ENERGYECOLAB

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

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1. **Arbitrage**:
   price in strong market $\downarrow$ $\downarrow$ + **price in weak market** $\uparrow$ $=$
   price discrimination $\downarrow$, but welfare?

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   price in strong market $\downarrow\downarrow$ + **price in weak market** $\uparrow$ =
   price discrimination $\downarrow$, but welfare?
2. **Reduce market power**:
   price in strong market $\downarrow\downarrow$ + **price in weak market** $\downarrow$ =
   price discrimination $\downarrow$, and **welfare** $\uparrow$

Electricity Markets

Electricity markets are typically organized as **sequential markets: day-ahead and real time markets**

- Evidence of forward premia (Longstaff et al., JF 2004)
- Consistent with market power (Ito and Reguant, AER 2016)

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Related policy debates:

1. Should virtual bidding be allowed to promote arbitrage?
2. **How should renewables be paid?**
   - Key question for the energy transition!
   - EUs 2030 climate target will require 260 billion per year, a fraction of which will finance need investment in renewables to achieve 32% of of final energy consumption.

Paying for Renewables

Most commonly used pricing schemes:

- **Feed-in-Premia** (FiP): market prices + fixed premium
  - This encompasses ROCs, RPS, tax credits...
- **Feed-in-Tariffs** (FiT): fixed prices
  - Acts like a forward contract (Allaz and Villa, JET 1993)

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This paper:

For given capacities,
what are the market impacts of **renewables regulation**?

Market Impacts of Renewables Regulation

Ito and Reguant (2016):

- Under market prices: wind firms arbitrage price differences
- This reduces price discrimination
- Under fixed prices: wind firms stop arbitraging

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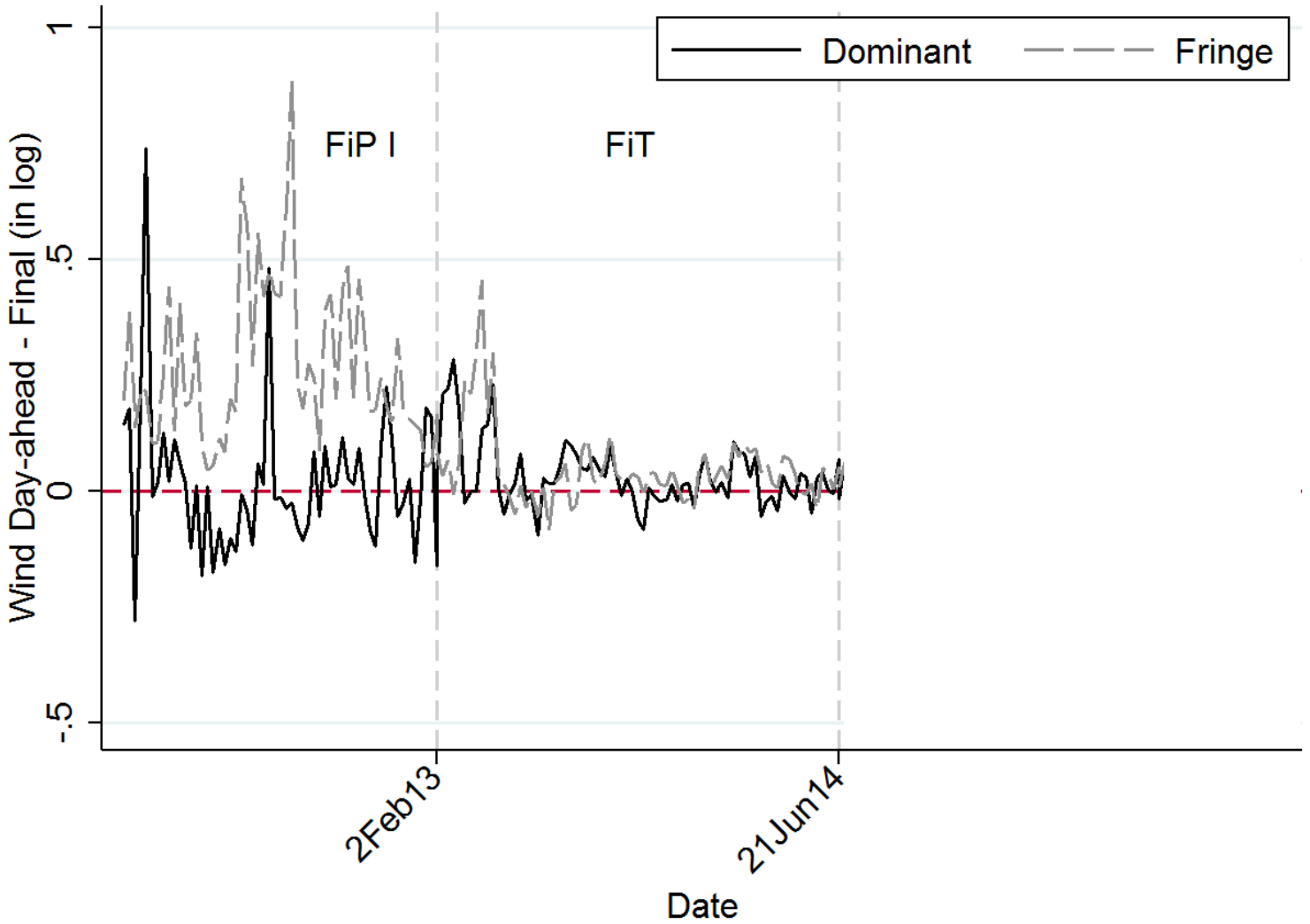
This Paper:

- Provides further evidence confirming the above results
- Uncovers the **forward-contract effect** of fixed prices (FiTs):
  - Dominant firms exercise less market power
  - Price discrimination reduced, despite weakening arbitrage

