Climate Transition Risk and the Energy Sector

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January 2025

Motivation

- Energy production accounts for 3/4 of global greenhouse gas emissions
  - Conventional view: Regulatory climate transition risks = threat to fossil fuel firms
  - Data: Despite an acceleration of the green transition, many fossil fuel firms are trading at or near all-time highs (e.g., Chevron, Exxon)
    - Alekseev et al (2024): Fund managers concerned with climate risks do not divest from XLE
- **This paper:** Theory & data to better understand the effect of different types of climate transition risks on the energy sector
  - What are the implications for prices, investment, production, and valuations?
  - Useful to better design and target policies

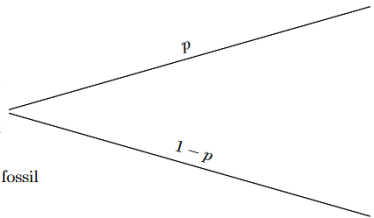
This paper

- Two-period general equilibrium model to study climate transition risk and energy sector
- Different firms can provide energy to the economy:
  - Fossil fuel firms can supply to entire economy, but production entails carbon emissions
    - Incumbent: Developed reserves to extract today or tomorrow
    - Entrant: No reserves, invest today to extract tomorrow
  - Renewable energy firms have no carbon emissions, but can only meet part of energy demand
    - Temporal: Intermittency
    - Sectoral: Non-electrifiable sectors (steel production, maritime and air transportation)
- Different types of transition risk [will have quite different effects]
  - Oil capacity restrictions: Affect entrants' ability to develop capacity for tomorrow
  - Tech breakthrough probability: Affect chance renewables can supply all demand
  - Higher future carbon taxes: Affect after-tax revenue of selling oil tomorrow

This paper

$t = 0$:

- Incumbent fossil fuel firm supplies energy.
- Entrant fossil fuel firm installs production capacity.
- Renewable energy firm installs production capacity.
- Government possibly imposes tax on new fossil fuel capacity.



$t = 1$: **Breakthrough Technology (BT) Scenario**

- All producers compete in integrated market for energy.
- Government might impose taxes on carbon emissions.

$t = 1$: **Current Technology (CT) Scenario**

- Fossil fuel firms supply in the Non-Electrifiable market.
- Green firm supplies in the Electrifiable market.

This paper

- Different effects of various transition risks on current energy price P_0
  - Oil capacity restrictions: $\uparrow P_0$
  - Tech breakthrough probability: $\downarrow P_0$
  - Higher future carbon taxes: Uncertain effect
- *This presentation:* Consider each transition risk separately with minimally required model components and notation required to understand main forces.
  - Paper: Full model including all firms & transition risks jointly

Transition Risk 1: Oil Capacity Restrictions

Transition Risk 1: Oil Capacity Restrictions

- Incumbent:
  - Some existing capacity of developed reserves
  - Key Decision: How much to extract today vs. tomorrow [convex costs]
- New Entrant:
  - No existing capacity
  - Key decision: How much to invest today to extract tomorrow [convex costs]
- Transition Risk: Tax τ on investment in new capacity by entrant
  - Drilling Restrictions; ESG restrictions on lending to oil & gas
- Main Force: $\uparrow \tau \quad \rightarrow \quad \downarrow$ Entrant capacity investment $\quad \rightarrow \quad \uparrow P_1$
  $\rightarrow$ Incumbent extracts more tomorrow, less today $\rightarrow \quad \uparrow P_0$

Transition Risk 1: Oil Capacity Restrictions

- Summary: Effects of restrictions on new capacity investments:
  - Hurt new entrants that are taxed
  - Drive up prices tomorrow and today (intertemporal inventory management by incumbent)
  - Help incumbents (and renewable firms) who now face less competition

"Lowering the cost of doing business — say, through less stringent environmental rules — could help smaller, wildcatter-type producers join the drilling party, potentially pinching profitability for the industry overall."

