Quantile merit order effects and network upgrades: The SAPEI cable case

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Outline of the talk

- Background
- Quantile regression model
- Data and results
- Conclusion

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Energy islands

- Integration of electricity markets in the 2030 Climate-Energy Package and in the ”Clean energy for all Europeans” package
- Energy islands among the main impediments towards the single electricity market
  - Baltic States
  - Spain-France bottleneck
  - Sardinia: the SAPEI cable
    - Internal bottleneck
    - Rich in renewables
    - Potential bridge towards Northern Africa
    - Lower demand needs in the future? (Alcoa, GALSI)

Network upgrades and the electricity price distribution

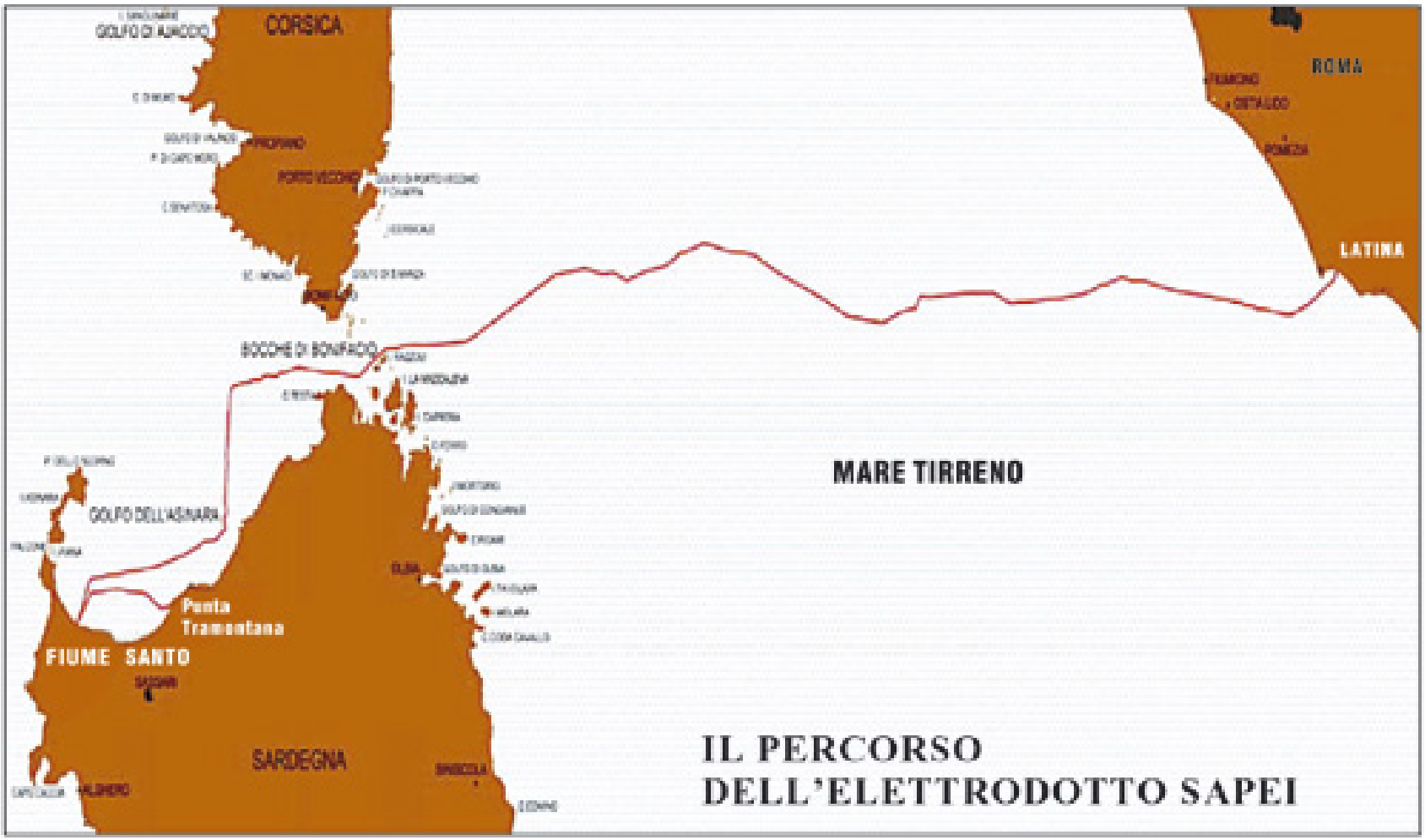
Quantile regressions allow to grasp, at the same time, the effects of a new transmission link