A First Look at the Data



Overselling and withholding by wind producers

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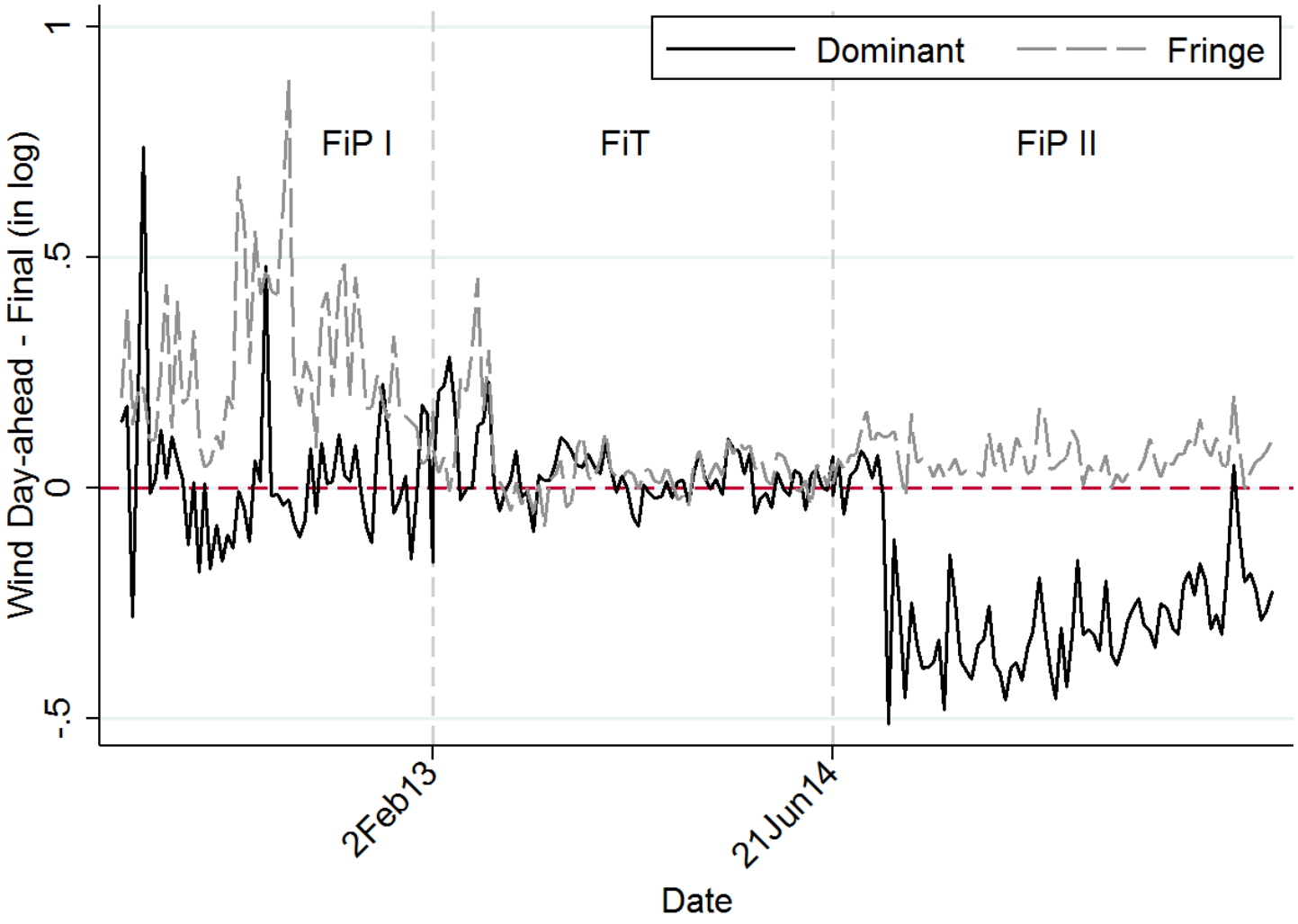

Overselling and withholding across markets by wind producers

Roadmap

- Related literature
- Theoretical analysis
- Institutional background
- Empirical analysis
  - Pricing incentives in the day-ahead market
  - Price discrimination across markets
  - Arbitrage across markets
  - Mark-ups 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:**
   - 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 (2019)

Theoretical Analysis

Model Description

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

- Demand A is inelastically bought in day-ahead market

Firms:

- Dominant firm (d) and fringe firms (f)

Technologies:

- Wind: zero marginal costs; availability $w_i \leq k_i$, $i = d, f$
- Conventional: marginal costs c for dominant; q/b for fringe

Technology Ownership:

- **Fringe firms** own either wind **or** conventional technologies
- **Dominant firm** owns **both**

Baseline (Ito and Reguant, 2016)

1. Wind producers are exposed to **variable prices**
2. Must sell all output day-ahead **(no arbitrage)**

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

- **Spot market**:

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

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- **Day-ahead market**:

