The Climate and Financial Effects of Fossil Fuel Power Plant Sales in the US

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Motivation

- Recent pressures on publicly traded firms to decarbonize and their decisions to sell dirty assets to private firms have sparked concerns about
  - Greenwashing

Motivation

- In January 2021, the sale of a Nigerian oil and gas field by publicly traded firms to a private equity backed operator made headlines because methane flaring **quadrupled** after sale completion.
- Reflective of broader concerns

POLITICO

SUSTAINABILITY

When companies go green, the planet doesn't always win

The New York Times

Oil Giants Sell Dirty Wells to Buyers With Looser Climate Goals, Study Finds

The transactions can help major oil and gas companies clean up their own production by transferring polluting assets to a different firm, the analysis said.

CNBC MARKETS BUSINESS INVESTING TECH POLITICS CNBC TV INVESTING CLUB PRO

An energy transition loophole is allowing Big Oil to offload high-polluting assets to private buyers

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Motivation

- Recent pressures on publicly traded firms to decarbonize and their decisions to sell dirty assets to private firms have sparked concerns about
  - Greenwashing
  - Financial incentives to sell to more opaque private operators

This Paper

Questions

- **Climate** and **financial** effects of public to private sales.
- In particular, whether they
  - Lead to innocuous or perverse greenwashing
  - Incentivized by the stock market

Setting

- Fossil fuel power plant sector from 2000-2022

This Paper

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  - Generates 25% of annual US GHG emissions via fossil fuel combustion

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  - Similarity to industrial assets that generate + 20% of emissions

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- **Climate** and **financial** effects of public to private sales.
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Setting

- Fossil fuel power plant sector from 2000-2022
  - Generates 25% of annual US GHG emissions via fossil fuel combustion
  - Similarity to industrial assets that generate + 20% of emissions
  - Availability of high quality emissions data at the weekly frequency that can be linked to sales data

Preview of Findings

Empirical: Climate Effects

- Use a difference in difference design to estimate sale effects on plant emissions
- **Finding #1:** Eighteen months after sale, power plant units sold to private firms are less emissive but effects are **small** and **statistically insignificant.**
  - Innocuous greenwashing ✓ , perverse greenwashing ✗
  - **Implication:** Private firms did not buy up dirty assets and drastically increase emissions
- **Finding #2:** Effects statistically indistinguishable from effects when units sold to public firms
  - **Implication:** Private firms did not operate in more emissive ways vis-a-vis public firms

Preview of Findings

Empirical: Financial Effects

- Use an event study methodology to estimate abnormal returns to sellers around sale announcements.
- **Finding:**
  - Announcing sale to public and private firm $\rightarrow$CAR of 1.4%, 0.6 %
  - Difference by buyer type is statistically insignificant.
  - **Implication:** No premium, and thus no incentive, to sell to more opaque, private firm over public firms.

Preview of Findings

Empirical

- Climate effects: Innocuous greenwashing ✓
- Financial effects: Incentivized by the stock market ✗

Preview of Findings

Theoretical: Model Results

- General equilibrium model that predicts effects on asset ownership and emissions of shocking public, but not private, firms with higher costs of emitting.
- There can be multiple equilibria, one of which is a Greenwashing equilibrium.

Roadmap

1. Literature Review
2. Hypotheses
3. Climate Effects
4. Financial Effects
5. Theoretical Model

Literature Review

- Environmental, financial effects of divestitures of pollutive assets (Duchin, Gao, and Xu, 2023; Jacqz, 2021; Andonov and Rauh, 2023; Bai and Wu, 2023; Kahn, Matsusaka, and Shu, 2023)
- Firm characteristics shape polluting behavior (Akey and Appel, 2021; Bellon, 2021; Andonov and Rauh, 2023)
- Emissions leakage (Akey and Appel, 2021; Bellon, 2021; Andonov and Rauh, 2023)
- Divestitures and firm value (Hite, Owers, and Rogers, 1987; Wright and Ferris, 1997)

Hypotheses

Climate Effects: Effect on Emissions

- Increase
- No change
- Decrease

Hypotheses

Financial Effects: Effect on Seller Valuations

- Increase
- No change
- Decrease

Outline

Data

- Panel dataset of plant
  - emissions,
  - production,
  - technological specifications,
  - ownership

  from this sector at the **weekly frequency**, and **plant unit level** from **1998-2023.**

