Does Environmental Policy Uncertainty Hinder Investments Towards a Low-Carbon Economy?

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Sustainable Economy
National Research Programme

Motivation

- ▶ Difficult to predict whether environmental regulations will be adopted or still be in place in the future
  - ▶ hinges on legislative process
  - ▶ costly regulations facing a lot of opposition
  - ▶ conflicts with other (econ) objectives

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  - conflicts with other (econ) objectives

- Environmental policy uncertainty as major barrier to firms' climate-related investments (EIB, 2021)

Figure 10. Obstacles to climate investment in the European Union and the United States (%)
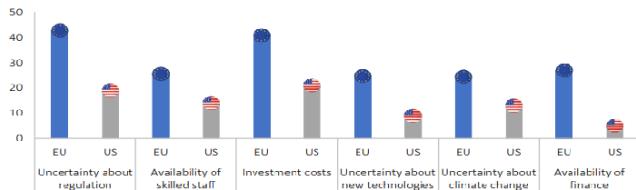
Note: The base is all firms (data not shown for those who said don't know/refused to answer).
Question: To what extent is the following an obstacle to investing in activities to tackle weather events and emissions reduction? Is it a major obstacle, minor obstacle or not an obstacle at all?
Source: EiBIS 2020

Objectives

- We construct a newspaper-based monthly index of US environmental policy uncertainty over 1990-2019 using **machine learning techniques**
  - unpredictability of legislative process
  - unexpected revision or rollback of regulations
  - legal challenges / awaiting for court decision

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  - legal challenges / awaiting for court decision

- How does environmental policy uncertainty relate to clean investments? (micro/firm-level and macro/VAR estimates)

  - venture capital funding for cleantech startups
  - stock price volatility of firms most exposed to environmental policy

Literature

- Theoretical work on uncertainty and investments
  - (policy) uncertainty in real-options framework (Dixit and Pindyck, 1994; Bloom, 2009)
  - Bretschger and Soretz (2018)

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  - Bretschger and Soretz (2018)
- **Empirical literature on policy uncertainty**
  - macroeconomics: Baker et al (2016), EPU index; Julio and Yook (2012)
  - environmental economics
    - Policy events: Dorsey (2019), Lemoine (2017), Sen and von Schickfus (2020)
    - Keywords-based news-index: Basaglia et al (2022)

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    - Keywords-based news-index: Basaglia et al (2022)
- Text-as-data methods in (environmental) economics
  - Gentzkow and Shapiro (2010); Dugoua, Dumas, Noailly (REEP, 2022)

Data and text extraction

- Automated access to 15.2 million articles from the archives of **10 US newspapers over 1981-2019**
  - *New York Times, Washington Post, Wall Street Journal, Houston Chronicle, San Francisco Chronicle, Tampa Bay Times, Dallas Morning News, San Jose Mercury News, San Diego Union Tribune, Boston Herald*

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- Broad query to narrow down the universe to 500,000 articles combining very general keywords on environmental topics and policy terms

- 2-step approach using **supervised machine learning algorithms**
  - Step 1: identify environmental policy (EnvP) articles
  - Step 2: identify sub-group environmental policy uncertainty (EnvPU) articles
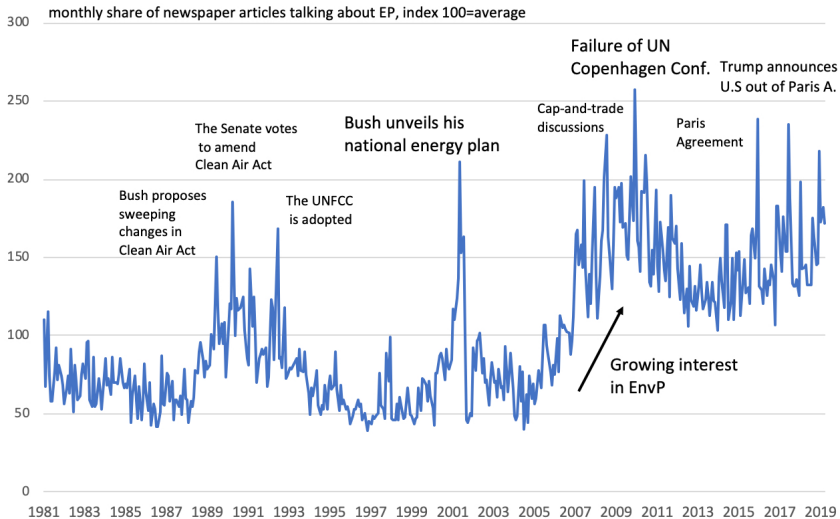
Step 1: Identifying relevant EnvP articles

