Stalling the Green Transition: Investment under Climate Policy Uncertainty

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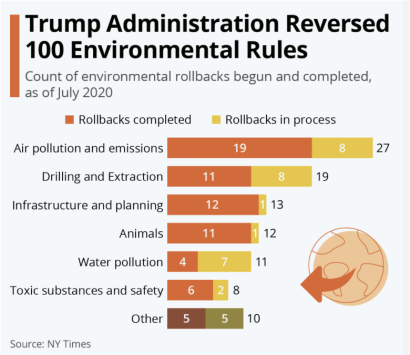
"President Trump, with help from his administration and Republicans in Congress, has reversed course on nearly two dozen environmental rules, regulations and other Obama-era policies during his first 100 days in office." (New York Times, May 3, 2017)



Motivation 1

Policy uncertainty affects rate and direction of investment

- it is well known that firms do not like uncertainty, especially when investments are often irreversible
- uncertainty along one policy dimension may lead firms to re-optimize their investment portfolio
  - Does **climate** policy uncertainty lead us to reduce **green** investment?
- literature: Aggregate policy uncertainty (Gulen and Ion, 2016), Trade policy uncertainty (Handley and Limão, 2015), Environmental policy uncertainty (Noailly et al., 2024; Palikhe et al., 2024)

Motivation 2

Production networks as shock propagation mechanism

- goods and services production involves a complex network of firms and industries
  - upstream and downstream transactions between multiple suppliers and customers
- input-output linkages may transmit disruption at certain firms or industries to other parts of the economy
  - **isolated** microeconomic shocks can turn into **systematic** macroeconomic fluctuations
- literature: China import shock, changes in government spending: (Acemoglu et al. 2016), natural disasters (Barrot and Sauvagnat 2016; Carvalho et al. 2021), extreme weather events (Balboni et al. 2024)

This Paper

- Investigate how firms respond to uncertainty surrounding climate and environmental policies
  - timing and size of carbon tax may affect firm's investment decisions, e.g. on use of dirty vs clean inputs, production technologies, etc
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- Do the results differ for new vs replacement investments? (Livdan and Nezlobin, 2021)
  - Can it proxy green investment?
  - Uncertainty discourages (net) investment
  - Propagation of shocks: Energy-intensive suppliers matter

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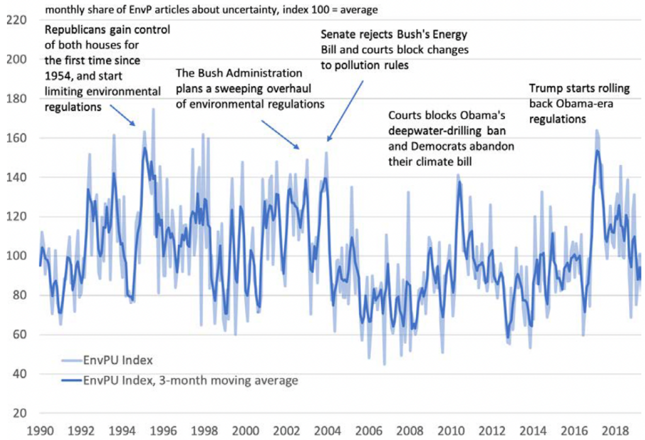
- Do the results differ for new vs replacement investments? (Livdan and Nezlobin, 2021)
  - Can it proxy green investment?
  - Uncertainty discourages (net) investment
  - Propagation of shocks: Energy-intensive suppliers matter
- (Work in progress) Putty-clay model with replacement investment
  - Uncertainty leads to a shift towards replacement (old) investment

Measuring Climate Policy Uncertainty

Noailly et al. (2024): news-based index of environmental policy, 1981–2019



▸ Other news-based indices

Measuring Net vs Replacement Investment

Investment data from Compustat, based on accounting relationships outlined in Livdan and Nezlobin (2021)

- **Total investment**: $PPENT_{t+1} - PPENT_t + WDP_{t+1} + DPC_{t+1}$ where $PPENT$, WDP and DPC are net book value of PP&E, pre-tax write-down and depreciation expenses respectively
  - Captures changes in net capital stock, taking into account write-down and depreciation
- **Net investment**: $PPEGT_{t+1} - PPEGT_t$, or changes in gross PP&E
- **Replacement investment** is simply the difference between the total investment and net investment
- In all regressions, we scaled the investment by the gross PP&E to calculate the investment rate