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

Baseline

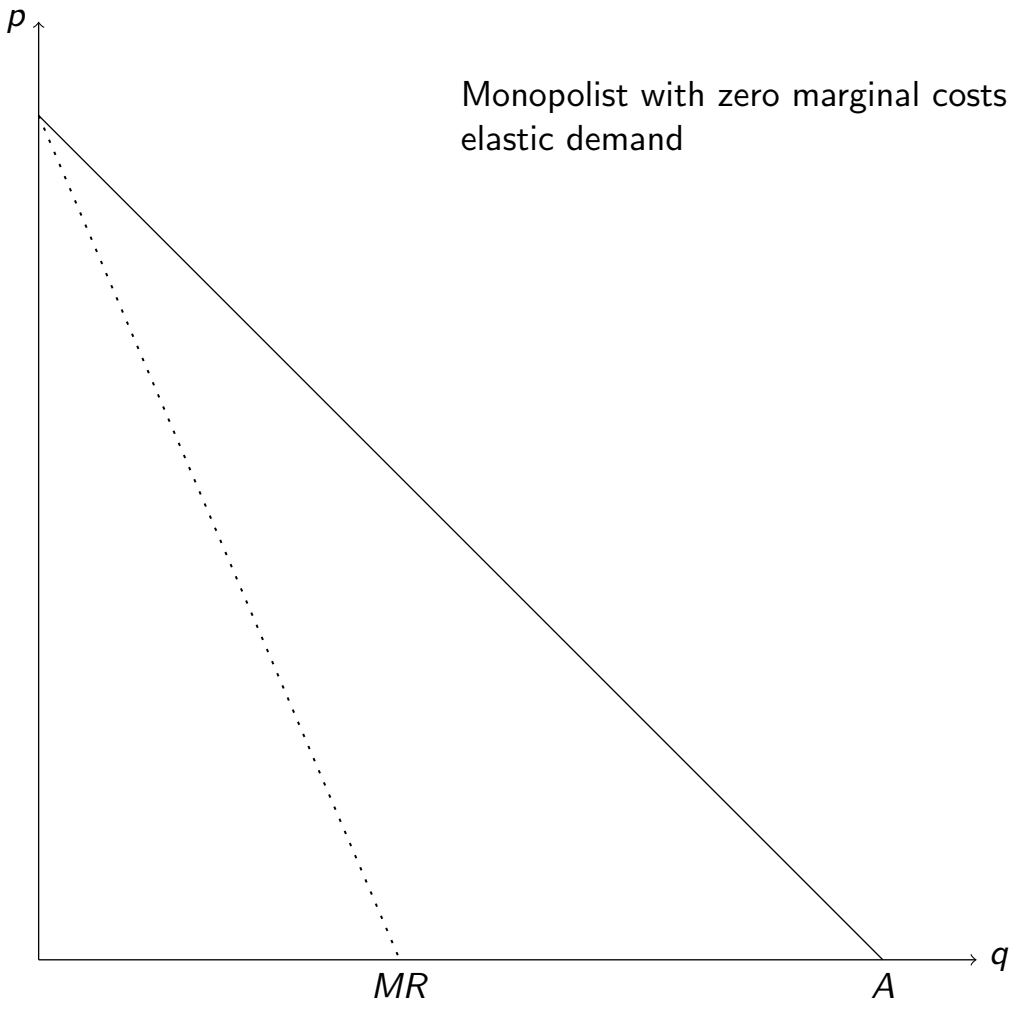
Equilibrium, for $\beta = (3b)^{-1} > 0$:

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

Properties of the equilibrium:

- Positive price premium: $p_1^B > p_2^B > 0$
- Wind w_f reduces prices in both markets
- Price premium increasing in $A - w_f$ and decreasing in b

Baseline



Monopolist with zero marginal costs facing elastic demand

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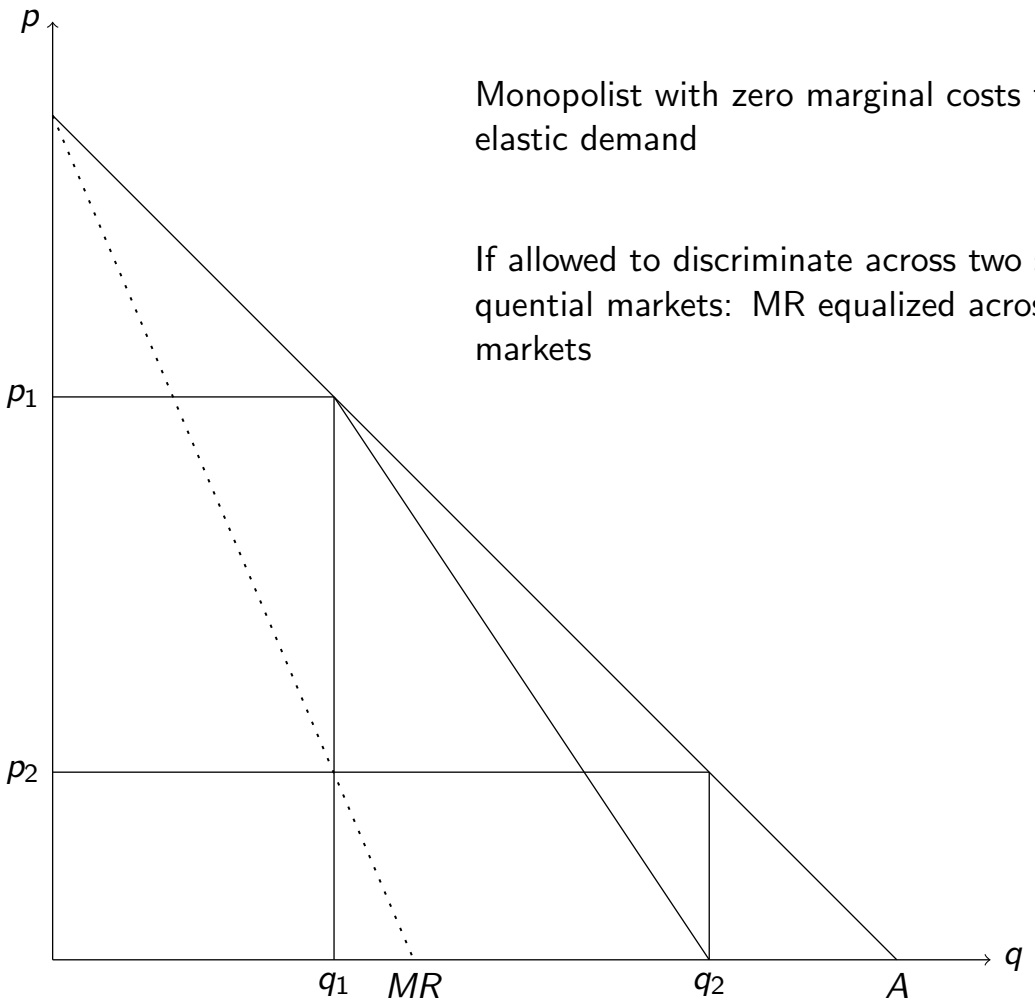

Monopolist with zero marginal costs facing elastic demand

If allowed to discriminate across two sequential markets: MR equalized across markets

Variable Prices (FiPs)

1. Wind producers receive **variable prices** + fixed premium
2. They are allowed to **arbitrage their idle capacity**

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- Lower day-ahead demand $-k_f$, higher spot demand $(k_f - w_f)$:

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

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- Otherwise, same profit maximization problem as in baseline:

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

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

Variable Prices (FiPs)

Equilibrium

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

Variable Prices (FiPs)

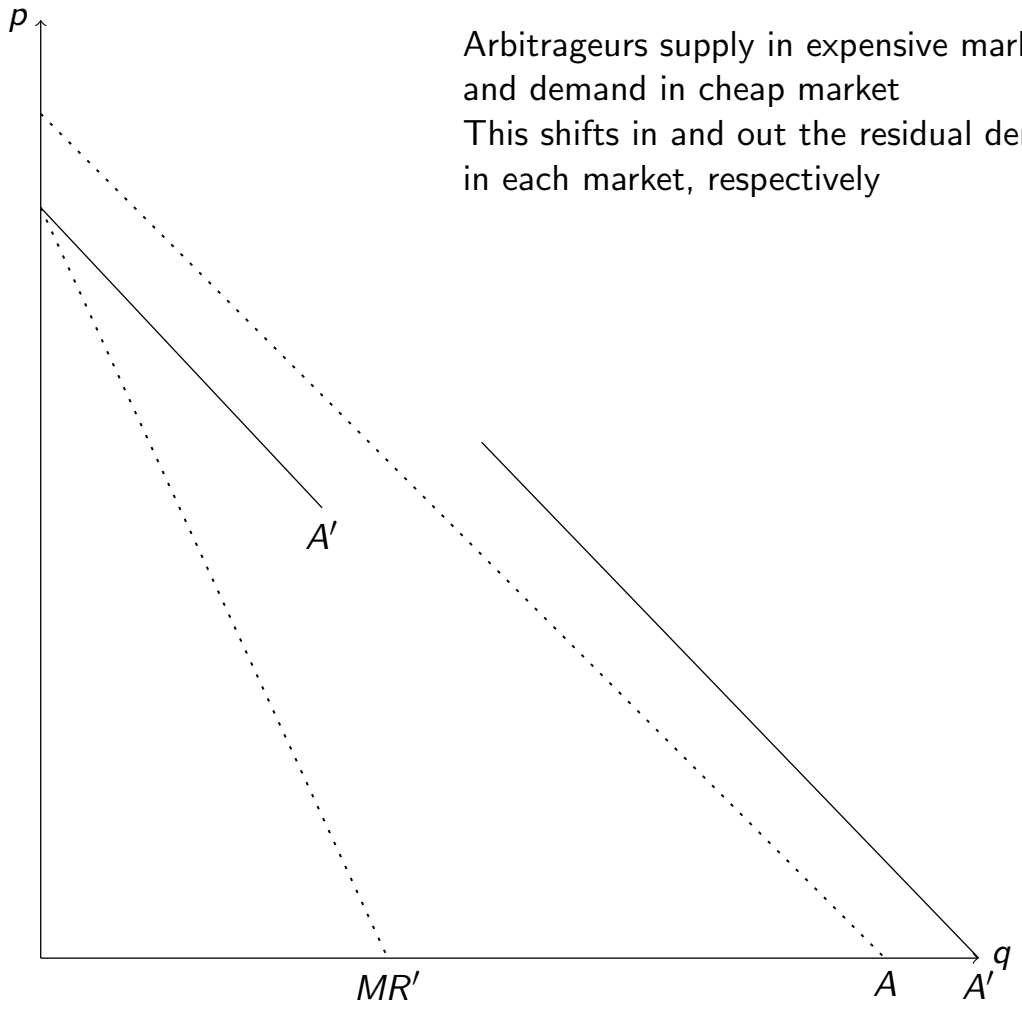
Equilibrium

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

The **arbitrage effect** is captured by $\pm\beta\left(k_f - w_f\right)$:

- Fringe oversells $\left(k_f - w_f\right)$ in the day-ahead market $\rightarrow p_1^P \downarrow$
- Fringe buys $\left(k_f - w_f\right)$ in the spot market $\rightarrow p_2^P \uparrow$
- Arbitrage lowers the prime premium $\Delta p^P \downarrow$

Variable Prices (FiPs)



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and demand in cheap market
This shifts in and out the residual demand
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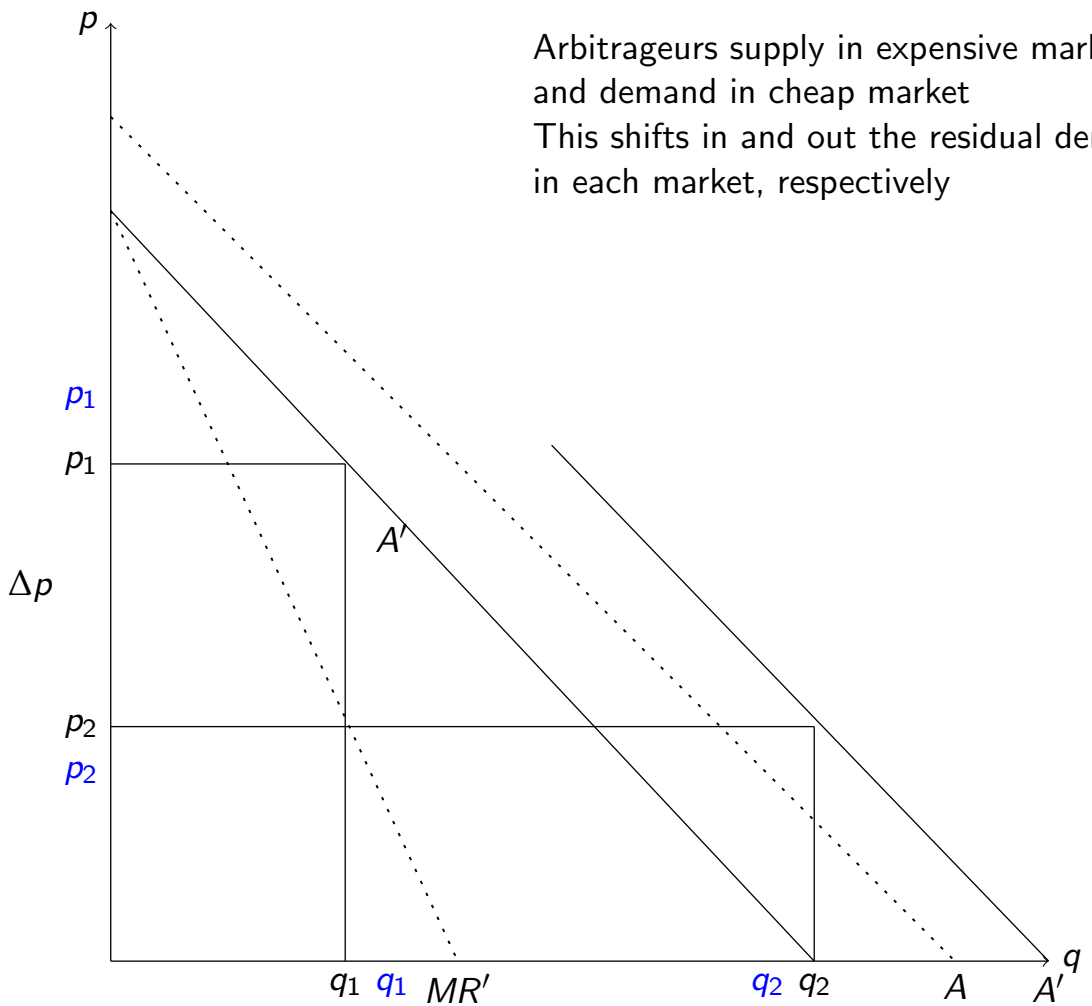

