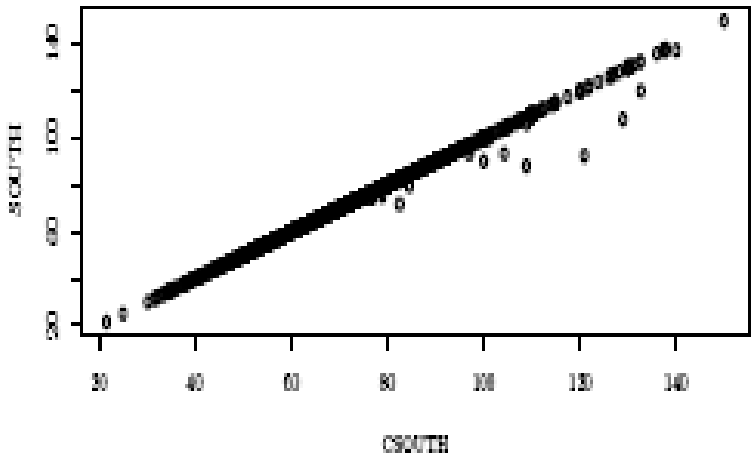
***Foreing Virtual* and *National Physical* Zones**

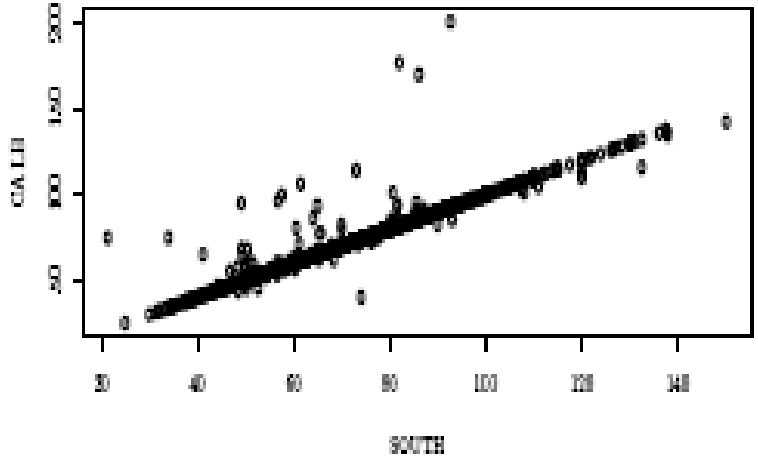
# Congestion Events

## Empirical Evidence



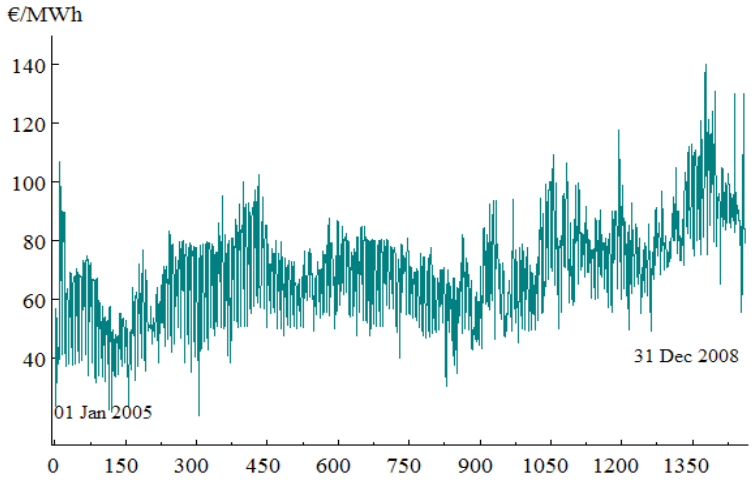



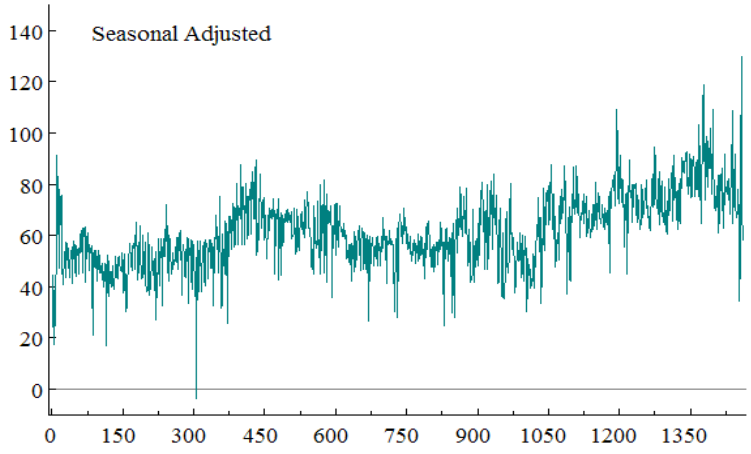
# Model Specifications

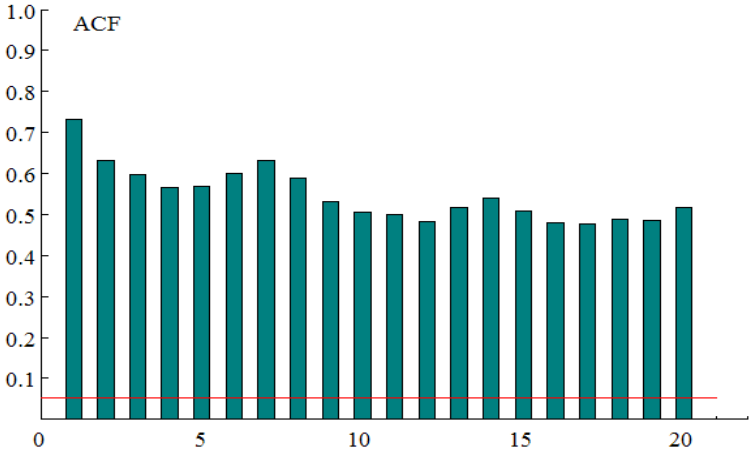
- Empirical Properties of Italian Spot Prices
- Basic model
