# The effect of a new power interconnector on energy prices volatility: the case of Sicily

Marina Bertolini, Pierdomenico Duttilo and Francesco Lisi
Dep. Of Statistical Science, University of Padova

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# Background

- The electricity market is influenced by the **infrastructures** available in the area that we are considering;
- **Integrating energy islands** into the European electricity market is a key challenge for the energy transition;
- Zonal markets might have strong differences, and not only in the **balancing market**, where trades take place almost in real-time and are used to address flow fluctuations, but **it also holds true for the day-ahead market**;
- This aspect highlights the **significance of infrastructure investments** in the relevant market, sometimes substantially altering its characteristics.

# Background and scope of the work (1/2)

- Islands have **fewer connection** opportunities compared to the mainland;
- For this reason, their markets often display unique patterns that make them **difficult to compare** with other areas and they are excluded from general analysis (Bertolini, D'Alpaos and Moretto, 2018; Caporin, Fontini and Santucci de Magistris, 2022);
- Each form of "energy islanding" (physical, political, and service islands) presents different challenges and opportunities that highlight the different context in which energy isolation occurs and must be addressed to achieve greater **market integration**
- Any modification to the energy infrastructure directly affects the operation of the system and the **formation of equilibrium prices** (Cheng et al., 2025)

# Background and scope of the work (2/2)

- Electricity price volatility can serve as an indicator of both market **competitiveness** (Bertolini et al., 2020) and the capacity of the network to **integrate** local producers (Tishler et al., 2008).
- Evidence from the **Italian market** shows that the commissioning of the SAPEI cable between Sardinia and mainland Italy intensified **volatility spillovers**, especially during off-peak periods, despite improved average price convergence (Sapio and Spagnolo, 2020).

- The purpose of this work is to **analyze the price variance** in the **Sicily** market area to see if it has undergone changes after the **connection of the Sorgente-Rizziconi power cable (May 28th, 2016)**

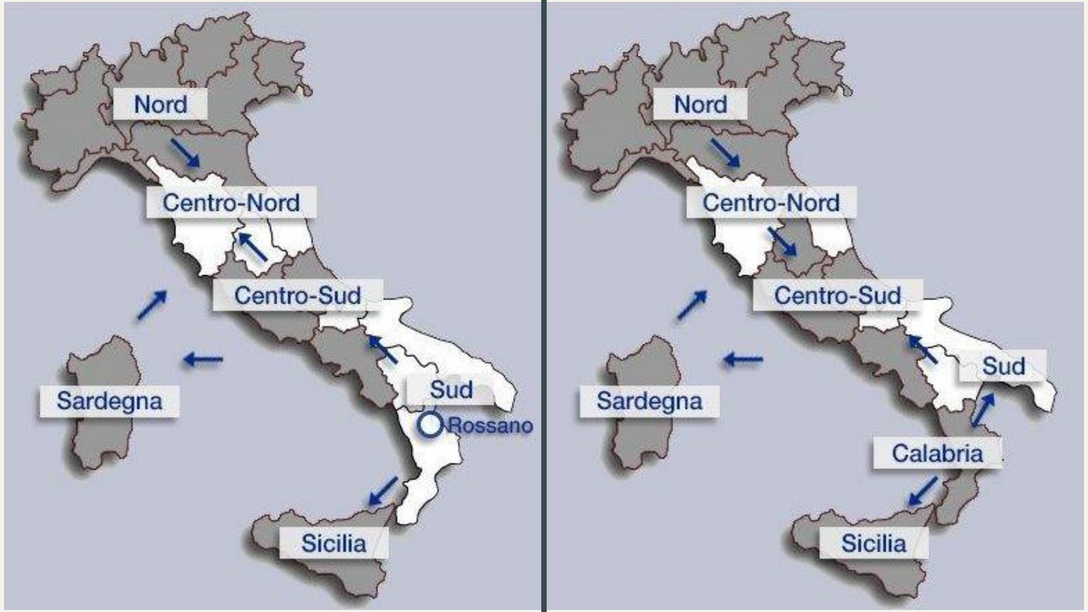
# The Sorgente Rizziconi Cable

- **The power line links Sicily and Calabria**;
- It is a double three-phase power line (a configuration where there are two sets of three-phase conductors, meaning two separate three-phase systems running in parallel);
- It is located more than 350 meters deep;
- It helps the integration of renewables in the power system.


