

Technology-Neutral versus Technology-Specific Procurement

Natalia Fabra, UC3M & CEPR
(joint with Juan Pablo Montero, PUC Chile)

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Research Questions

An imperfectly-informed principal needs to procure multiple units of a good that can be produced with heterogeneous sources (technologies)

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- **Energy storage:** batteries, hydrogen, pumped hydro...
- **Central bank's liquidity:** good and bad collateral
- **A firm procuring inputs** from various countries

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If she is indifferent between the various sources....

- 1 Should she run **technology-specific or -neutral** auctions?
- 2 Should she allow for **partial separation** across technologies?
- 3 How does **market power** affect the choice?
- 4 Should she instead post separate **prices** for each technology?

What are the trade-offs and what do they depend on?

Leading Example: Investments in Renewables

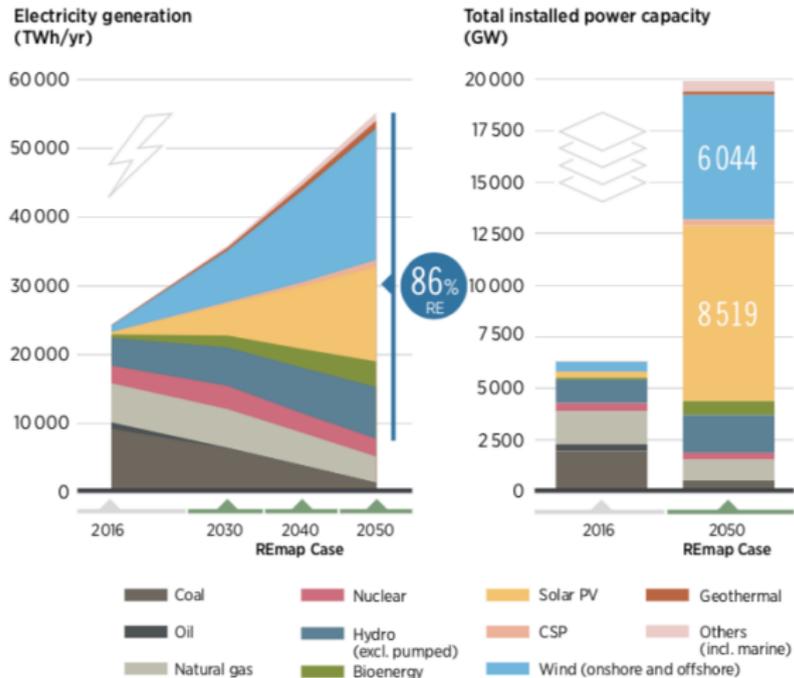


Figure: Electricity generation mix and power generation installed capacity by fuel, 2016-2050. Source: IRENA (2019b)

Renewable Support Schemes in Practice

Commonly used renewables support instruments regulate...

- **Quantity:** Auctions, tradable quotas...
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- **Technology specific:** different instruments/levels of support used depending on technology, scale, location, etc.
- **Technology neutral:** all technologies treated equally
- **Hybrid schemes:** corrected technology-neutral approach
 - Auctions: bids of some technologies are deflated
 - Green certificates: some technologies are granted more certificates than others (*banding*)

An Example: Technology Specific Renewable Auctions

		2020	2021	2022	2023	2024	2025
Eólica	Incremento	1.000	1.500	1.500	1.500	1.500	1.500
	Acumulado	1.000	2.500	4.000	5.500	7.000	8.500
Fotovoltaica	Incremento	1.000	1.800	1.800	1.800	1.800	1.800
	Acumulado	1.000	2.800	4.600	6.400	8.200	10.000
Solar Termoeléctrica	Incremento		200		200		200
	Acumulado		200	200	400	400	600
Biomasa	Incremento		140		120		120
	Acumulado		140	140	260	260	380
Otras tecnologías (biogás, hidráulica, mareomotriz, etc.)	Incremento		20		20		20
	Acumulado		20	20	40	40	60

Figure: Calendar of technology-specific renewables auction targets (Spain)

An Example: Banding and Tradable Permits

Bands	Support in ROCs/MWh for new generating stations accrediting in the period:	
	2015/16	2016/17
Solar PV (building mounted)	1.5	1.4
Solar PV (ground mounted)	1.3	1.2

Figure: Amount of Renewable Obligation Certificates granted to Solar PV (UK)

Roadmap

- 1 (*Literature review*) [▶ GO](#)
- 2 Model description [▶ GO](#)
- 3 Technology-neutral auctions [▶ GO](#)
- 4 Technology-specific auctions [▶ GO](#)
- 5 Adding market power [▶ GO](#)
- 6 (*Technology banding*) [▶ GO](#)
- 7 (*Price regulation*) [▶ GO](#)
- 8 Simulations: renewable investments in Spain [▶ GO](#)
- 9 Conclusions