- Augmented Models

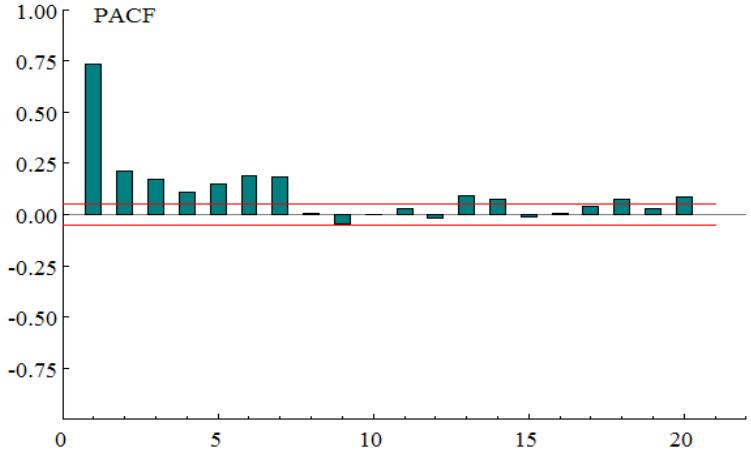
# Empirical Properties of Italian Spot Prices

Looking at the Northern Zone



# Basic Model

To account for seasonality, heteroskedasticity and a long memory autocorrelation structure, we propose a Reg–ARFIMA(1,7)–GARCH(1,1) model

$$(1-L)^d(y_t-\mu_t)=\varepsilon_t+\theta_1\varepsilon_{t-1}+\ldots+\theta_7\varepsilon_{t-7}$$

