Market Power and Price Discrimination:
Learning from Changes in Renewables Regulation

Natalia Fabra and Imelda
Universidad Carlos III de Madrid

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Market power and price discrimination

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  - **Price discrimination** across locations, time, customer groups

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  - **Price discrimination** across locations, time, customer groups
- Increasing concerns about its **distributional implications**:
  - Non-discrimination clauses, promotion of arbitrage
- Lowering price discrimination need not be welfare-enhancing
  - High price $\downarrow$ + low price $\uparrow$ $\rightarrow$ Welfare?
- ...but it typically makes consumers better-off.

Market power and price discrimination

Instead of promoting arbitrage,
other policies that reduce price discrimination to the benefit of consumers while also enhancing welfare?

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General answer:

- If price discrimination stems from market power...
- addressing market power directly reduces price discrimination
- and it is more efficient than promoting arbitrage.

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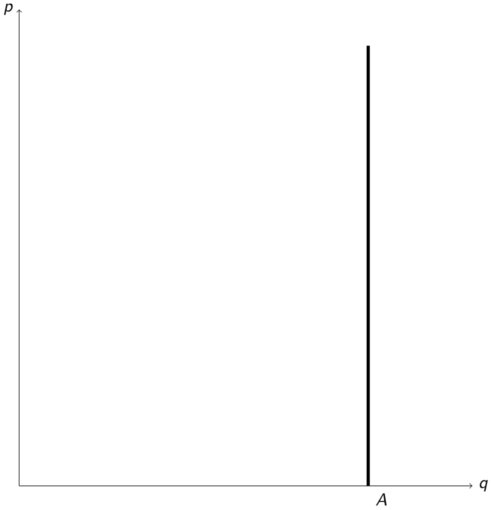
Focus of this paper:

- Sequential markets
- Which role can forward contracts play in reducing market power and price discrimination?

Sequential markets (Ito and Reguant, 2016)



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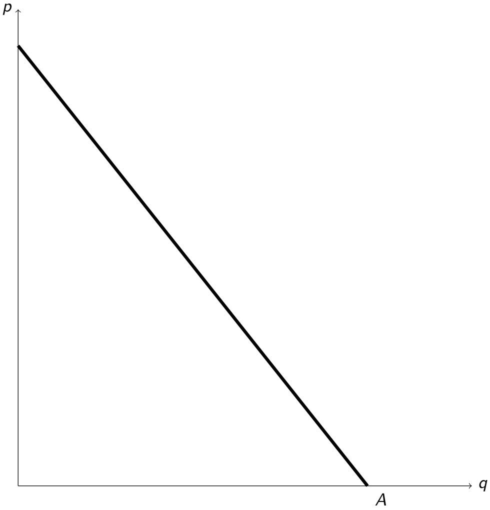

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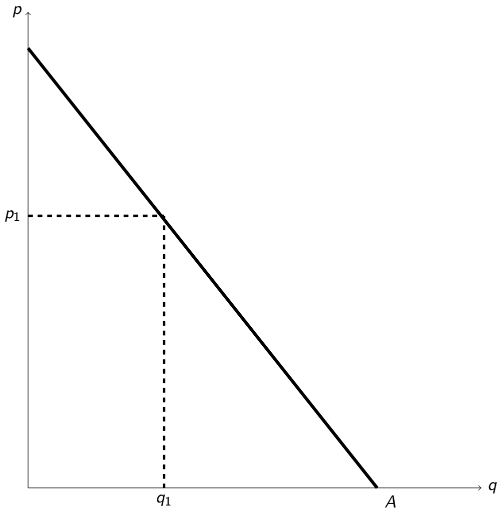

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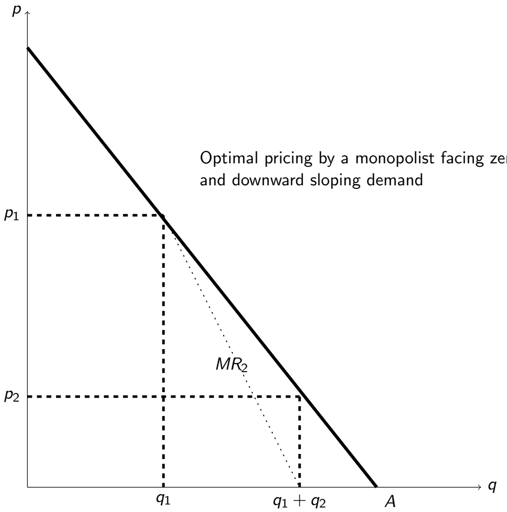

Optimal pricing by a monopolist facing zero marginal costs and downward sloping demand

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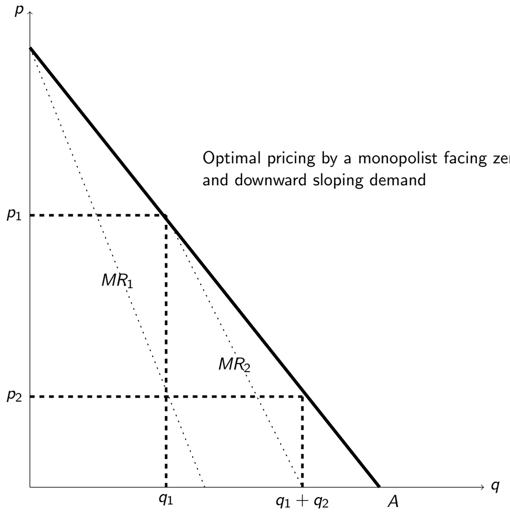