Training a supervised ML algorithm for text classification

- ▶ Training set of 2'500 articles randomly drawn and manually labeled as input for our support vector machine (SVM) classifier. ▸ What is SVM?

- ▶ SVM algorithm with 10-fold cross validation produces a rule predicting whether an article is about EnvP, based on words in a given article

- ▶ Best-performing algorithm: precision: 78% (close to average inter-annotator agreement of 83%), and recall 67%.

- ▶ Using the SVM prediction rule out-of-sample, we identify 80,045 news articles classified as 'environmental policy' (EnvP) articles.

  ▸ Top keywords   ▸ Top SVM articles

EnvP articles (scaled by total news volume)

monthly share of newspaper articles talking about EP, index 100=average

Bush proposes sweeping changes in Clean Air Act

The Senate votes to amend Clean Air Act

The UNFCC is adopted

Bush unveils his national energy plan

Cap-and-trade discussions

Failure of UN Copenhagen Conf.

Paris Agreement

Trump announces U.S out of Paris A.

Growing interest in EnvP

Source: Dow Jones, EPFL, IHEID, SIB & HES-SO

Step 2: Identifying relevant EnvPU articles

▶ Identifying the sub-set of articles pertaining to 'policy uncertainty' is a difficult task → Baker et al (2016) search for articles including the keyword *uncertain**

▶ Training set of random draw of 622 articles that annotators label manually ▸ How we code EnvPU
  ▶ about 1/3 of articles mention a form of uncertainty about environmental regulations
  ▶ exclude uncertainty not related to regulation
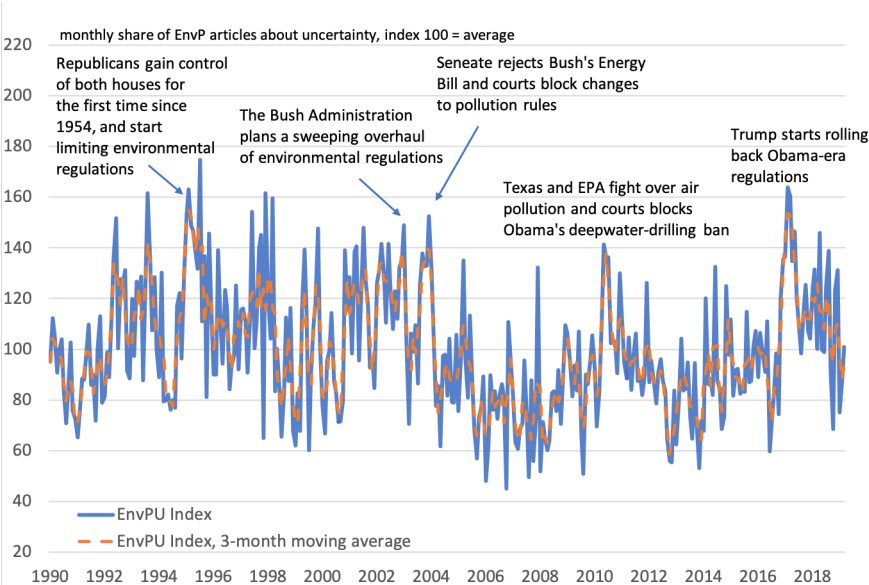
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▶ Best-performing SVM algorithm: precision: 56% and recall 70%.
  ▶ much better than random (30%)
  ▶ two-step approach makes job of the classifier harder – easier to separate topics in a more heterogeneous set of articles

▶ Using SVM prediction rule on our set of 80,000 EnvP articles, we identify 25,174 news articles classifed as EnvPU.