$y_t$ is the zonal median electricity prices,

$\varepsilon_t|I_{t-1}\sim t(0,\sigma_t^2)$ with $\sigma_t^2=\omega+\alpha\varepsilon_{t-1}^2+\beta\sigma_{t-1}^2$,

$\mu_t=E(y_t|I_{t-1})$ is the mean equation conditioned to the set of information available at time $(t-1)$ with

$$\mu_t=\nu_1D_1+\ldots+\nu_7D_7+\gamma CalEf+\phi_1y_{t-1}+\lambda_v x_t$$

# Augmented Models

Then we propose the following 4 different specifications for the conditional mean function:

$$\mu_t = \nu_1 D_1 + \ldots + \nu_7 D_7 + \gamma CalEf + \phi_1 y_{t-1} + \lambda_1 Tech_t$$
$$\mu_t = \nu_1 D_1 + \ldots + \nu_7 D_7 + \gamma CalEf + \phi_1 y_{t-1} + \lambda_2 MarPow_t$$
$$\mu_t = \nu_1 D_1 + \ldots + \nu_7 D_7 + \gamma CalEf + \phi_1 y_{t-1} + \lambda_3 Cong_t + \lambda_4 Cong_{t-1}$$
$$\mu_t = \nu_1 D_1 + \ldots + \nu_7 D_7 + \gamma CalEf + \phi_1 y_{t-1} + \lambda_5 Volume_t + \lambda_6 Volume_{t-1}$$

$$\mu_t = \nu_1 D_1 + \ldots + \nu_7 D_7 + \gamma CalEf + \phi_1 y_{t-1} + \lambda_1 Tech_t + \lambda_2 MarPow_t + \lambda_3 Cong_t + \lambda_4 Cong_{t-1}$$

# Estimates

## **Reg–ARFIMA**$(1,7)$–**GARCH**$(1,1)_{all}$

| | NORTH | | CNORTH | | CSOUTH | |
|---|---|---|---|---|---|---|
| Const (mean) | 54.09 | (***) | 50.64 | (***) | 54.35 | (***) |
| CC | -1.37 | (**) | -0.68 | | -1.44 | (**) |
| TNC | 1.30 | | 1.38 | (*) | 1.84 | (***) |
| TRSI | 0.77 | (***) | 0.11 | (**) | 0.04 | |
| Cong | -2.89 | (***) | 1.18 | (**) | 2.15 | |
| CalEf | -12.55 | (***) | -21.83 | (***) | -22.32 | (***) |
| d–Arfima | 0.50 | (***) | 0.49 | (***) | 0.48 | (***) |
| $\omega$ | 1.08 | | 2.39 | (*) | 1.74 | (*) |
| ARCH $\alpha$ | 0.06 | (***) | 0.12 | (***) | 0.10 | (***) |
| GARCH $\beta$ | 0.92 | (***) | 0.86 | (***) | 0.89 | (***) |
| Student | 6.37 | (***) | 4.42 | (***) | 4.85 | (***) |

# Preliminary Conclusions

1. *Fractionally integration* indicates that these Italian Electricity Zonal price processes have long memory.
2. The *autoregressive structure* is an important fact to take into account since it captures stylized facts, as day–of–the–week effect.
3. As expected, *technologies* used to produce electricity influence zonal prices.
4. The exercise of *market power* always increases electricity prices.
5. *Congestions* generally tend to increase prices.

# Policy Indications

## On Technologies...

**a.** Looking at technologies:

- *other* or renewable generation sources, and *wind* have been excluded from this analysis since there were not important, therefore demanding for massive investments;
- *combined cycles*, as CCGT and GT, reduce electricity prices as well as *coal*, and this gives a priority to the former technologies when investing in new generation plants, since the latter ones are highly polluting;
- finally investments in *thermal* power plants without coal (TNC) should be discouraged because this technology seems to increase zonal prices.

