# Pension Funds and Infrastructure Investments: The Shifting Finance of Electricity Generation

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# Motivation

**The gap between demand for infrastructure and the provision of capital:**

- Infrastructure needs far exceed the resources that countries can hope to raise in a fiscally responsible and macroeconomically sustainable way (IMF 2020).
- Basic infrastructure owned by governments has aged dramatically (Bennett et al., 2020).
- World Bank: $15 trillion gap between global need and projected infrastructure investment to 2040.
- Calls for recourse to private capital in infrastructure (G20 Global Infrastructure Initiative, 2017).

**Pension funds and other institutional investors have committed more capital to infrastructure:**

- Limited Partners: CalSTRS is doubling its allocation to infrastructure from 2% to 4% of its $250 billion; Norwegian SWF will start investing 2% ($20 billion) in unlisted renewable energy.
- General Partners: Global Infrastructure Partners IV with $22 billion and life span of 10 years (plus separate accounts); Brookfield Infrastructure Fund IV with $20 billion and life span of 12 years.
- We estimate AUM by closed infrastructure funds in 2019 have increased 8.5x since 2008.

**The economic implications of changing ownership of infrastructure can be large.**

# Outline

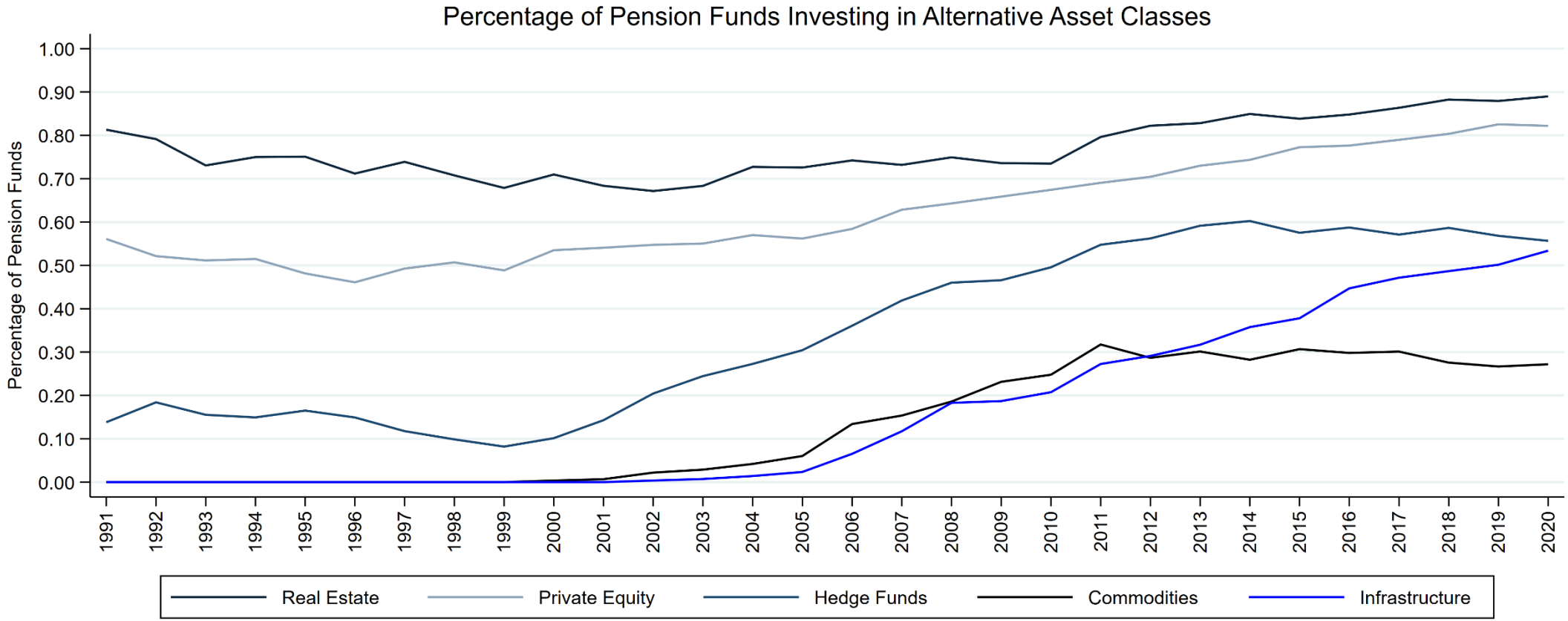
1. **Andonov, Kraussl, and Rauh (2021): Institutional investors and infrastructure investing.**
   - **The growth of infrastructure as an asset class.**
   - **How do institutional investors invest in infrastructure?**

2. Andonov and Rauh (2025): The shifting finance of electricity generation.
   - Which channels drive the shifting ownership? Creating, selling, or decommissioning?
   - Which economic factors facilitate creation and ownership changes?

3. Andonov and Rauh (2025): Economic implications of institutional investments in electricity.
   - Operating efficiency and operating intensity.
   - Contractual terms and electricity pricing.

# Infrastructure Asset Class in Institutional Portfolios

- **CEM data:** International sample of pension funds and other investors (Andonov, 2022).
- Broad trend in increased allocation to alternative assets, but infrastructure is a newer asset class.

