Competition among Renewables

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Universidad Carlos III and CEPR

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The Energy Transition

A challenge for the power sector

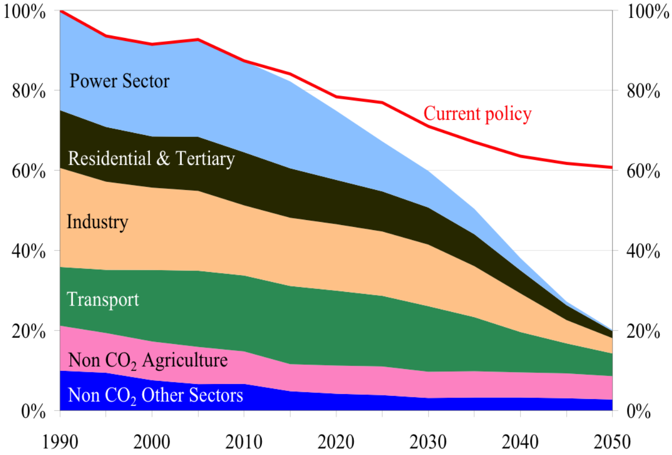

Figure: Emissions reductions in Europe with respect to 1990 levels (Source: EC's 2050 Energy Roadmap)

The Energy Transition

A pletora of questions regarding renewables

1. Will the needed **investments in renewables** take place?
2. Will the right **technologies** be chosen?
3. Will it all be **at least cost** for consumers?
4. How will **100% renewables markets** work?
5. How does it depend on the **pricing scheme** faced by renewables?
6. Is there a need to rethink electricity **market design**?
7. Will investment in **storage** facilities be enough?
8. Will **demand response** contribute to balancing the market?
9. ....

Renewables

An ongoing research agenda

How will 100% renewables markets work?

- "Auctions with Unknown Capacities: Understanding Competition among Renewables", with G. Llobet

Renewables

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How will 100% renewables markets work?

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How does competition depend on the renewables' pricing scheme?

- "Pricing Schemes and Market Power: the Role of Forward Contracts and Arbitrage", with Imelda

Renewables

An ongoing research agenda

How to promote investments in renewables?

- "Prices *vs* Quantities with Multiple Technologies", with JP. Montero

Will investment in storage facilities be enough?

- "Storing Power: Market Structure Matters", with D. Andres-Cerezo

What to expect from demand response?

- "Real-Time Pricing for Everyone", with D. Rapson and M. Reguant

Auctions with unknown capacities: Understanding competition among renewables

A new paradigm in electricity markets:

- The shift from fossil fuels to renewables: new paradigm
- Competition-wise, two key differences:
  - **Conventional plants**: known capacities, plausibly unknown (heterogeneous) marginal costs
  - **Renewables**: unknown capacities, known (zero) marginal costs

Auctions with unknown capacities: Understanding competition among renewables

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Renewables fundamentally **change the nature of strategic interaction** among electricity producers.

Renewables are difficult to forecast

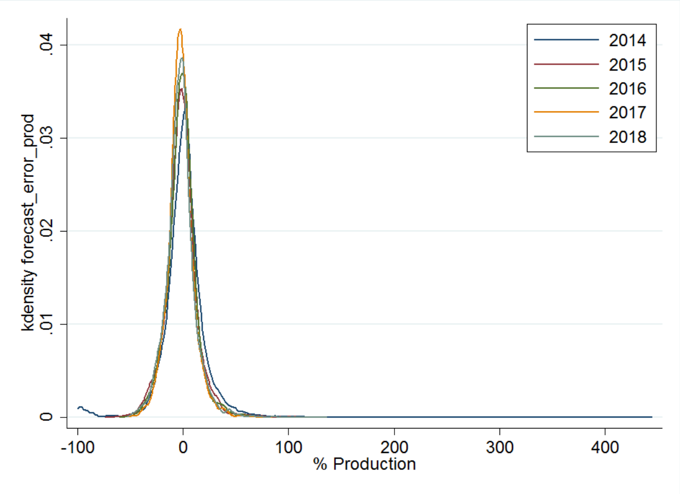

Figure: Distribution of wind forecast errors (Spanish Electricity Market)

Firms have private information on their available capacities

(a) Meteo station (wind)

(b) Meteo station (solar)