Data

Data Sources

- **Environmental Protection Agency** (CAMD program, eGrid)
  - Production, emissions, characteristics data (e.g. fuel input, electricity output, emissions, unit technological characteristics, state)
  - Emissions data are comprehensive, high quality:
    - 96% of sectoral emissions
    - misreporting bounded by federal audits and physics and chemistry of combustion
- **Energy Information Administration** (Forms 860 and 920/923)
  - Power plant characteristics data (e.g., regional electricity market, state)
- **S&P Capital IQ Pro**
  - Power plant deals characteristics (e.g.,buyer and seller identities, share percentages transferred, announcement dates, completion dates)
  - Deals data are comprehensive, detailed:
    - virtually complete because power plant deals require public, FERC approval

Summary Statistics

- 82 deals (56% to public firms, 44% to private)
- 601 power plant units transferred (55% to public firms, 45% to private firms)
- 27% of annual, 2022 sectoral emissions.

Outline

Model

- **Difference in Difference** framework to estimate average treatment effects on treated
- Two treatments: Sale by a public firm to
  - a public firm,
  - a private firm.
- Effects on four key operational decisions that affect emissions

$$y_{it} = \begin{bmatrix} \textit{Weekly Starts} \\ \textit{Capacity Factor} \\ \ln(\textit{Emissions}\ \text{Intensity}) \\ \textit{Fuel Mix} \end{bmatrix}_{it} = \begin{bmatrix} 1(MWh > 0) \\ ln(\frac{MWh}{MW})|_{MWh>0} \\ ln(\frac{CO_2}{MWh})|_{MWh>0} \\ 1(\textit{Secondary Fuel})_{\textit{Can Cofire}=1} \end{bmatrix}_{it}$$

Model

Specification

Let $i = unit$, $t = week$.

$$\begin{aligned} y_{it} = & \quad \beta_1 (Post \times Public\,Buyer)_{it} \\ + & \quad \beta_2 (Post \times Private\,Buyer)_{it} + X_{it} + \alpha_i + \eta_{it} \end{aligned}$$

Standard errors clustered at the plant level.

Independent Variables

- $Post \times Public\,Buyer$: Unit sold to a public firm and is in the post-divestment period
- $Post \times Private\,Buyer$: Unit sold to a private firm and is in the post-divestment period

Model

Specification

Let $i = unit$, $t = week$.

$$y_{it} = \beta_1(Post \times Public\,Buyer)_{it} + \beta_2(Post \times Private\,Buyer)_{it} + X_{it} + \alpha_i + \eta_{it}$$

Standard errors clustered at the plant level.

Independent Variables

- X_{it}: State $\times$Regional Electricity Market $\times$Feasible fuel set $\times$ Combined cycle $\times$ Week $\times$ Year FE
- α_i : Unit FE
- η_{it}: Error term

Tech Type | Institutional Background

Model

Comparison of Treatment and Controls

Model

Comparison of Treatment and Controls

Model

Specification

$$
\begin{aligned}
y_{it} = \quad & \beta_1 (Post \times Public\,Buyer)_{it} \\
+ \quad & \beta_2 (Post \times Private\,Buyer)_{it} + X_{it} + \alpha_i + \eta_{it}
\end{aligned}
$$

Hypotheses

- Absolute effect of divestment to a private firm

$$H_0 : (Post \times Private\,Buyer) = 0$$
$$H_a : (Post \times Private\,Buyer) \neq 0$$

- Relative effect of a divestment to a private firm vis-a-vis divestment to a public firm

$$H_0 : (Post \times Private\,Buyer) = (Post \times Public\,Buyer)$$
$$H_a : (Post \times Private\,Buyer) \neq (Post \times Public\,Buyer)$$

Identification Assumptions

- Absolute effect
  - Parallel trends

    Parallel Trends
  - Stable unit treatment value assumption (SUTVA)
  - Exogeneity
- Relative effect
  - Units involved in public to public sales and public to private sales have identical opportunities to be operated in more or less emissive ways