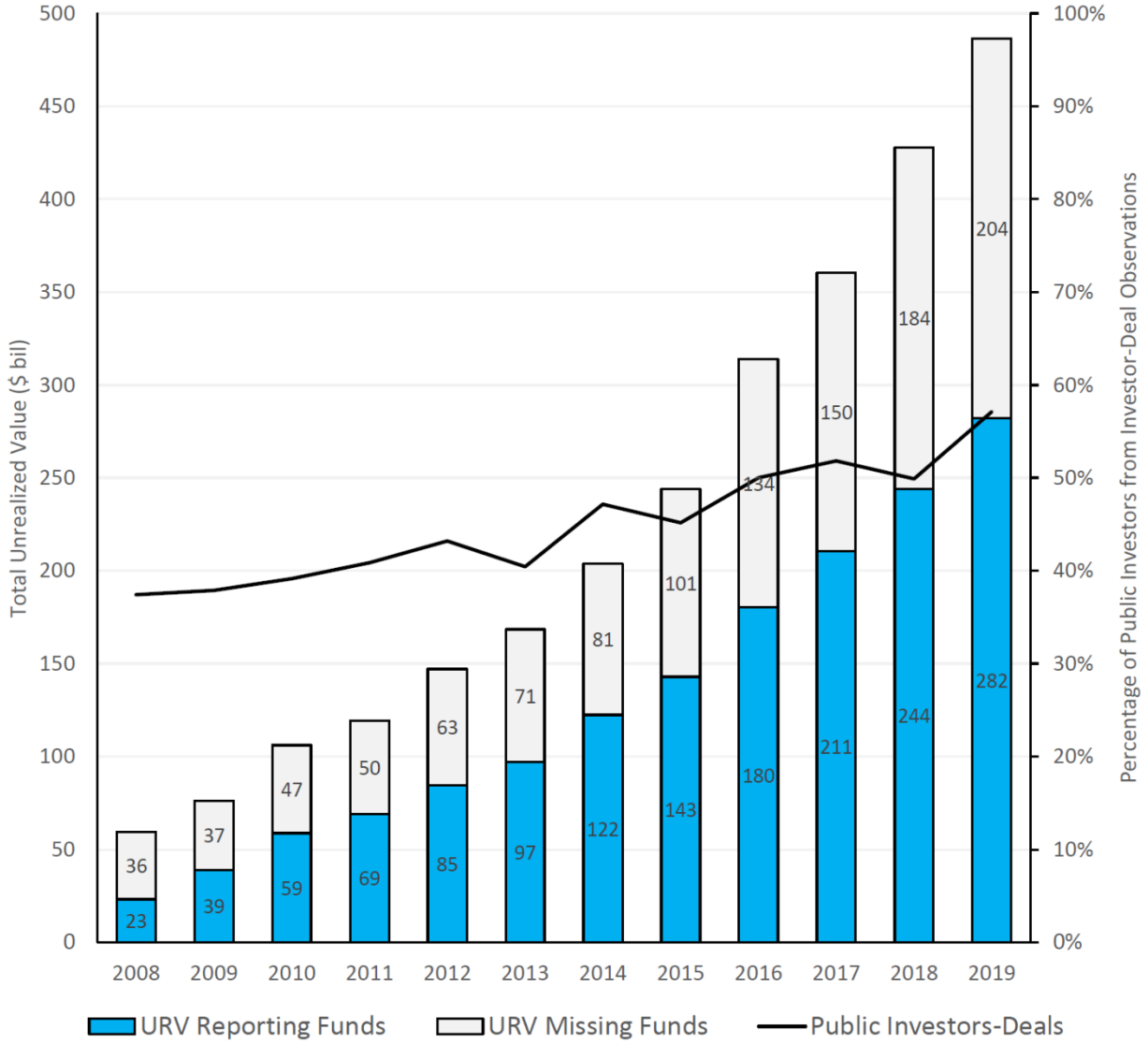


# Rapid Growth of Private Equity Funds in Infrastructure

**The growth is driven primarily by more commitments from public investors:**

- Public investors: public pension funds, government agencies, and sovereign wealth funds.
- Public investors account for 57% of investor-deal observations in 2019 vs 37% in 2008.
- Their relative importance increased further as their share in recent commitments is >60%.

**The outcome of privatization in many cases is that the assets are (indirectly) owned by other governmental entities or another government.**



# Main Industries and Assets in Infrastructure (Preqin Data)

**Traditional energy (17.8% assets):**
Coal, natural gas and nuclear power plants, natural resources pipelines, refineries and storage facilities.

**Renewable energy (43.1% assets):**
Wind, solar, hydro, biomass, and geothermal power generation facilities.

**Transportation (15.2% assets):**
Toll roads, parking lots, tunnels, bridges, railroads and rolling stocks, airports, and seaports.

**Social (13.9% assets):**
Hospitals, senior homes, student accommodation, prisons, defense accommodation, and police stations.


**Utilities (5.5% assets):**
Water and sewage treatment plants, water and power distribution, sewage networks, and waste management.

**Telecom (4.5% assets):**
Mobile phone, landline phone, wireless, internet, cable television, and satellite networks.

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# Data - U.S. Power Plants

**All U.S. power plants reporting to the Energy Information Administration over 2005–2020 period:**

- EIA Form 860 and Form 923 data on plant characteristics and net electricity generation
- Ownership data: Regulatory announcements, Preqin, S&P Global, and newswire articles

**Ownership categories:**

- U.S. investor-owned utilities (IOUs): traditional utilities and independent power producers
- New entrants: private equity, institutional investors (mostly Canadian and Dutch pension funds) and foreign publicly listed corporations
- Other traditional owners: government, cooperatives, and industrial corporations

| | All | NatGas | Coal | Nuclear | Hydro | Wind | Solar |
|---|---|---|---|---|---|---|---|
| **Panel A: Power Plants Sample** | | | | | | | |
| # Unique Plants | 11,593 | 3,024 | 751 | 66 | 1,500 | 1,294 | 3,941 |
| # Unique Plants-Prime-Mover | 13,261 | 4,142 | 867 | 66 | 1,500 | 1,294 | 3,941 |
| # Unique Greenfield | 6,082 | 752 | 36 | 0 | 53 | 1,031 | 3,630 |
| # Unique Decommissioned | 1,949 | 950 | 311 | 10 | 94 | 94 | 42 |
| Observations | 1,509,346 | 572,867 | 115,426 | 12,215 | 270,290 | 135,683 | 188,066 |

