Was PUN the value of a bad portfolio?

Alessandro Sapio

Parthenope University of Naples - DiSAE

8^{th} AIEE Symposium - University of Padua - 28-30 Nov 2024

The end of regulated end user tariffs . . .

- In 2023, 9 million electricity users in Italy still benefited from the *maggior tutela* (”enhanced protection”) regime
  - end user tariffs were set by the regulatory authority and revised quarterly
  - 4.5 million non-vulnerable end users had to choose a free-market retailer not later than July 2024
- End user prices set by retailers
  - possibly PUN (wholesale price index) plus a markup
  - Federconsumatori expected $+8.5\%$ in the energy bill for households
- but PUN will be replaced by zonal prices from Jan 1, 2025 on

. . . makes volatility a problem for end users, too

- Less attention paid to a potential surge in end user price volatility
  - Despite the evidence of risk aversion (Qiu et al. 2017) and loss aversion (Nicolson et al. 2017) preventing switches to TOU pricing
  - . . . and the exposure to shocks that affect volatility at lower frequencies
    - Pandemics, critical minerals crisis, Ukraine war, Red Sea crisis, extreme climate events
  - Hedging through derivatives is inaccessible to households and SMEs, lacking assets and financial literacy

Infra-annual variance in a real-world retail contract

- Let us consider a real-world retail contract: *plenitude*
  - *Corrispettivo Luce Index* = monthly average of PUN plus a markup; revised monthly

$$CLI_{my} = \frac{1}{H_m} \sum_{h=1}^{H_m} PUN_{hmy} + \mu \tag{1}$$

where

- CLI_{my}: Corrispettivo Luce Index in month m, year y
- PUN_{hmy}: PUN for hour h, month m, year y
- H_m: number of hours in month m
- μ: markup

Infra-annual variance in a real-world retail contract

- PUN (Prezzo Unico Nazionale) is defined as follows:

$$PUN_{hmy} = \sum_{z=1}^{N} \theta_{z,hmy} \cdot p_{z,hmy} \tag{2}$$

where

- $p_{z,hmy}$: zonal wholesale electricity price
- $\theta_{z,hmy} \equiv \frac{d_{z,hmy}}{d_{hmy}}$: zonal share in national electricity demand
- $\sum_{z=1}^{N} \theta_{z,hmy} = 1$
- N: number of market zones

Infra-annual variance in a real-world retail contract

- Plugging Eq. 2 into Eq. 1 yields

$$CLI_{my} = \frac{1}{H_m} \sum_{h=1}^{H_m} \sum_{z=1}^{N} \theta_{z,hmy} \cdot p_{z,hmy} + \mu \tag{3}$$

  - Looks like the value of a portfolio including N assets

- Risk-averse users care about the annual variance of CLI_{my}, which depends on:
  - variances of asset values (zonal prices $p_{z,hmy}$)
  - covariances across zones between the values of asset purchases, i.e. between $(\theta_{z,hmy} \cdot p_{z,hmy})$ and $(\theta_{w,hmy} \cdot p_{w,hmy})$

PUN: the value of a *bad* portfolio?

- Yet, PUN (or CLI) is the value of a portfolio characterised by major shortcomings:
  - Given number of 'assets' (electricity generated in the market zones)
  - Portfolio weights (zonal demand shares) not freely chosen by traders
  - Positive correlation between asset values, i.e. the zonal prices

PUN: the value of a *bad* portfolio?

- Correlation is perfect when transmission lines are not congested
  - In that case, the choice of portfolio weights is irrelevant - all zonal prices are the same
- With congestion, zonal prices correlate less and may in principle correlate negatively
- Focus on a frequent congestion pattern: Sicily vs. rest of Italy
  - Sicily was congested out in 66.4% of market sessions between 2005 and 2019
  - a Sicily vs. rest-of-Italy congestion pattern was observed in 37.3% of sessions

PUN: the value of a *bad* portfolio?

Table: Correlations between zonal prices and between zonal purchase values. IPEx 2005-2014.