Outline

Results

Asset-level Implication

- Assets became less emissive but effects were small and insignificant

Results

	All			
	Starts (1)	Capacity Factor (2)	$ln(Emissions\,Intensity)$ (3)	$1(Secondary\,Fuel)$ (4)
$Post \times Public\,Buyer$	-0.017	-0.005	-0.011	0.010
	(0.013)	(0.008)	(0.010)	(0.01)
$Post \times Private\,Buyer$	-0.028	-0.011	0.00	-0.04
	(0.017)	(0.013)	(0.017)	(0.04)
Sample				
Observations	356,704	273,278	273,278	103,983
R-squared	0.40	0.72	0.93	0.81
R-squared contribution	0.00	0.00	0.00	0.01
Wald Test P-value				
All	0.58	0.68	0.61	0.20

Results

Asset-level Implication

- Assets became less emissive but effects were small and insignificant

Aggregate Implications

- Replacement by zero-emissions, clean technology $\Longrightarrow \leq 10$ bp decline in US annual emissions
  - Replacement by dirty technology $\Longrightarrow \leq 10$ bp increase in US annual emissions
  - Public to private sales were innocuous. Near zero climate impacts.

Results

- At existing technological constraints, firms can change emissions via production, but not capture, decisions.
- Production is bounded above by capacity constraints.
- Changes in emissions bounded by ~inelastic demand.

Robustness and Heterogeneity

- Cluster by deal
- Weight by nameplate
- Drop private equity deals
- Heterogeneity in estimates
  - split the data to pre and post COP 21
  - lengthen the horizon to five years,
  - weigh observations by nameplate capacity

Results

By fuel type

- Asset-level Implication
  - Assets became less emissive but effects were small and insignificant

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- Aggregate Implications
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Results

Decompose Change in the Emissions Intensity

- Changes in emissions intensity can be from
  - fuel mixing
  - changes in reporting/fuel subtype (e.g. subbituminous coal to coke)
  - changes in productive efficiency, the efficiency at which fuel is converted to electricity
- Ruled out fuel mixing
- May be concerned about changes coming from 1) because of literature on privately held firms engaging in apparent value creation (Eaton, Howell, and Yannelis, 2019)
- Where are declines in the emissions rate coming from?

Results

Decomposition of Emissions Intensity Change

- Do the following decomposition by modifying regression to take out effects of fuel mixing

$$\underbrace{\Delta ln(\frac{CO_2}{Generation})}_{\Delta Emissions\ Intensity} = \underbrace{\Delta ln(\frac{CO_2}{Heat\ Input})}_{\Delta Reporting\ /\ Fuel\ Subtype} + \underbrace{\Delta ln(\frac{Heat\ Input}{Generation})}_{\Delta Productive\ Efficiency} + \Delta Fuel\ Mix$$

Results

Decomposition of Emissions Intensity Change

Specification

$$\begin{aligned} y_{it} = & \quad \beta_1 (Post \times Public\, Buyer)_{it} \\ & + \beta_2 (Post \times Private\, Buyer)_{it} \\ & + X_{it} + \alpha_i + \eta_{it} \end{aligned}$$

Independent Variables

X_{it}: State $\times$Regional Electricity Market $\times$ **Feasible Fuel Set** $\times$ Combined cycle $\times$ Week $\times$ Year FE

Results

Decomposition of Emissions Intensity Change

Specification

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\begin{aligned}
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+ \quad & \beta_2(Post \times Private\,Buyer)_{it} \\
+ \quad & X_{it} + \alpha_i + \eta_{it}
\end{aligned}
$$

Independent Variables

X_{it}: State $\times$Regional Electricity Market $\times$ **Primary and Secondary Fuel Burned** $\times$ Combined cycle $\times$ Week $\times$ Year FE

Results

Decomposition of Emissions Intensity Change

$$\underbrace{\Delta ln(\frac{CO_2}{Generation})}_{\Delta Emissions\ Rate} = \underbrace{\Delta ln(\frac{CO_2}{Heat\ Input})}_{\Delta Reporting\ /\ Fuel\ Subtype} + \underbrace{\Delta ln(\frac{Heat\ Input}{Generation})}_{\Delta Productive\ Efficiency}$$

Coal :	$-0.043**$	0.005	$-0.038**$
Gas :	$-0.016**$	$.000$	-0.015

- Emissions rate declines entirely due to efficiency improvements Decomp Reg
- Physical efficiency = Economic efficiency = Environmental efficiency
- Fossil fuel combustion generates 73% of total GHG emissions and 45% of total industrial GHG emissions

Selection

What might explain emissions intensity reductions at coal fired plants ?