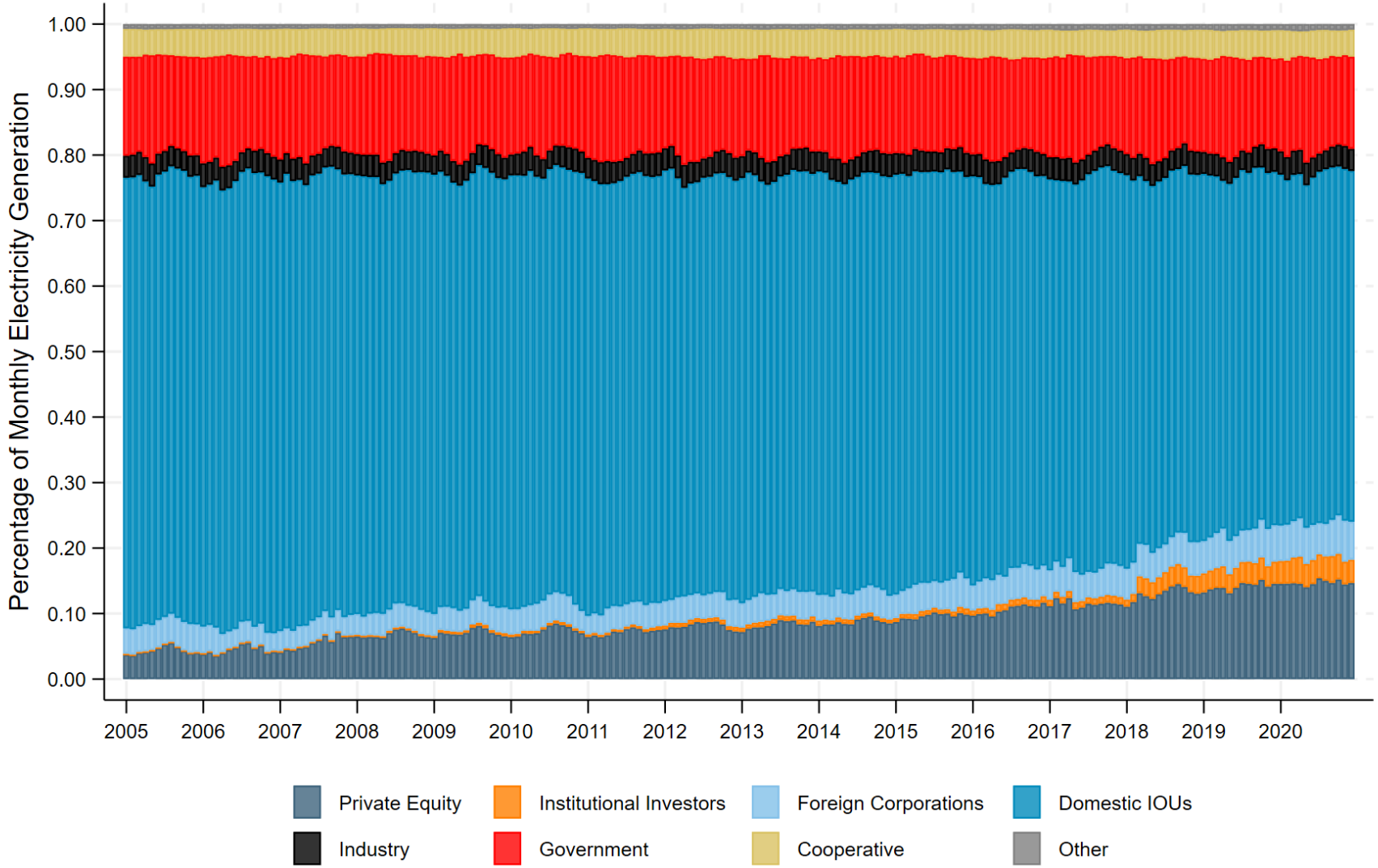
# The Shifting Finance of Electricity Generation

**Incumbent domestic investor-owned utilities (IOUs):**

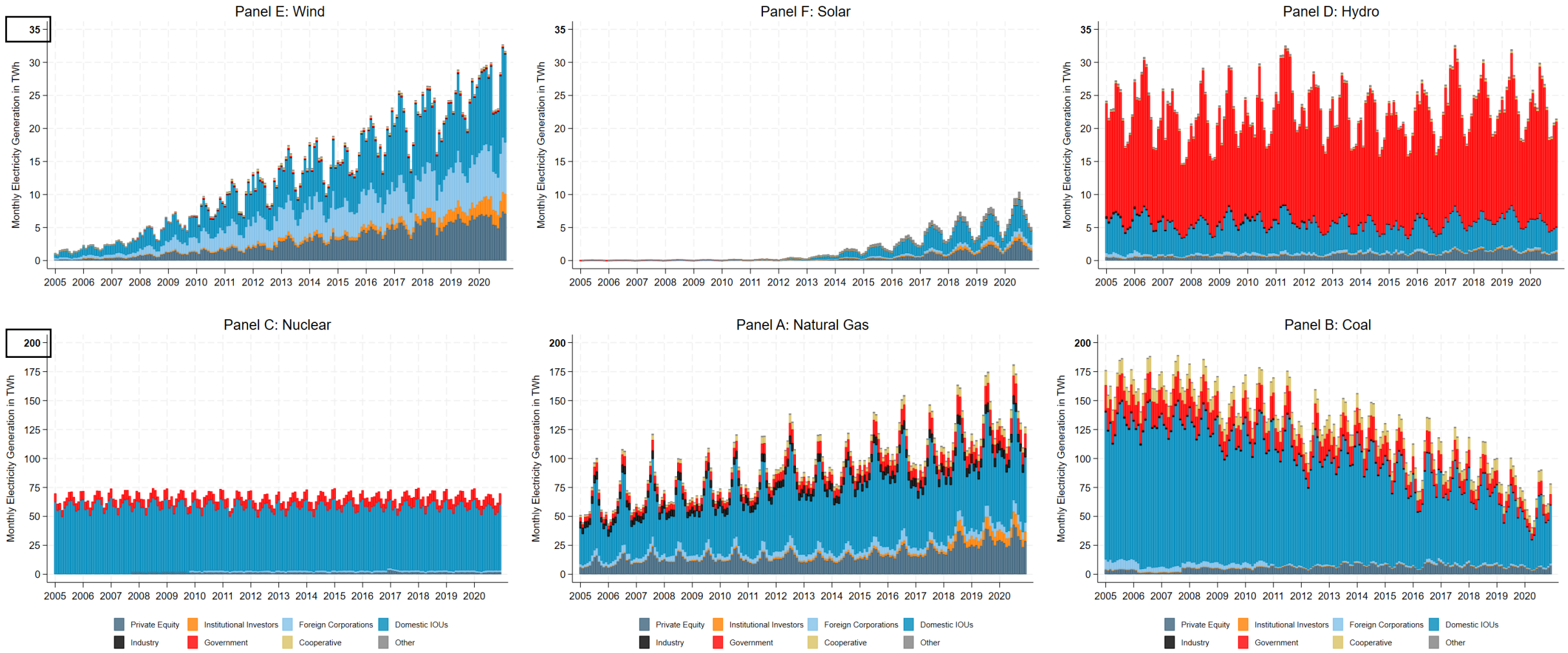
- Their share of electricity generation declined from 70% in 2005 to 54% in 2020.