# Policy Indications

## ... and on Concentration and Congestions

**b.** 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 more intrinsic factors of the electricity sector.

**c.** Finally the expansion of the transmission network capacity together with more efficient and capable extra–country interconnections can solve *congestions*, reducing prices and improving market competition.

# Forecasting Models

We consider the following models:

- a simple random walk, ***RW1***;
- a weekly random walk, ***RW7***;
- the ARFIMA(1,7)–GARCH(1,1) without regressors, ***Basic***;
- the Basic plus regressors, ***Final***;
- the Basic plus Volumes, ***Volume***

using daily data until 30/06/2008 and measure the models forecasting performance until the end of 2008.

# 1 Day–Ahead Forecasts

## Models Performances

| | | 1 step–ahead | | | | |
|---|---|---|---|---|---|---|
| | | RW1 | RW7 | Basic | Final | Volume |
| CNORTH | RMSE | 15.852 | 14.789 | 11.563 | **10.941** | 11.090 |
| | MAPE | 11.603 | 11.089 | 9.192 | 8.724 | **8.577** |
| | Theil's U | - | 0.933 | 0.729 | **0.690** | 0.700 |
| | DM | - | 0.571 | 2.344 | **3.109** | 1.480 |
| | p–value | - | 0.284 | 0.010 | 0.001 | 0.069 |
| NORTH | RMSE | 14.072 | 13.001 | 10.710 | **9.577** | 10.413 |
| | MAPE | 10.696 | 10.103 | 8.384 | **7.252** | 8.070 |
| | Theil's U | - | 0.924 | 0.761 | **0.681** | 0.740 |
| | DM | - | 0.693 | 2.393 | **2.325** | 1.557 |
| | p–value | - | 0.244 | 0.008 | 0.010 | 0.060 |

As we use the one–sided test to evaluate the superiority of one model, the null hypothesis of equal performance is rejected at 1% level when $|DM| > 2.33$.

# 1 Day–Ahead Forecasts

## Conclusions based on previous Models Performances

Given the values for MSE, MAPE, Thail's U and DM test,
we can conclude that
our Reg–ARFIMA(1,7)–GARCH(1,1) model
do preform well in explaining and forecasting
Italian median zonal prices through explanatory variables,
that is *Technologies, Market Power and Congestions.*

Moreover, given the difficulties related to the true out–of–sample forecasting, we have also performed a *scenario forecasting analysis.*

# Scenario Forecasting

Recalling regressors estimates and signs for two zones:

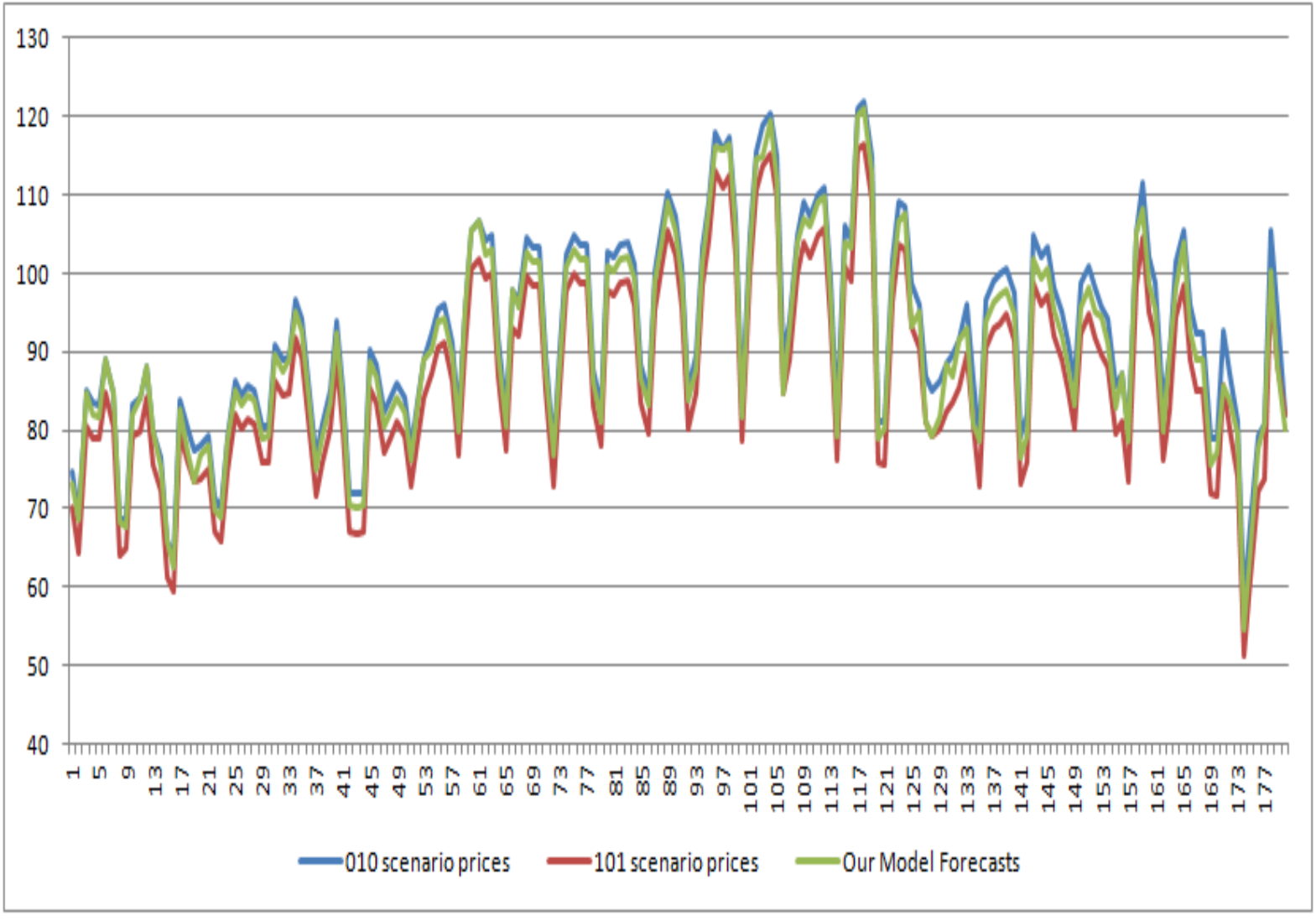
| | NORTH | | CNORTH | |
|---|---|---|---|---|
| CC | -1.37 | (**) | -0.68 | |
| TNC | 1.30 | | 1.38 | (*) |
| TRSI | 0.77 | (***) | 0.11 | (**) |
| Cong | -2.89 | (***) | 1.18 | (**) |

we have defined the following scenarios, accounting for two Technologies (CC and TNC) and Congestions (Cong):