Year	$corr(p_s, p_{ri})$	$corr(\theta_s \cdot p_s, \theta_{ri} \cdot p_{ri})$
2005	.7737	.7553
2006	.7781	.2936
2007	.9422	.8388
2008	.8609	.7432
2009	.7156	.7748
2010	-.4811	-.2825
2011	.1256	.1586
2012	.0968	.4273
2013	.4536	.4317
2014	-.0309	-.2155

Statistics computed on market sessions between Jan 1, 2005 and Dec 31, 2014 when only Sicily was congested out. θ_s: Sicily demand share. $\theta_{ri} \equiv 1 - \theta_s$. p_s: Sicily price. p_{ri}: price in the remaining market zones.

PUN: the value of a *bad* portfolio?

Table: Correlations between zonal prices and between zonal purchase values. IPEx 2015-2019.

Year	$corr(p_s, p_{ri})$	$corr(\theta_s \cdot p_s, \theta_{ri} \cdot p_{ri})$
2015	.7018	.5459
2016	.7928	.7775
2017	.7127	.5659
2018	.4787	.4658
2019	.7630	.7613

Statistics computed on market sessions between Jan 1, 2005 and Dec 31, 2014 when only Sicily was congested out. θ_s: Sicily demand share. $\theta_{ri} \equiv 1 - \theta_s$. p_s: Sicily price. p_{ri}: price in the remaining market zones.

Research question and proposals

- Question: can one identify an alternative vector of portfolio weights, θ^* such that

$$V[CLI_{my}|\theta^*] < V[CLI_{my}|\theta] \qquad E[CLI_{my}|\theta^*] = E[CLI_{my}|\theta]$$

  - If weighting schemes different from zonal demand shares perform better in risk terms, then there is room for consumers to bargain better retail price-setting rules

- Comparing PUN weights with:

  1. $\theta^* \equiv \text{argmin}_\theta V[CLI_{my}]$
  2. $\theta^* \equiv L^\tau \theta$, with L: lag operator, τ: lag

Proposal 1 - *Variance minimisation*

- Compute θ^* by solving the following variance minimisation problem:

$$\min_{\theta \in (0,1)} \frac{1}{2} \theta' \Sigma \theta$$

s.t.

$$\theta' Ep = E[PUN] \qquad \theta' \vec{1} = 1$$

where

- Σ: covariance matrix of monthly average zonal prices in year y
- Ep: vector of average zonal prices in year y
- $E[PUN]$: PUN average in year y

Proposal 1 - *Variance minimisation*

- Remarks on θ^*:
  - it is computed for the whole year, whereas zonal demand shares vary with a hourly frequency
  - it may underperform the zonal demand shares if these react to high volatility quickly enough
  - computing it ex-ante requires variance forecasts (and not realised variance)

Proposal 1 - *Variance minimisation*

Table: Infra-annual standard deviation of monthly PUN and of a price index computed using variance-minimising zonal demand shares, 2005-2014

Year	PUN, avg.	PUN, s.d.*	θ^*, Sicily	min. s.d.	Δ s.d. (%)
2005	57.090	6.3363	.0650	6.3038	-.51
2006	69.268	7.1923	.2628	7.2227	.42
2007	63.717	9.4164	.0674	9.4171	.01
2008	89.123	10.5857	.0601	10.5521	-.32
2009	62.374	12.3926	.0646	12.3432	-.40
2010	62.490	3.4172	.0651	3.3620	-1.62
2011	71.971	6.1352	.0656	6.1507	.25
2012	74.854	5.6834	.0700	5.6233	-1.06
2013	62.703	5.3845	.0704	5.3139	-1.31
2014	52.016	5.6918	.0683	5.7533	1.08

Proposal 1 - *Variance minimisation*

Table: Infra-annual standard deviation of monthly PUN and of a price index computed using variance-minimising zonal demand shares, 2015-2019

Year	PUN, avg.	PUN, s.d.*	θ^*, Sicily	min. s.d.	Δ s.d. (%)
2015	51.478	5.2783	.0578	5.2676	-.20
2016	42.616	8.9676	.0636	8.9511	-.18
2017	55.193	8.0894	.0638	8.0616	-.34
2018	65.353	8.1834	.0640	8.1370	-.57
2019	57.950	5.8020	.0624	5.7369	-1.12

Statistics computed on IPEx market sessions between Jan 1, 2015 and Dec 31, 2019 when Sicily was congested and all other market zones were integrated.
*: standard deviation computed, for each year, on the sample of 12 monthly average PUN values.