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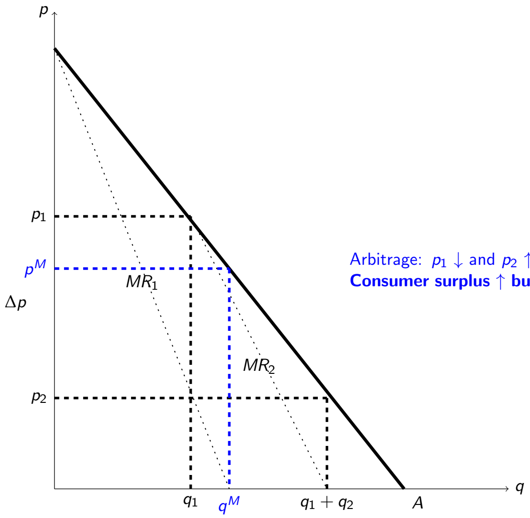

Arbitrage: $p_1 \downarrow$ and $p_2 \uparrow$

Consumer surplus $\uparrow$ but welfare $\downarrow$

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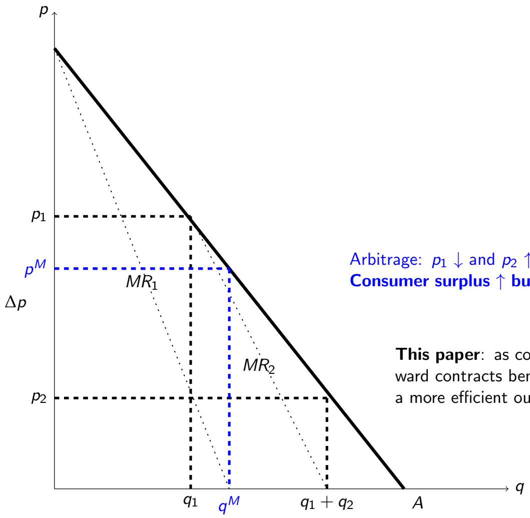

Arbitrage: $p_1 \downarrow$ and $p_2 \uparrow$
Consumer surplus ↑ but welfare ↓

This paper: as compared to arbitrage, could forward contracts benefit consumers while achieving a more efficient outcome?

A policy relevant question for renewables

How should we pay for renewables' output?

1. Through **fixed prices**: Feed-in-Tariffs (FiT)
   - Prices set ex-ante by regulators or through auctions
   - Act like **forward contracts**
2. Through **variable prices**: Feed-in-Premia (FiP)
   - Prices in wholesale energy markets + fixed premium
   - Also encompasses ROCs, RPS, tax credits...
   - Promote **arbitrage** across markets

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This paper:

For given capacities, what are the market impacts of **paying renewables** according to **variable** or **fixed prices**?

Iberian electricity market: an ideal laboratory

1. Organized as a **sequential market**:
   - Day-ahead market followed by real-time markets
2. **Price discrimination**: day-ahead price premium
   - Consistent with **market power** (Ito and Reguant, 2016)
3. High wind penetration (20-23% total demand)
4. **Changes in wind regulation**:
   - 02/2013: from variable to fixed prices
   - 04/2014: from fixed to variable prices (+other changes)
   - No changes in market structure during this period

Market impacts of renewables regulation

Ito and Reguant (2016):

- 2010-2012: wind firms engage in arbitrage
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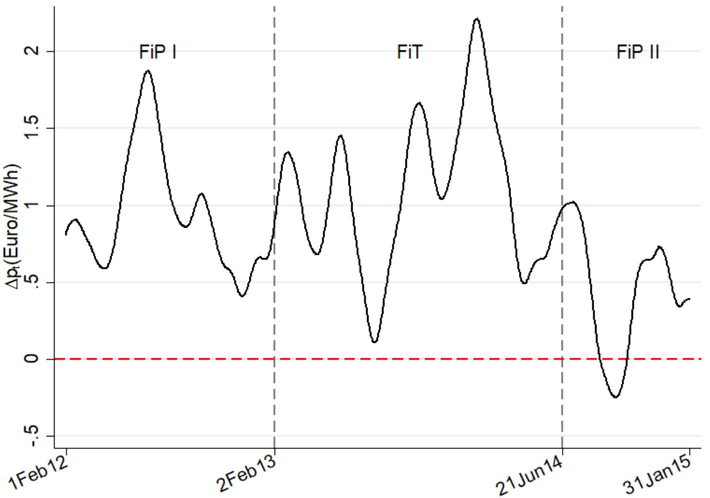
This Paper: [sample 2012-2015]