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Firms and Technologies:

- One good can be produced with two technologies $t = 1, 2$

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Costs:

- Aggregate cost function, for $t = 1, 2$:

$$C_t(q_t) = (c_t + \theta_t) q_t + \frac{C''}{2} q_t^2$$

- Cost parameters: $c_2 - c_1 \equiv \Delta c > 0$
- Cost shocks: $E[\theta_t] = 0$, $E[\theta_t^2] = \sigma > 0$ and $E[\theta_1\theta_2] = \rho\sigma \geq 0$

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Social Benefits:

- $B(Q)$, where $Q = q_1 + q_2$, with $B' > 0$ and $B'' < 0$
- Ass.: Always optimal to procure units from both technologies

The Principal's Problem

The principal maximizes (expected) **social welfare**:

$$\max W = E \left[B(Q) - \sum_{t=1,2} C_t(q_t, \theta_t) - \lambda T(q_1, q_2, \theta_1, \theta_2) \right]$$

- λ : **shadow cost of public funds**
- $T(q_1, q_2, \theta_1, \theta_2)$: Total payment from procuring $Q = q_1 + q_2$

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The principal must decide ex-ante between...

- 1 **Technology-neutral** approach: $Q \rightarrow P(Q)$
- 2 **Technology-specific** approach: q_1 and $q_2 \rightarrow p_1(q_1)$ and $p_2(q_2)$

Technology-Neutral Auctions

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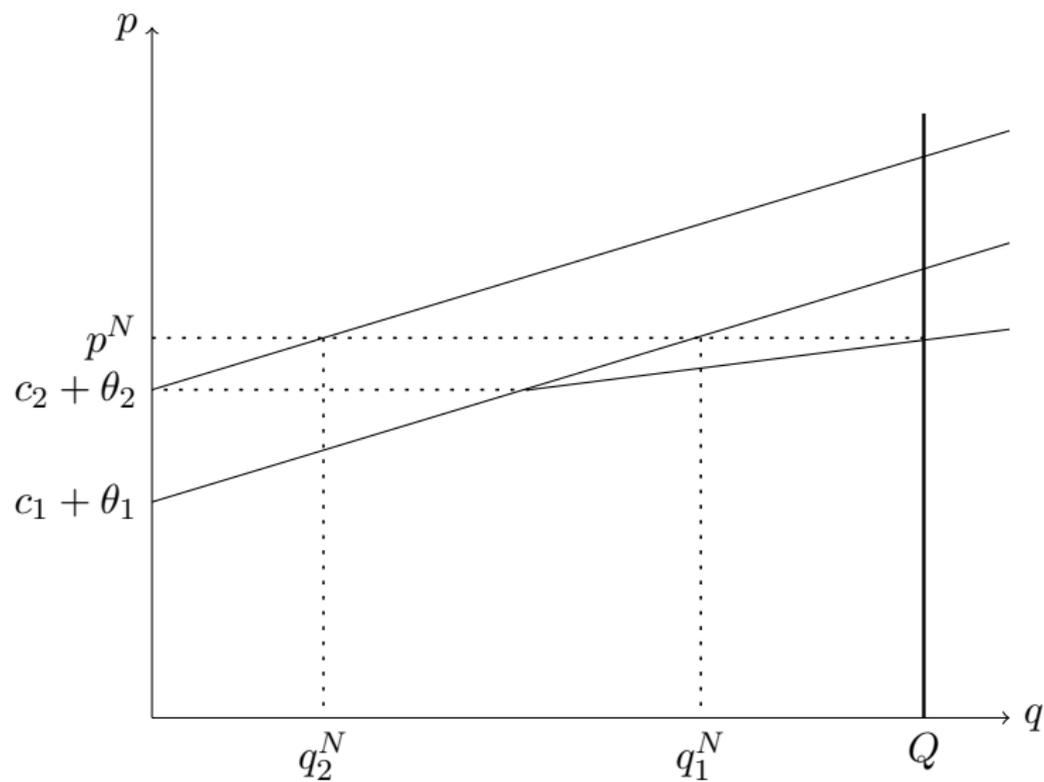
- **Quantities** for each technology are given by

$$q_1^N = \frac{Q^N + \Phi^N}{2} + \frac{\Delta\theta}{2C''} > q_2^N = \frac{Q^N - \Phi^N}{2} - \frac{\Delta\theta}{2C''}$$