Proposal 1 - *Variance minimisation*

- What if we allow for risk premia or risk penalties with respect to the annual PUN average?
- Let us modify the variance minimisation problem as follows:

$$\min_{\theta \in (0,1)} \frac{1}{2} \theta' \Sigma \theta$$

s.t.

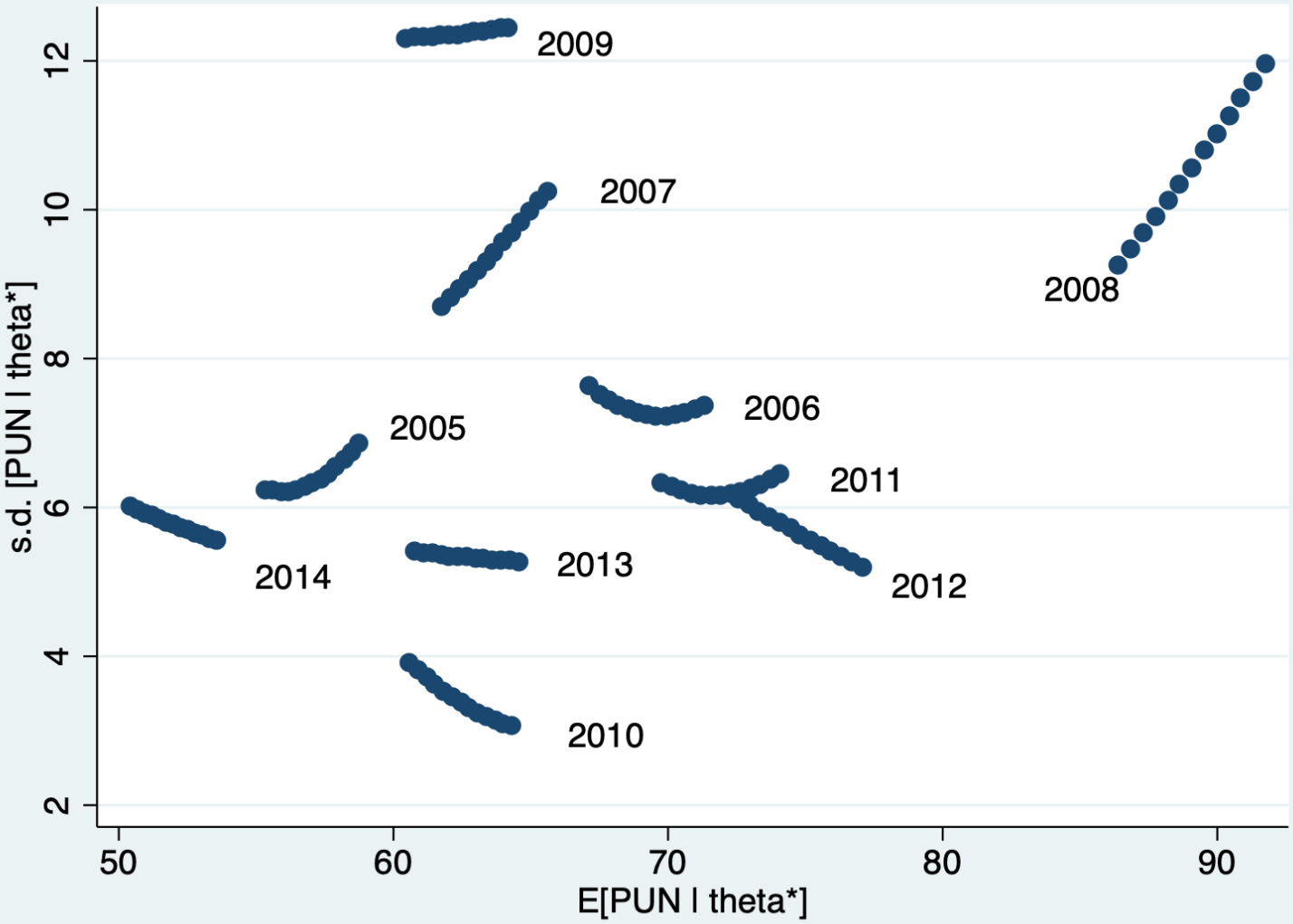
$$\theta' Ep = \rho \cdot E[PUN] \qquad \theta' \vec{1} = 1$$