– The Wall Street Journal, August 2nd 2024

Transition Risk 1: Oil Capacity Restrictions

Empirical Results: Systematic Evidence

Transition Risk 1: Oil Capacity Restrictions

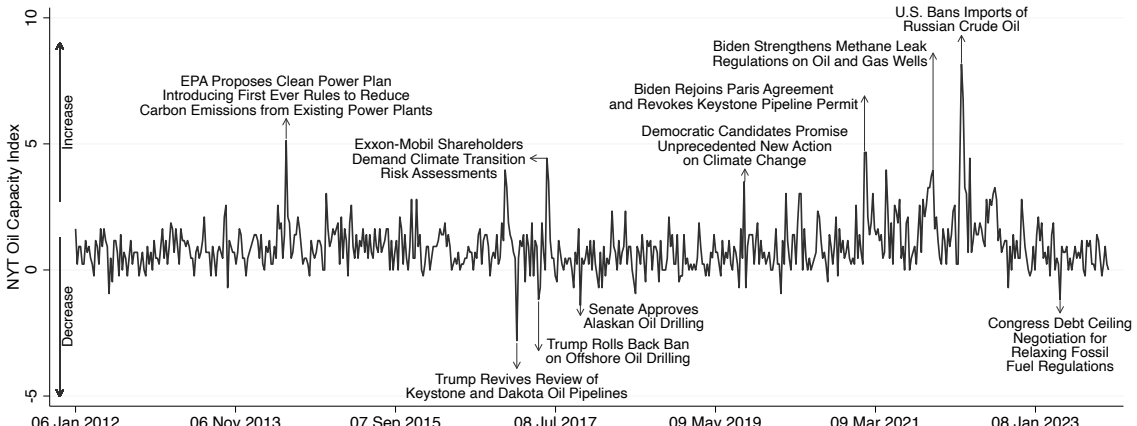
Empirical Results: Systematic Evidence

- Create *NYT-Oil Capacity News Index* by using GPT-4o Mini to identify articles in the full text of the New York Times (NYT) that describe oil capacity restrictions
  - Extract articles over 12-year sample period (2012–2023) with energy-related keywords
  - Prompt GPT-4o Mini on likelihood and impact of restrictions on fossil fuel companies
  - Create index where positive scores indicate more restrictions on the fossil fuel capacity

More

Transition Risk 1: Oil Capacity Restrictions

Empirical Results: Systematic Evidence



Transition Risk 1: Oil Capacity Restrictions

Empirical Results: Systematic Evidence for Stock Returns

How do weekly innovations in news index affect the stock returns of different firms?

- Fossil fuel entrants vs. incumbents
  - In practice, most fossil fuel firms are some mix of existing and prospective wells
  - Developed Ratio: Importance of developed vs. undeveloped reserves (existing vs. new wells)
- Renewable firms; Those held by solar and wind ETFs TAN and FAN

Transition Risk 1: Oil Capacity Restrictions

Empirical Results: Systematic Evidence for Stock Returns

$$R_{i,t} = \alpha + \gamma_i + \beta_1 \nu_t^{OC} \mathsf{Fos}_i + \beta_2 \nu_t^{OC} \mathsf{Fos}_i \times \mathsf{DevRat}_{i,t} + \beta_3 \nu_t^{OC} \mathsf{Ren}_i + \epsilon_{i,t},$$

	Stock Returns
Fossil Fuel Company × Oil Capacity Index AR(1) Innovation	-0.0050**
	(0.0023)
Fossil Fuel Company × Oil Capacity Index AR(1) Innovation × Developed Ratio	0.0074*
	(0.0039)
Renewable × Oil Capacity Index AR(1) Innovation	0.0023*
	(0.0012)
Company FE	Yes
Remove Market from Stock Returns	Yes
R^2	0.507
Observations	46805