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1. Wind producers receive **fixed prices**
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- No arbitrage $\rightarrow$ **Demands** as in baseline
- No arbitrage $\rightarrow$ **Spot market price** as in baseline
- **Day-ahead market**: w_d does not receive p_1

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

Fixed prices (FiTs)

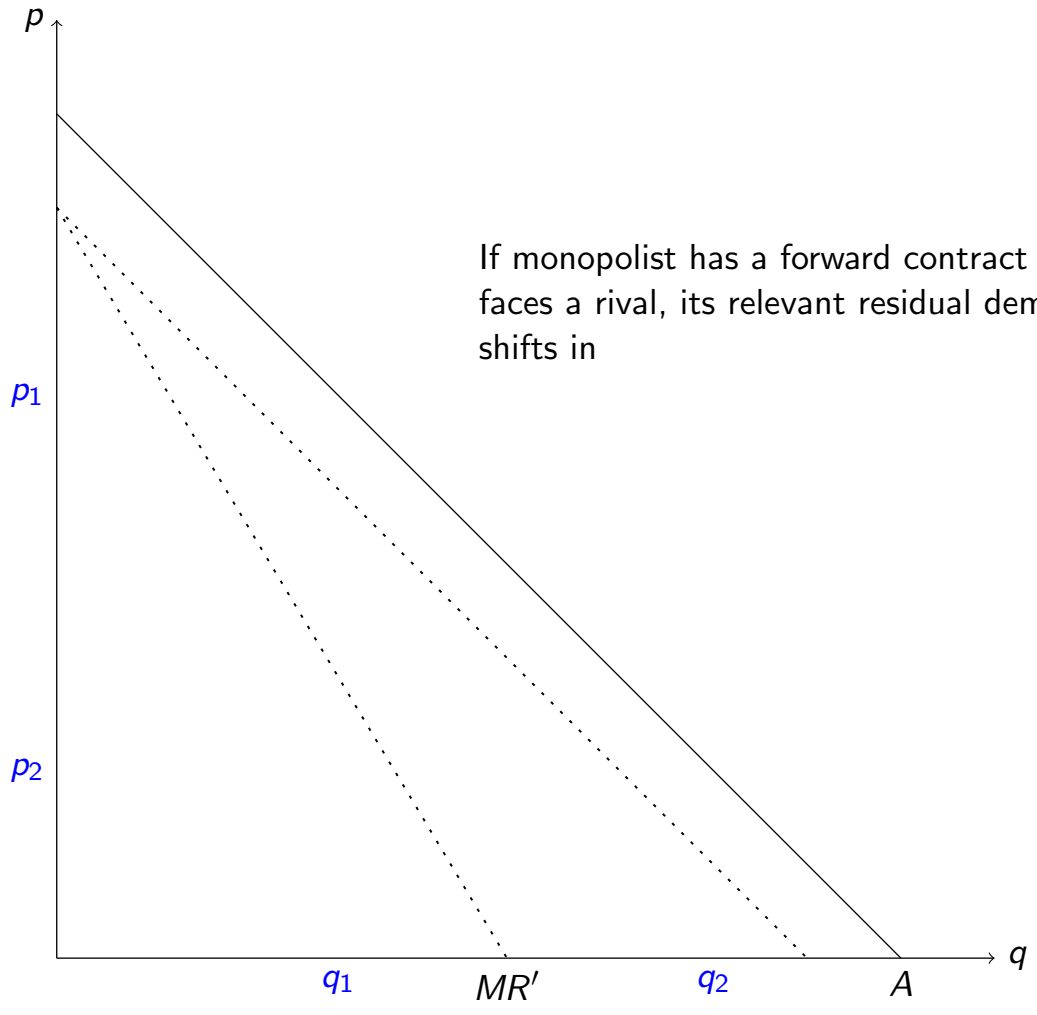
Equilibrium

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

The **forward contract effect** is captured by $-2\beta w_d$:

- Dominant firm exerts less market power day-ahead $\rightarrow p_1^T \downarrow$
- This lower price is passed on to the real-time market $\rightarrow p_2^T \downarrow$
- Reduced market power lowers the prime premium $\Delta p^T \downarrow$

Fixed prices (FiTs)