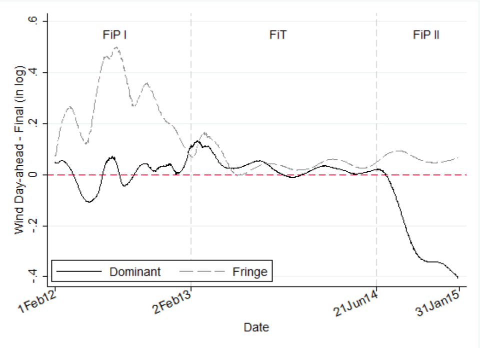
- Provides further evidence confirming the above results
- Uncovers the **forward-contract effect** of fixed prices (FiTs):
  - Dominant firms exercise less market power
  - This reduces price discrimination
  - Overall, this dominates the arbitrage effect

A first look at the data



Price differences between day-ahead and real time markets

A first look at the data



Overselling and withholding across markets by wind producers ▸ Overselling by hour

Roadmap

- Related literature
- Theoretical analysis
- Institutional background
- Empirical analysis
  - Pricing incentives in the day-ahead market
  - Arbitrage across markets
  - Price discrimination across markets
  - Market power in the day-ahead market
- Conclusions

Related Literature

1. **Forward contracting and market power:**
   - Allaz and Villa (JET, 1993)
   - Bushnell *et al.* (AER, 2008); Wolak (IEJ, 2000)
2. **Welfare effects of price discrimination:**
   - Robinson (1933), Aguirre *et al.* (AER, 2010)
3. **Price arbitrage in electricity markets:**
   - Ito and Reguant (AER, 2016)
   - Borenstein, Bushnell, Knittel and Wolfram (JIE, 2008); Jha and Wolak (2019); Mercadal (2019)
4. **Pricing schemes for renewables:**
   - Dressler (EE, 2016); Bohland and Schwenen (2020)

The Theoretical Analysis

The Theoretical Analysis

1. Baseline (Ito and Reguant, 2016)
2. Variable prices (FiPs)
3. Fixed prices (FiTs)
4. Testable predictions

Model Description

Sequential markets: day-ahead and spot markets, $m = 1, 2$

- Demand A is inelastically bought in day-ahead market
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Technologies:

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- Wind: zero marginal costs; availability $w_i \leq k_i$

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Firms and technology ownership:

- Fringe firms (f) own wind
  - They decide in which market to sell w_f
- Dominant firm (d) owns **both technologies**
  - It maximizes profits given residual demands in both markets

Residual demands faced by dominant firm

1. **Day-ahead residual demand**: $D_1(p_1) = A - w_{1f} - bp_1$
   - A: inelastic demand.
   - w_{1f}: wind sold by the fringe.
   - bp: supply of competitive firms with linear marginal costs.

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   - A: inelastic demand.
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2. **Spot residual demand**: $D_2(p_1, p_2) = (p_1 - p_2)\, b - w_{2f}$
   - If $p_1 > p_2$, competitive firms better off buying $(p_1 - p_2)\, b$.
   - $w_{2f} = w_f - w_{1f}$: wind sold by the fringe.

Baseline

1. Wind producers are exposed to **variable prices**
2. **Arbitrage not allowed**: $w_{1f} = w_f$ and $w_{2f} = 0$

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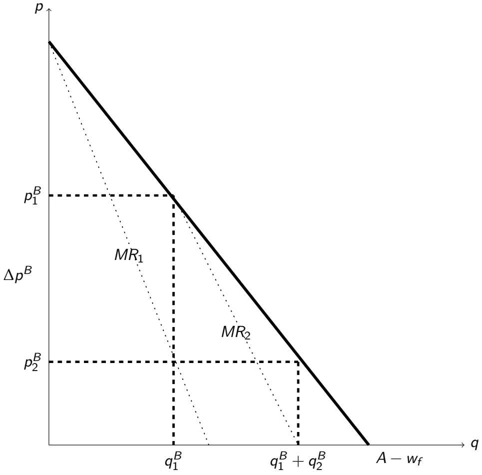
\begin{aligned}
D_1(p_1) &= A - w_f - bp_1 \\
D_2(p_1, p_2) &= (p_1 - p_2)\, b
\end{aligned}
$$

- **Equilibrium:**

$$
p_1^B = 2\beta(A - w_f) > p_2^B = \beta(A - w_f)
$$

Baseline



Incentives to arbitrage?

Since $p_1^B > p_2^B$, **potential gains from arbitrage:**

- Sell more in the day-ahead market at p_1^B
- Undo the long-position in the spot market at p_2^B

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Limits on arbitrage:

- Firms cannot offer to produce above capacity
- Only wind producers can engage in arbitrage: $w_{1f} = k_f$ and $w_{2f} = -(k_f - w_f)$

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Do wind farms have incentives to arbitrage?
It depends on the pricing rule in place