Private information allows for better forecasts

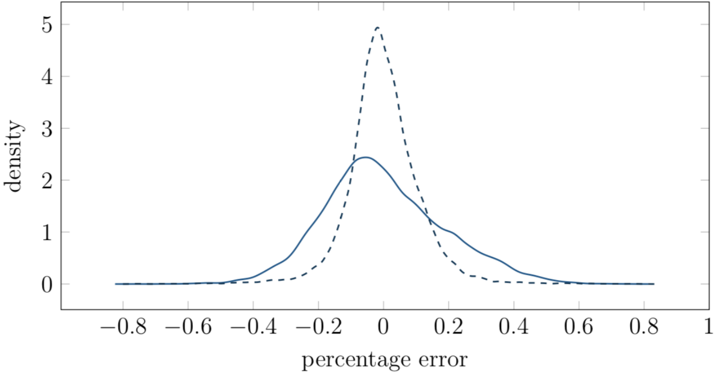

Figure: Kernel distribution of wind forecasts errors at the plant level using private (dashed) vs. plubic (solid) information (Private info increases R^2 from 0.4 to 0.8)

Main Model Ingredients

Firms' and Demand:

- Ex-ante symmetric firms, with costs $c \geq 0$
- Available capacities: common + idyosincratic component
- Firms have private information about their idyosincratic component
- Demand is price inelastic; price cap $P > c$
- Demand is known at the time of bidding

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Equilibrium concept: Bayesian Nash equilibrium

Symmetric equilibrium

Small installed capacities

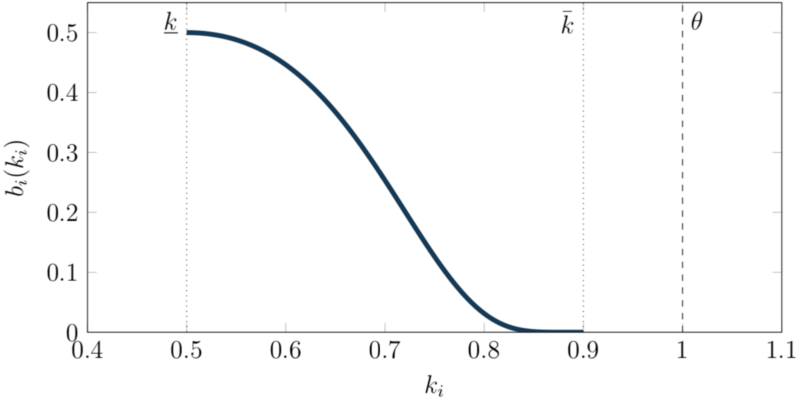


Figure: Equilibrium bids when $k_i \sim U[0.5, 0.9]$, $\theta = 1$, $c = 0$, and $P = 0.5$.

Symmetric equilibrium

Small installed capacities

Proposition

Assume $\overline{k} < \theta$.

At the unique symmetric BNE, each firm $i = 1, 2$ *offers all its capacity,* $q^*(k_i) = k_i$, *at a price*

$$p^*(k_i) = c + (P - c)\exp\left(-\omega(k_i)\right),$$

where

$$\omega(k_i) = \int_{\underline{k}}^{k_i} \frac{(2k - \theta)g(k)}{\int_{k}^{\bar{k}}(\theta - k_j)g(k_j)dk_j} dk.$$

Symmetric equilibrium

Large installed capacities

Proposition

Assume $\overline{k} > \theta$.

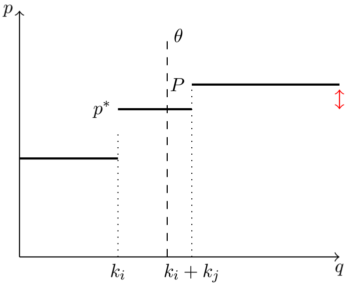
(i) For $k_i \leq \theta$, *bidding is as in the small installed capacity case.*

(ii) For $k_i > \theta$, $b_i^*(k_i) = c$ *and firm* i *withholds output,* $q_i^*(k_i) = \theta$.

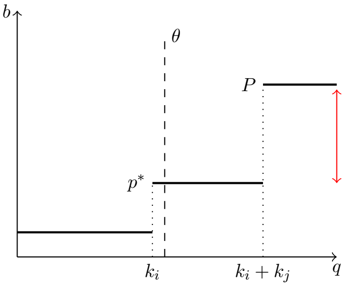
Comparative statics

More available capacity

- When realized capacities are larger relative to demand...
  - Supply functions shift downwards and outwards
  - Market prices fall



(a) Small price reduction



(b) Large price reduction

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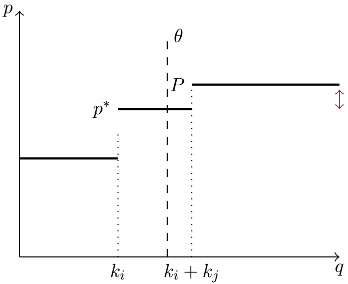