- Selection of assets that would have improved on their own

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- Selection of relatively emissions intense units to improve
  - Coal units sold to private and public had emissions rates that were 5.7% and 0.8% higher vis-a-vis comparables, respectively, in the pre-divestment period.
  - Imprecise estimates

Summary

Climate Effects

- Public to private sales are innocuous
- Private firms did not operate in more emissive ways vis-a-vis public firms

Outline

Data

Data Sources

- **Datasets covered previously**
- **Center for Research in Security Prices (CRSP)**
  - Stock price, factor return, risk-free rate data of publicly traded firms in the US from 2000-2022

Deal Counts

Sale Type	Study of Seller Valuations Deal Count
Publicly Traded to Publicly Traded	45
Publicly Traded to Private	88
All	133

Outline

Empirical Strategy and Data

Empirical Strategy

- **Methodology:** Event study
- **Return model:** Carhart four-factor model

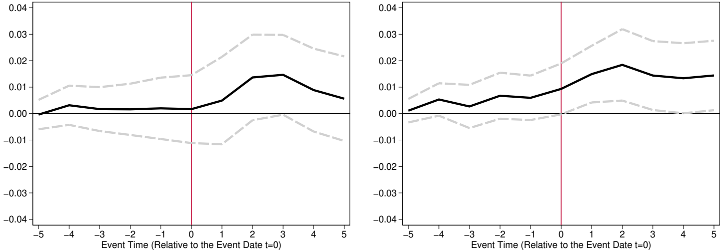
$$
\begin{aligned}
AR^i_{t-1,t} &\equiv r^i_{t-1,t} - \mathbb{E}_{t-1}(r^i_{t-1,t}) && (1)\\
&= (r^i_{t-1,t} - r^{Risk-free}_{t-1,t}) && (2)\\
&- (\alpha^i + \beta_1 f^{Market}_{t-1,t} + \beta_2 f^{SMB}_{t-1,t} + \beta_3 f^{HML}_{t-1,t} + \beta_4 f^{Mom}_{t-1,t}) && (3)
\end{aligned}
$$

- **Event window:** 11 day symmetric window

Outline

CAR(-5,5)

Figure: Average Cumulative Abnormal Returns Around Plant Sale Announcements

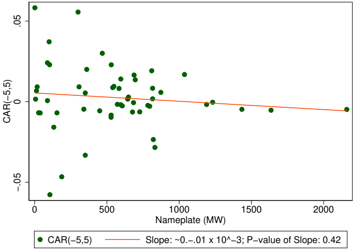


(a) Publicly Traded to Publicly Traded (b) Publicly Traded to Private

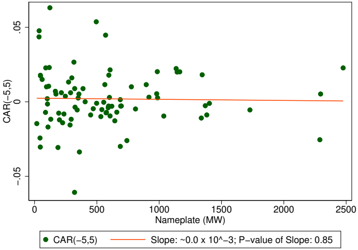
Notes: This figure shows the average cumulative returns (CARs) around plant sale announcements by sale type: Publicly Traded to Publicly Traded and Publicly Traded to Private of the seller. The event window is plotted on the x-axis and starts five business days before the event, and ends five business days after the event. The CARs averaged across firms are plotted on the y-axis; daily CARs are based on expected return estimates generated using the Fama-French factor plus Momentum model. Dashed lines indicate the 95% confidence interval.

Cross Section

Cross section of returns not meaningfully correlated with nameplate capacities



(c) Publicly Traded to Publicly Traded



(d) Publicly Traded to Private

Summary

Financial effects

- Sales to private firms earn announcement returns of 1.4%. However, statistically indistinguishable from announcement returns in public to public sales.
- Implication: No premium, and thus incentive, to sell to more opaque, private firm

Outline

Model

- What are the effects of ESG pressure on public but not private firms when there is trading in assets?
- **Static, general equilibrium** model of asset ownership and emissions
  - Firms
  - Consumers
  - Equilibrium

Outline

Firms

- Two firm types in unit continuum: public and private firms
  - Identical endowments of production technologies
  - Different cost of emitting
- Private firm variables denoted by tilde

Firms

Endowments

- Each firm is endowed with two types of assets–a clean asset and a dirty asset– indexed by $f \in \{C, D\}$.
- No firm entry or asset creation.
- Asset f takes input x_f and produces final goods ouptut y_f and emissions e_f.