▸ Specification Details ▸ Case Study

Transition Risk 1: Oil Capacity Restrictions

Empirical Results: Systematic Evidence for Oil Prices

$$f_t^h = \alpha + \beta_1 \nu_t^{\mathsf{EC}} + \beta_2 \nu_t^{\mathsf{BT}} + \beta_2 \nu_t^{\mathsf{OC}} + \mathit{Controls}_t + \epsilon_t,$$

	Monthly Level		
	Avg 1-12m	Avg 13-60m	Avg 1-60m
	(1)	(2)	(3)
Index AR(1) Innovation - Oil Capacity	-0.0085	-0.0023	-0.0036
	(0.0057)	(0.0035)	(0.0043)
Controls	Yes	Yes	Yes
R^2	0.509	0.482	0.540
Observations	131	131	131

▸ Specification Details

Transition Risk 2: Technological Breakthrough

Transition Risk 2: Technological Breakthrough

- Renewable firm:
  - Invest in capacity today to supply zero-marginal-cost green energy tomorrow
- Current Technology (CT): Can only supply share q of energy demand (normalize to zero)
  - Intermittency, Non-electrifiability
- Breakthrough Technology (CT): Can supply energy to all sectors of economy
  - Battery Storage + Electrifiability
  - Breakthrough arrives with probability $Prob^{BT}$
- **Technological Transition Risks:** Changes in $Prob^{BT}$

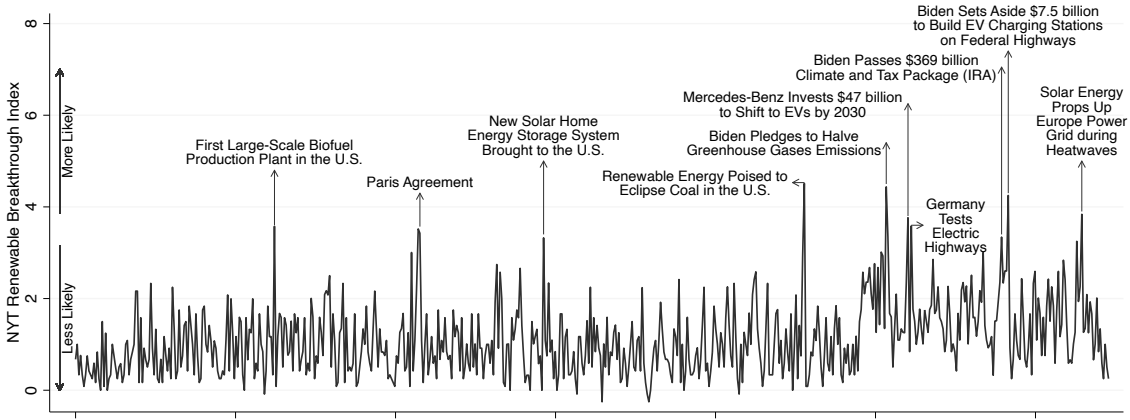
Transition Risk 2: Technological Breakthrough

- Main Force: $\uparrow Prob^{BT}$ $\rightarrow$ $\uparrow$ Renewable Capacity $\rightarrow$ $\downarrow P^{BT}$ $\rightarrow$ $\downarrow E(P_1)$
  $\rightarrow$ New entrant: invests less capacity today $\rightarrow$ $\uparrow E(P_1)$
  $\rightarrow$ Incumbent: extracts more today, less tomorrow $\rightarrow$ $\downarrow P_0$

- Effects of increasing chance of technology breakthrough:
  - Lower prices today and tomorrow
  - Raise oil extraction today (do it while you still can, intertemporal choice $\rightarrow$ "green paradox")
  - Raise valuation of renewable firms
  - Hurt valuation of fossil fuel firms, but less for incumbents (who benefit from less entry in non-breakthrough state, and can partially benefit from inventory management).