A glimpse into our SVM's decision rule

Word	Weight	Word	Weight	Word	Weight
epa	1.77	cut	0.74	treaty	0.64
agency	1.24	trump	0.73	delay	0.64
rule	1.06	court	0.73	oil	0.64
state	0.93	new	0.71	regulation	0.64
congress	0.93	bill	0.69	economy	0.63
could	0.91	emission	0.69	canada	0.62
administration	0.91	clean	0.69	official	0.62
pipeline	0.90	wind	0.68	fracture	0.62
review	0.90	arpae	0.67	sand	0.61
permit	0.88	issue	0.67	federal	0.61
group	0.86	fight	0.67	lease	0.60
proposal	0.85	clinton	0.67	republican	0.60
drilling	0.81	acid	0.66	lead	0.60
law	0.78	txi	0.66	ballot	0.59
auto	0.75	forest	0.64	cape wind	0.58

Environmental Policy Uncertainty

EnvPU Index (scaled by EnvP)

monthly share of EnvP articles about uncertainty, index 100 = average

Republicans gain control
of both houses for
the first time since
1954, and start
limiting environmental
regulations

The Bush Administration
plans a sweeping overhaul
of environmental regulations

Seneate rejects Bush's Energy
Bill and courts block changes
to pollution rules

Texas and EPA fight over air
pollution and courts blocks
Obama's deepwater-drilling ban

Trump starts rolling
back Obama-era
regulations

— EnvPU Index
--- EnvPU Index, 3-month moving average

EnvPU and political transitions

monthly share of EnvP articles about uncertainty, index 100 = average, 12 month backward moving average

First two years of Bush's presidency
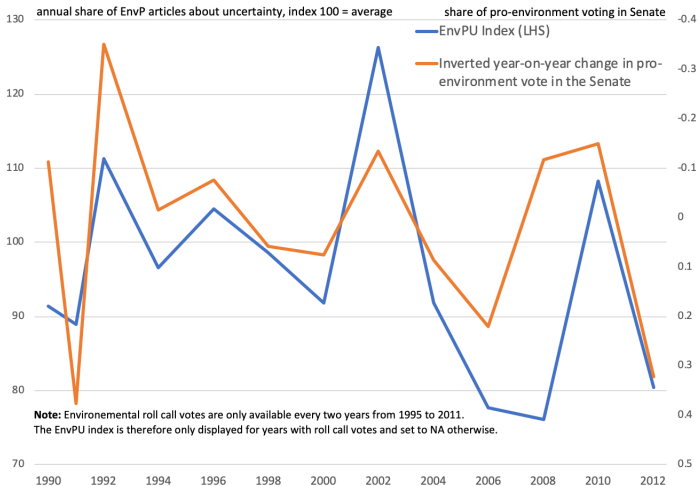
First two years of Obama's presidency

First two years of Trump's presidency
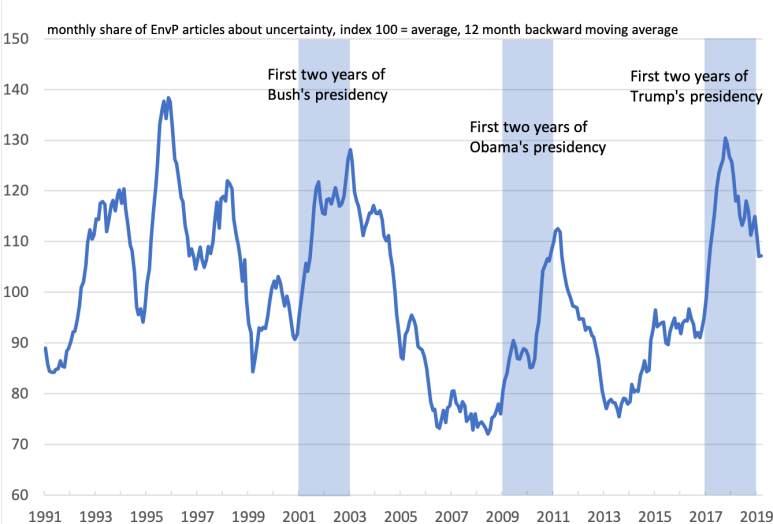
Source: Dow Jones, EPFL, IHEID, SIB & HES-SO