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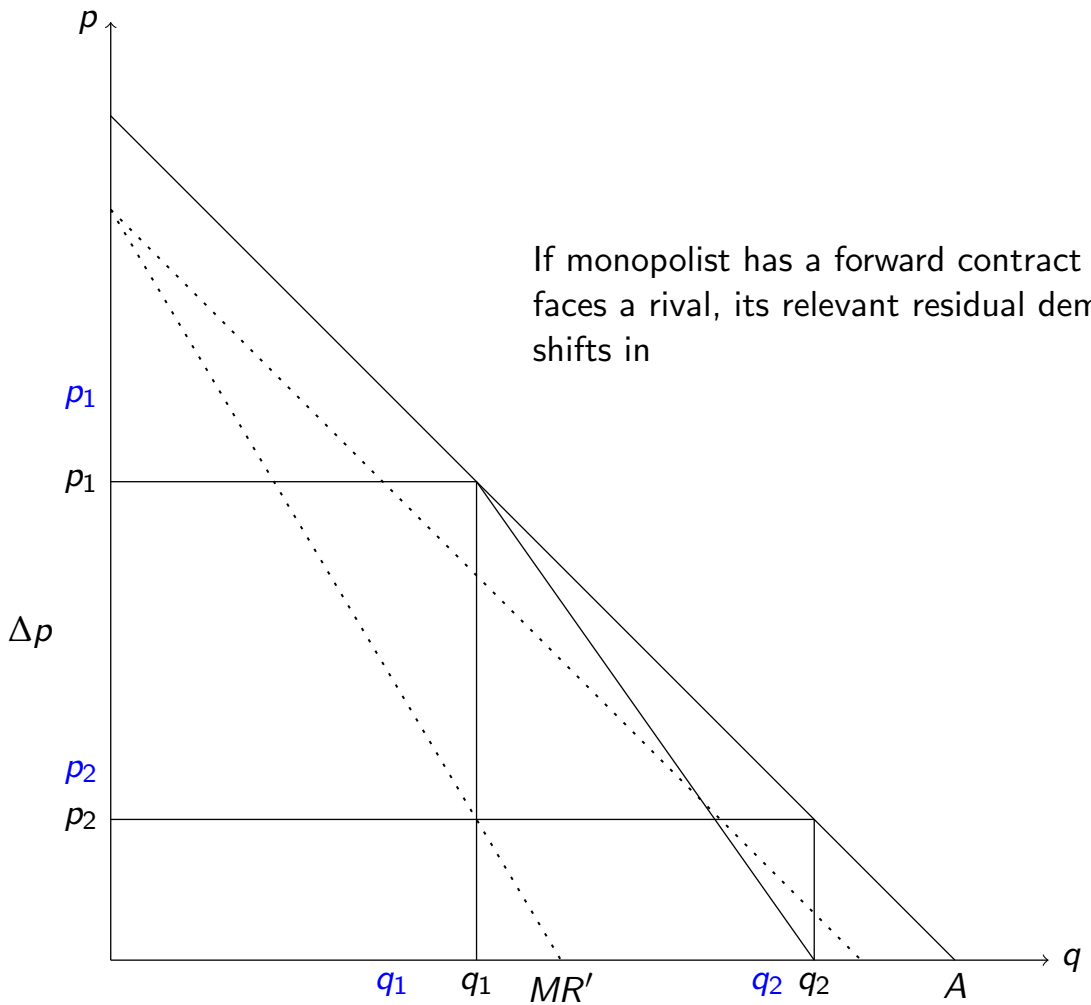

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Summary of Results

	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

Testable predictions

1. **Price-setting incentives in the day-ahead market:**
   - *Forward contract effect* under fixed, not under variables prices

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Institutional Setting

The Spanish 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

	FiP I		FiT		FiP II	
	Mean	SD	Mean	SD	Mean	SD
Price DA	50.2	(13.8)	38.1	(22.2)	52.0	(11.2)
Price ID 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)

The Empirical Analysis

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:

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

Price-setting incentives in the day-ahead market

	2SLS			
	(1)	(2)	(3)	(4)
Marginal Cost$_{it}$	0.72*	0.79***	0.85***	0.63**
	(0.38)	(0.25)	(0.26)	(0.29)
FiP I $\times \frac{w_{it}}{DR'_{it}}$	0.63	-6.43	-7.26	-8.84*
	(6.82)	(4.68)	(4.68)	(4.95)
FiT $\times \frac{w_{it}}{DR'_{it}}$	-32.5***	-26.2***	-27.4***	-18.4***
	(8.56)	(7.19)	(7.03)	(6.71)
FiP II $\times \frac{w_{it}}{DR'_{it}}$	-0.78	0.69	-0.92	2.45
	(9.45)	(7.41)	(7.58)	(6.34)
$\frac{q_{it}}{DR'_{it}}$				3.61**
				(1.42)
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 only under variable prices (FiPs) – **arbitrage effect**

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Does overselling respond to the predicted price premium?

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

- Overselling captured by **overselling** $\Delta \ln q_{tg}$, could be due to:
  - Arbitrage: if $\theta > 0$, it responds to price premium.