Transition Risk 2: Technological Breakthrough

Empirical Evidence: *NYT-Renewable Breakthrough News Index*



▸ More

Transition Risk 2: Technological Breakthrough

Empirical Results: Systematic Evidence for Stock Returns

$$R_{i,t} = \alpha + \gamma_i + \beta_1 \nu_t^{BT} \text{Fos}_i + \beta_2 \nu_t^{BT} \text{Fos}_i \times \text{DevRat}_{i,t} + \beta_3 \nu_t^{BT} \text{Ren}_i + \epsilon_{i,t},$$

	Stock Returns
Fossil Fuel Company × Tech Breakthrough Index AR(1) Innovation	-0.0053***
	(0.0015)
Fossil Fuel Company × Tech Breakthrough Index AR(1) Innovation × Developed Ratio	0.0115***
	(0.0024)
Renewable × Tech Breakthrough Index AR(1) Innovation	0.0007**
	(0.0003)
Company FE	Yes
Remove Market from Stock Returns	Yes
R^2	0.550
Observations	46805

▸ Specification Details

Transition Risk 2: Technological Breakthrough

Empirical Results: Systematic Evidence for Oil Prices

$$f_t^h = \alpha + \beta_1 \nu_t^{\mathsf{EC}} + \beta_2 \nu_t^{\mathsf{BT}} + \beta_2 \nu_t^{\mathsf{OC}} + \mathit{Controls}_t + \epsilon_t,$$

	Monthly Level		
	Avg 1-12m	Avg 13-60m	Avg 1-60m
	(1)	(2)	(3)
Index AR(1) Innovation - Oil Capacity	-0.0085	-0.0023	-0.0036
	(0.0057)	(0.0035)	(0.0043)
Index AR(1) Innovation - Renewable Breakthrough	-0.0141**	-0.0093**	-0.0140***
	(0.0068)	(0.0047)	(0.0052)
Controls	Yes	Yes	Yes
R^2	0.509	0.482	0.540
Observations	131	131	131

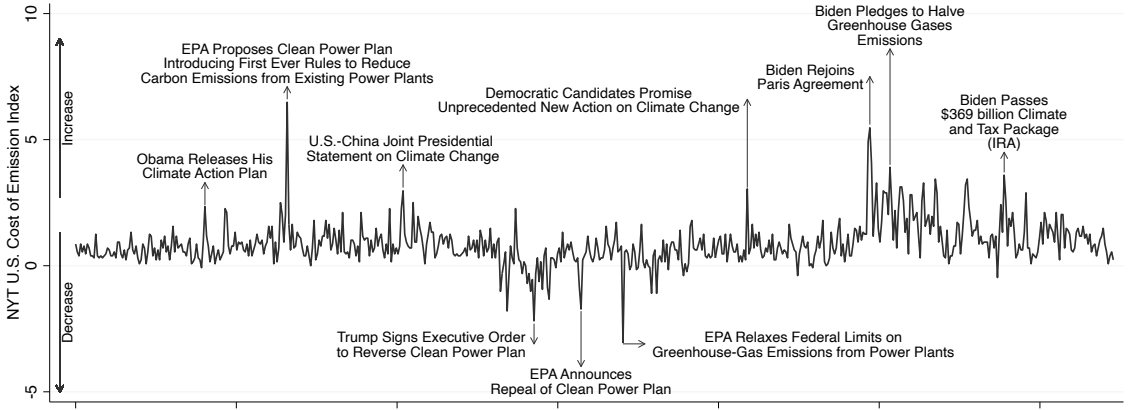
▸ Specification Details

Transition Risk 3: Carbon Tax Expectation

- Carbon taxes in some states of the world, but not others.
  - In paper: Optimal policy has higher carbon taxes in BT state (allows reducing carbon emissions without driving up energy prices, since renewable alternative available)
  - Transition Risk: Carbon tax level in BT state (normalize non-BT state carbon taxes to zero)
- Main forces similar to tech breakthrough probability, but some additional subtlety
  - Possibility of "stranded assets" by incumbent in BT state means that marginal inventory decision may no longer depend on $\partial E(P_1)$ may only depend on ∂P^{CT}
    - Value of *marginal* unit in BT state already zero, so further declines in P^{BT} do not affect value of inventory at $t = 1$
  - As entrant continues to reduce investment with higher taxes, P^{CT} increases
  - Incumbent may actually shift more inventory to $t = 1$, even if $E(P_1)$ falls, could raise P_0
- Same result holds for increases in renewable efficiency, lowering energy price in BT state