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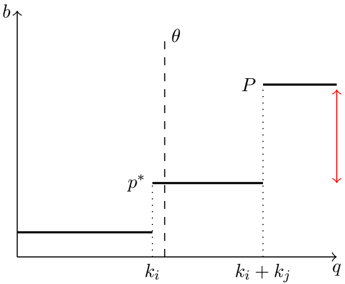

(b) Large price reduction

- Market power mitigates the price-depressing effects of renewables

Comparative statics

More installed capacity

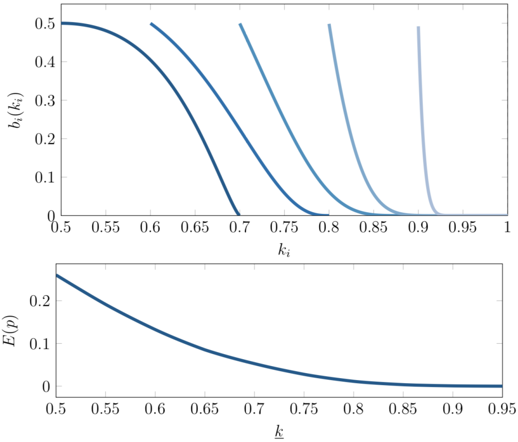

Figure: Equilibrium bids and expected prices as installed capacity increases; $\theta = 1$, $c = 0$, and $P = 0.5$

What have we learnt

Understanding competition among renewables

1. Because of their uncertainty, **renewables mitigate market power**.
2. Still, **market power and price dispersion** will prevail.
3. Market power will involve **above marginal cost pricing when capacities are small**, or **capacity withholding** when large.
4. Lower bids and prices at times with more renewables availability.
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Can we avoid these market distortions through market design?
How would the market perform with alternative pricing schemes?

Pricing Schemes and Market Power: the Role of Forward Contracts and Arbitrage

How we pay for renewables has a broad impact on overall market performance, not just renewables

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Most commonly used pricing schemes for renewables:

- **Feed-in-Tariffs** (FiT): fixed price per unit of output
- **Feed-in-Premia** (FiP): mkt price + fixed premium
- **Contracts-for-Diff** (CfDs): mkt price + payment by diff

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The debate has mainly focused on the **impact on investment**

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This paper: How do renewables' pricing schemes affect market power?

Research Approach

1. **Theoretical analysis**:
   Bidding with forward contracts and sequential arbitrage

2. **Empirical analysis**:
   Bidding in the Spanish electricity market before/after regulatory changes for wind producers

   - 2013: From FiP to FiT
   - 2014: From FiT to FiP

3. **Counterfactual analysis:**
   Bidding behavior and market outcomes under alternative pricing schemes and market structures

Main Theoretical Predictions

Market power in sequential markets (Ito and Reguant, 2013):

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A First Look at the Data

Regulatory Changes affected Bidding

Figure: Average bids per day for all renewable plants (fringe and dominant)

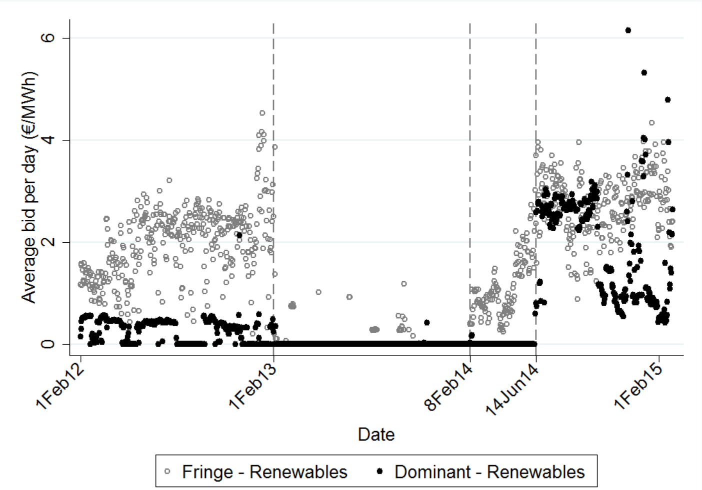

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Figure: Average bids per day at the plant level (fringe)