Variable Prices (FiPs): arbitrage effect

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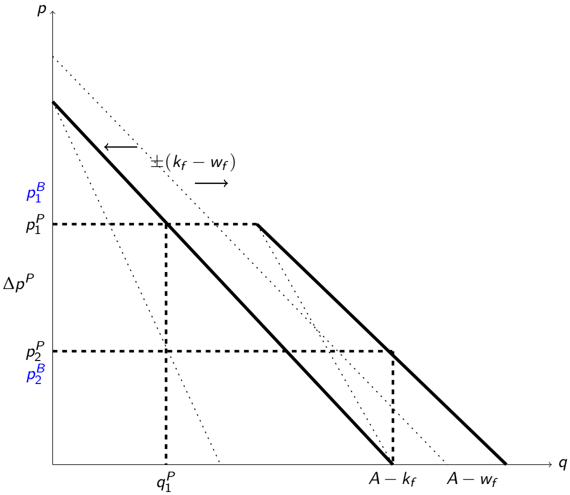
- **Equilibrium:**

$$\begin{aligned} p_1^P &= p_1^B - \beta(k_f - w_f) < p_1^B \\ p_2^P &= p_2^B + \beta(k_f - w_f) > p_2^B \end{aligned}$$

Variable Prices (FiPs)



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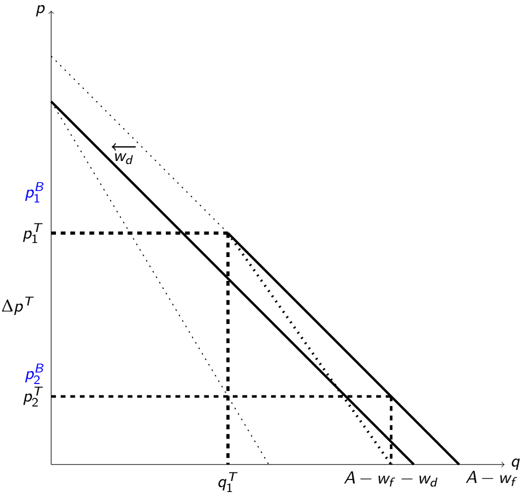
3. Fixed prices $\rightarrow$ More competitive bidding at **day-ahead**

$$p_1^* = \arg\max \left[p_1 \left(q_1 - w_d \right) + p_2^* q_2^* - c \left(q_1 + q_2^* - w_d \right) + \overline{p} w_d \right]$$

- **Equilibrium:**

$$\begin{aligned} p_1^T &= p_1^B - 2\beta w_d < p_1^B \\ p_2^T &= p_2^B - \beta w_d < p_2^B \end{aligned}$$

Fixed prices (FiTs)



Summary of Results

	Variable prices	Fixed prices
p_1	$\downarrow\downarrow$	$\downarrow\downarrow$
p_2	$\uparrow$	$\downarrow$
Δp	$\downarrow$	$\downarrow$
Channel	Arbitrage	Forward contract

p_1, p_2 **Consumer surplus** comparison depends on w_d / w_f

p_2 **Total welfare** is higher with fixed prices

Δp **Price discrimination** comparison depends on w_d / w_f

CfDs

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4. **Market power in the day-ahead market:**
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The Empirical Analysis

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1. Institutional setting
2. Price-setting incentives in the day-ahead market
3. Arbitrage by fringe firms
4. Price discrimination across markets
5. Market power in the day-ahead market

The Iberian electricity market

Market design and market structure:

- Day-ahead market + intra-day markets + balancing markets
- Mix of dominant and fringe firms
- Mix of vertically integrated and stand-alone firms
- Mix of various technologies

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Rich data:

- Sample: 2012-2015
- Detailed bid data at the unit level, including data on:
  - net positions of vertically integrated companies
  - bilateral contracts
- Hourly data on equilibrium outcomes
- Detailed data on marginal costs at plant level

▸ Summary Statistics

Price-setting incentives in the day-ahead market

- Dominant firms do not internalize the effects of price increases on wind output under fixed prices (FiTs) – **forward-contract effect**

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Profit maximization in day-ahead market:

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

where $I_t = 1$ with fixed prices and $I_t = 0$ with variable prices.

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Empirical bidding equation:

$$b_{ijt} = \rho c_{ijt} + \beta \left| \frac{q_{it}}{DR'_{it}} \right| + \theta \left| \frac{w_{it}}{DR'_{it}} \right| I_t^s + \alpha_{ij} + \gamma_t + \epsilon_{ijt}$$

where I_t^s is an indicator for $s =$FIPI, FIT, FIPII. Slopes Residual Demands

Price-setting incentives in the day-ahead market

	2SLS			
	(1)	(2)	(3)	(4)
Marginal Cost$_{it}$	0.72*	0.79***	0.85***	0.65**
	(0.38)	(0.25)	(0.26)	(0.31)
FiP I $\times$ $\frac{w_{it}}{DR'_{it}}$	0.63	-6.43	-7.26	-9.58*
	(6.82)	(4.68)	(4.68)	(5.39)
FiT $\times$ $\frac{w_{it}}{DR'_{it}}$	-32.5***	-26.2***	-27.4***	-12.9*
	(8.56)	(7.19)	(7.03)	(6.61)
FiP II $\times$ $\frac{w_{it}}{DR'_{it}}$	-0.78	0.69	-0.92	0.77
	(9.45)	(7.41)	(7.58)	(6.37)
$\frac{q_{it}}{DR'_{it}}$				4.23***
				(1.47)
Month and DoW FE	N	Y	Y	Y
Hour FE	N	N	Y	Y
Observations	20,100	20,100	20,100	20,100

Arbitrage by fringe firms

- Fringe wind firms engage in arbitrage (overselling) only under variable prices (FiPs) – **arbitrage effect**

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Does overselling capture arbitrage?