Transition Risk 3: Carbon Tax Expectation

Empirical Evidence: *NYT-Emission Cost News Index*



▸ More

Transition Risk 3: Carbon Tax Expectation

Empirical Results: Systematic Evidence for Stock Returns

$$R_{i,t} = \alpha + \gamma_i + \beta_1 \nu_t^{CT} \text{Fos}_i + \beta_2 \nu_t^{CT} \text{Fos}_i \times \text{DevRat}_{i,t} + \beta_3 \nu_t^{CT} \text{Ren}_i + \epsilon_{i,t},$$

	Stock Return
Fossil Fuel Company × Carbon Tax Index AR(1) Innovation	-0.0055***
	(0.0019)
Fossil Fuel Company × Carbon Tax Index AR(1) Innovation × Developed Ratio	0.0073**
	(0.0028)
Renewable × Carbon Tax Index AR(1) Innovation	0.0020**
	(0.0010)
Company FE	Yes
Remove Market from Stock Returns	Yes
R^2	0.512
Observations	46805

▸ Specification Details

Transition Risk 3: Carbon Tax Expectation

Empirical Results: Systematic Evidence for Oil Prices

$$f_t^h = \alpha + \beta_1 \nu_t^{\text{EC}} + \beta_2 \nu_t^{\text{BT}} + \beta_2 \nu_t^{\text{OC}} + \textit{Controls}_t + \epsilon_t,$$

	Monthly Level		
	Avg 1-12m	Avg 13-60m	Avg 1-60m
	(1)	(2)	(3)
Index AR(1) Innovation - Oil Capacity	-0.0085	-0.0023	-0.0036
	(0.0057)	(0.0035)	(0.0043)
Index AR(1) Innovation - Renewable Breakthrough	-0.0141**	-0.0093**	-0.0140***
	(0.0068)	(0.0047)	(0.0052)
Index AR(1) Innovation - Emission Cost	0.0122*	0.0080**	0.0104**
	(0.0064)	(0.0040)	(0.0045)
Controls	Yes	Yes	Yes
p-value Emission Cost = Renewable Breakthrough	0.021	0.019	0.0031
p-value Emission Cost = Oil Capacity	0.027	0.062	0.040
p-value Renewable Breakthrough = Oil Capacity	0.55	0.25	0.14
R^2	0.509	0.482	0.540
Observations	131	131	131

▸ Specification Details

This paper

Increase in:	P(Tech Breakthrough)	Carbon tax in BT state	Drilling restrictions
Current energy price (P_0)	Decreases	Uncertain	Increases
Future energy price ($E[P_1]$)	Decreases	Increases	Increases
Incumbent fossil fuel producer			
Inventory	Decreases	Uncertain	Increases
Stock price	Decreases (less)	Decreases (less)	Increases
Entrant fossil fuel producer			
Production capacity	Decreases	Decreases	Decreases
Stock price	Decreases (more)	Decreases (more)	Decreases
Renewable energy producer			
Production capacity	Increases	Increases	Increases
Stock price	Increases	Increases	Increases

This paper

Increase in:	P(Tech Breakthrough)	Carbon tax in BT state	Drilling restrictions
Current energy price (P_0)	Decreases	Uncertain	Increases
Future energy price ($E[P_1]$)	Decreases	Increases	Increases
Incumbent fossil fuel producer			
Inventory	Decreases	Uncertain	Increases
Stock price	Decreases (less)	Decreases (less)	Increases
Entrant fossil fuel producer			
Production capacity	Decreases	Decreases	Decreases
Stock price	Decreases (more)	Decreases (more)	Decreases
Renewable energy producer			
Production capacity	Increases	Increases	Increases
Stock price	Increases	Increases	Increases