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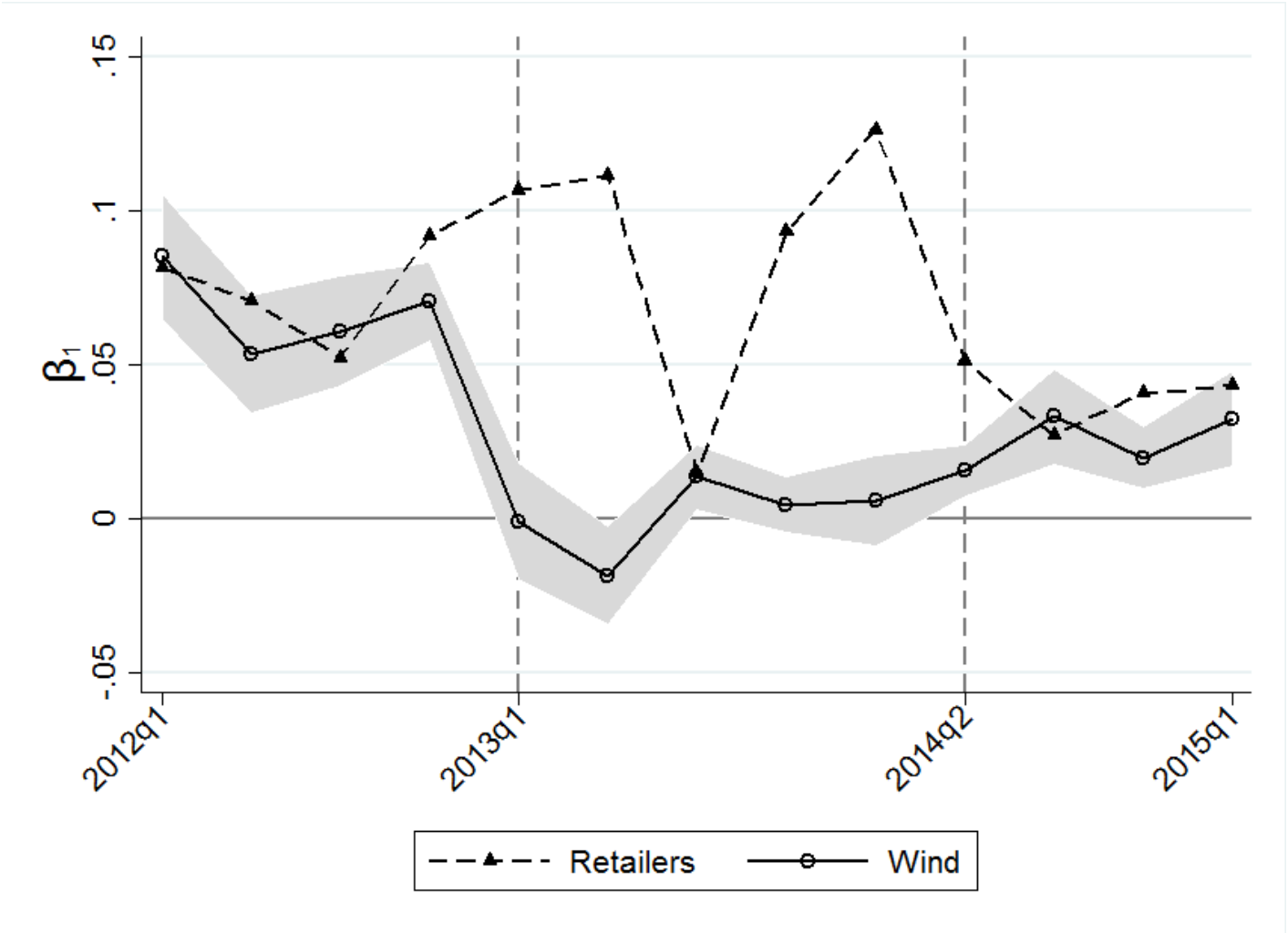
Two alternative control groups: $(g = 1, 2)$

1. Retailers: always incentives to arbitrage
2. Other renewables under FiTs: no incentives to arbitrage

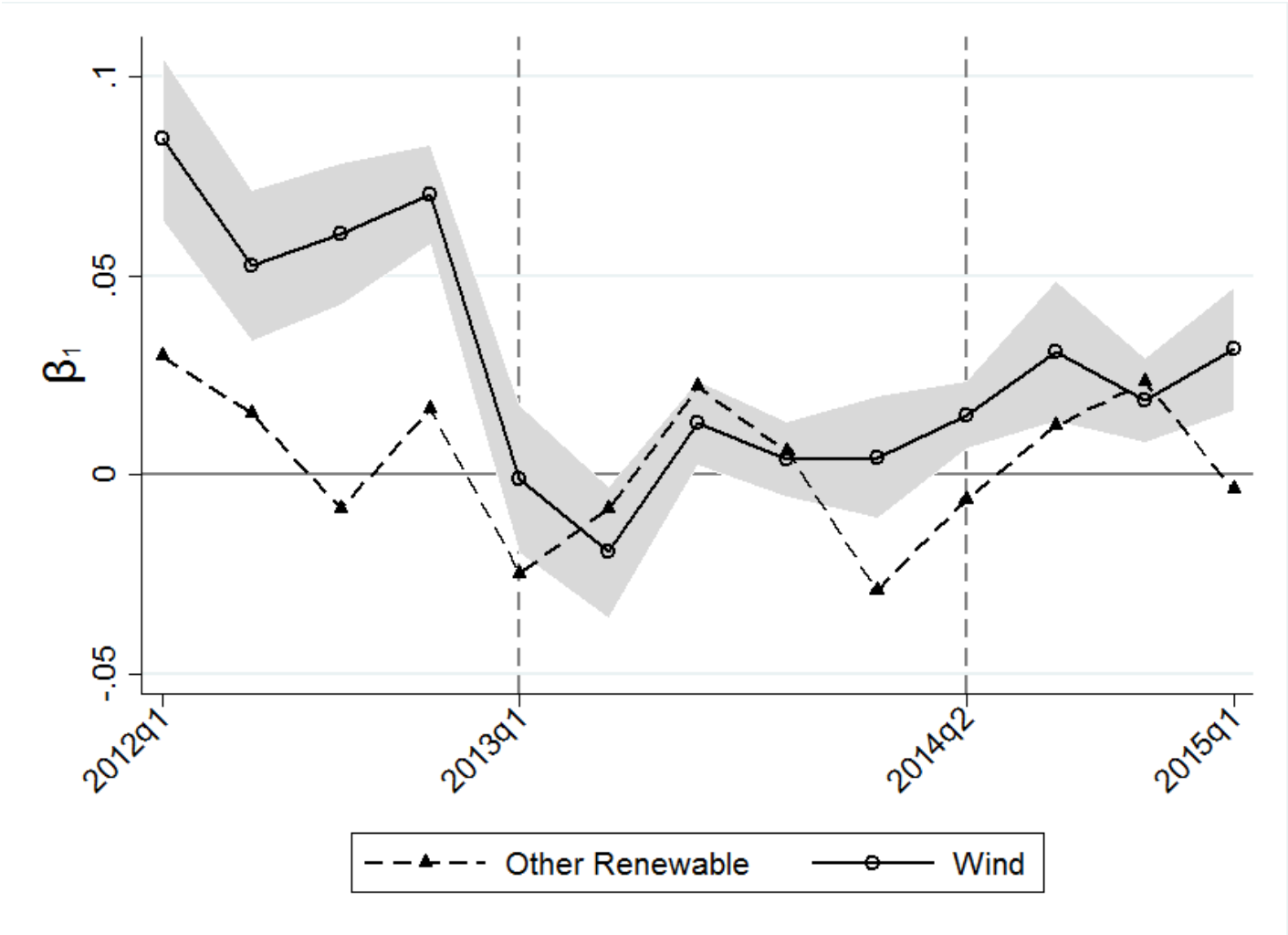
Response of overselling to price premium