Source: TERNA, https://lightbox.terna.it/

# Context – market zones

*Before 2021* | *After 2021*




Source: TERNA, https://lightbox.terna.it/ t/insight/riorganizzazione-zone-mercato-elettrico

# Dataset

- To perform the analysis, we build a dataset of **daily** energy prices in the day-ahead electricity market in Italy, by zones (source: GME);
- We use data from 2015 to 2018;
- The «event» (new connection) happened on May 28°, 2016.

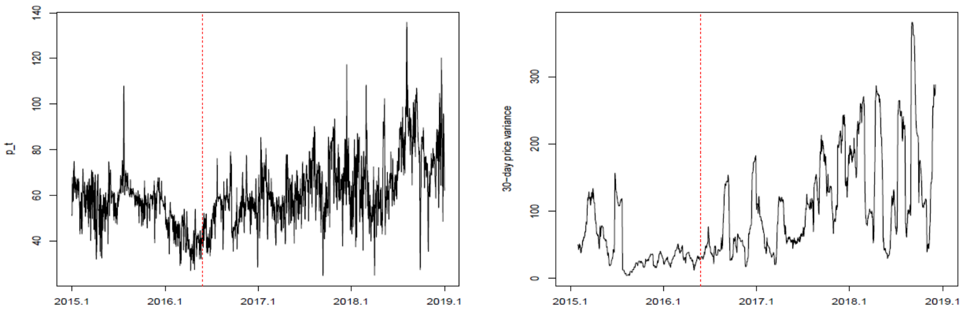



Figure 2: Left: series of the mean daily electricity price in Sicily between 2015 and 2018. Right: 30-day rolling variance of price in the same period. The dashed vertical line is set at May, 28th 2016.

# Methodology

1. Explorative data analysis to identify models for electricity prices and volatility
2. Estimation of the mean of electricity prices (non parametric additive model)
3. Conditional price variance:

✓ The analysis applies a **semi-parametric GARCH model** with a **logistic intervention function** to estimate changes in conditional price variance;

✓ A **fully non-parametric additive model** is employed as a robustness check, allowing the data to shape volatility dynamics without imposing a predefined structure.

4. t test on the logistic coefficients of the GARCH-L and ANOVA for the non parametric model

# Model

Let $p_t$ be the daily volume-weighted spot electricity prices for day $t = 1, ..., T$ and $\mathbf{x}_t = (x_{1,t}, ..., x_{p,t})$ a vector of $p$-covariates referred to time $t$. According to our model, the dynamics of $p_t$ is given by:

$$\begin{aligned} p_t &= \mu(\mathbf{x}_t) + \sigma_t z_t, \\ &= \mu(\mathbf{x}_t) + \epsilon_t, \end{aligned} \tag{1}$$

where $z_t \overset{\text{i.i.d.}}{\sim} N(0, 1)$, while $\mu(\mathbf{x}_t)$ and $\sigma_t$ represent the conditional mean and the conditional variance, possibly as a function of the vector of covariates $\mathbf{x}_t$, so that:

$$\mathrm{E}(p_t|\mathbf{x}_t) = \mu(\mathbf{x}_t), \tag{2}$$

and

$$\mathrm{Var}(\epsilon_t|\mathbf{x}_t) \equiv \sigma_t^2 \equiv \mathrm{E}[(p_t - \mu(\mathbf{x}_t))^2|\mathbf{x}_t] = \mathrm{E}(\epsilon_t^2|\mathbf{x}_t). \tag{3}$$

In this context, also for prices in financial markets, the definition of volatility refers to the conditional variance $\sigma_t^2$ of the residuals of the conditional mean.

# Conditional variance

For the conditional variance, two different specifications are considered. The first is a parametric GARCH(1,1) with an additive intervention function, $Int_t$, devoted to describe the effect of the new interconnector. In this case, the measure of volatility is given by:

$$\sigma_t^2 = \omega + \alpha\, \epsilon_{t-1}^2 + \beta\sigma_{t-1}^2 + Int_t \qquad (5)$$

where $\omega$, $\alpha$ and $\beta$ are the GARCH parameters.

The second form of conditional variance is non-parametric, meaning that any specific functional form is not imposed but leave the data to shape the effect. This can be done by modelling $\sigma_t^2$ through spline functions and has also been done for the conditional mean. In this case, the measure of volatility is given by:

$$\sigma_t^2 \equiv \sigma^2(\mathbf{x}_t) = \gamma_0 + \sum_{j=1}^{q} h_j(x_{j,t}, \lambda_j), \qquad (6)$$

where, again, $h_j$ are smoothers (spline functions) describing the effect that the variables in $\mathbf{x}_t$ have on the conditional variance and $\lambda_j$ are smoothing parameters.

