Modeling European electricity market integration during turbulent times

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Motivation

- The **Russian invasion of Ukraine** plunged Europe into an energy crisis, highlighting vulnerabilities from the disruption of gas supplies.
- Under the **marginal pricing rule**, electricity prices are set by the last and most polluting power unit on the supply curve — typically gas — which has driven recent price surges.
- Initiatives like **REPowerEU** aim to reduce short-term dependence on Russian fossil fuels while increasing the share of renewable energy sources (**RES**). Yet, these add complexity to markets due to intermittency.
- This context raises urgent questions about the role of **market integration** as both a safeguard and a channel for shock propagation, and as a cornerstone of European competitiveness (Draghi speech in Sep–2024).

Context: the energy crisis

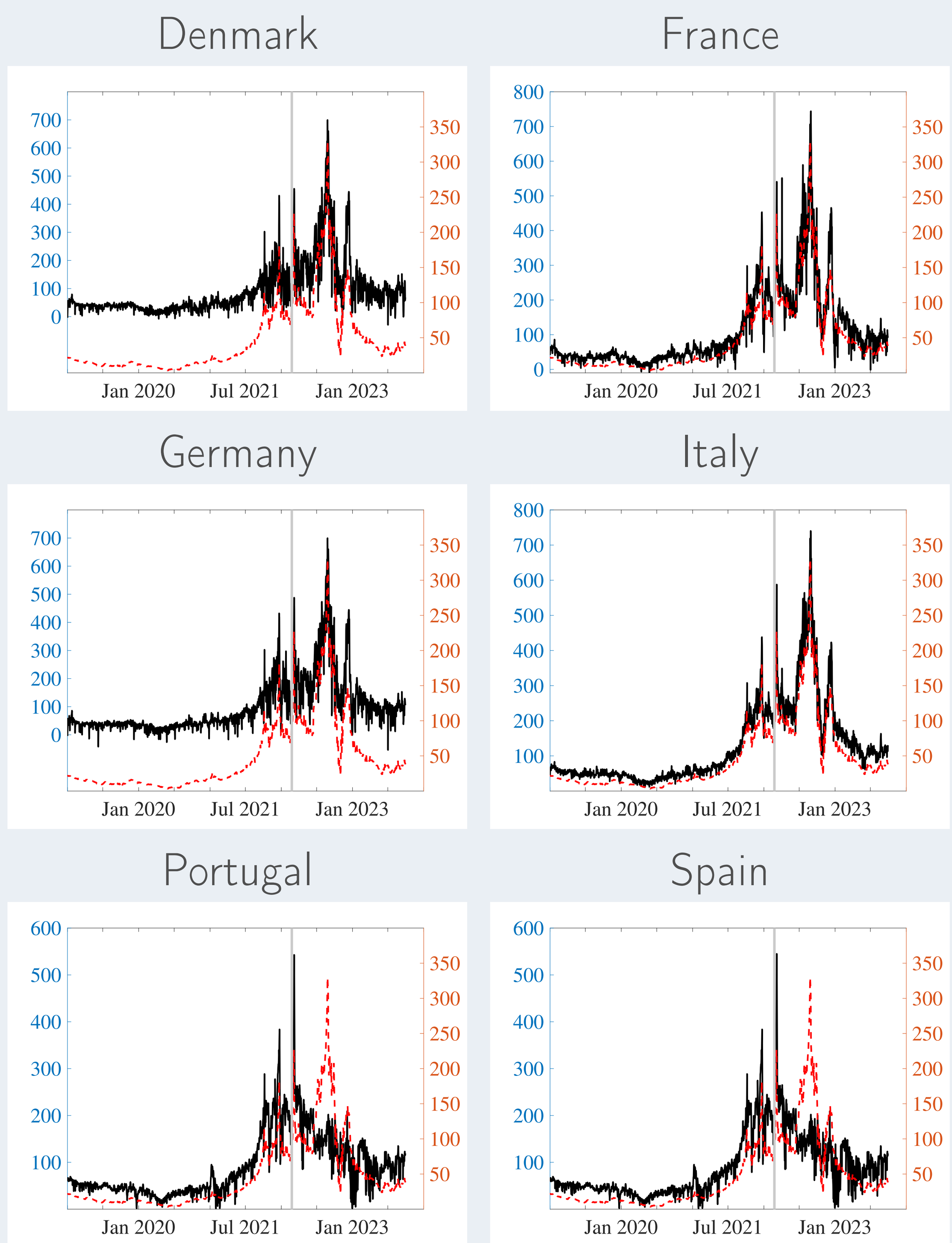


Figure 1: Daily average electricity **(black)** vs. gas **(red)** prices for Denmark, France, Germany, Italy, Portugal, and Spain.