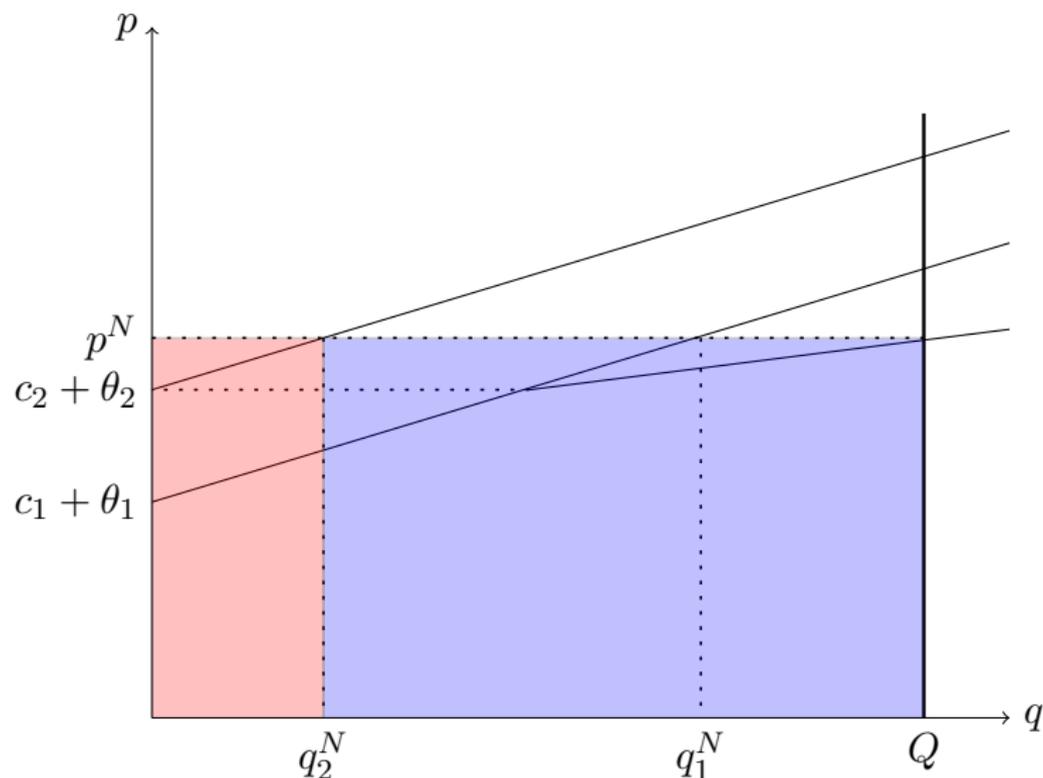
where

$$\Phi^N \equiv E[q_1^N] - E[q_2^N] = \frac{\Delta c}{C''} > 0$$

Graphical Representation: Technology-Neutrality



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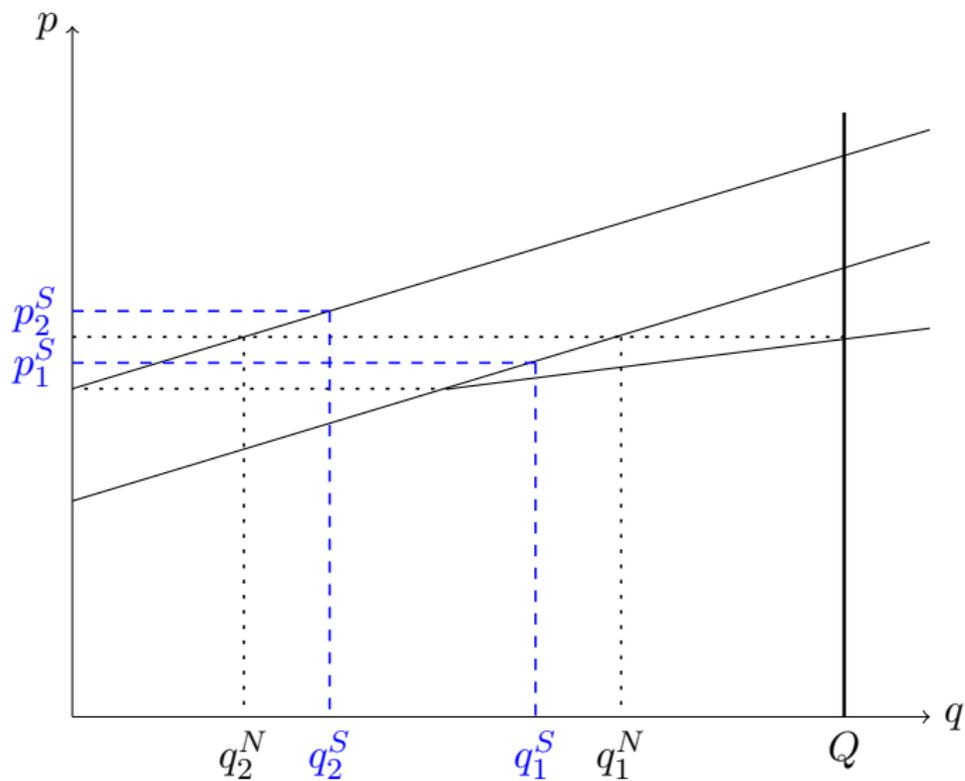
- This leads to