**New entrants – private equity (PE), institutional investors, and foreign listed corporations:**

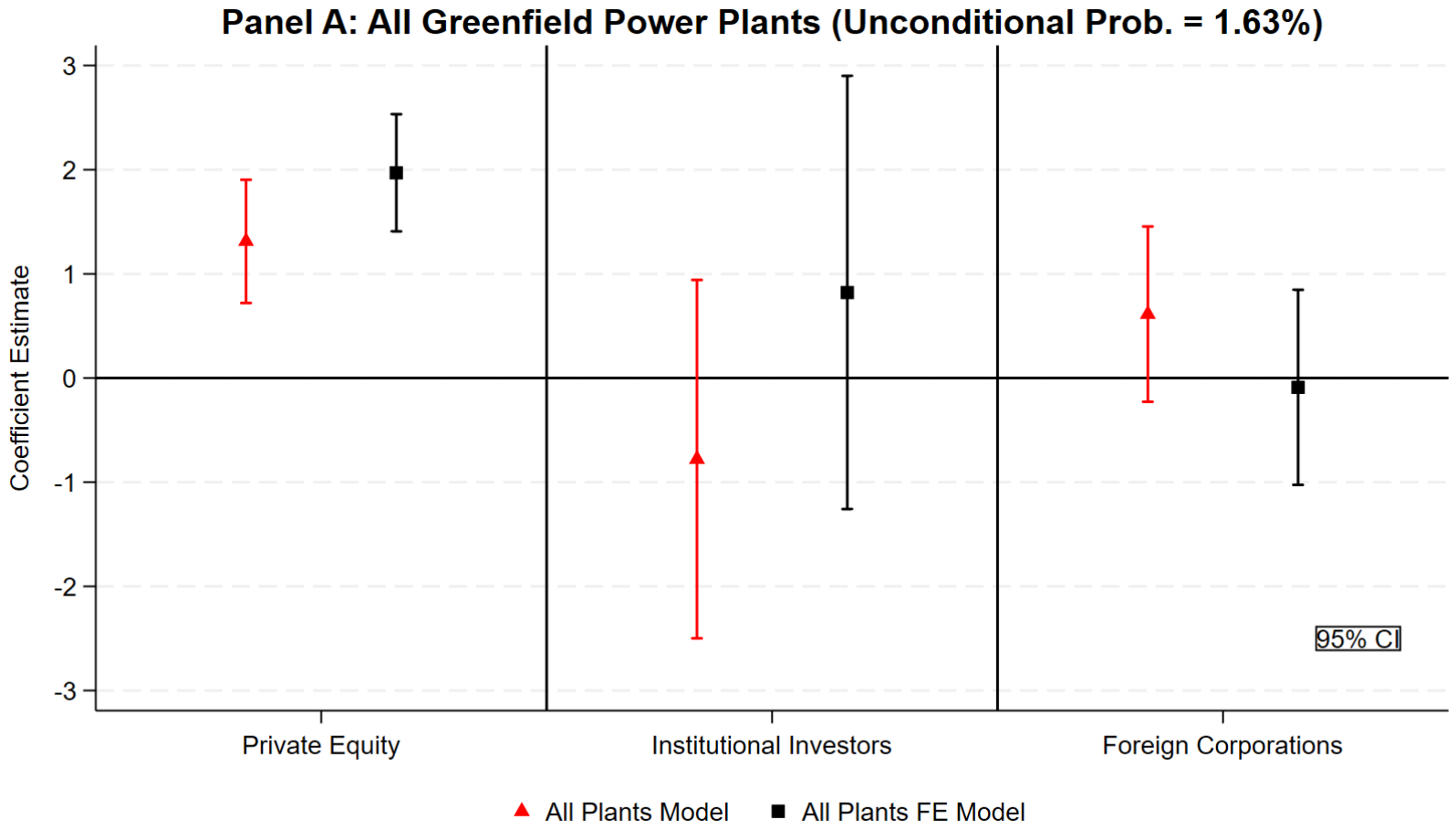
- Their joint share increased from 7% to 24%.
- Jointly own 58% of wind, 47% of solar, and 34% of natural gas electricity production.



# Ownership and Electricity Generation by Fuel Type



# Channel 1: Creating New Greenfield Power Plants



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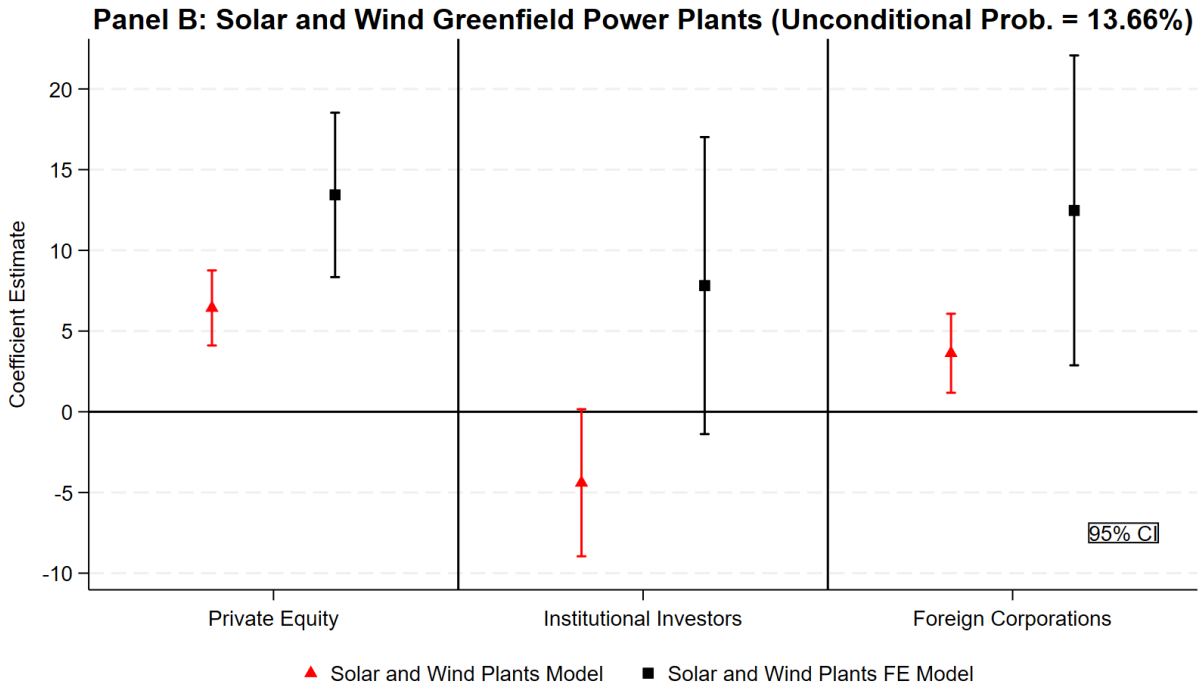
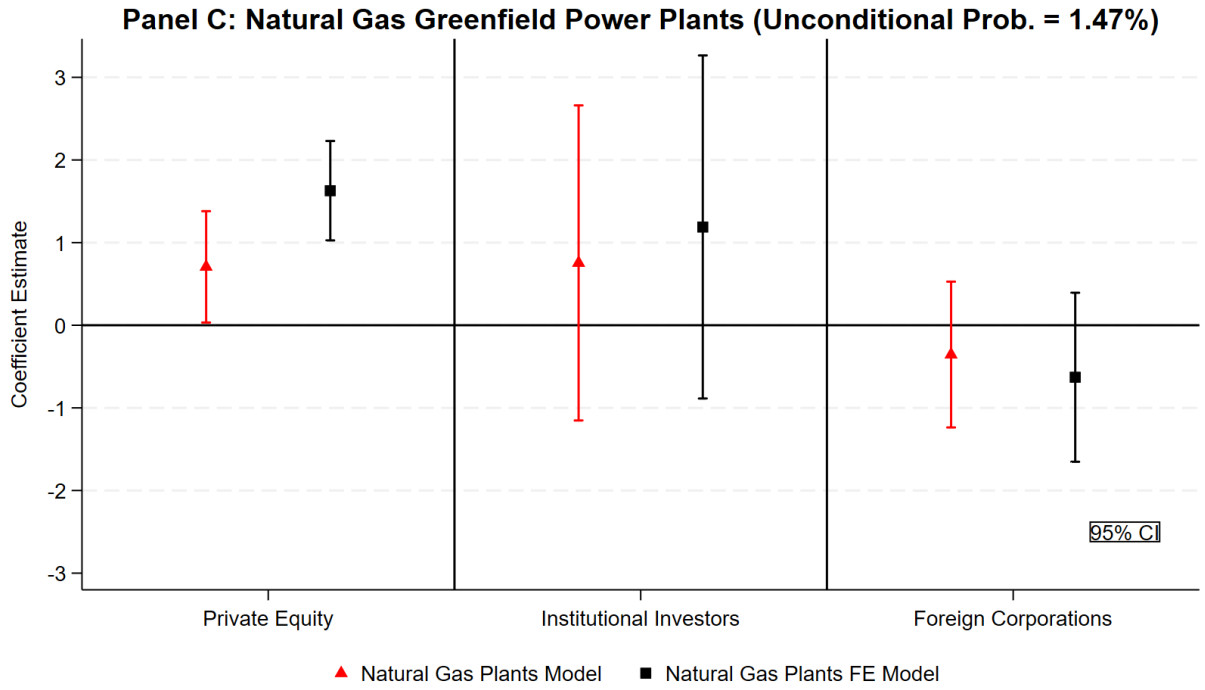