EnvPU and changes in pro-environmental votes

Data on environmental roll call votes for US Congress 1990-2013. Increases in EnvPU corresponds to important drops (inverted) in pro-environmental votes

annual share of EnvP articles about uncertainty, index 100 = average

share of pro-environment voting in Senate

— EnvPU Index (LHS)

— Inverted year-on-year change in pro-environment vote in the Senate

Note: Environemental roll call votes are only available every two years from 1995 to 2011. The EnvPU index is therefore only displayed for years with roll call votes and set to NA otherwise.

EnvPU around elections

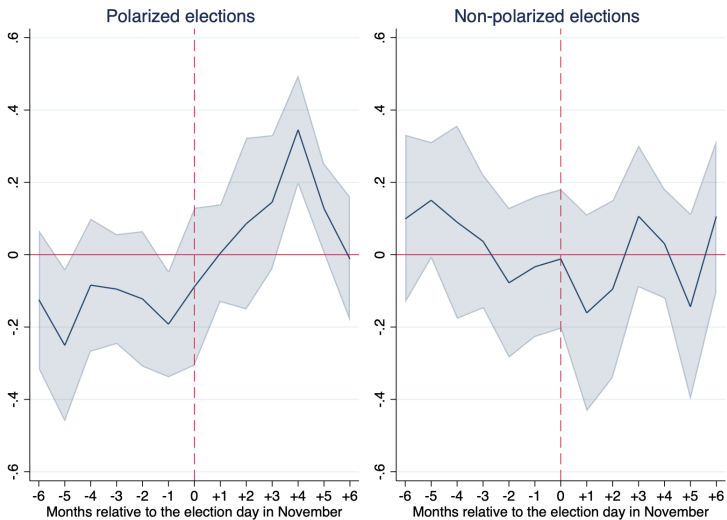Evolution of EnvPU in the months before and after a presidential election (Baker et al, 2020)

$$ln(EnvPU_t) = \gamma_m + \gamma_c + \sum_{n=-6}^{6} \beta_n 1(ElectionMonth_{t-n} = 1) + \epsilon_t \qquad (1)$$
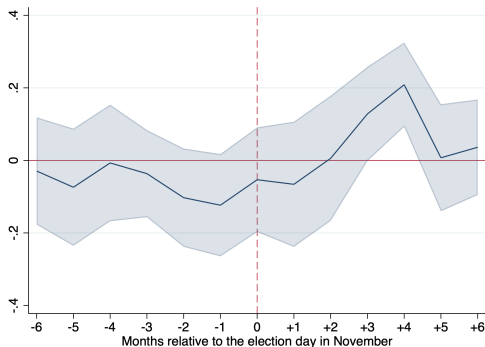
Low EnvPU before presidential elections reflect typical pro-environment consensus (McAlexander and Urpelainen, 2020)

EnvPU around polarized elections

Figure: EnvPU and presidential elections

Further validation

1. Machine-learning index performs significantly better than
   - naive index (uncertain*)
   - dictionary-based methods (uncertainty thesaurus)

2. Manual audit on 900 articles over 2008-2011

3. Liberal vs. conservative newspapers

EnvPU and investments in clean markets

- How does our measure of environmental policy uncertainty relate to investments in clean firms?
  - venture capital investments
  - stock returns volatility of clean firms

- Conceptually, we expect clean startups and firms to be negatively affected (lower investments, higher stock volatility) by EnvPU:
  - more dependent on policy support (environmental externality)
  - cumulate several additional risks (immaturity of markets/technology)

- Causality is challenging - many omitted variables could affect both clean markets and policy uncertainty

- Identification strategy that differentiates firms by exposure to environmental policy uncertainty

Firm-level VC investments (1)

- Crunchbase: 31,808 active startup firms, venture capital funding rounds over Jan 1998-Mar 2019, firm-quarter panel dataset