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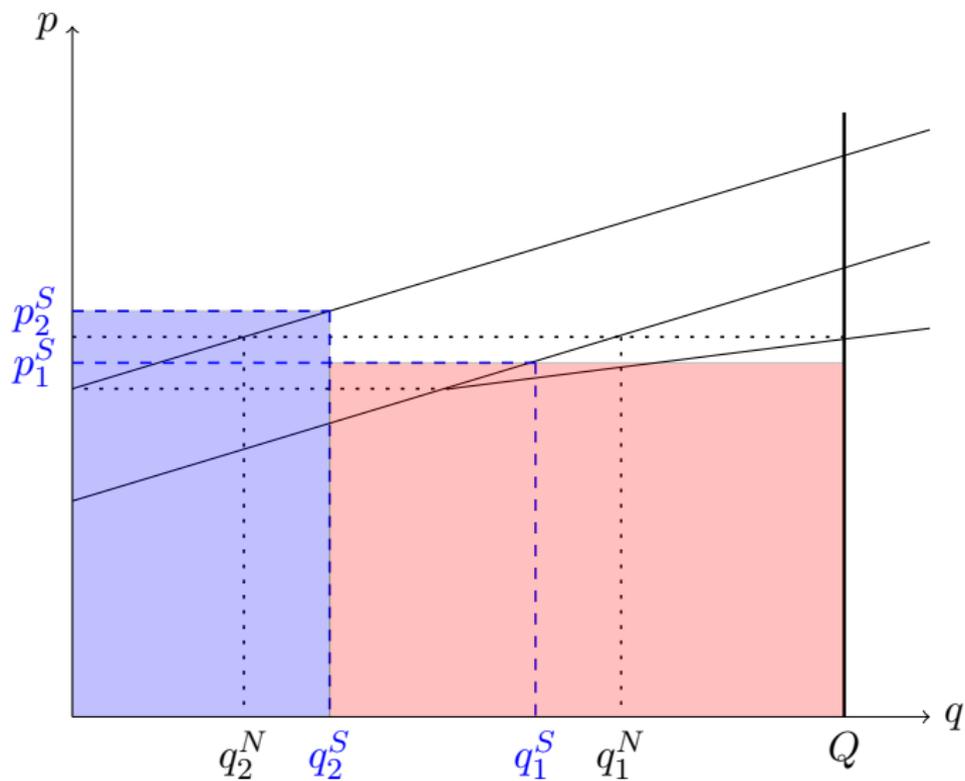
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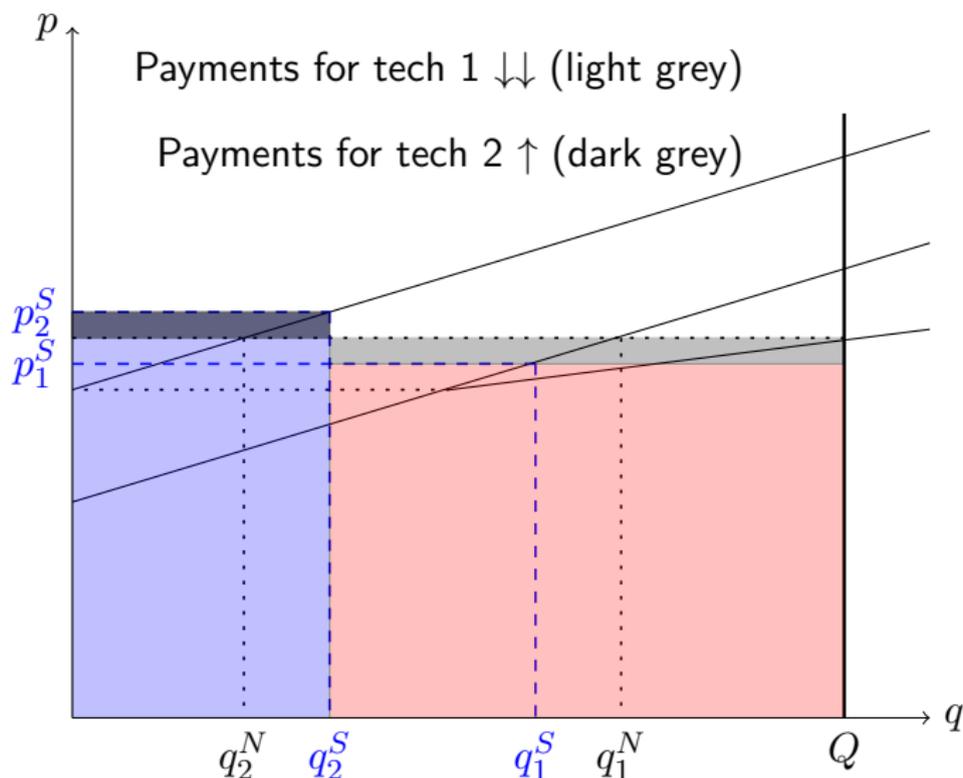
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- ...at the expense of **increasing expected costs**:

$$E[C^S] - E[C^N] = \frac{C'''}{4} [(\Phi^S(\lambda) - \Phi^N)^2] + \frac{E[(\Delta\theta)^2]}{4C'''} > 0$$

Technology-neutral vs. Technology-specific Auctions

Comparing Welfare under the two approaches:

$$\Delta W^{NS} \equiv W^N - W^S = \frac{1}{4C''} \left[2\sigma(1 - \rho) - \frac{\lambda^2}{1 + 2\lambda} (\Delta c)^2 \right]$$

Rents-efficiency trade-off:

- 1 1st term: efficiency gain under tech-neutrality (quantity adjustment)
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2 Tech-specificity always dominates if:

- Strong concern for rents: $\lambda \rightarrow \infty$
- Perfectly correlated cost shocks: $\rho = 1$

Adding Market Power

Consider a **monopolist** on both technologies:

- It charges the monopoly price for the two technologies
- Under technology-neutral auctions, it allocates production across technologies to minimize costs
- Under technology-specific auctions, it produces the quantities allocated to each technology

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How general is this result for lower degrees of market power?

Adding Market Power

- Existing units divided btw dominant firm (d) and fringe (f)
 - Shares $\omega_d = \omega$ and $\omega_f = 1 - \omega$
- Costs for each firm $i = d, f$ are now given by

$$C_{it}(q_{it}, \theta_t) = (c_t + \theta_t) q_{it} + \frac{1}{2} \frac{C''}{\omega_i} q_{it}^2$$

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- ...resulting in a **higher market share for the fringe:**

$$E[q_f^N] - E[q_d^N] = \frac{1 - \omega}{1 + \omega} Q^N > 0$$

$$q_{ft}^S - q_{dt}^S = \frac{1 - \omega}{1 + \omega} q_t > 0$$

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Welfare:

- Market power reduces welfare under both approaches
- Greater welfare reduction under technology-specific auctions
- ΔW^{NS} is increasing in $\omega \rightarrow$ Technology-neutrality favoured

Further Results (in the paper)

Technology Banding [▶ GO](#)

- The price paid to one technology is increased by $\alpha > 1$
- Technology-neutrality: special case with $\alpha = 1$
- Technology-specific auctions: not a special case of banding
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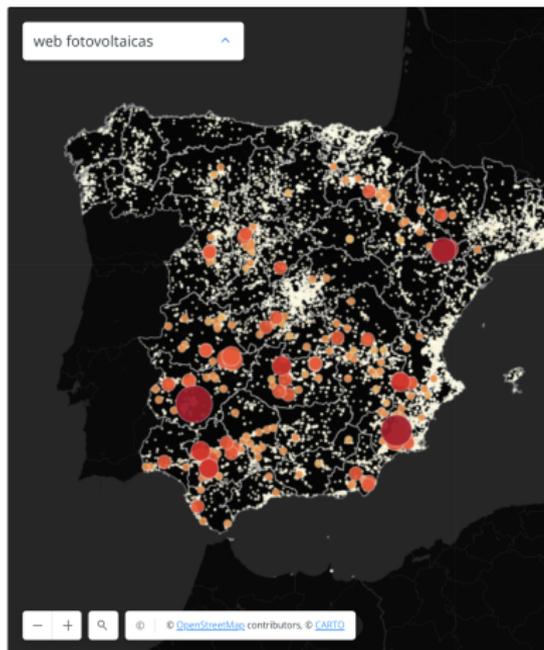
Price Regulation [▶ GO](#)

- Technology-specific prices always dominate a single price
- Comparison P vs. Q follows a corrected Weitzman formula:
 - Multiple technologies favour price regulation
 - The cost of public funds λ (weakly) benefits price regulation

[▶ Ex-post](#)