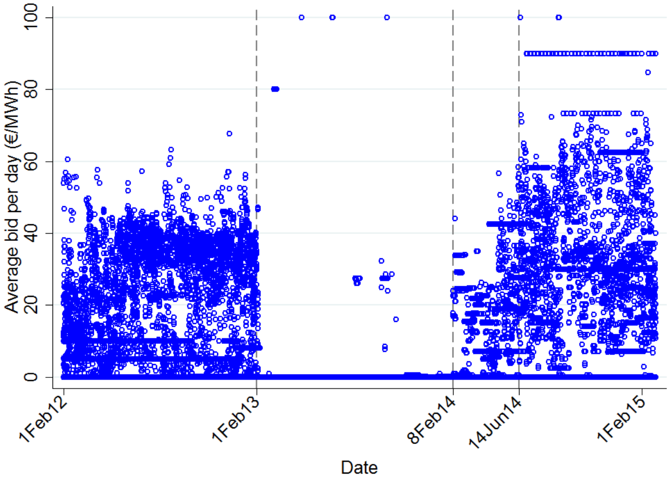

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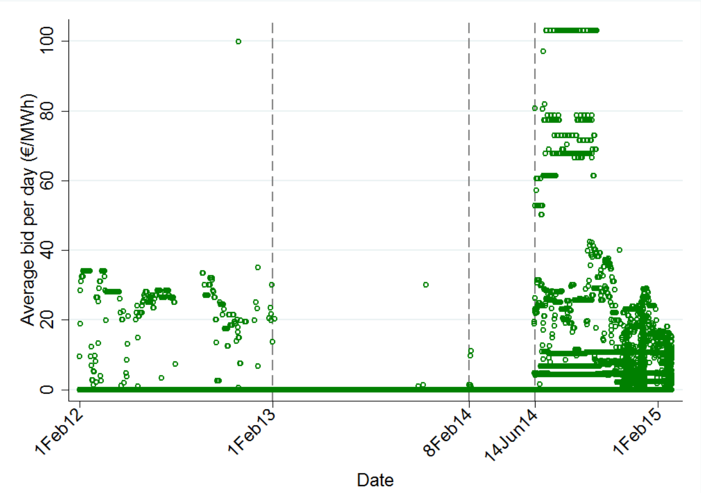
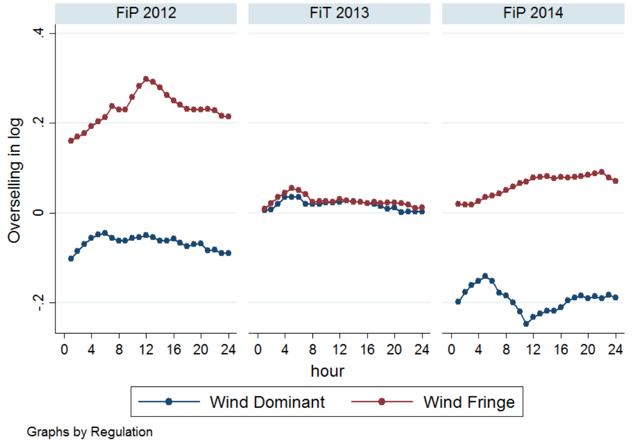
Figure: Average bids per day at the plant level (dominant)



A First Look at the Data

Regulatory Changes affected Arbitrage

Figure: Overselling and withholding by dominant and fringe wind producers



The Empirical Strategy

The forward contract effect:

- **Structural bidding** equation from profit max. in day-ahead market
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The impact on market power:

- Evolution of markups:
  - Direct measurement (engenieering cost estimates)
  - Indirect measurement through the elasticities of residual demands

What have we learnt

Pricing schemes and market power

1. Pricing schemes affect market power (for given capacities):
   - Exposing producers to **fixed prices** (FiTs) mitigates market power as fixed prices act like **forward contracts**
   - Exposing producers to **market prices** (FiPs) mitigates market power as it **incentivizes arbitrage** across sequential markets
2. The Spanish electricity market provides a unique opportunity to compare FiTs and FiPs
3. We find evidence consistent with this:
   - Dominant had weaker incentives to raise bids under FiTs
   - Fringe producers engaged in more arbitrage under FiPs

Still lots of work ahead....

Thank You!

Questions? Comments?

More info at nfabra.uc3m.es

This Project has received funding from the European Research Council (ERC) under the European Unions Horizon 2020 research and innovation programme (grant agreement No 772331)

The Forward Contract Effect (structural approach)

Profit maximization in day-ahead market:

$$p - c_i = \left| \frac{\partial DR_i}{\partial p} \right|^{-1} (q_i - w_i + I_t w_i)$$

where $I_t = 1$ if FiP and $I_t = 0$ if FiT.