Firms

Asset Types

- Production function

$$y_C \equiv min(x_C^{1/2}, \bar{np}_C),$$
$$y_D \equiv min(x_D^{1/2}, \bar{np}_D)$$

  - np_C: clean asset's capacity constraint
  - np_D: dirty asset's capacity constraint

- Emissions function

$$e_C = 0,$$
$$e_D = x_D.$$

Firms

Optimization Problem

- Firm i chooses input demands x_C^i, x_D^i to maximize

$$\max_{\{x_C, x_D\}} \underbrace{py_C^i + py_D^i}_{Revenue} - \underbrace{cx_D^i}_{Cost\,of\,Inputs} - \underbrace{\phi^i x_D}_{Cost\,of\,Emitting}$$

$$s.t.\; py_C^i + py_D^i - cx_D^i - \phi^i x_D^i \geq 0,$$

  - c: dirty asset input price, exogenous
  - p: final goods price, as if exogenous
  - ϕ^i : cost of emitting, exogenous

Representative Consumer

Aggregate Demand Function

- Aggregate demand function is

$$d = \bar{n}p_C + a - bp, \tag{4}$$

  where $a, b > 0$.
- Assume clean assets are operating at maximum capacities and the dirty asset is the marginal asset.

Equilibrium

[redacted]

An equilibrium is the set of ownership choices, input demands, production quantities, and the final goods price $\{s^*, x^*, \tilde{x}^*, y^*, \tilde{y}^*, p^*\}$ such that shocked firms and unshocked firms maximize their objective functions and the final goods market clears.

Timing

- **Timing**
  - Firms begin with identical endowments and costs of emitting
  - Public (but not private) firms experience an unanticipated positive shock Φ to their cost of emitting?
$$\Phi \equiv \frac{\phi}{\tilde{\phi}} > 0.$$
  - Firms trade assets
  - Firms make input demands, produce and emit, and sell in the final goods market

Trading

Assumptions

- Within a firm type, firms have symmetric beliefs and strategies
  - If trading occurs, one firm type will own all assets
- Relative bargaining power of public firms is fixed and parameterized by $\lambda \in (0, 1)$.

Outline

Preview of Findings

Theoretical: Model Insights

- There can be multiple equilibria. The prevailing equilibrium is pinned down by the final good's demand elasticity.
- The emissions consequence is equilibrium-dependent and sensitive to the choice of the baseline for emissions, which may be an unobservable counterfactual.

Equilibrium	Demand Elasticity	Change in Emissions (Traded Asset)	
		Baseline	
		Pre-shock	No Trade
Greenwashing	High	0	$\uparrow$
No Trade	Medium	$\downarrow$	0
Impact	Low	$\downarrow$	0

Preview of Findings

Theoretical: Model Insights

- There can be multiple equilibria. The prevailing equilibrium is pinned down by the final good's demand elasticity.
- The emissions consequence is equilibrium-dependent and sensitive to the choice of the baseline for emissions, which may be an unobservable counterfactual.

Equilibrium	Demand Elasticity	Change in Emissions (Traded Asset, Aggregate)	
		Baseline	
		Pre-shock	No Trade
Greenwashing	High	$0, 0$	$\uparrow, \uparrow$
No Trade	Medium	$\downarrow, \downarrow$	$0, 0$
Impact	Low	$\downarrow, \downarrow$	$0, \downarrow$

Conclusion

- This paper was motivated by concerns that ESG pressure incentivize public to private sales
  - that lead to emissions increases and
  - financially rewards public sellers above and beyond **public to public** sales.
- I find **no evidence** to support these hypotheses in the past two decades using unit level emissions data at the weekly frequency in an asset class that generates 25% of US emissions.
- I develop a model that confirms that greenwashing by public firms can occur in a competitive equilibrium when public firms are shocked with higher costs of emitting.