# Channel 2: Selling Existing Plants (vs. Decommissioning)

**Competing risks model with two exit causes:**

- For each power plant $i$ owned by domestic IOUs, we observe the time to exit $t_i$ and the exiting cause $c$, where $c_1$ is selling and $c_2$ is decommissioning

**Leakage concerns** (e.g., Benthem et al., 2022; Bolton and Kacperczyk, 2022; Duchin, Gao, and Xu, 2024)

**Two proxies for leakage:**

- Older plants
- Coal plants

| **Event of Interest:** | Sell All (1) | Sell All (2) | Sell to PE (3) | Sell to II (4) | Sell to Fgn (5) | Dec. (6) | Dec. (7) |
|---|---|---|---|---|---|---|---|
| #Events of Interest: | 656 | 656 | 323 | 147 | 59 | 377 | 377 |
| #Competing Events: | 377 | 377 | 710 | 886 | 974 | 656 | 656 |
| #Total Power Plants: | 2,767 | 2,767 | 2,767 | 2,767 | 2,767 | 2,767 | 2,767 |
| ln Plant Capacity | 0.883*** | 0.884*** | 1.002 | 1.066 | 0.648*** | 0.686*** | 0.615*** |
| | [0.036] | [0.039] | [0.057] | [0.087] | [0.083] | [0.031] | [0.030] |
| ln Plant Age | 1.204*** | 1.166*** | 1.260*** | 1.114 | 1.016 | 5.332*** | 5.443*** |
| | [0.045] | [0.049] | [0.066] | [0.075] | [0.112] | [0.835] | [0.921] |
| Coal | 0.315*** | 0.438*** | 0.324*** | 0.102*** | 0.618 | 1.794*** | 1.994*** |
| | [0.059] | [0.088] | [0.080] | [0.057] | [0.295] | [0.256] | [0.292] |
| Hydro | 0.203*** | 0.248*** | 0.238*** | 0.195*** | 0.101** | 0.010*** | 0.010*** |
| | [0.048] | [0.064] | [0.077] | [0.101] | [0.104] | [0.006] | [0.006] |
| Nuclear | 0.043*** | 0.033*** | 0.074*** | 0.000*** | 0.000*** | 0.936 | 1.188 |
| | [0.043] | [0.034] | [0.074] | [0.000] | [0.000] | [0.339] | [0.457] |
| Solar | 0.180*** | 0.166*** | 0.465** | 0.000*** | 0.000*** | 0.000*** | 0.000*** |
| | [0.049] | [0.047] | [0.154] | [0.000] | [0.000] | [0.000] | [0.000] |
| Wind | 0.654*** | 0.874 | 0.611** | 0.505** | 0.049*** | 0.565 | 0.523 |
| | [0.087] | [0.119] | [0.134] | [0.143] | [0.052] | [0.233] | [0.215] |
| Fuel-Type FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Plant State FE | | Yes | | | | | Yes |
| Observations | 326,312 | 326,312 | 326,312 | 326,312 | 326,312 | 326,312 | 326,312 |

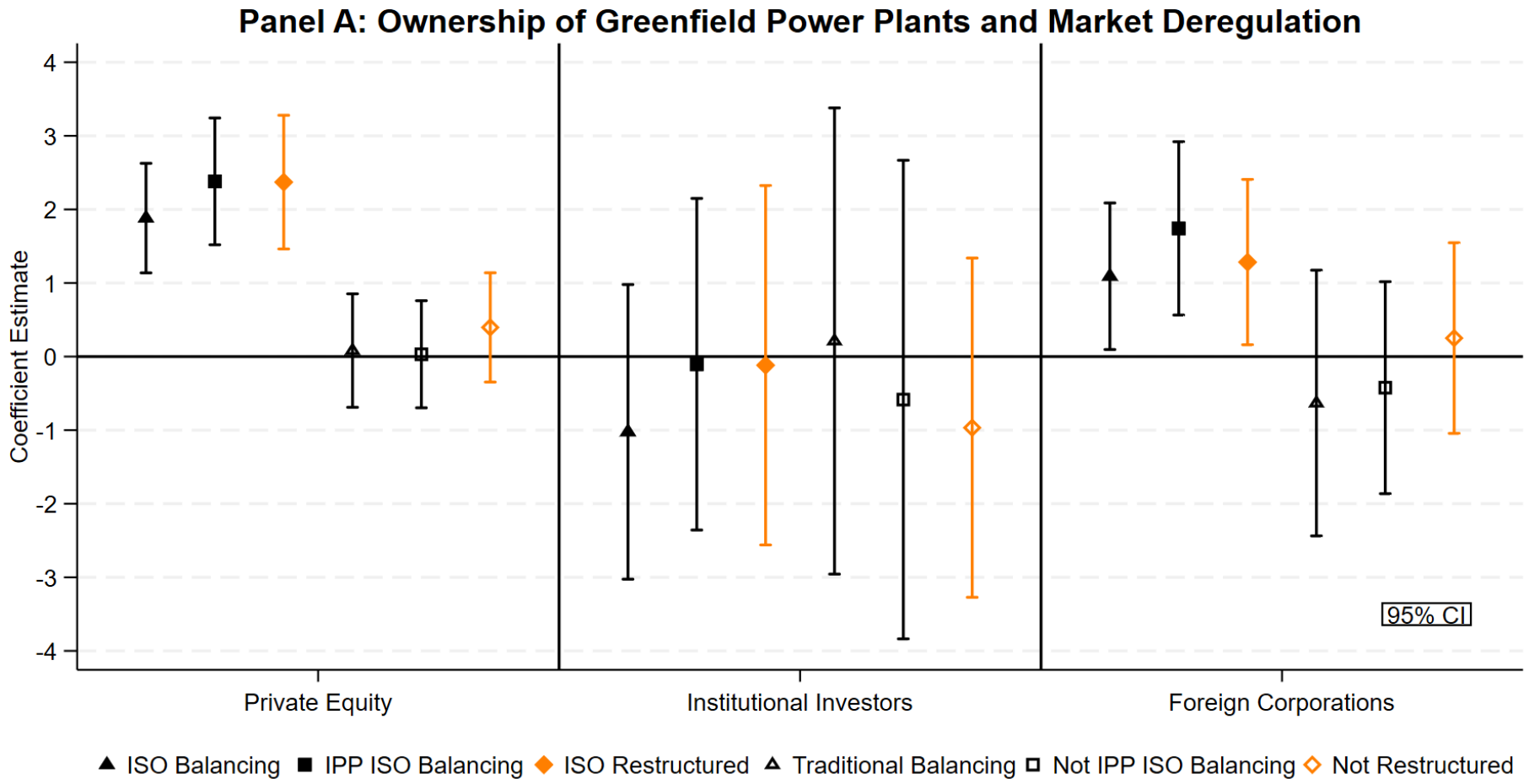
# Channel 3: Decommissioning Power Plants