  - ρ in $0.97 : 0.005 : 1.03$,

    i.e. risk premia and risk penalties up to 3% of the annual PUN average

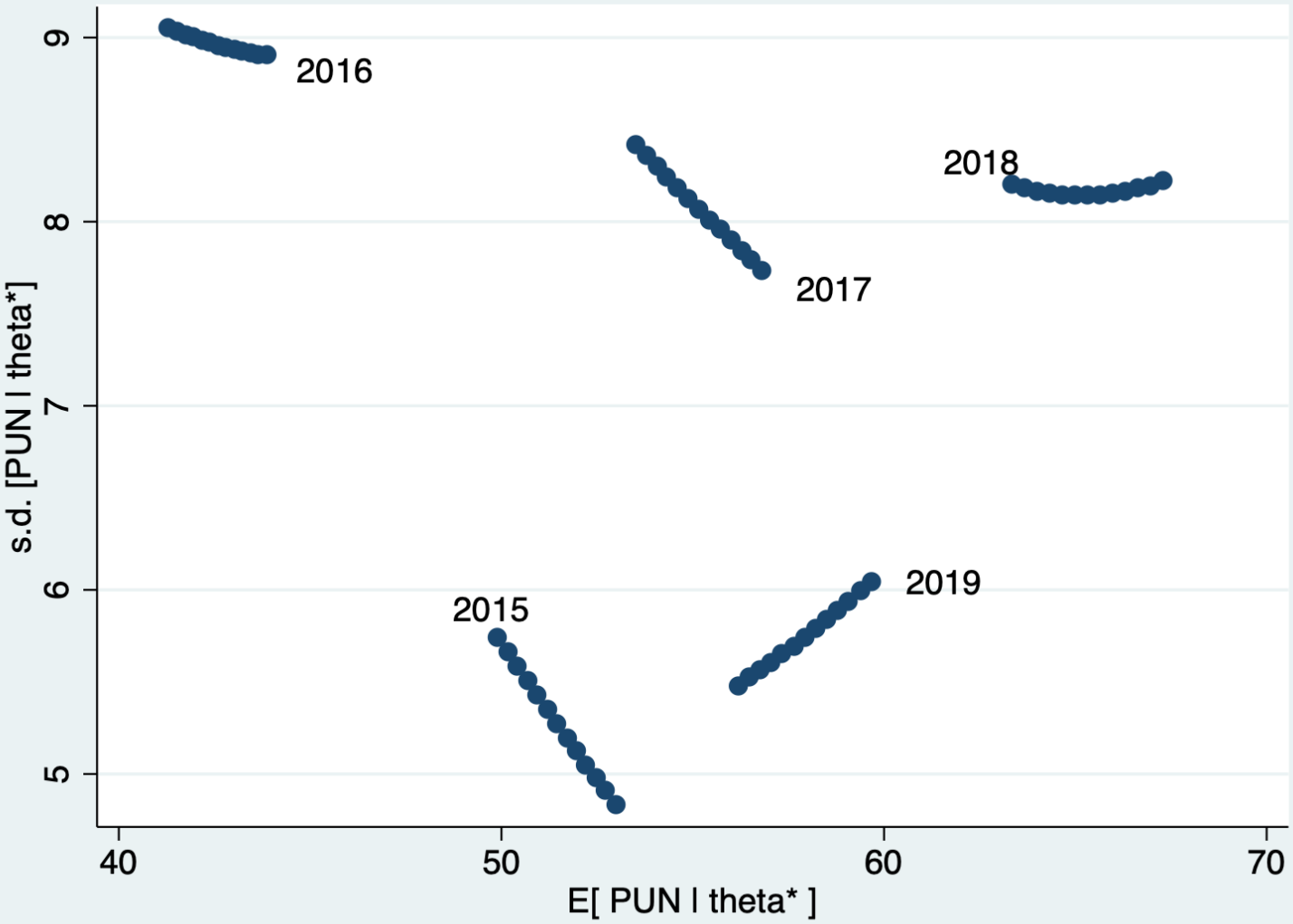
Proposal 1 - *Variance minimisation*

Annual PUN *efficient frontiers*, 2005-2014



Proposal 1 - *Variance minimisation*

Annual PUN *efficient frontiers*, 2015-2019



Proposal 2 - *Lagged demand shares*

- Use lagged zonal demand shares if they are less correlated with current zonal prices
- Indeed, the variance of a PUN computed using lagged zonal demand shares $\theta_{z,t-\tau}$ instead of θ_{zt},