# Identified model

$$\mu_t = \beta_0 + f_1(\texttt{trend}_t, \lambda_1) + f_2(\texttt{dayyear}_t, \lambda_2) + f_3(\texttt{dayweek}_t, \lambda_3) + \delta_1 \texttt{bank}_t + f_4(p_{t-1}, \lambda_4) + f_5(p_{t-7}\lambda_5) + f_6(\texttt{res}_t, \lambda_7), \quad (7)$$

where:

- $\texttt{trend}_t$ is the long-term dynamics on day $t$ and is represented by the sequence $1, 2, ..., n$;
- $\texttt{dayyear}_t$ represents the yearly periodicity of the data. It is a vector that repeats the sequence cyclically $1, ..., 365$;
- $\texttt{dayweek}_t$ represents the weekly periodicity of the data. It is a vector that cyclically repeats the sequence $1, ..., 7$;
- $\texttt{bank}_t$ is a dummy variable for bank holidays;
- $p_{t-1}$ and $p_{t-7}$ are the electricity price levels one day and seven days earlier;
- $\texttt{res}_t$ is the daily generation of renewable energy in MWh.

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# Intervention function(s)

- Logistic specification for the intervention function in the parametric form

$$\sigma_t^2 = \omega + \alpha\, \epsilon_{t-1}^2 + \beta \sigma_{t-1}^2 + I(t_0) \cdot \frac{a}{1 + b \cdot exp(-c \cdot t)}$$

- Non parametric additive model

$$\begin{aligned} \sigma_t^2 = & \gamma_0 + h_1(\texttt{Int}_t) + h_2(\texttt{dayyear}_t) + h_3(\texttt{dayweek}_t) \\ & + \gamma_1 \texttt{bank}_t + h_4(\epsilon_{t-1}^2) + h_5(\texttt{MA}_{t-1}) + h_6(\texttt{res}_t), \end{aligned} \qquad (9)$$

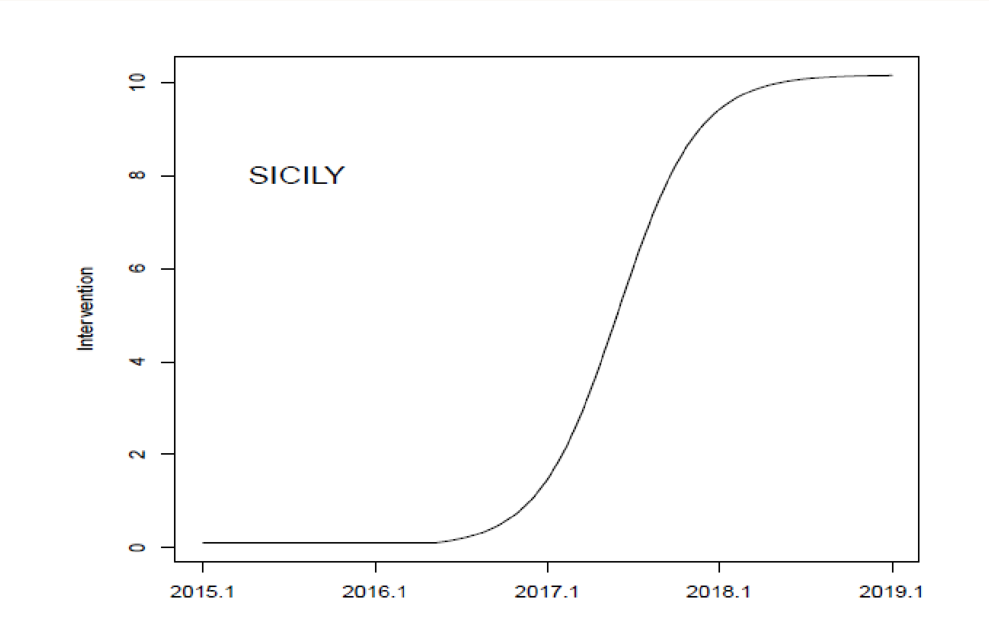
where:

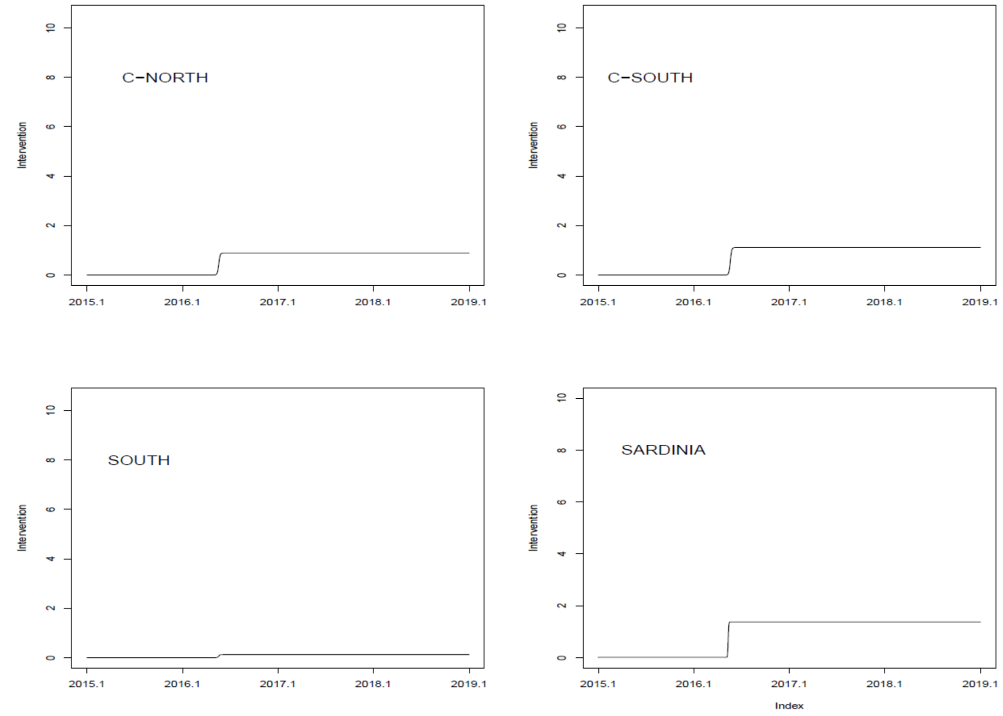
- $\texttt{Int}_t$ is the intervention variable that takes value 0 before the cables' activation and increases linearly after that day;
- $\epsilon_{t-1}^2$ denotes the squared residual with one-day of lag;
- $\texttt{MA}_t$ is a simple 14-day moving average on $\epsilon_{t-j}^2$ for $j = 1, ..., 14$.

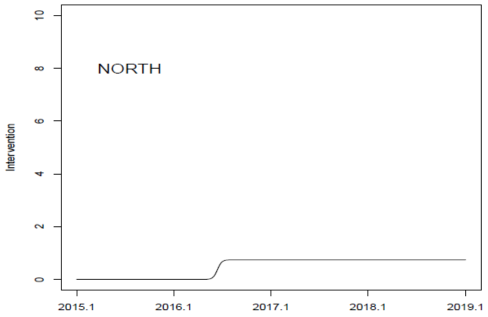
| Parameters | $\hat{\omega}$ | $\hat{\alpha}$ | $\hat{\beta}$ | $\hat{a}$ | $\hat{b}$ | $\hat{c}$ |
|---|---|---|---|---|---|---|
| SICILY | **7.391** | **0.222** | **0.565** | **10.171** | 101.2 | **0.012** |
| | (<0.001) | (<0.001) | (<0.001) | (<0.001) | (0.671) | (<0.028) |
| NORTH | **2.224** | **0.126** | **0.784** | 0.742 | 101.0 | 0.112 |
| | (0.001) | (<0.001) | (<0.001) | (0.058) | (0.724) | (0.178) |
| CENTER-NORTH | **4.417** | **0.189** | **0.653** | 0.890 | 110.0 | 0.389 |
| | (<0.001) | (<0.001) | (<0.001) | (0.163) | (0.870) | (0.504) |
| CENTER-SOUTH | **2.752** | **0.165** | **0.705** | 1.110 | 150.0 | 0.377 |
| | (0.014) | (<0.001) | (<0.001) | (0.054) | (0.820) | (0.384) |
| SOUTH | **2.410** | **0.193** | **0.715** | 0.124 | 206.9 | 0.427 |
| | (<0.001) | (<0.001) | (<0.001) | (0.773) | (0.970) | (0.821) |
| SARDINIA | **4.420** | **0.179** | **0.651** | 1.378 | 99.1 | 0.881 |
| | (0.002) | (<0.001) | (<0.001) | (0.055) | (0.906) | (0.670) |

Table 1: Estimated parameters and, in brackets, corresponding p-values for the GARCH-Logistic model and for each zone. Significant estimates are emphasized in bold.