This paper

Increase in:	P(Tech Breakthrough)	Carbon tax in BT state	Drilling restrictions
Current energy price (P_0)	Decreases	Uncertain	Increases
Future energy price ($E[P_1]$)	Decreases	Increases	Increases
Incumbent fossil fuel producer			
Inventory	Decreases	Uncertain	Increases
Stock price	Decreases (less)	Decreases (less)	Increases
Entrant fossil fuel producer			
Production capacity	Decreases	Decreases	Decreases
Stock price	Decreases (more)	Decreases (more)	Decreases
Renewable energy producer			
Production capacity	Increases	Increases	Increases
Stock price	Increases	Increases	Increases

This paper

Increase in:	P(Tech Breakthrough)	Carbon tax in BT state	Drilling restrictions
Current energy price (P_0)	Decreases	Uncertain	Increases
Future energy price ($E[P_1]$)	Decreases	Increases	Increases
Incumbent fossil fuel producer			
Inventory	Decreases	Uncertain	Increases
Stock price	Decreases (less)	Decreases (less)	Increases
Entrant fossil fuel producer			
Production capacity	Decreases	Decreases	Decreases
Stock price	Decreases (more)	Decreases (more)	Decreases
Renewable energy producer			
Production capacity	Increases	Increases	Increases
Stock price	Increases	Increases	Increases

Conclusion

- Different climate transition risks have different effects on energy prices and valuations of fossil fuel firms
  - Model can rationalize the good performance of oil majors with high developed reserves even as (some) transition risks materialize
  - Key to understand the effects on energy prices
- Important to better understand these distinctions for optimal climate policy design

"Historically, though, traditional energy has performed slightly better under Democrats [...]. That is because they tend to favor putting roadblocks on new supply, which helps limit capital spending and boost oil prices [...]. And those roadblocks tend to be more damaging to small producers rather than giants."

– The Wall Street Journal, November 18th 2024

Appendix

NYT News Index Construction

- Extract energy-related articles with 8 keywords: "carbon", "renewable", "drilling", "fossil", "oil and gas", "emissions", "solar", and "pipeline"
- Filter articles from 9 of 10 most frequent sections in the NYT: "business financial", "national", "foreign", "metropolitan", "science", "climate", "us", "editorial", "business"
  - Exclude "opinion" to capture direct news like new policy announcements
- For each article, we ask GPT to identify if it represents news about carbon taxes, a potential renewable energy breakthrough, or oil capacity restrictions ▸ GPT Prompt

▸ Oil Capacity Index ▸ Renewable Breakthrough Index ▸ Carbon Tax Index

GPT Prompt Format

Carbon Tax Prompt

Here is a news article:

"%s"

Please answer the following questions and present your findings as a single JSON object, conforming to the following structure:

{'Question1': '(choice id)'};
{'Question2': '(choice id)'};
{'Question3': '(choice id)'};
{'Question4': '(choice id)'};
{'Question5': Provide detailed explanations on Question1 to Question4, identifying specific parts of the article or exact policies discussed that contribute to this score. The explanation should be concise and precise, directly relating to the aspects mentioned in the article. (less than 150 words)};

- - -

Question1: Does this article discuss U.S. carbon pricing policy, or factors related to U.S. carbon pricing policy?
(a) Yes
(b) No

GPT Prompt Format

Carbon Tax Prompt

Question2: Does this article indicate a tightening or loosening U.S. carbon pricing policy?
(a) Tightening
(b) Loosening
(c) Neutral - The article does not provide specific details or evidence regarding changes in U.S. carbon pricing policy.

Question3: How likely is the change you indicated in Question2?
(a) Extremely Likely
(b) Very Likely
(c) Somewhat Likely
(d) Slightly Likely
(e) Neutral - if answered Neutral in Question2.