$$PUN_t^{\tau} = \sum_{z=1}^{N} \theta_{z,t-\tau} \cdot p_{zt}$$

should be lower than the variance of the *traditional* PUN

Proposal 2 - *Lagged demand shares*

Table: Infra-annual standard deviation of monthly PUN$^{\tau}$, computed using simultaneous and lagged zonal demand shares, 2005-2014

Lag τ Year	s.d. PUN$^{\tau}$ 0	s.d. PUN$^{\tau}$ 1 month	s.d. PUN$^{\tau}$ 2 months	s.d. PUN$^{\tau}$ 3 months	s.d. PUN$^{\tau}$ 4 months	s.d. PUN$^{\tau}$ 5 months	s.d. PUN$^{\tau}$ 6 months
2006	7.1923	7.2679	7.2567	7.2360	7.2202	7.1822	7.1694
2007	9.4164	9.4270	9.3960	9.4534	9.3669	9.3282	9.2662
2008	10.586	10.5945	10.5399	10.5000	10.4707	10.5006	10.5935
2009	12.393	12.5218	12.4355	12.3064	12.2627	12.3476	12.4004
2010	3.4172	3.4042	3.4221	3.3660	3.3637	3.3251	3.3386
2011	6.1352	6.1889	6.2146	6.1810	6.1580	6.1368	6.0978
2012	5.6834	5.6658	5.5817	5.5478	5.5795	5.6312	5.6937
2013	5.3845	5.3574	5.2954	5.2400	5.2719	5.2892	5.3161
2014	5.6918	5.8357	5.8611	5.8111	5.8088	5.858	5.7878

Statistics computed on IPEx market sessions between Jan 1, 2005 and Dec 31, 2014 when Sicily was congested and all other market zones were integrated.

Proposal 2 - *Lagged demand shares*

Table: Infra-annual standard deviation of monthly PUN^{τ}, computed using simultaneous and lagged zonal demand shares, 2015-2019

Lag τ Year	s.d. PUN^{τ} 0	s.d. PUN^{τ} 1 month	s.d. PUN^{τ} 2 months	s.d. PUN^{τ} 3 months	s.d. PUN^{τ} 4 months	s.d. PUN^{τ} 5 months	s.d. PUN^{τ} 6 months
2015	5.2783	5.2652	5.2681	5.2688	5.2774	5.2666	5.2644
2016	8.9676	8.9725	8.9813	8.9933	8.9865	8.9763	8.9838
2017	8.0894	8.0806	8.0849	8.1032	8.0754	8.0947	8.0896
2018	8.1834	8.1465	8.1709	8.1655	8.1699	8.1497	8.1200
2019	5.8020	5.8219	5.7857	5.7769	5.7731	5.8408	5.8534

Statistics computed on IPEx market sessions between Jan 1, 2015 and Dec 31, 2019 when Sicily was congested and all other market zones were integrated.

Proposal 3 - *MAVER and Time Shift*

- Confindustria (2022) proposed a market reform to decouple the valuations of renewable and programmable electricity, based on two separate market segments:
  - MAVER (Mercato per l'Acquisto e per la Vendita dell'Energia Rinnovabile, 'market for the purchase and sale of renewable energy', based on renewables Power Purchase Agreements (PPAs)
  - Time Shift market, including only programmable sources able to provide 'flexibility services'

Conclusion and future research

- PUN was not the first best in terms of variance minimisation, but was not so bad
- More research is needed regarding:
  - other congestion patterns, involving higher dimensional portfolios
  - other risk management objectives (e.g. VaR minimisation)

Thank you very much! Questions and comments welcome