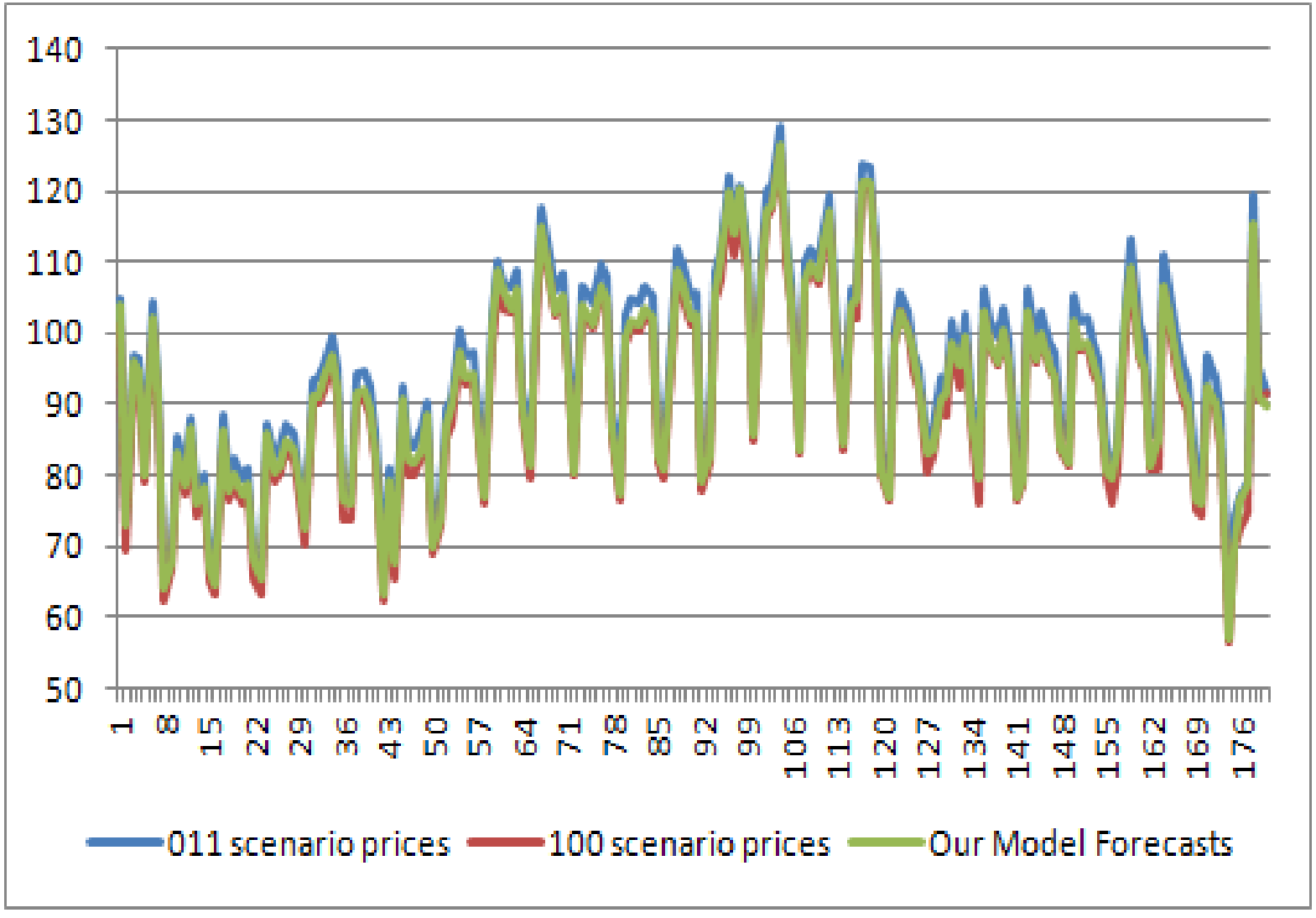
**North:** **(1,0,1)** as the best scenario for lower prices;
**(0,1,0)** as the worst scenario for higher prices.

**CNorth:** **(1,0,0)** as the best scenario for lower prices;
**(0,1,1)** as the worst scenario for higher prices.

# Scenario Forecasting for North



# Scenario Forecasting for Central North



# Conclusion and further work

*Technologies, Concentration and Congestions* ***do affect*** *Italian Electricity Zonal Prices* and proposed forecasting models perform reasonably well.

For the future, we would like to explore the inclusion of an index for the Market Power (TRSI) in our forecasting scenarios.

**Reference**: This presentation is based on a paper titled ***Forecasting Italian Electricity Zonal Prices with Exogenous Variables***, coauthored with Luigi Grossi, available at `http:dse.univr.itindex.php?option=com_facileforms&Itemid=89`, before revision undertaken according to referees' comments to worth publication on a special issue "Quantitative Analysis of Energy Markets" to appear on *Energy Economics*.