- Only if it responds to the predicted price premium $\Delta \hat{p}_t$.
- Other reasons: demand and wind forecast errors, outages...

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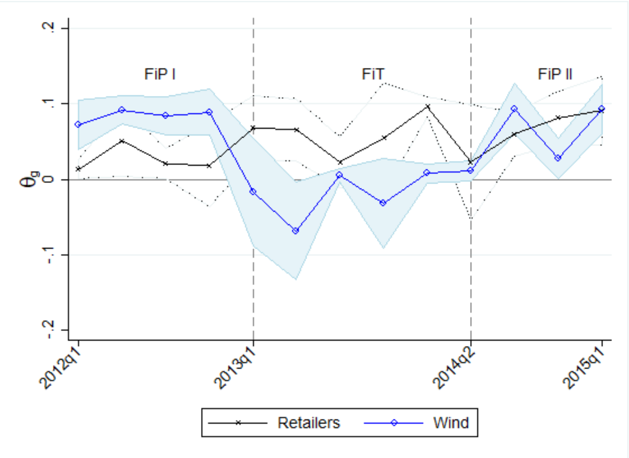
$$\Delta \ln q_{tg} = \alpha + \theta_g \Delta\hat{p}_t + \gamma D_t^{er} + \delta w_t^{er} + \rho \mathbf{X}_t + \eta_{tg}$$

Response of overselling to predicted price premium

Figure: (1) using retailers as the control group



▸ Other renewables

Arbitrage by fringe firms: Diff-in-Diff

Two subsamples:

- $d = 1$: Feb 2012-Feb 2013 (includes FiP I $\rightarrow$ FiT)
- $d = 2$: Feb 2013-Feb 2014 (includes FiT $\rightarrow$ FiP II)

Arbitrage by fringe firms: Diff-in-Diff

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Estimating equation (one for each sample; each control group):

$$\begin{aligned}\Delta \ln q_t = & \alpha + \boldsymbol{\beta_1} R_t^d W \Delta \hat{p}_t + \boldsymbol{\beta_2} W \Delta \hat{p}_t + \beta_3 R_t^d W + \beta_4 R_t^d \Delta \hat{p}_{ht} + \\ & \beta_5 \Delta \hat{p}_t + \beta_6 W + \beta_7 R_t^d + \rho \mathbf{X}_t + \eta_t\end{aligned}$$

- $W = 1$ treated group (Wind)
- $R_t^d = 1$ after regulatory change (R_t^1: FiTs; R_t^2: FiPs)
- Treatment effect captured by β_1

Overselling by the fringe (DID estimates)

	Non-wind renewables	Retailers	
	(1)	(2)	(3)
$\Delta\hat{p}\times$ Wind $\times$ FiT	-0.071***	-0.069***	
	(0.0068)	(0.014)	
$\Delta\hat{p}\times$ Wind $\times$ FiP			0.059***
			(0.011)
Observations	41,080	41,080	34,194

Notes: this shows that wind plants reduced (increased) their arbitrage when moved from variable prices to fixed prices (vice-versa).

Full table

Wrapping up results so far...

We have found evidence of:

1. **Forward contract effect** under fixed prices (FiTs)
2. **Arbitrage effect** under variable prices (FiPs)

Our theory model predicts that:

- Both should reduce market power and price discrimination
- Which one dominates? It depends on market structure

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What does the empirical evidence tell us?

Price discrimination across markets

- Factors than enhance market power $\rightarrow$ Price discrimination $\uparrow$
- Wind reduces price differential more under fixed prices
- Dominant/fringe's wind share reduces the price differential

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Estimating equation:

$$\Delta p_t = \alpha + \beta_1 w_t + \beta_2 I_t^s + \beta_3 w_t I_t^s + \alpha_1 DR'_{1t} + \alpha_2 DR'_{2t} + \gamma \mathbf{X}_t + \epsilon_t$$

- I_t^s= FiP I, FiP II (FiT is reference point)
- β_2: impact of pricing regimes on price discrimination
- β_3: impact of wind across pricing regimes
- w_t: wind forecast; or dominant/fringe's wind share

Price discrimination across markets

	2SLS			
	(1)	(2)	(3)	(4)
Wind Forecast (GWh)	-0.1***			
FiP I	-1.7***	3.0***	-5.2***	-0.6
FiP II	-1.4***	-0.2	-1.1**	-1.9***
FiP I $\times$ Wind Forecast (GWh)	0.2***			
FiP II $\times$ Wind Forecast (GWh)	0.1***			
Demand Forecast (GWh)	0.07***	0.2***	0.07***	0.1***
$\frac{w_{dt}}{w_{ft}}$		-0.5***	-0.7***	-0.4***
FiP I $\times$ $\frac{w_{dt}}{w_{ft}}$		0.9***	0.4*	0.7***
FiP II $\times$ $\frac{w_{dt}}{w_{ft}}$		0.7***	0.7***	0.7***
DoW FE	Y	Y	N	Y
Year X Month FE	N	Y	N	Y
Week FE	N	N	Y	Y
Hour FE	N	N	N	Y
Observations	25,334	25,334	25,334	25,334