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Empirical bidding equation:

$$b_{ijth} - c_{jt} = \alpha + \theta_i \left| \frac{\partial DR_{ijth}}{\partial p_{th}} \right|^{-1} (q_{ijth} - w_{ith}) + \gamma_i I_t \left| \frac{\partial DR_{ijth}}{\partial p_{th}} \right|^{-1} w_{ith} + \epsilon_{ijth}$$

The Arbitrage Effect (DID approach)

Differences-in-Differences approach:

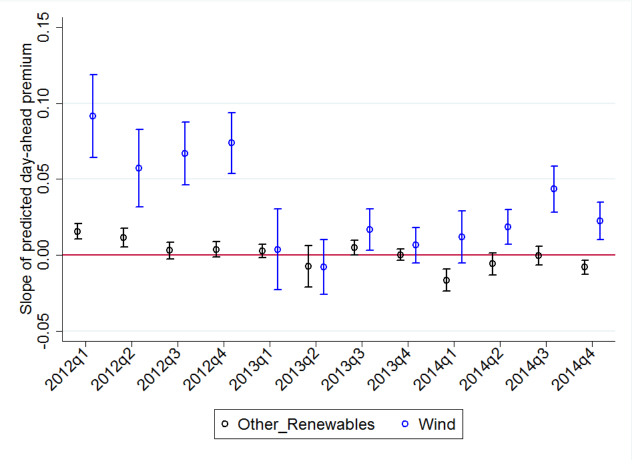
$$\begin{aligned}\Delta \text{ln} q_{th} =& \alpha + \beta_1 \hat{p}_{th}.T_w.R_{td} + \beta_2 \hat{p}_{th}.T_w + \\ & \beta_3 T_w.R_{td} + \beta_4 \hat{p}_{th}.R_{td} + \beta_5 \hat{p}_{th} + \\ & \beta_6 T_w + \beta_7 R_{td} + D_{th} + w_{htd} + X_{th} + \eta_{th},\end{aligned}$$

where

- $T_w = 1$ for wind, and 0 for the control group
- $d = 1{,}2$ (first or second regulatory change)
- $R_{t,d=1} = 1$ for FiT, $= 0$ for FiP
- $R_{t,d=2} = 1$ for FiP, $= 0$ for FiT
- First stage: $p_{th} = \alpha D_{th} + \beta w_{th} + X_h + Y_t + \epsilon_{th}$
- β_1: treatment effect (average changes in price response)

The Arbitrage Effect (DID approach)

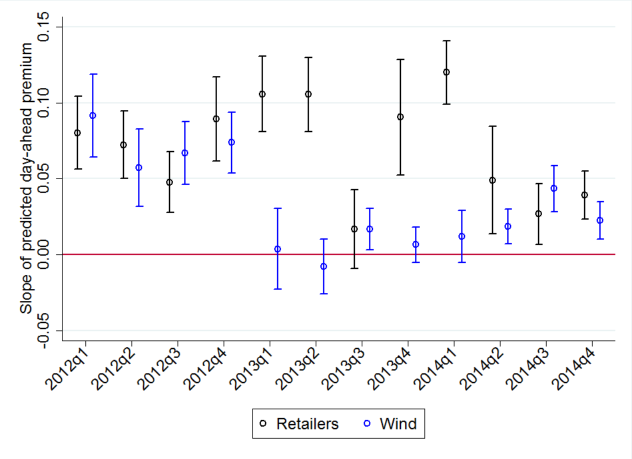
Figure: Response of Overselling to Price Premium (control: other renewables)



Note: Other renewables include solar, small hydro and co-generation

The Arbitrage Effect (DID approach)

Figure: Response of Overselling to Price Premium (control: retailers)



The Arbitrage Effect (DID estimates)

	Pre-trends		FiT		FiP	
	(1)	(2)	(3)	(4)	(5)	(6)
$\hat{p}\times$ Wind (β_2)	-0.007	0.02*	0.08***	0.02*	-0.007	-0.06***
	(0.004)	(0.01)	(0.006)	(0.01)	(0.004)	(0.01)
$\hat{p}\times$ Wind $\times$ FiT (β_1)			-0.09***	-0.07***		
			(0.007)	(0.02)		
$\hat{p}\times$ Wind $\times$ FiP (β_1)					0.04***	0.03*
					(0.005)	(0.02)
Control	Renewables	Retailers	Renewables	Retailers	Renewables	Retailers
Week FE	Y	Y	Y	Y	Y	Y
Days of week FE	Y	Y	Y	Y	Y	Y
Observations	15,644	19,018	34,662	34,662	32,780	32,780