Question4: How significant do you anticipate the impact of this news about U.S. carbon pricing policy will be on the market prices and operational strategies of companies in oil/gas industry?
(a) Most Significant Impact
(b) Highly Significant Impact
(c) Moderate Impact
(d) Minimal Impact
(e) No Impact

Full Regression Specification

- Stock return regression specification for news index k:

$$R_{i,t} = \alpha_k + \gamma_i + \beta_{1,k}\nu_t^k + \beta_{2,k}\nu_t^k \text{Fos}_i + \beta_{3,k}\nu_t^k \text{Fos}_i \text{DevRat}_{i,t} + \beta_{4,k}\nu_{k,t}\text{Ren}_i + \epsilon_{k,i,t},$$

  - $R_{i,t}$: 3-year rolling market beta-hedged return of stock i at week t from CRSP
  - γ_i: firm fixed effects
  - ν_t^k: AR(1) innovations of NYT Transition News Index k
  - Fos_i: fossil fuel companies engaged in the exploration and production of oil and gas (GICS codes 10102010 and 10102020)
  - $\text{DevRat}_{i,t}$: ratio of dollar amount of proved developed reserves for oil, natural gas, and natural gas liquids over total proved reserves
  - Ren_i: renewable firms identified by holdings of Invesco Solar & First Trust Global Wind Energy ETFs

▸ Oil Capacity Regression ▸ Renewable Breakthrough Regression ▸ Carbon Tax Regression

Oil Futures Price Regression Specification

- Oil futures price regression specification:

$$f_t^h = \alpha + \beta_1 \nu_t^{\text{EC}} + \beta_2 \nu_t^{\text{BT}} + \beta_2 \nu_t^{\text{OC}} + \textit{Controls}_t + \epsilon_t,$$

  - f_t^h: percentage change in the WTI oil futures price at maturity h from month $t-1$ to t
    - Equal-weighted average returns at different maturities from 1 to 60 months
  - ν_t^k: scaled AR(1) innovations of NYT Transition News Index
    $k \in \{\text{Emission Costs (EC), Renewable Breakthrough (BT), Oil Capacity (OC)}\}$
  - $\textit{Controls}_t$ include other determinants of oil prices (Alquist et al. 2013):
    - U.S. inflation rate and real GDP growth
    - Percentage change in M1 and M2 money supply
    - Chicago Fed National Activity Index (CFNAI)
    - Kilian's (2009) global real activity index
    - Percentage change in zero-coupon treasury yield and stock market excess return
    - OECD liquid fuel consumption change from EIA
  - Sample is 2011-2022

Oil Capacity Regression | Renewable Breakthrough Regression | Carbon Tax Regression

Transition Risk 1: Oil Capacity Restrictions

Empirical Results: Case Study on Drilling Restrictions

- 2024 Trump election: Drill, Drill, Drill ($\downarrow \tau$)

Transition Risk 1: Oil Capacity Restrictions

Empirical Results: Case Study on Drilling Restrictions

- 2024 Trump election: Drill, Drill, Drill ($\downarrow \tau$)
  - Spot oil prices have fallen substantially (obviously other forces too)

Oil prices hit as Trump signals increasing support for more drilling

Transition Risk 1: Oil Capacity Restrictions

Empirical Results: Case Study on Drilling Restrictions

- 2024 Trump election: Drill, Drill, Drill ($\downarrow \tau$)
  - Spot oil prices have fallen substantially (obviously other forces too)
  - Effect on energy firm valuations?

Trump Wins: Here Are the Implications for the Energy Sector

Q. Drill, drill, drill and deregulation is good for oil, right?

A. Well, it will reduce drilling and operating costs (no more pesky regulation) and open up more acreage for drilling. And that will increase oil supply without increasing demand, so draw your own conclusions about where price goes. So, who really comes out ahead except the drilling companies?

Back