- Empirical association between EnvPU and probability of receiving VC funding (and amount) in next quarter (OLS and probit)

- Identification strategy differentiates startups by exposure to environmental policy
  - cleantech vs. other startups
  - within cleantech startups, clean energy startups involve more irreversible investments

- Cleantech = 4% , clean energy = 2.4% of VC deals

- Controls: **EnvP**, GDP growth, Fed funds rate, oil price, firm's age

Firm-level VC investments (2)

|	(1) Funded (Q+1)	(2) Funded (Q+1)	(3) Amount (Q+1)
EnvPU index	0.000957**	0.000960**	0.0241**
	(0.000475)	(0.000475)	(0.0116)
EnvPU x Cleantech	-0.00352***		
	(0.00121)		
EnvPU x Cleantech excl. Energy		-0.00159	-0.0734**
		(0.00116)	(0.0294)
EnvPU x Clean Energy		-0.00338***	-0.0703**
		(0.00122)	(0.0316)
EnvP index	-0.00366***	-0.00370***	-0.0345*
	(0.000807)	(0.000807)	(0.0196)
EnvP x Cleantech	0.00516***		
	(0.00102)		
EnvP x Cleantech excl. Energy		0.00272***	0.0565*
		(0.000982)	(0.0314)
EnvP x Clean Energy		0.00501***	0.0729***
		(0.00106)	(0.0255)
Firm FE	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Controls	Yes	Yes	Yes
Industry-time trend	Yes	Yes	Yes
Series FE	Yes	Yes	Yes
Observations	1056221	1056221	57319
Firms	35637	35637	28297

1 SD increase in EnvPU is associated with a decrease of 0.25%-pt in the probability of receiving VC funding (25-pt increase in EnvPU $\rightarrow$ 4% decrease in probability of cleantech startup to get funded)

EnvPU and volatility at the firm level (1)

How does environmental policy uncertainty affect stock volatility of firms most exposed to environmental regulations?

- ▶ exposure measured by firms' Green Revenues share (FTSE Russell) - fixed at pre-sample value or average over period
- ▶ 500 US firms, annual data 2008-2019
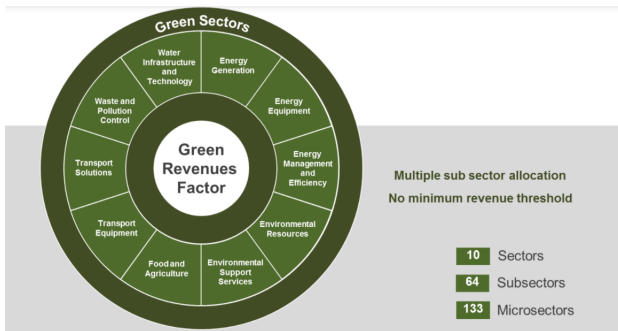
Firm-level stock returns (2)

► Dependent variable: monthly volatility of continuously compounded log returns in excess of safe interest rate for each firm (Datastream)

► Since stock markets may anticipate news endogenously, we extract 'innovation news' (white noise) of the EnvPU index by extracting the residuals from an AR(5) model (Brogaard and Detzel, 2015)

► Additional controls: **EnvP**, size, profitability, leverage and fixed effects.

EnvPU and volatility at the firm level (3)

	(1) Log volatility	(2) Log volatility	(3) Log volatility
EnvPU × AVG GR share	0.0050**		
	(0.0024)		
EnvP × AVG GR share	0.0006		
	(0.0018)		
EnvPU × Top 10% Green		0.0133*	
		(0.0082)	
EnvP × Top 10% Green		0.0043	
		(0.0062)	
EnvPU × Pre-sample GR share			0.0097***
			(0.0030)
EnvP × Pre-sample GR share			-0.0017
			(0.0016)
Firm FE	Yes	Yes	Yes
Month FE	Yes	Yes	Yes
Firm controls	Yes	Yes	Yes
Observations	39955	39955	17869
Firms	438	438	158