# Estimated intervention function for Sicily





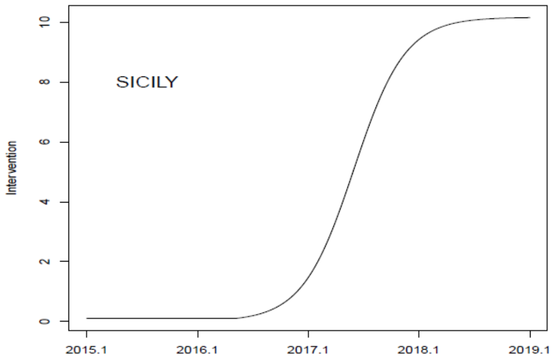




Figure 5: Estimated intervention functions for the six zones on the same scale.

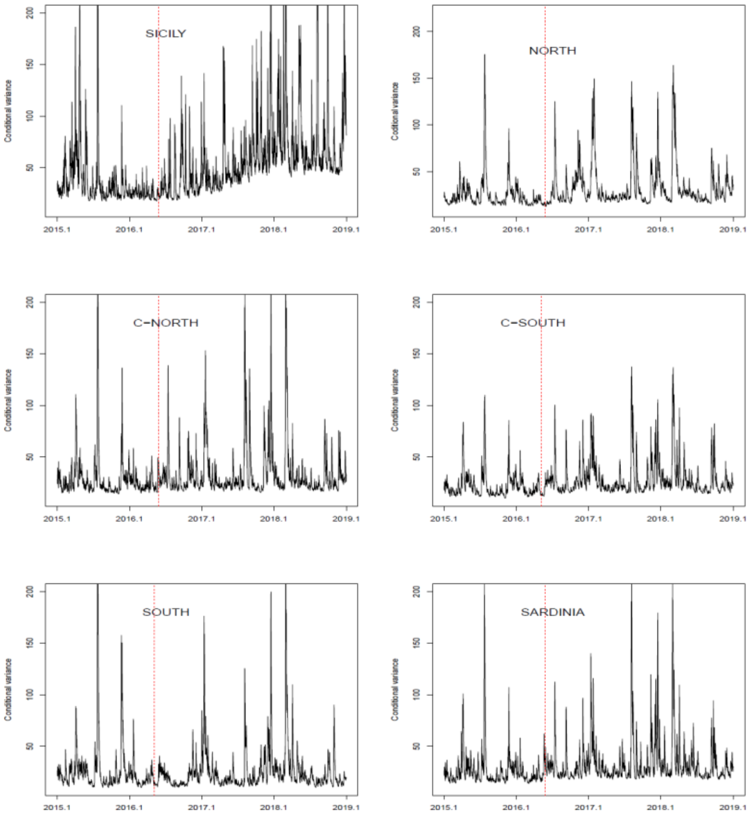



Figure 6: Estimated conditional variance for the six zones on the same scale. The dashed red line is set at 28 May 2016.