Market power in the day-ahead market

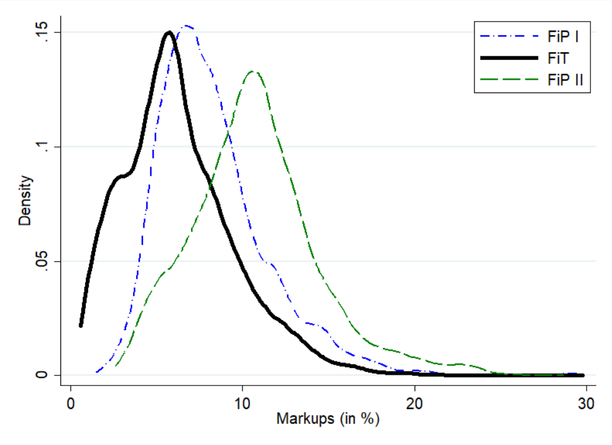
- We leverage on structural estimates to **compute mark-ups**:

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

for $I_t = 1$ with fixed (FiTs); $I_t = 0$ with variable prices (FiPs).

Market power in the day-ahead market

Figure: Markup Distribution by Pricing Regime (All Firms)

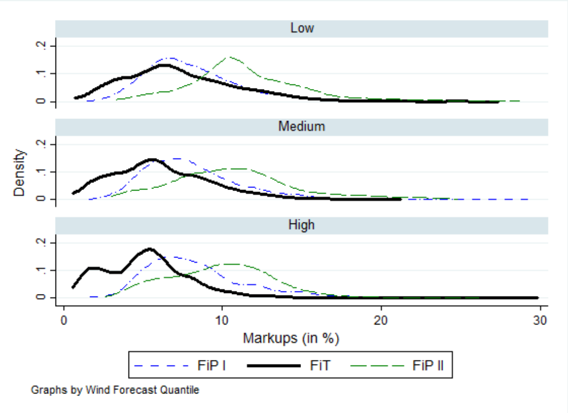


Notes: This figure plots the markup distributions of all firms by pricing regimes for hours with prices above 25 Euro/MWh.

▸ Table ▸ Markups by firm

Market power in the day-ahead market

Figure: Markup Distribution by Amount of Wind and Pricing Regime



Notes: This figure plots the markup distributions for all firms by amount of wind and by the pricing regimes for hours with prices above 25 Euro/MWh.

Conclusions

1. **Arbitrage** need not be the most efficient way to reduce price discrimination and mitigate market power
2. **Addressing market power directly** might be more efficient
3. **Forward contracts** can play that role

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   - Fixed prices: market power $\downarrow$ and overall efficiency $\uparrow$
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Policy relevant for:

- Renewables regulation
- Other sequential markets:

  e.g. emissions markets in the presence of market power

Thank you!

Comments? Questions?

natalia.fabra@uc3m.es

Contracts-for-Differences

1. Payments settled by differences wrt reference price
2. Firms exposed to market prices: incentives to arbitrage

Contracts-for-Differences

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2. Firms exposed to market prices: incentives to arbitrage

Combining results under fixed and variables prices:

- **Arbitrage effect** reflected in the residual demands:

$$D_1(p_1) = A - bp_1 - k_f \text{ and } D_2(p_1, p_2) = \Delta pb + (k_f - w_f)$$

- **Forward contract effect** reflected in day-ahead profit:

$$p_1^* = \arg\max\left[p_1(q_1 - w_d) + p_2^* q_2^* - c(q_1 + q_2^* - w_d) + \overline{p} w_d\right]$$

Contracts-for-Differences: equilibrium

$$\begin{aligned} p_1^C &= p_1^B - \beta\left(2w_d + \left(k_f - w_f\right)\right) \\ p_2^C &= p_2^B - \beta\left(w_d - \left(k_f - w_f\right)\right) \\ \Delta p^C &= \Delta p^B - \beta\left(w_d + 2\left(k_f - w_f\right)\right) \end{aligned}$$

- **Forward contract effect** is captured by $-2\beta w_d$
- **Arbitrage effect** is captured by $\pm\beta\left(k_f - w_f\right)$

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- Day-ahead prices: $p_1^C < p_1^T$ and $p_1^C < p_1^P$
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- Price premium: $\Delta p^C < \Delta p^T$ and $\Delta p^C < \Delta p^P$
- Spot prices (efficiency): $p_2^T < p_2^C < p_2^P$