Taking the Model to the Data

Renewable Investments in Spain



(a) Solar Installations



(b) Wind Installations

Technology-Neutral

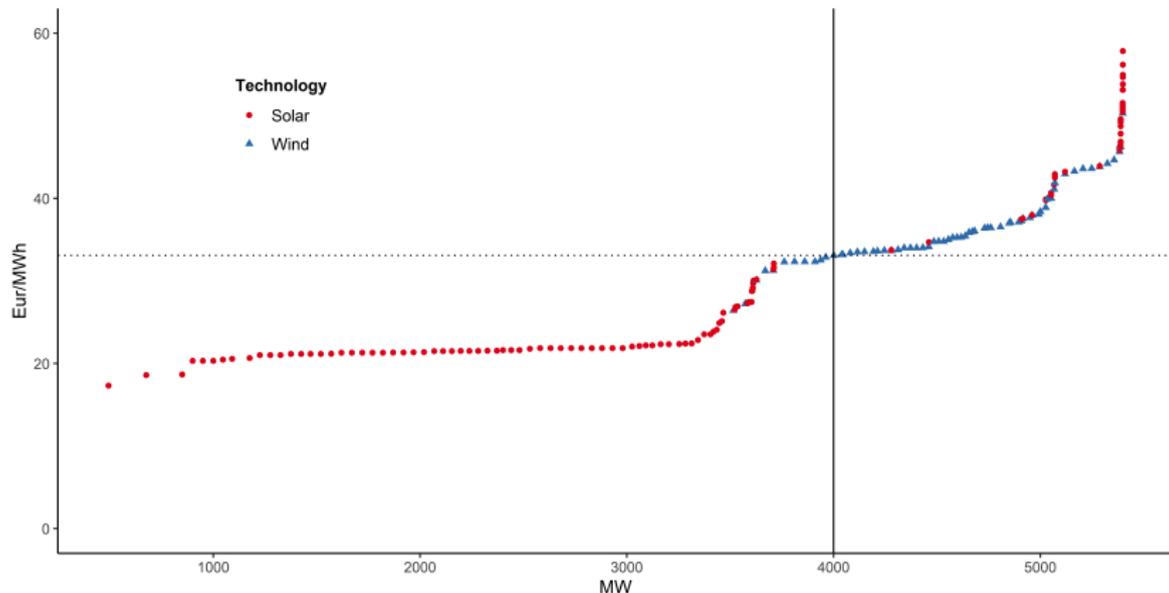
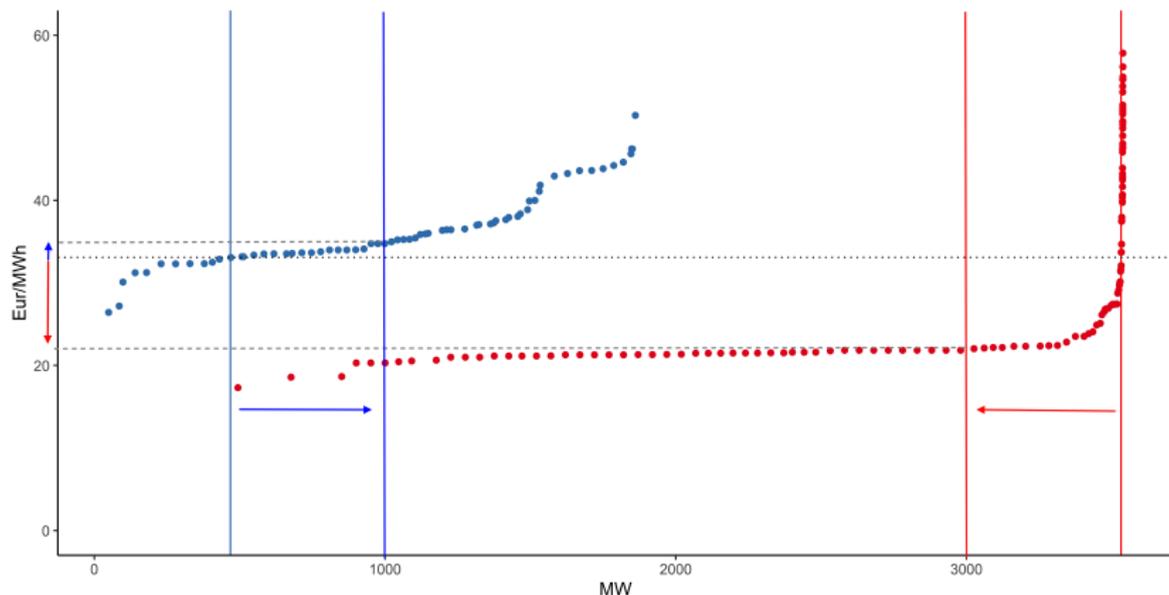