▸ Graphical explanation ▸ Investment rate trend ▸ Trend by energy intensity

Correlation of net investment with greenness of a firm

	Scope 1 CO_2	Scope 2 CO_2	Scope 3 CO_2	Energy Use
	(1)	(2)	(3)	(4)
Net Investment$_{t+1}$	-0.008*	-0.012*	-0.011	-0.018**
	(0.0702)	(0.0723)	(0.229)	(0.0898)
Replacement Investment$_{t+1}$	-0.002	0.010	-0.041**	-0.005
	(0.168)	(0.223)	(0.509)	(0.300)
Firm FE	yes	yes	yes	yes
Year FE	yes	yes	yes	yes
Mean of dep. var.	11.9	12.2	12.8	6.43
Observations	3411	3331	1861	2991
R-squared	0.974	0.955	0.815	0.889

- Some evidence that firms with a higher net investment is correlated with lower direct carbon emissions (Scope 1) and lower energy use (Scope 2)

Measuring firm-level input-output linkages

Main data source: Capital IQ

- We observe the list of customers + suppliers for each firm, and it allows us to link this to the list in Compustat
- We compute upstream and downstream links (up to four 'network distance') (Carvalho et al., 2021)
- Today: measure if the linkage has any impact + the linked firm is energy-intensive or not
- Future: we plan to measure the intensity of the linkage by
  - gathering (and cleaning!) the customer segment data in Compustat
  - combining the firm network with BEA industry-level network

Proposed strategy

Empirical Strategy

We estimate the effect of climate policy uncertainty $EnvPU_t$ in a standard two-way fixed effect model:

$$Y_{i,t+1} = \beta EI_{i,2012} \times EnvPU_t + X'_{it}\delta + \alpha_i + \alpha_t + \epsilon_{i,t}$$

- $Y_{i,t+1}$ is firm i's investment rate, e.g., total, net and replacement investment rates
- $EI_{i,2012}$ is the energy intensity of i's industry in 2012
- Identification by comparing the effect of uncertainty on energy-intensive firms with non-energy-intensive firms
- Standard errors clustered at 3 digit NAICS level

Result 1 - Uncertainty Discourages Investment

	Total Investment Rate_{t+1}		
	(1)	(2)	(3)
High EI x Env. Policy Uncertainty (mean)	-0.0319***	-0.0322***	-0.0350***
	(0.00734)	(0.0108)	(0.0125)
High EI x Env. Policy (mean)		-0.00191	-0.00342
		(0.0472)	(0.0532)
Energy Prices			-0.0130*
			(0.00747)
Mean of dep. var.	-.00116	-.00116	.0138
Observations	91,601	91,601	72,833
R-squared	0.366	0.366	0.364

Standardized beta coefficients reported. Standard errors clustered at 3 digit NAICS level.

Result 1 - Uncertainty Discourages (Net) Investment

	Net Investment Rate$_{t+1}$			Replacement Investment Rate$_{t+1}$		
	(1)	(2)	(3)	(4)	(5)	(6)
High EI x Env. Policy Unc.	-0.0533***	-0.0519***	-0.0551***	0.0250**	0.0233*	0.0223*
	(0.00941)	(0.0154)	(0.0174)	(0.0101)	(0.0118)	(0.0118)
High EI x Env. Policy		0.00732	0.00779		-0.00984	-0.0124
		(0.0520)	(0.0594)		(0.0161)	(0.0215)
Energy Prices			-0.00727			-0.0109**
			(0.00781)			(0.00523)
Firm FE	yes	yes	yes	yes	yes	yes
Year FE	yes	yes	yes	yes	yes	yes
Mean of dep. var.	-.000332	-.000332	.00773	-.000955	-.000955	.019
Observations	91,242	91,242	72,567	90,991	90,991	72,354
R-squared	0.272	0.272	0.270	0.484	0.484	0.480

Standardized beta coefficients reported. Standard errors clustered at 3 digit NAICS level.

- 1 s.d. increase in uncertainty $\Rightarrow$ 0.05 s.d. decrease in net investment for energy intensive industries ($\sim$ 10% reduction in net investment rate)

Result 2 - Energy-intensive suppliers matters

	Net Investment$_{t+1}$			Replacement Investment$_{t+1}$		
Firms	All	Manu.	Trade	All	Manu.	Trade
	(1)	(2)	(3)	(4)	(5)	(6)
Env. Unc. x EI	-0.0134***	-0.00837**	-0.0124*	0.00341**	0.00275***	0.00132
	(0.00244)	(0.00326)	(0.00645)	(0.00137)	(0.000705)	(0.00118)
Env. Unc. x EI DS1	-0.00121***	-0.000542*	-0.00226***	0.0000325	-0.0000108	0.0000158
	(0.000280)	(0.000297)	(0.000566)	(0.0000837)	(0.000119)	(0.000172)
Mean of dep. var.	.131	.11	.134	.0771	.0662	.0579
Observations	91,242	43,846	13,970	90,991	43,836	13,954
R-squared	0.272	0.256	0.261	0.484	0.383	0.416

- Conditional on own energy intensity, firms using energy-intensive supplier also reduce their investment
- Results are robust to different ways of measuring energy intensity of supplier
- The effect also propagates to suppliers of the suppliers