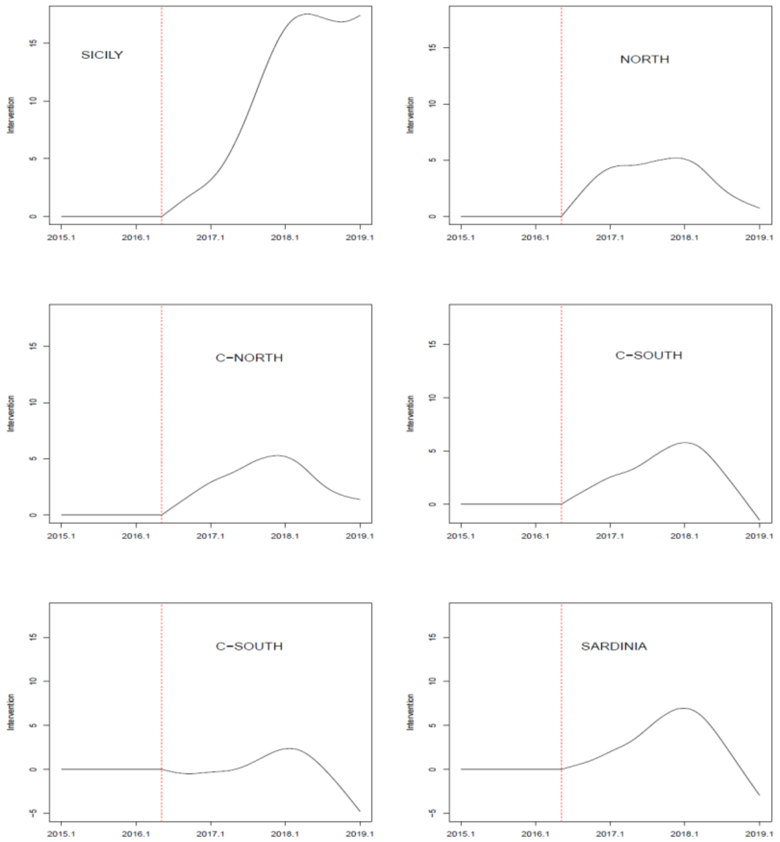



Figure 8: Estimated intervention functions for the six zones on the same scale.

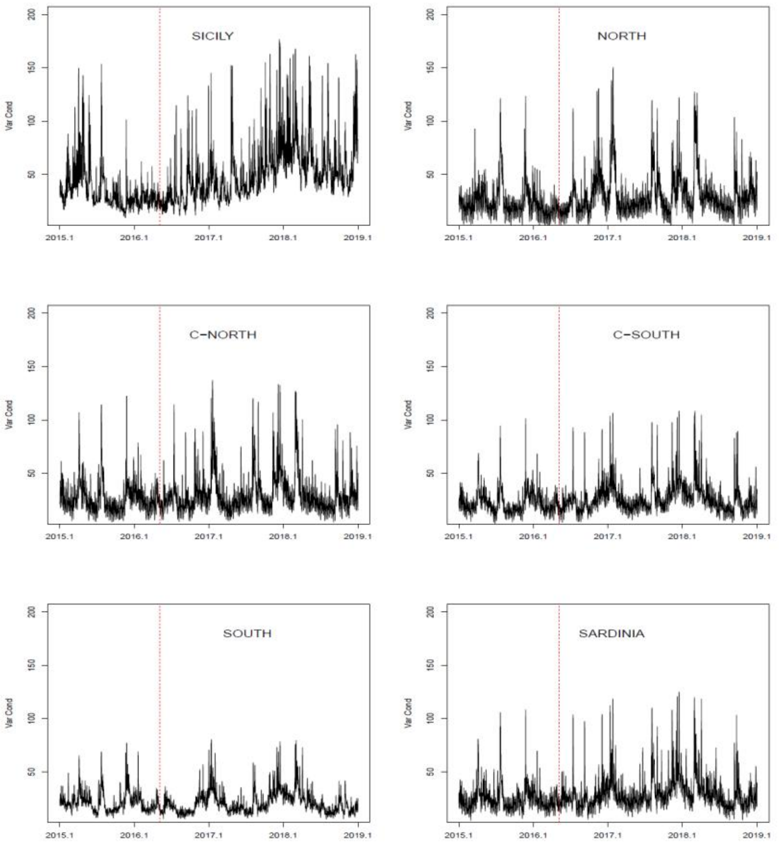



Figure 9: Estimated conditional variance for the six zones on the same scale.

# Conclusions

- Hypothesis 1 (**H1**): *New interconnectors reduce electricity price volatility (Turvey, 2006; Álvaro Cartea and González-Pedraz, 2012; Malaguzzi Valeri, 2009; Denny et al., 2010; Pean et al., 2016; Lobato et al., 2017);*

- Hypothesis 2 (**H2**): *New interconnectors increase electricity price volatility (European Commission, 2023; Sapio and Spagnolo, 2020; Tsaousoglou et al., 2022; Fabra, 2023; Yang et al., 2024);*

- Hypothesis 3 (**H3**): *New interconnectors do not have a significant effect on electricity price volatility (Ries et al., 2016; Denny et al., 2010; Lo Prete et al., 2025; Dudjak et al., 2021).*

Sicily

Other

# Conclusions

- We consider evolution in time, identifying the “intervention” from data variation
- The findings indicate that the interconnector activation led to an increased zonal price volatility *only for the island*
- Price variance delivers information about the **market competition** level
- Following Sapio and Spagnolo (2020), interconnerctors redestribute volotility across regions
- Effects however vary according to specific characteristics of the market involved (market structure, share of renewables, direction of power flows)

# Thank you for your attention!

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DIPARTIMENTO DI SCIENZE STATISTICHE

UNIVERSITÀ DEGLI STUDI DI PADOVA


# Marina Bertolini

Department of Statistical Science
University of Padova - Italy

Marina.bertolini@unipd.it



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