Figure: Average cost curve of solar and wind investments in the Spanish electricity market: Technology Neutral

Technology-Specific



Technology-specific vs. technology-neutral auctions

ρ	λ	Costs	Payments	Social Costs
-0.8	0	1.03	0.73	1.03
-0.8	0.2	1.04	0.72	0.96
-0.8	0.4	1.04	0.71	0.91
0	0	1.02	0.75	1.02
0	0.2	1.02	0.75	0.95
0	0.4	1.03	0.72	0.91
0.8	0	1.00	0.88	1.00
0.8	0.2	1.01	0.76	0.95
0.8	0.4	1.02	0.74	0.91

Table: Technology-specific auctions relative to technology-neutrality

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Note of caution:

- **Constraints when implementing *optimal* technology separation**
- “Bad” technology separation might be worse than neutrality
- ...even in settings where optimal technology separation dominates

Thank You!

Questions? Comments?

More info at nfabra.uc3m.es and energyecolab.uc3m.es



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Related Literature

1 Regulation and Procurement

- Laffont and Tirole (1993); Laffont and Martimort (2002)

2 Auctions and Mechanism Design

- Segal (2003)
- Klemperer (2010)
- Manzano and Vives (2020)

3 Other multi-good auction settings

- Mason and Plantinga (2013)
- Montero (2001)

▶ BACK

Banding in a technology-neutral auction

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subject to (equalization of *adjusted* marginal costs)

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leading to

$$q_1^B = \frac{Q^B}{1 + \alpha^B} + \frac{c_2 + \theta_2 - \alpha^B (c_1 + \theta_1)}{(1 + \alpha^B) C''} < q_1^N$$
$$q_2^B = \frac{\alpha^B Q^B}{1 + \alpha^B} - \frac{c_2 + \theta_2 - \alpha^B (c_1 + \theta_1)}{(1 + \alpha^B) C''} > q_2^N$$

Technology-Banding

- Banding results in a steeper price curve:

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If no uncertainty ($\sigma \rightarrow 0$)

- Banding replicates a technology-specific design:

$$\alpha^B = p_2^S / p_1^S$$

- Either design dominates the technology-neutral design, i.e.,

$$W_q^B = W_q^S > W_q^N$$

Technology-Banding

If uncertainty ($\sigma > 0$)

- Suppose $W_q^S > W_q^N$
- There exists a correlation cut-off, $\bar{\rho} < 1$, above which technology-specific auctions also dominate technology banding:

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- The critical $\bar{\rho}$ is decreasing in α^B
- When is the optimal α^B low?
 - When low σ , low λ , small Δc and high C''

Technology-Banding

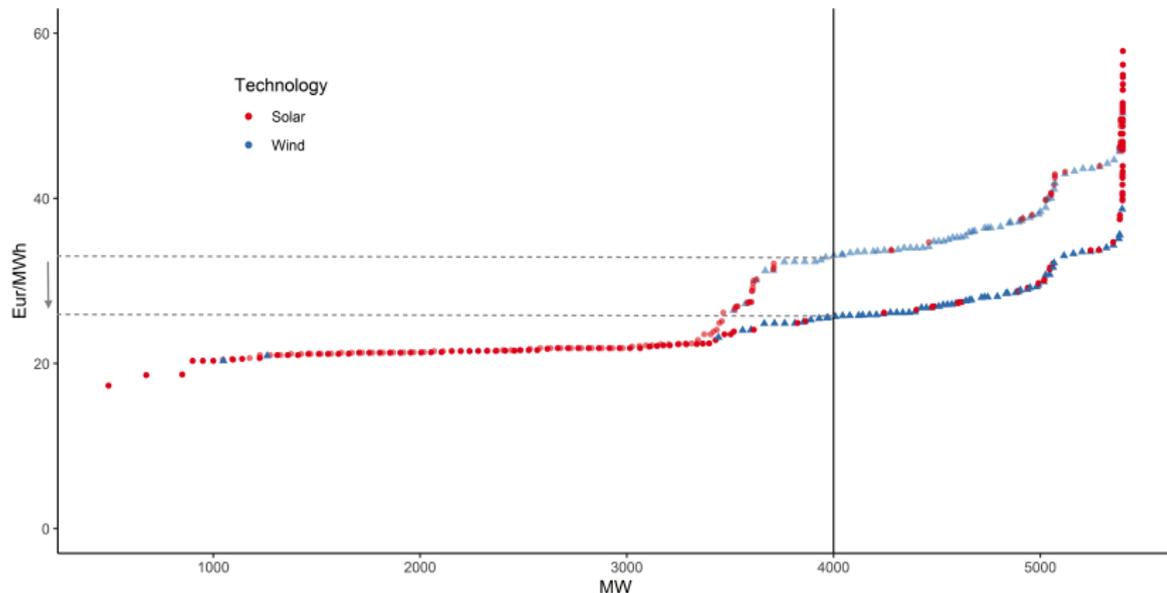


Figure: Average cost curve of solar and wind investments in the Spanish electricity market: Technology Banding