A Model of New and Replacement Investment

- Why does policy uncertainty incentivize firms to substitute new investment with replacement investment?
- To answer this question, we develop a putty-clay model of investment with replacement investment based on Gilchrist and Williams (2000) and Wei (2003)
  - Firms decide on the characteristics of capital (e.g., energy intensity) at the time of investment
  - Once capital is installed, they remain fixed
  - Replacement investment: allow firms to 'replenish' the depreciated capital (but not its characteristics)
  - Proxy policy uncertainty with uncertainty on energy price

Illustration: a two-period model

- Firms decide how many machines to build in each period. The production function of each machine i of vintage j follows:

$$Y_{i,j} = \theta_{i,j} k_j^{\lambda\alpha} e_j^{\alpha} L_{i,j} \equiv \theta_{i,j} X_j L_{i,j} \tag{1}$$

  where k, e are capital-energy and energy-labor ratios ("characteristics"), and X is the 'average productivity'

- θ_i is the idiosyncratic productivity shock, follows a log-normal distribution, and each machine is operated by one worker only

- Putty-clay nature: once capital is built, "characteristics" are fixed but firms can still decide which machines to operate

Illustration: a two-period model

- Timing of the model:
  1. Firms inherited old capital. Firms decide on (1) the characteristics and the level for the new capital ('new investment') (2) the level (only) for the old capital ('replacement investment')
  2. Energy price P is obtained from a known distribution. Productivity shock is realized for each machine installed. Then, the firm decides which machines to operate, and profits are realized.
- Second stage: firms operate the machine iff $\theta_i X_j \geq P \cdot e_j + W \Rightarrow$ we can deduce the probability that the machine operates $1 - \Phi(z_j)$ where z_j is a function of X_j and prices P, W
- First stage: Firms decide on investment after forming expectations on the energy price, conditional on $1 - \Phi(z_j)$

Some findings

Proposition

The new capital Q_2 is more exposed to large values of P and is therefore more risky than the old capital Q_1. Furthermore, greater uncertainty in P discourages investment, particularly in new capital.

- Some intuitions:
  - new investment: option value of waiting $\Rightarrow$ invest in replacement (old) capital as an outside option
  - When the energy price is high, we show that the variance of profits is higher for new capital
  - Analogous to a portfolio choice where investors shift towards a safer asset (in this case, old capital)

Concluding remarks

- Climate policy uncertainty reduces investment, but only for net investment
- Given the (weak) correlation that net investment is cleaner, this means uncertainty may slow the green transition
- This uncertainty shock appears to propagate through the firm's network

- Next step:
  - To calibrate a quantitative model of new and replacement investment with input-output linkages
  - To quantify the impact of policy/energy price uncertainty on investment and CO_2 emissions

Measuring Climate Policy Uncertainty

News-based indices:

- Baker, Bloom and Davis (2016): seminal work using newspaper coverage frequency (keyword search) to measure economic policy uncertainty
- Engel et al. (2020): captures climate risks as perceived by investors using climate change news from The Wall Street Journal
- Noailly et al. (2024): news-based index of environmental policy 1981-2019
  - 10 major US newspapers
  - EnvP: articles containing keywords relating to ”climate change and the environment” and ”policy and regulations”
  - EnvPU: monthly share of environmental policy uncertainty articles over all environmental and climate policy articles

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Measuring Net vs Replacement Investment

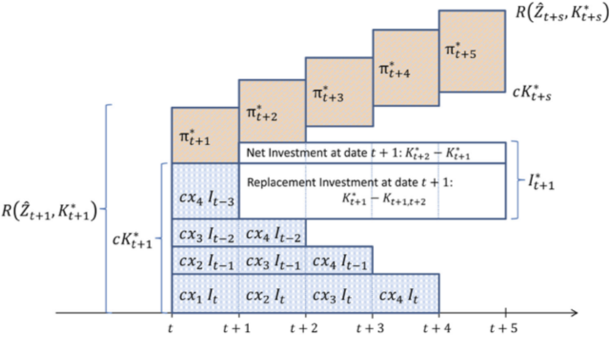

Fig. 3. Optimal investment and valuation with vintage capital. Assets have a useful life of four periods. In period $t+1$, the firm's capital stock, K^*_{t+1}, consists of four vintages corresponding to investments I_{t-3} through I_t, depicted along the vertical axis. The firm generates revenues of $R(\hat{Z}_{t+1}, K^*_{t+1})$ and has a current cost of capital of cK^*_{t+1}, leaving it with optimal economic profits of π^*_{t+1}. At the end of period $t+1$, the oldest vintage, I_{t-3}, is fully retired, and the firm experiences a positive demand shock. The firm's total investment at date $t+1$ is decomposed into its replacement component, $K^*_{t+1} - K_{t+1,t+2}$, and net investment, $K^*_{t+2} - K^*_{t+1}$.