**Domestic IOUs are more likely to decommission plants than institutional investors and foreign corporations:**

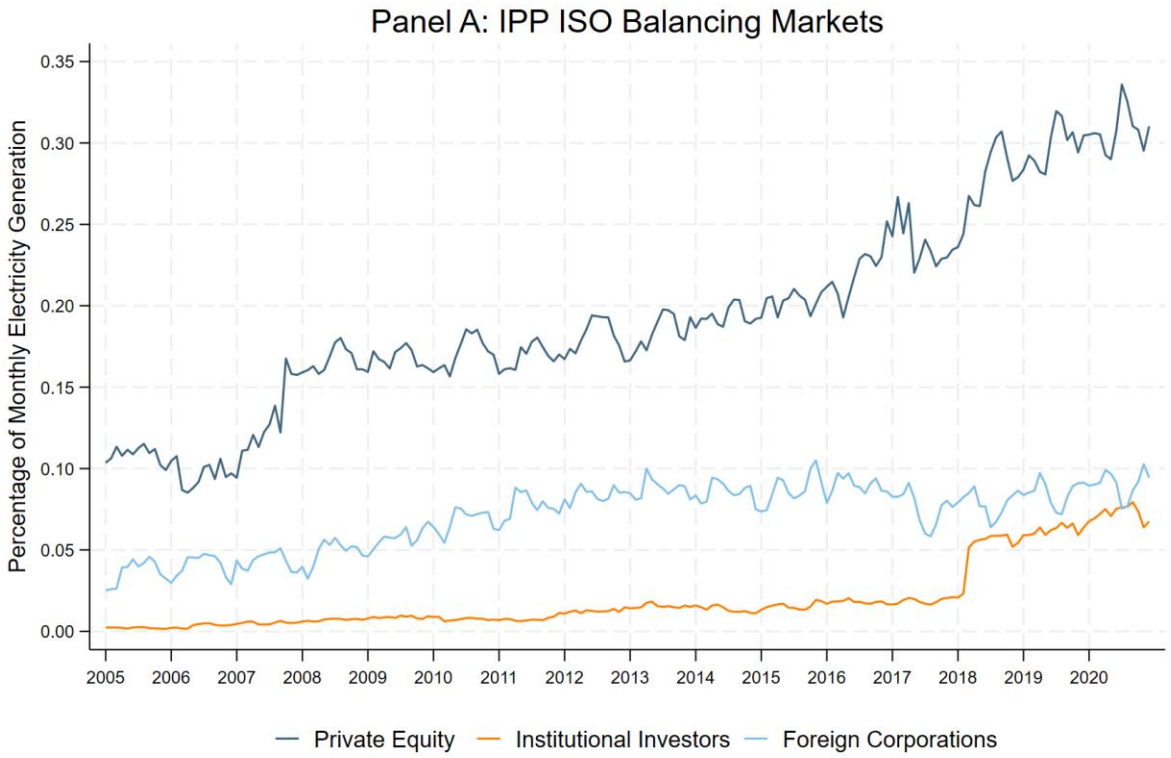
- No difference with **PE**
- **Foreign corps:** would need to double the number of retired plants to reach the rate of Domestic IOUs and PE (23 additional plants over the entire period; 1.43 plants per year)
- **Institutional investors (pension funds) directly:** no creation, no decommissioning; look for stable assets