Our contribution

We propose a novel approach to analyzing European electricity prices where we:

- consider a **mixed-frequency** model using hourly RES/demand and daily fossil fuel prices.
- adopt a **hierarchical panel specification** to model interdependencies across 9 countries.
- disentangle the **common** from **idiosyncratic** drivers of electricity prices across countries, thus identifying **divergence** from market integration.

Data

- **Countries:** Denmark, Finland, France, Germany, Italy, Norway, Portugal, Spain, Sweden.
- **Period:** Jan 2019 – Oct 2023.
- **Data, in levels:** hourly (day-ahead electricity prices, demand, RES generation) and daily (fossil fuel prices).

Methodology: PRUMIDAS Model (Canova and Ciccarelli, 2010; Foroni et al., 2018)

We develop a **Panel Reverse Unrestricted Mixed Data Sampling (PRUMIDAS)** model. The core equation for country g at hour h ($h = 1\dots,H, H = 24$ hours) is:

$$y_{g,t+h} = \mu_{gh} + \sum_a \alpha_{gha} y_{g,t+h-a} + \sum_j \sum_b \beta_{gjhb} x_{gj,t+h_j-bH_j} + e_{g,t+h}, \quad e_{g,t+h} \sim \mathcal{N}(0,\sigma^2_{gh}).$$

Our specification:

$$y_{g,t+h} = \mu_{gh} + \sum_{a\in\{H,2H,7H\}} \alpha_{gha} y_{g,t+h-a} + \sum_{j=1}^{6} \beta_{gjh0} x_{gj,t+h_j} + e_{g,t+h}.$$

This is motivated by the co-movement between electricity and fossil fuel prices, and by the impact of RES. **Hierarchical specification:** The coefficients are decomposed into common, hourly, and country-specific effects, thereby shrinking the coefficients toward group-specific effects but possibly allowing them to "diverge":

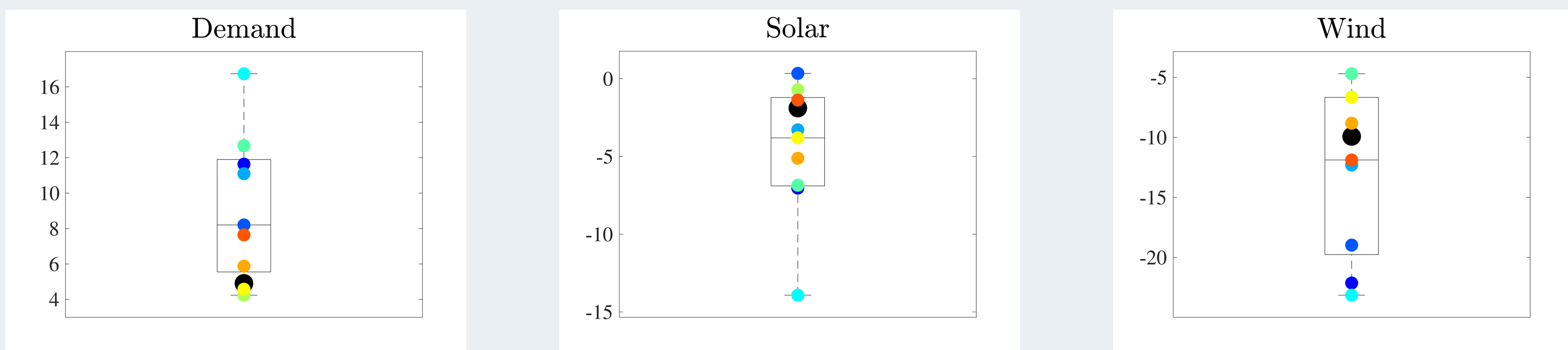
$$\mu_{gh} = \mu + \psi_{\mu,h} + \zeta_{\mu,g}, \qquad \alpha_{gha} = \alpha_a + \psi_{\alpha,ha} + \zeta_{\alpha,ga}, \qquad \beta_{gjhb} = \beta_{jb} + \psi_{\beta,jhb} + \zeta_{\beta,gjb}.$$

Prior specification & Posterior approximation (Casarin et al., 2018)

- **Common effects:** independent Normal priors for the intercept μ and coefficients α_a, β_{jb}.
- **Random effects:** hierarchical Normal priors for the hourly (ψ) and country (ζ) effects, with zero mean and variances equal to q_μ and r_μ, respectively; q_μ and r_μ have Inverse-Gamma priors.
- **Error variance:** specified hierarchically as $\sigma^2_{gh} = \sigma^2 \lambda_h^{-1} \chi_g^{-1}$, where σ^2 has a Gamma prior, and λ_h and χ_g have Inverse-Gamma priors.