Figure: (1) using retailers as the control group



Response of overselling to price premium

Figure: (2) using other renewable units as the control group



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)

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

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

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

▸ Pre-trends

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: we use demand, wind forecast, and date fixed effects to compute forecasted price premium.

▸ Full table

Price Discrimination Across Markets

Predictions:

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

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Estimating equation:

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

- I_t^s= FiP I, FiP II (FiT is reference point)
- β_1: impact of wind across pricing regimes
- Two measures: wind forecast; dominant/fringe's wind

Price discrimination across markets

	2SLS			
	(1)	(2)	(3)	(4)
Wind Forecast (GWh)	-0.1***			
	(0.03)			
FiP I × Wind Forecast (GWh)	0.2***			
	(0.03)			
FiP II × Wind Forecast (GWh)	0.1***			
	(0.03)			
$\frac{w_{dt}}{w_{ft}}$		-0.5***	-0.7***	-0.4***
		(0.1)	(0.1)	(0.1)
FiP I × $\frac{w_{dt}}{w_{ft}}$		0.9***	0.4*	0.7***
		(0.2)	(0.2)	(0.2)
FiP II × $\frac{w_{dt}}{w_{ft}}$		0.7***	0.7***	0.7***
		(0.2)	(0.2)	(0.2)
DoW FE	Y	Y	N	Y
Year X Month FE	N	Y	N	Y
Week FE	N	N	Y	Y
Observations	25,334	25,334	25,334	25,334

Market power in the day-ahead market

We have found evidence of:

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What does the evidence tell us?

- 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

Table: Average Markups on Day-ahead Market

	FiP I		FiT		FiP II	
	Mean (%)	SD	Mean (%)	SD	Mean (%)	SD
All	**8.3**	**(3.3)**	**6.3**	**(3.3)**	**10.9**	**(3.7)**
Firm 1	7.0	(2.2)	7.0	(2.6)	11.9	(4.4)
Firm 2	12.3	(4.1)	8.2	(5.1)	14.4	(4.6)
Firm 3	7.7	(2.3)	6.0	(3.3)	10.5	(3.4)

Notes: Simple average of markups using structural estimates.

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Work ahead!

- **Counterfactual analysis**: effects of combining the forward contract and arbitrage effects

Thank you!

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Comments? Questions?

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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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A combination of the results under FiTs and FiPs:

- **Arbitrage effect** reflected in the residual demands (FiPs):

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

- **Forward contract effect** reflected in day-ahead profit (FiTs):

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

Contracts-for-Differences: equilibrium

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

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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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Testing the pre-trends assumption

Using quarterly splitted data, we regress:

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

Coefficients of interest:

1. β_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.

▸ Back

DiD estimates (other renewables as control group)

	Pre-trends	FiT	FiP
	(1)	(2)	(3)
Wind	0.05***	0.2***	0.03***
	(0.01)	(0.009)	(0.009)
$\hat{p}$	-0.002	-0.002	-0.004**
	(0.002)	(0.002)	(0.002)
$\hat{p}\times$ Wind	-0.004	0.08***	0.005
	(0.004)	(0.006)	(0.003)
FiT		0.09***	
		(0.01)	
Wind $\times$ FiT		-0.1***	
		(0.02)	
$\hat{p}$ $\times$ FiT		0.0001	
		(0.003)	
$\hat{p}\times$ Wind $\times$ FiT		-0.08***	
		(0.007)	
FiP			-0.01
			(0.010)
Wind $\times$ FiP			-0.04***
			(0.01)
$\hat{p}\times$ FiP			-0.003
			(0.004)
$\hat{p}\times$ Wind $\times$ FiP			0.03***
			(0.006)
Control	Renewables	Renewables	Renewables
Observations	16,900	34,478	32,780

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DiD estimates (retailers as control group)

	Pre-trends	FiT	FiP
	(1)	(2)	(3)
Wind	-0.4***	-0.4***	-0.3***
	(0.02)	(0.02)	(0.02)
$\hat{p}$	0.07***	0.07***	0.08***
	(0.006)	(0.006)	(0.007)
$\hat{p}\times$ Wind	0.006	0.006	-0.06***
	(0.009)	(0.009)	(0.010)
FiT		-0.01	
		(0.02)	
Wind $\times$ FiT		0.1***	
		(0.03)	
$\hat{p}$ $\times$ FiT		0.003	
		(0.01)	
$\hat{p}\times$ Wind $\times$ FiT		-0.07***	
		(0.02)	
FiP			0.04***
			(0.02)
Wind $\times$ FiP			0.08***
			(0.02)
$\hat{p}\times$ FiP			-0.04***
			(0.008)
$\hat{p}\times$ Wind $\times$ FiP			0.06***
			(0.01)
Control	Retailers	Retailers	Retailers
Observations	17,578	34,478	32,780

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Response of overselling to price premium

Pricing Regimes	Price Response of Group: Wind	Non-wind Renewables	Retailers	Difference in the Price Response	
	(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		0.059
	(0.000)	(0.812)	(0.000)		(0.000)

Notes: This table reports the coefficient of $\Delta\hat{p}_t$ from 14 different regressions similar to equation (**??**).

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