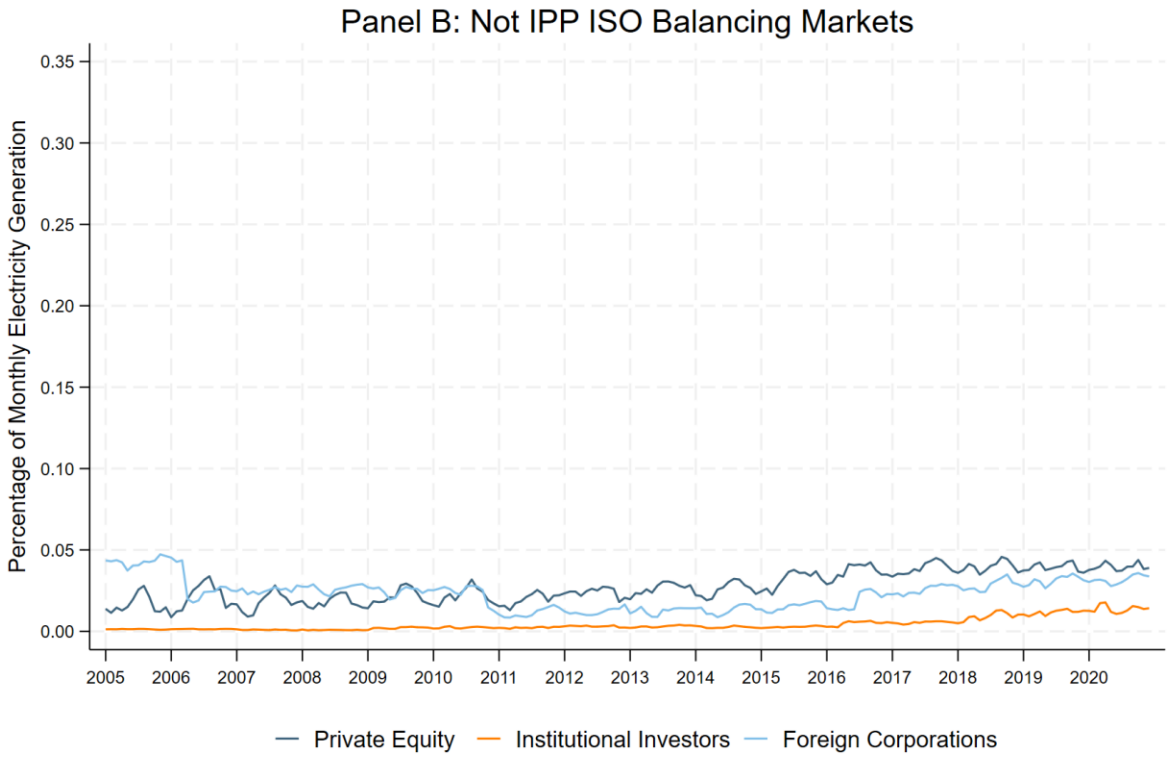
| | All Plants | | Coal | | Natural Gas | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| #Power Plants: | 5,392 | 5,392 | 988 | 988 | 2,315 | 2,315 |
| #Decommissioned: | 758 | 758 | 311 | 311 | 335 | 335 |
| Domestic IOUs | 1.316** | | 1.502* | | 1.035 | |
| | [0.156] | | [0.317] | | [0.182] | |
| Private Equity | | 1.007 | | 0.712 | | 1.351 |
| | | [0.128] | | [0.161] | | [0.256] |
| Institutional Investors | | 0.002*** | | | | 0.004*** |
| | | [0.004] | | | | [0.008] |
| Foreign Corporations | | 0.508*** | | 0.568 | | 0.676 |
| | | [0.117] | | [0.229] | | [0.231] |
| ln Plant Capacity | 0.606*** | 0.610*** | 0.523*** | 0.524*** | 0.649*** | 0.657*** |
| | [0.023] | [0.023] | [0.029] | [0.029] | [0.043] | [0.043] |
| ln Plant Age | 3.230*** | 3.221*** | 3.941*** | 3.920*** | 3.243*** | 3.246*** |
| | [0.281] | [0.275] | [0.810] | [0.805] | [0.371] | [0.369] |
| Other Owners | Yes | Yes | Yes | Yes | Yes | Yes |
| Fuel-Type FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Plant State FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 753,396 | 753,396 | 132,948 | 132,948 | 344,290 | 344,290 |

# Creation Channel and Market Deregulation



# Implications of Market Deregulation for Plant Ownership



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# Measures of Operating Performance

## Operating Intensity – Capacity Factor:

- The ratio of net electricity generation to monthly capacity (the maximum potential output).
- Could be an alternative channel for changing the generation composition without ownership changes.
- Operating a plant less intensively is not necessarily a sign of weaker performance.
- Higher intensity could be an alternative form of leakage.

## Operating Efficiency – Heat Rate:

- The ratio of fuel consumption in millions of Btu to electricity generation in MWh.
- Available for fossil fuel and nuclear plants.
- Lower values imply lower fuel consumption and higher efficiency.
- Lower heat rate automatically implies reduced carbon emissions and pollution.

# Operating Performance: IOUs Plants Are Less Efficient

| | Capacity Factor | | | | Heat Rate | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean Dependent Variable = 0.412 | | | | Mean Dependent Variable = 11.324 | | | |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Domestic IOUs | 0.016* | | 0.086*** | 0.050** | 0.616*** | | 0.184 | 0.325 |
| | [0.010] | | [0.015] | [0.022] | [0.131] | | [0.164] | [0.221] |
| Private Equity | | -0.029*** | | | | -0.434*** | | |
| | | [0.011] | | | | [0.150] | | |
| Institutional Investors | | 0.097*** | | | | -1.607*** | | |
| | | [0.033] | | | | [0.440] | | |
| Foreign Corporations | | -0.014 | | | | -0.873*** | | |
| | | [0.013] | | | | [0.232] | | |
| IPP ISO Balancing | | | 0.085*** | | | | -0.508** | |
| | | | [0.016] | | | | [0.203] | |
| Domestic IOUs × IPP ISO Balancing | | | -0.108*** | | | | 0.671*** | |
| | | | [0.017] | | | | [0.224] | |
| ISO Restructured | | | | 0.057* | | | | -0.478 |
| | | | | [0.033] | | | | [0.318] |
| Domestic IOUs × ISO Restructured | | | | -0.108*** | | | | 0.449 |
| | | | | [0.038] | | | | [0.361] |
| Controls | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Other Owners | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Fuel-State-Year-Month FE | Yes | Yes | Yes | | Yes | Yes | Yes | |
| Fuel-Year-Month FE | | | | Yes | | | | Yes |
| Observations | 1,398,265 | 1,398,265 | 1,398,265 | 1,478,395 | 590,140 | 590,140 | 590,140 | 664,027 |
| Adjusted R-squared | 0.635 | 0.636 | 0.638 | | 0.336 | 0.336 | 0.336 | |
| K-P F-Stat | | | | 199.203 | | | | 156.032 |

# Operating Performance: Stacked DID with Sold Plants

**Treated sample:** All power plants sold by domestic IOUs to new entrants

**Matched control sample:** Never-treated plants that are always owned-and-operated by domestic IOUs

- Matching plants owned by domestic IOUs and new entrants based on prime mover technology, main fuel type, year-month, and age (creation year); plus nearest neighbor on capacity

| | **Capacity Factor** | | **Heat Rate** | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| **Panel A: Plants Sold by Domestic IOUs** | | | | |
| | Only Treated | Matched DID | Only Treated | Matched DID |
| Post × Treated | -0.005 | 0.000 | -0.309* | -0.441** |
| | [0.006] | [0.006] | [0.181] | [0.176] |
| Controls | Yes | Yes | Yes | Yes |
| State-Year-Month FE | Yes | Yes | Yes | Yes |
| Plant-Prime-Mover FE | Yes | | Yes | |
| Fuel Type FE | Yes | | Yes | |
| Plant-Prime-Mover × Cohort FE | | Yes | | Yes |
| Year-Month × Cohort FE | | Yes | | Yes |
| Observations | 54,064 | 87,003 | 19,822 | 37,952 |
| Adjusted R-squared | 0.805 | 0.812 | 0.738 | 0.733 |