→ The posterior is intractable: we employ a Gibbs sampler and apply Rao–Blackwellization; as a by-product, this also provides a time-varying error variance (σ^2_{ght}).

Key results I: the country-specific effects of demand & renewable generation

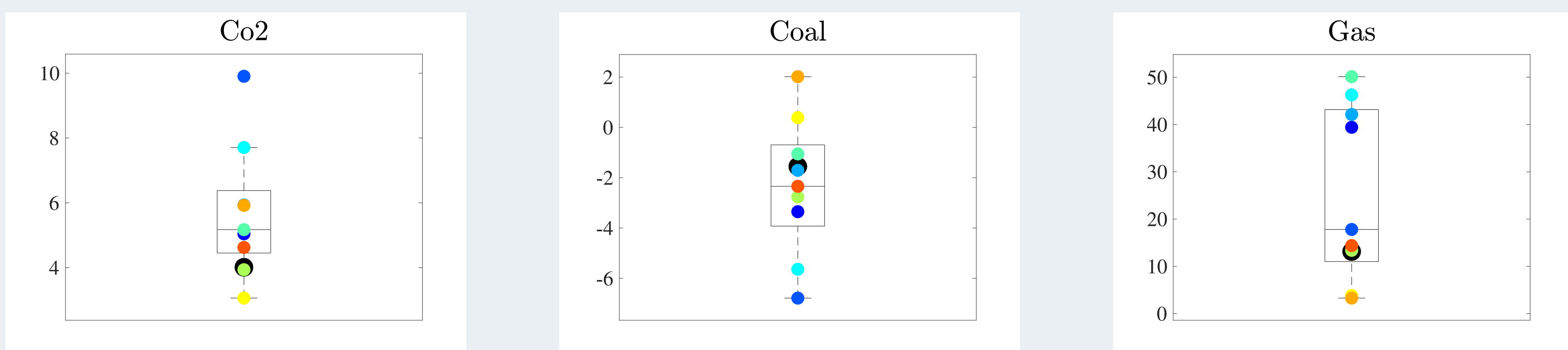


● Common effect ● Denmark ● Finland ● France ● Germany ● Italy ● Portugal ● Spain ● Sweden

Figure 2: Sum of common and country random effects $\beta_j + \zeta_{\beta,gj}$ for demand and RES generation.

- **Widespread price-reducing impact** of wind and solar on electricity.
- Germany has benefited the most from solar, followed by Denmark, Italy, and Spain.
- Germany, Denmark, and France have experienced even stronger price reductions from wind power.

Key results II: the country-specific effects of fossil fuel prices



● Common effect ● Denmark ● Finland ● France ● Germany ● Italy ● Portugal ● Spain ● Sweden

Figure 3: Sum of common and country random effects $\beta_j + \zeta_{\beta,gj}$ for Co_2, coal, and gas prices.

- **Gas as a key driver of divergence:** surging gas prices particularly affect Italy, Germany, France, and Denmark (France due to nuclear outages, Italy and Germany due to concentration to Russian gas import).
- **Three groups emerge:** 1. Severely affected (IT, DE, FR, DK); 2. Moderately affected (FI, SE, NO); 3. Shielded (PT, ES) due to the "Iberian exception".

Conclusions & Policy implications

- **Integration is a double-edged sword:** benefits from integrated markets in times of lower prices, and propagation of energy shocks to different electricity markets when external shocks hit the economy.
- **Renewables are key to lowering prices**, while high gas prices generate disparities across Europe.
- Further results (not shown) indicate that the impact of both RES and and of gas prices are larger in the aftermath of the Russian invasion of Ukraine, reflecting higher volatility and uncertainty.
- These findings highlight the critical need for **coordinated policy frameworks**, strategic **energy diversification**, **"shielding" mechanisms**, and reforms of the **auction** system.