Source: Livdan and Nezlobin (2021)

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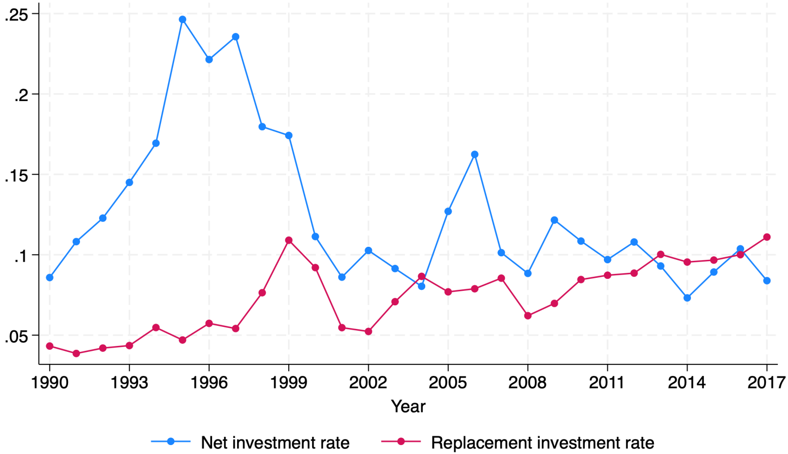
Net and Replacement Investment



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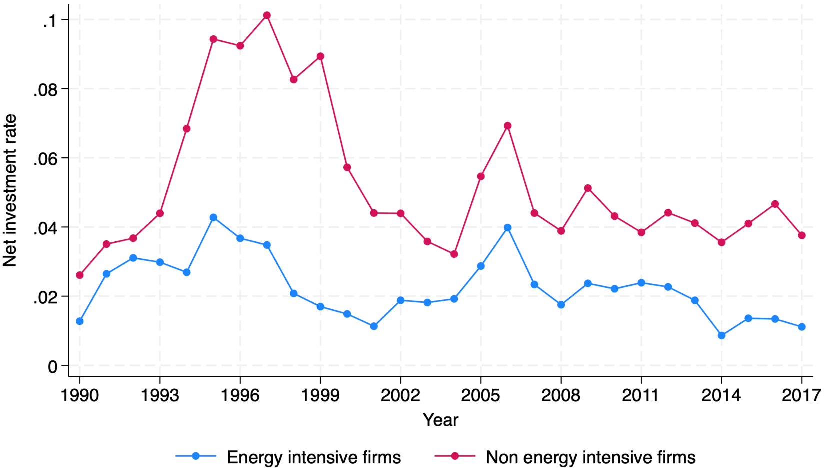
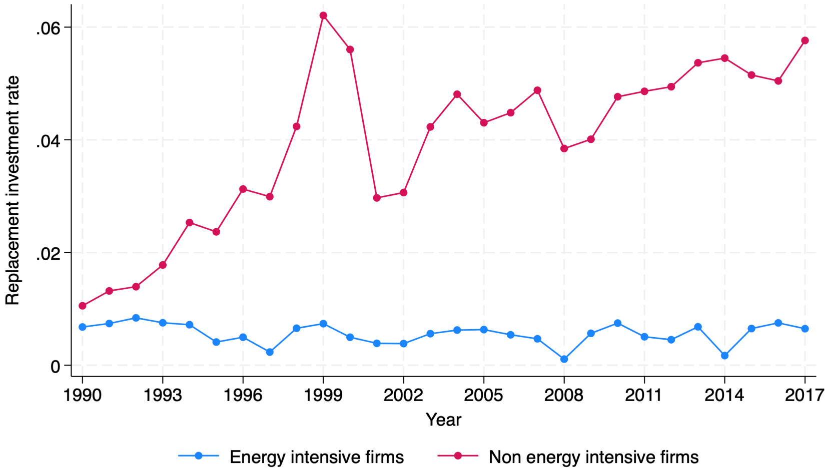
Net Investment

By energy intensity of firm



Replacement Investment

By energy intensity of firm



Measuring Firm-Level Input-Output Linkages

Proposed measure (extension of Herskovic et al. 2020):

$$\alpha_{ij} = \bar{\alpha_{ij}} \times \left[\frac{b_{ij} S_j}{\sum_{k \in ind(j)} b_{ik} S_k} \right]$$

- network is a weighted measure of the strength of relationship between final goods firm i and intermediate goods firm j
- α_{ij} denotes transactions from firm j to firm i
- b_{ij} is a dummy variable indicating whether there are transactions between firms j and i
- S_j is the sales of inputs from firm j to firm i
- $\bar{\alpha_{ij}}$ denotes transactions from j's industry to i's industry

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