# Two Main Products that Power Plants Sell

**Capacity sales:**

- Used in some wholesale markets to pay power plants for being available to meet predicted demand
- Cover the fixed costs of building and maintaining power plants
- Ensure having sufficient capacity in the future
- Do not represent a commitment to produce electricity

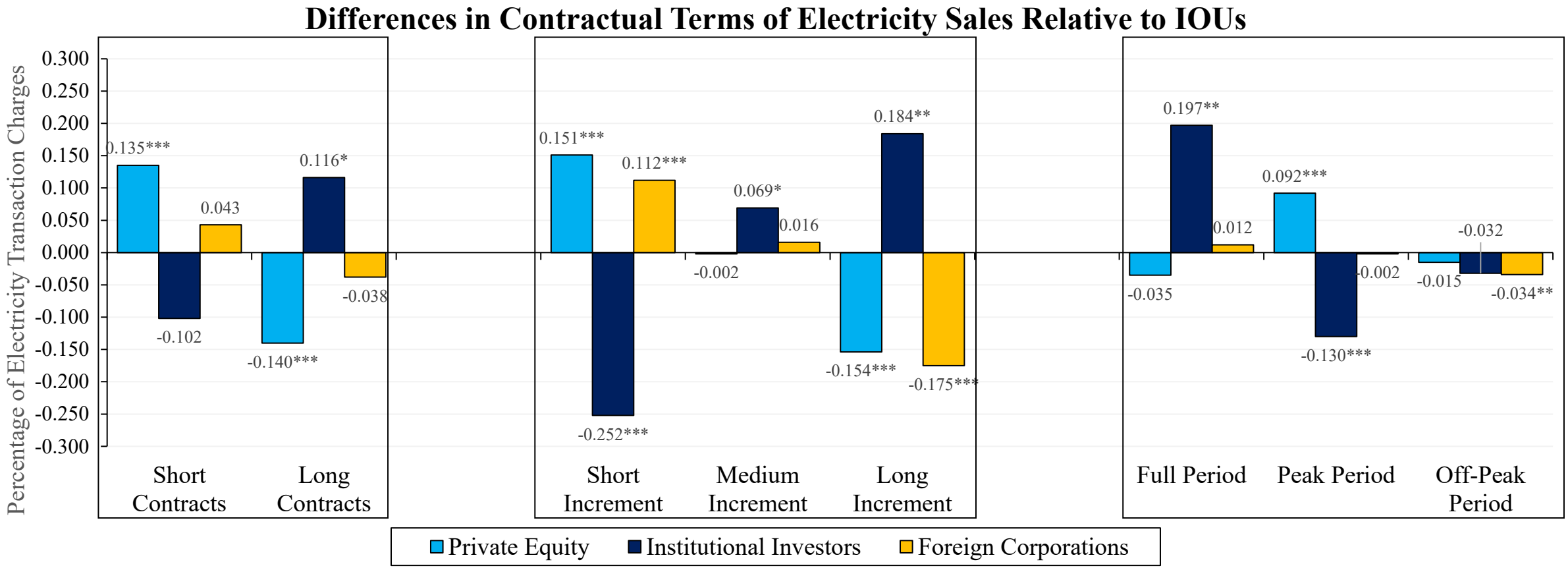
**Electricity sales:**

- Contract length: short (<1 year) vs. long term
- Increment pricing terms: short, medium, and long increments
- Peaking terms: full-period, peak, and off-peak sales

**Data:** Federal Energy Regulatory Commission (FERC) Electric Quarterly Reports (EQR)

# Contractual Terms of Electricity Sales

**Private equity and foreign corporations:** Short duration, short increments, and peak period sales
**Institutional investors:** Long duration, long increments, and full period sales; stable cash flows



# Pricing of Electricity Sales

**Private equity** sells electricity for **$4.36 or $2.59** higher average price per MWh than DLCs

**Flexible choices** which plants to operate in a given state-month situation drive part of the higher prices

**Panel A: All Power Plants**

| | Mean Price | | | | Median Price | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean Dependent Variable = 30.836 | | | | Mean Dependent Variable = 28.706 | | | |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Domestic Listed Corp (DLC) | -3.917*** | | -1.213 | | -4.045*** | | -1.294 | |
| | [0.845] | | [0.828] | | [0.815] | | [0.806] | |
| Private Equity | | 4.357*** | | 2.593*** | | 4.252*** | | 2.593*** |
| | | [0.931] | | [0.963] | | [0.867] | | [0.902] |
| Institutional Investor | | -1.646 | | -1.566 | | 0.207 | | -0.426 |
| | | [2.343] | | [1.884] | | [2.242] | | [1.645] |
| Foreign Corp | | 4.929*** | | -0.102 | | 5.300*** | | 0.089 |
| | | [1.774] | | [1.604] | | [1.718] | | [1.556] |
| Controls | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| State-Year-Month FE | Yes | Yes | | | Yes | Yes | | |
| Fuel FE | Yes | Yes | | | Yes | Yes | | |
| Fuel-State-Year-Month FE | | | Yes | Yes | | | Yes | Yes |
| Observations | 238,201 | 238,201 | 218,746 | 218,746 | 238,201 | 238,201 | 218,746 | 218,746 |
| Adjusted R-squared | 0.497 | 0.498 | 0.647 | 0.647 | 0.458 | 0.459 | 0.617 | 0.618 |

# Conclusion and Implications

1. **Pension funds have significantly increased their exposure to infrastructure assets.**
   - Most of their investments are in private markets, organized through private equity funds.
   - Changing ownership structure of infrastructure, especially electricity generating assets.

2. **Which channels drive the shifting ownership? Creating, selling, or decommissioning?**
   - Listed IOUs are less likely to create new plants, PE funds raising money from PFs are more likely.
   - Sales channel has limited effects on the composition of technologies, limited evidence of leakage.
   - Deregulated electricity markets attract PE and pension capital, facilitate creation.

3. **What are the implications for operating performance, contracting, and pricing?**
   - No differences in operating intensity, but power plants of new entrants are 5% more efficient.
   - PE establishes shorter flexible contracts and sells electricity for $2.59 higher price per MWh.

4. **The impacts of new ownership types on consumers are yet to be determined:**
   - Implications for grid stability?
   - Implications for contractual terms and pricing of electricity sales in retail markets?

# References


1. Andonov, A., Kräussl, R. and Rauh, J., 2021. Institutional investors and infrastructure investing. *Review of Financial Studies*, 34(8), pp.3880-3934. [Link]

2. Andonov, A. and Rauh, J., 2025. The shifting finance of electricity generation. Working Paper. [Link]

3. Andonov, A., 2024. Delegated Investment Management in Alternative Assets. *Review of Corporate Finance Studies*, 13(1), pp.264–301. [Link]