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Summary Statistics

	FiP I		FiT		FiP II	
	Mean	SD	Mean	SD	Mean	SD
Price Day-ahead	50.2	(13.8)	38.1	(22.2)	52.0	(11.2)
Price Intra-day 1	48.9	(14.2)	37.2	(22.1)	51.7	(11.7)
Price premium	1.2	(5.0)	1.0	(5.6)	0.3	(3.9)
Marginal Cost	47.5	(6.6)	42.3	(7.2)	37.0	(3.8)
Demand Forecast	29.8	(4.8)	28.5	(4.6)	28.1	(4.3)
Wind Forecast	5.7	(3.4)	6.5	(3.6)	5.0	(3.2)
Dominant wind share	0.6	(0.0)	0.7	(0.0)	0.6	(0.0)
Fringe wind share	0.4	(0.0)	0.3	(0.0)	0.4	(0.0)
Dominant non-wind share	0.8	(0.0)	0.8	(0.1)	0.8	(0.1)
Fringe non-wind share	0.2	(0.0)	0.2	(0.1)	0.2	(0.1)

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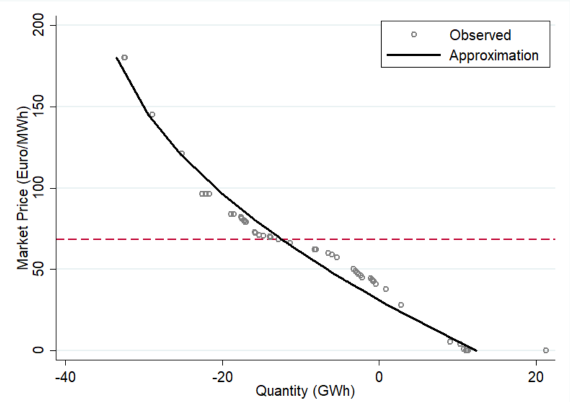
Slopes of the residual demands

Figure: Approximating the slopes of the residual demands



Notes: This figure illustrates how we use quadratic approximation to compute the local slope around the market clearing price (the horizontal line) for each dominant firm's residual demand curve.

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Testing the pre-trends assumption

Using quarterly splitted data, we regress:

$$\Delta \ln q_t = \alpha + \boldsymbol{\beta_2} W \hat{p}_t + \beta_5 \hat{p}_t + \beta_6 W + \gamma D_t^{er} + \delta w_t^{er} + \rho X_t + \eta_t$$

Coefficients of interest:

1. $\boldsymbol{\beta_2}$ price response to predicted price premium.
2. **Pre-trends assumption** holds when the overselling behavior of treatment and control groups trend similarly when they face similar incentives.

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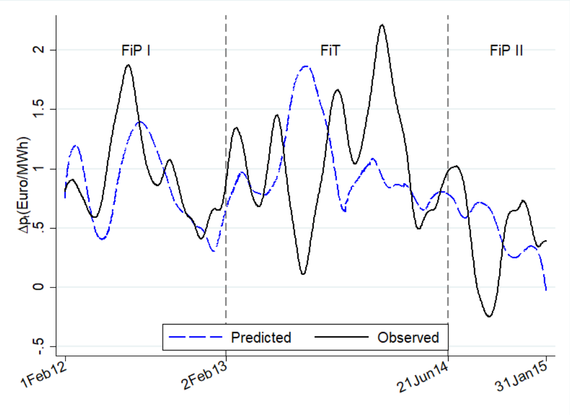
Predicted and observed price premium



Notes: This figure shows locally weighted linear regressions of $\Delta\hat{p}_t$ (predicted) and Δp_t (observed) from February 2012 to February 2015.

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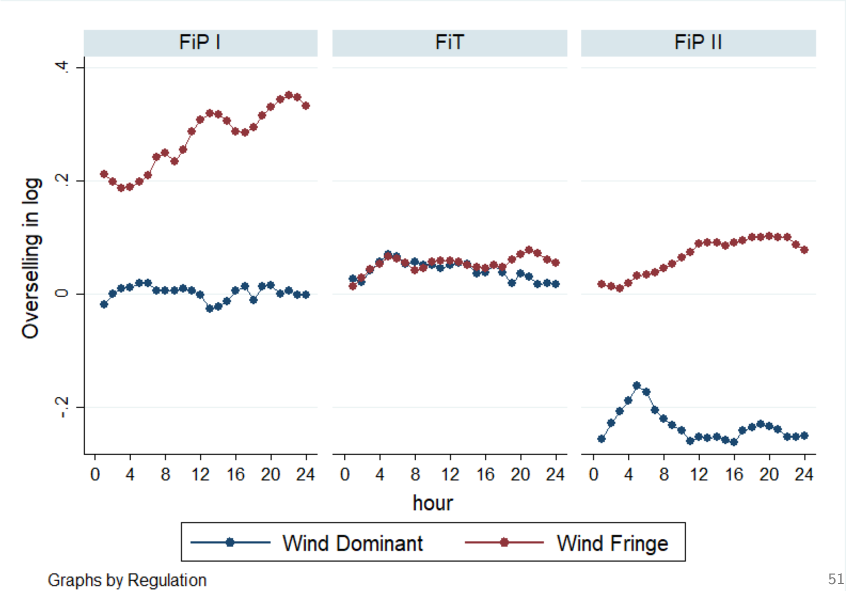
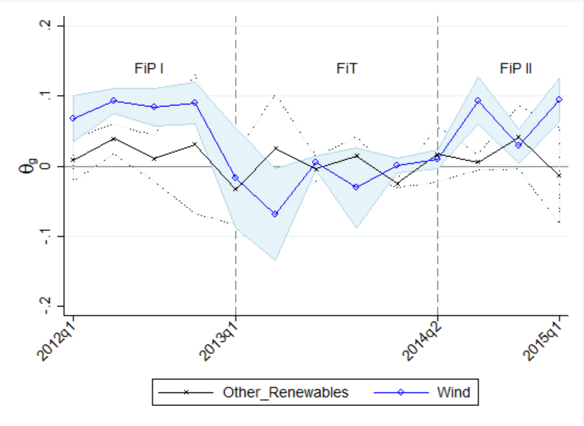
A first look at the data



