Italian Energy Market Econometrics

Time Series Modelling of Electricity Prices, Gas, and Renewables

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5	2021–2025	3	5+	TFM_Gas
Model Families	Crisis Period	Time Series	Competing Models	Best Forecaster

Overview

We study the dynamic relationships between three key variables in the Italian electricity market over 2021–2025 — a period shaped by the global energy crisis: the **National Electricity Price (PUN)**, the **Natural Gas price**, and **Renewable Energy** fed into the grid. Using daily data from GME and Terna, we investigate how these series influence each other, whether a stable long-run equilibrium exists, and which model best forecasts electricity prices.

Data

Sources: GME (electricity & gas spot prices), Terna (renewable generation). All series aggregated to daily frequency.

Period: January 2021 – December 2025. The 2022 energy crisis (PUN exceeding 700 €/MWh) dominates the sample and strongly tests model robustness.

Key series:

- **PUN**: Italian day-ahead electricity reference price (€/MWh)
- **Gas**: natural gas spot price (€/MWh), main generation cost driver
- **Renewables**: average MW fed into the grid from clean sources

All series log-transformed to stabilize variance and enable elasticity interpretation.

Models

Four complementary frameworks, applied sequentially:

- **SARIMA:** univariate baseline capturing weekly seasonality (period 7) for each series independently.
- **Cointegration & VECM:** Johansen tests confirm one cointegrating vector between Gas and PUN. Estimated long-run relationship:

$$\log(\text{PUN}_t) = 0.839 \cdot \log(\text{Gas}_t) + 1.677$$

  Gas acts as a weakly exogenous driver; PUN corrects ≈13% of disequilibrium per period.
- **Transfer Function Models (TFM):** isolate the dynamic causal impact of Gas (and Renewables) on PUN. Gas effect: +0.54% on PUN contemporaneously, +0.24% lagged one period.
- **VAR(7):** trivariate system (Gas, Renewables, PUN) on seasonally adjusted series. Restricted via sequential elimination; stability confirmed.

Results

Long-run equilibrium: Gas and PUN are cointegrated with elasticity ≈ 0.84, confirmed by Johansen, Engle-Granger, and DOLS, all converging to the same estimate. Renewables are I(0) and excluded from the cointegrating relationship.

Causal structure: Gas Granger-causes the system; PUN is the most endogenous variable. IRF analysis shows PUN reacts within 2–3 periods to Gas shocks, and Renewables exhibit a persistent response to Gas price signals.

Variance decomposition: Gas explains 10–15% of PUN forecast variance; Renewables ≈5%. Each variable is primarily driven by its own shocks.

Model	Avg. RMSE	Avg. MAE
TFM_Gas	**best**	**best**
VECM	2nd	2nd
VAR(7)	3rd	3rd
TFM_Renew	4th	4th
ARIMA	5th	5th

Out-of-sample forecasting: rolling forecast over 14-day horizons. TFM_Gas dominates across all horizons; superiority confirmed by Diebold-Mariano tests ($p \ll 0.05$ for all $h = 1, \ldots, 14$).

Key Findings

- **Gas is the dominant driver:** a 1% rise in gas prices raises PUN by ≈0.84% in the long run and ≈0.78% in the short run, confirming gas as the primary driver.
- **Renewables have short-run impact only:** no cointegrating link; positive contemporaneous effect followed by a hard-to-interpret negative lagged correction.
- **Heteroskedasticity is a persistent limitation:** the 2022 shock introduces volatility clustering not captured by the linear models used.
- **VAR(7) is the best multivariate model:** the weekly lag order successfully captures the dominant seasonal pattern in all three series; BIC and residual diagnostics agree.

Technologies

Languages & tools: R, `forecast`, `vars`, `urca`, `dynlm`, `MTS`, tidyverse, ggplot2.
Data: GME Mercato Elettrico (PUN & Gas), Terna Download Center (Renewables).

Future work: GARCH-type models for volatility, regime-switching around the 2022 crisis, intra-day hourly data for higher-resolution renewable impact analysis.