- on the median price (more robust than the mean to outliers) due to increased competition
- on price volatility (contagion due to renewables vs. volatility smoothing due to improved allocation)
- on the tails of the price distribution (better assessment of risk)

What the paper does

- Quantile regressions models
- IPEx data on zonal electricity prices
  - Sardinia, South
  - 2005-2015 period
  - Daily frequency
  - Hourly auctions: 4 am, 11 am, 7 pm
- How the SAPEI cable dummy coefficient changes across quantiles of the electricity price distribution
  - Theoretical analysis suggests it is informative about volatility and skewness after the cable

The SAPEI cable



The SAPEI cable

SAPEI = SArdegna PEnisola Italiana

- HVDC connecting Fiume Santo (Sardinia) to Latina (Center-South zone)
- 420 km (260 mi) submarine cable, 15 kms (9.3 mi) land cables
- Depth: 1,600 m (5,200 ft) below sea level in the Tyrrhenian Sea $\rightarrow$ the *deepest submarine power cable* in the world
- Total capacity: 1,000 megawatt at 500 kV of voltage
- Owned and operated by Terna (the Italian TSO)
- Inaugurated on March 17, 2011, after laying of a second submarine cable
  - The converter stations in Latina and Fiume Santo already entered into operation in 2009

Main references

- Quantile regressions of electricity prices: Bunn et al. (2013); Hagfors et al. (2016a, b); Paraschiv et al. (2016) - describing how coefficients change across quantiles
  - Expected stronger autocorrelation and effects of reserve margins in the right tail due to market power, but some exceptions in night auctions
  - Stronger effects of fuel prices in the body of the price distribution - due to fuel switching?
  - Renewables: unclear patterns across quantiles
- Several previous works on the Italian zones by the session speakers and other friends and colleagues
- Similar case studies: Ireland-Scotland-Wales (Valeri 2009, McInerney and Bunn 2013), Spain-Portugal-France (Ciarreta and Zarraga 2015), Australian zones (Higgs 2009, Ignatieva and Trück 2011)

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Model

Consider the following model for the electricity price y:

$$y = X\beta + \epsilon \tag{1}$$

where

- X: a matrix of explanatory variables (continuous or discrete), with coefficient vector β
- ϵ: a vector of error terms; assumptions:
  - Moments of ϵ are finite and can be functions of X
  - Laplace or Asymmetric Laplace distribution

Laplace error term

The p-th quantile of y, conditional on X, reads

$$Q_p(y|X) = \begin{cases} \mu + \sigma \ln(2p), & \text{if } 0 < p \leq \frac{1}{2} \\ \mu - \sigma \ln(2(1-p)), & \text{if } \frac{1}{2} \leq p < 1 \end{cases} \tag{2}$$

where

- $\mu = X\beta$
- $\sigma = \sigma(X)$

Laplace error term

Proposition 1: Let the error term in the model $y = X\beta + \epsilon$ be distributed as a Laplace with $\sigma = \sigma(X)$.

a. The quantile regression coefficients associated to the continuous explanatory variable X_i are:
   - Monotonically decreasing if $\frac{\partial \sigma(X)}{\partial X_i} < 0$
   - Constant if $\frac{\partial \sigma(X)}{\partial X_i} = 0$
   - Monotonically increasing if $\frac{\partial \sigma(X)}{\partial X_i} > 0$

b. The quantile regression coefficients associated to the dummy variable X_i are:
   - Monotonically decreasing if $\sigma_1 < \sigma_0$
   - Constant if $\sigma_1 = \sigma_0$
   - Monotonically increasing if $\sigma_1 > \sigma_0$

$\Rightarrow$ If price volatility has decreased after the SAPEI cable, we should find monotonically decreasing quantile coefficients associated to the SAPEI dummy

Asymmetric Laplace error term

The p-th quantile of y, conditional on X, reads

$$Q_p(y|X) = \begin{cases} \mu + \sigma\kappa \ln(\frac{1+\kappa^2}{\kappa^2}p), & \text{if } 0 < p \leq \frac{\kappa^2}{1+\kappa^2} \\ \mu - \frac{\sigma}{\kappa}\ln((1+\kappa^2)(1-p)), & \text{if } \frac{\kappa^2}{1+\kappa^2} \leq p < 1 \end{cases} \quad (3)$$

where

- $\mu = X\beta$
- $\sigma = \sigma(X)$
- $\kappa = \kappa(X)$
  - $\kappa > 0$
  - $\kappa = 1$: symmetry
  - $\kappa > 1$: negative skewness