Technology-banding vs. Technology-neutrality

ρ	λ	Costs	Payments	Social Costs	Banding α
-0.8	0	1.00	1.00	1.00	1.0
-0.8	0.2	1.01	0.87	0.98	1.3
-0.8	0.4	1.02	0.86	0.96	1.4
0	0	1.00	1.00	1.00	1.0
0	0.2	1.01	0.86	0.97	1.3
0	0.4	1.02	0.84	0.95	1.4
0.8	0	1.00	1.00	1.00	1.0
0.8	0.2	1.01	0.82	0.97	1.3
0.8	0.4	1.01	0.82	0.94	1.3

Table: Technology-banding relative to technology-neutrality

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Price Regulation

- Two tech-specific prices dominate a single tech-neutral price

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$$\max_{p_1, p_2} E \left[B \left(\sum_{t=1,2} q_t(p_t) \right) - \sum_{t=1,2} C_t(q_t(p_t)) - \lambda T(p_1, p_2) \right]$$

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- Quantities adjust so that **each** market price equals the marginal costs of **each** technology:

$$p_t = c_t + \theta_t + C'' q_t(p_t)$$

One price vs. one quantity (Weitzman)

- One price dominates one quantity iff

$$W_p^S - W_q^S = \frac{2\sigma}{(C'')^2} \left(B'' + \frac{C''}{2} \right) > 0$$

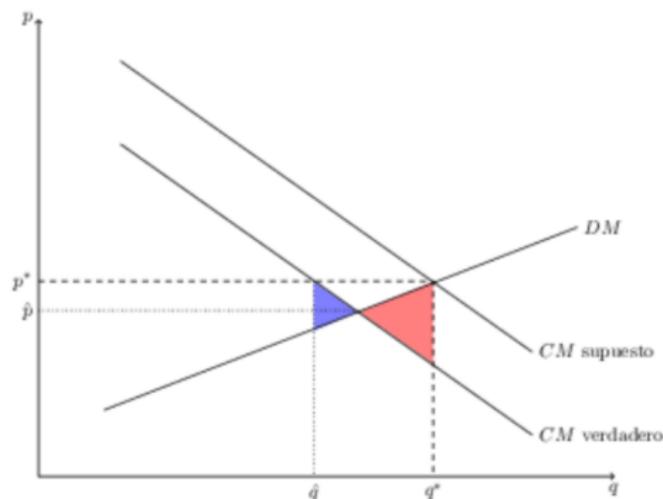


Figure: P vs Q: Price regulation is superior when marginal benefit is relatively flat

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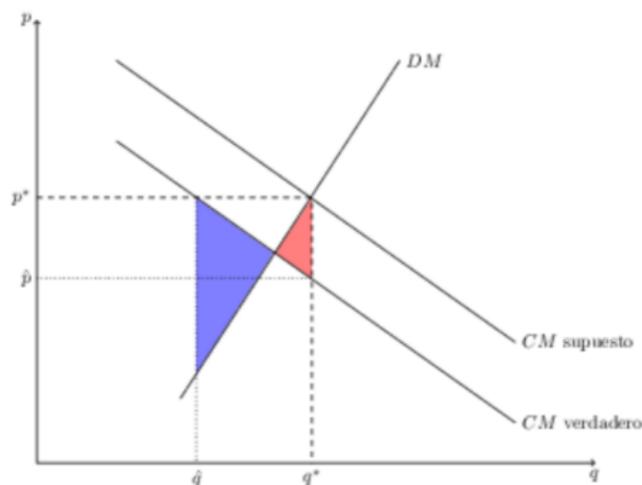


Figure: P vs Q: Quantity regulation is superior when marginal benefit is relatively steep

Two Prices vs Two Quantities

- Two prices dominate two quantities iff

$$W_p^S - W_q^S = \frac{\sigma(1 + \rho)}{(C'')^2} \left(B'' + \frac{C''}{2} \frac{2}{1 + \rho} \right) > 0$$

- **Modified Weitzman (1974)'s formula**

- A relative more convex cost favours prices because mistakes on the supply becomes costlier than on the benefit side
- With multiple technologies, prices favoured (costs more convex)

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- **Cost of public funds:**

- λ does not affect comparison (equal expected payments)

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- *Conjecture:* optimality of moving ex-ante vs. ex-post depends on the degree of market power

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