Response of overselling to predicted price premium

Figure: (2) using non-wind renewables as the control group



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Response of overselling to price premium

	Wind	Non-wind Renewables	Retailers	Diff	
	(1)	(2)	(3)	(1)-(2)	(1)-(3)
FiPI	0.064	0.008	0.079	-0.076	-0.006
	(0.000)	(0.000)	(0.000)	(0.000)	(0.529)
FiT	-0.001	-0.004	0.086	-0.005	0.063
	(0.882)	(0.004)	(0.000)	(0.151)	(0.000)
FiPII	0.032	-0.006	0.053	-0.036	0.004
	(0.000)	(0.000)	(0.000)	(0.000)	(0.503)
FiPI→FiT	-0.065	-0.013	0.008	-0.071	-0.069
	(0.000)	(0.000)	(0.334)	(0.000)	(0.000)
FiT→FiPII	0.026	-0.000	-0.049	0.03	0.059
	(0.000)	(0.812)	(0.000)	(0.000)	(0.000)

Notes: This table reports the coefficient of $\Delta\hat{p}_t$ from 14 different regressions..

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Average markups and elasticities at day-ahead

	FiP I		FiT		FiP II	
	Mean	SD	Mean	SD	Mean	SD
Markups (in %) – Simple average						
All	8.3	(3.3)	6.3	(3.3)	10.7	(3.7)
Firm 1	7.0	(2.2)	7.0	(2.6)	12.1	(4.4)
Firm 2	12.3	(4.1)	8.2	(5.1)	14.7	(4.4)
Firm 3	7.7	(2.3)	6.0	(3.3)	10.3	(3.3)
Slope of day-ahead residual demand (in MWh/euros)						
All	524.2	(78.2)	553.6	(120.7)	418.2	(73.0)
Firm 1	506.6	(50.5)	458.4	(72.7)	411.0	(62.4)
Firm 2	508.5	(71.8)	556.4	(165.0)	453.8	(99.8)
Firm 3	538.2	(88.7)	573.3	(117.2)	418.0	(73.2)

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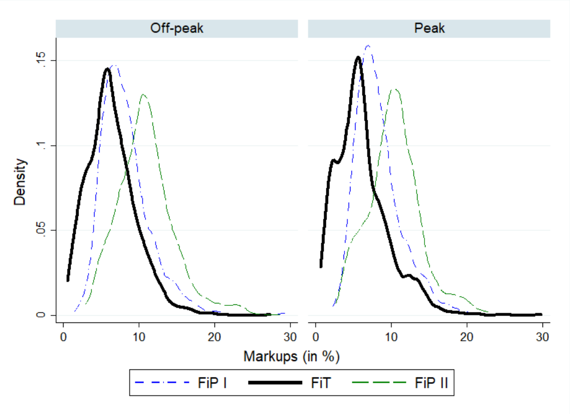
Market power in the day-ahead market

Figure: Markup Distribution by Type of Hour and Pricing Regime



Notes: This figure plots the markup distributions for all firms by peak vs. off-peak hours and by the pricing regimes for hours with prices above 25 Euro/MWh.

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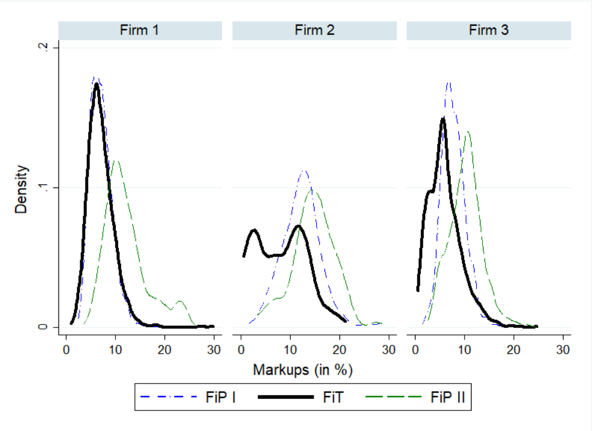
Market power in the day-ahead market

Figure: Markup Distribution by Firm and Pricing Regime



Notes: This figure plots the markup distributions for each of the dominant firms by their pricing regimes for hours with prices above 25 Euro/MWh.

Peak vs. off-peak markups