Asymmetric Laplace error term

Case	$p < T_0$	$p \in (T_0, T_1)$	$p > T_1$
$\frac{\sigma_1}{\sigma_0} > \frac{\kappa_1}{\kappa_0} > 1 > \frac{\kappa_0}{\kappa_1}$	increasing	increasing	increasing
$\frac{\kappa_1}{\kappa_0} > \frac{\sigma_1}{\sigma_0} > 1 > \frac{\kappa_0}{\kappa_1}$	increasing	inverse U-shaped	decreasing
$\frac{\kappa_1}{\kappa_0} > 1 > \frac{\sigma_1}{\sigma_0} > \frac{\kappa_0}{\kappa_1}$	increasing	inverse U-shaped	decreasing
$\frac{\kappa_1}{\kappa_0} > 1 > \frac{\kappa_0}{\kappa_1} > \frac{\sigma_1}{\sigma_0}$	decreasing	decreasing	decreasing

where $T_x \equiv \frac{\kappa_x^2}{1+\kappa_x^2}$ with $x \in \{0, 1\}$

(similarly for continuous regressors)

$\Rightarrow$ If price volatility has decreased after the SAPEI cable and skewness has changed less, we should find a monotonically decreasing pattern of quantile regression coefficients associated to the SAPEI dummy

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Data

- Zonal prices, wholesale day-ahead electricity market, from the IPEx website (www.mercatoelettrico.org)
- 3864 daily observations between Jan 1, 2005 and Jul 31, 2015
- Daily log-price in zone z: $p_z = \ln\left\{\frac{1}{24}\sum_{h=1}^{24} P_{z,h}\right\}$
  - Focus on the Sardinian and Center-South market zones (linked by SAPEI)
  - Not using renewables due to gaps in the Terna database
- Model specification:

$$Q_p(y_t) = \beta_{p,1} \cdot y_{t-1} + \beta_{p,7} \cdot y_{t-7} + \beta_s \cdot S_t \tag{4}$$

where $S \in \{0, 1\}$ is the SAPEI dummy

Quantile regression estimates, Sardinian IPEx prices

	SAPEI dummy		
Quantiles	4am	11am	7pm
0.10	.085***	-.067***	.036***
0.25	.032***	-.005	.020**
0.40	.030***	-.032***	-.015***
0.50	.037***	-.061***	-.016 ***
0.60	.044***	-.094***	-.002***
0.75	.047***	-.149***	-.042***
0.90	.060***	-.313***	-.133***

	LogPrice, $t-1$			LogPrice, $t-7$		
Quantiles	4am	11am	7pm	4am	11am	7pm
0.10	.437***	.401***	.402***	.351***	.427***	.274***
0.25	.538***	.372***	.485***	.332***	.522***	.294***
0.40	.602***	.339***	.579***	.312***	.546***	.311***
0.50	.601***	.322***	.623***	.324***	.543***	.313***
0.60	.567***	.307***	.642***	.318***	.520***	.309***
0.75	.474***	.280***	.615***	.301***	.468***	.310***
0.90	.323***	.219***	.557***	.240***	.254***	.292***

Quantile regression est., Center-South IPEx prices

	SAPEI dummy		
Quantiles	4am	11am	7pm
0.10	.085***	.005	.029***
0.25	.032***	.013	.011*
0.40	.030***	-.008	-.004
0.50	.037***	-.022***	-.005
0.60	.044***	-.043***	-.011***
0.75	.047***	-.094***	-.023***
0.90	.060***	-.308***	-.044***

	LogPrice, $t-1$			LogPrice, $t-7$		
Quantiles	4am	11am	7pm	4am	11am	7pm
0.10	.437***	.391***	.430***	.351***	.598***	.432***
0.25	.538***	.338***	.475***	.332***	.631***	.423***
0.40	.602***	.292***	.499***	.312***	.653***	.436***
0.50	.601***	.271***	.515***	.324***	.653***	.448***
0.60	.567***	.252***	.508***	.318***	.636***	.456***
0.75	.474***	.241***	.484***	.301***	.571***	.471***
0.90	.323***	.191***	.432***	.240***	.325***	.517***

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Summary and conclusion

- After the SAPEI cable
  - Day-time decrease in prices in both Sardinia and South, but higher price in night-time auctions
  - The decrease was stronger in Sardinia and in the right tail of the price distribution
  - Lower volatility in both zones (as from decreasing quantile coefficient patterns)
  - Perhaps some change in skewness, yet seemingly less relevant than changes in volatility (no inverse-U shaped patterns)
- Quantile coefficient patterns associated to lagged prices
  - Variable across hours, with some inverse-U shaped patterns
  - Suggesting that price skewness depends on where the price was (issues: market power, price persistence)


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With papers by F. Wolak, M. Pollitt, C.A. Bollino among others

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Thanks

Thank you very much for your attention!

Comments welcome