Conclusions and next steps

- ▶ Novel methods based on text-mining ML algorithms to build high-frequency news-based index of environmental policy uncertainty

- ▶ Electoral cycles affect environmental policy uncertainty

- ▶ Negative relationship between EnvPU and cleantech startups' probability of receiving VC funds

- ▶ Positive relationship between our news-based EnvPU index and firm stock volatility of exposed firms with larger green revenues

- ▶ Further work on how environmental policy uncertainty deters greenfield FDIs in environmental technology

Supplementary Slides

Sample composition pre and post query
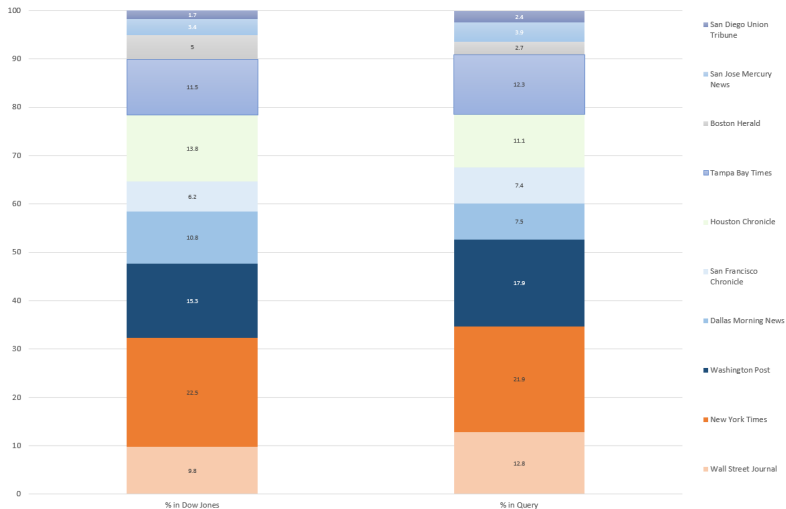
Query

At least one keyword from each category within a proximity of 40 characters.

- ▶ **Climate change and the environment** (e.g. renewable energy generation, energy storage, transport, low-carbon infrastructure and efficiency, water and wastewater, air pollution, waste and recycling, etc.)

- ▶ **Policy and regulation** (e.g. standards, certification, feed-in tariffs, carbon taxes,clean subsidies, emissions trading schemes, international agreements, etc.)

This excludes natural resource issues likely less important for clean investments.

Source: Climate Thesaurus from Climate Tagger.

▶ Back

Our codebook

| 0	Article is about foreign (non US) environmental policy (and is not discussed/compared to or in relation to US env policy)	
	RELEVANT below	
1	Article is about environment/climate, with minor but significant (=explicit and specific, not a general statement) reference to environmental policy. (even if it's a opinion piece) - Article is about local environmental impacts in a very specific geographical area, with some reference to *state or federal* env/climate policy - Note: env policy implies legislation, laws, but also the financing of <u>large</u> demonstration projects, renewable power plants, etc by a (local) <u>public</u> authority.	

Support Vector Machines (SVM)

SVM maximizes the distance between the two closest articles on both sides of the decision boundary:
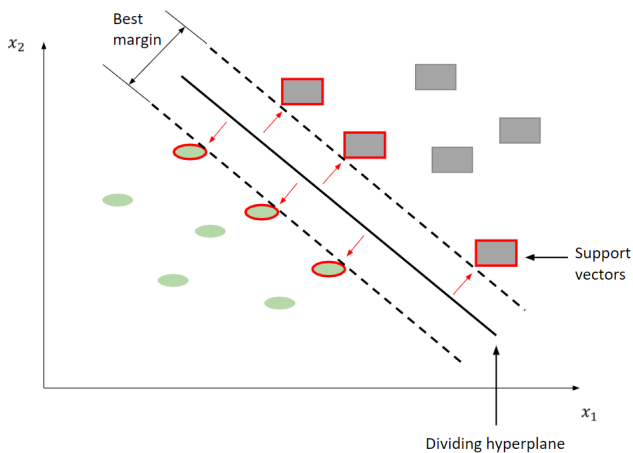
Precision & Recall
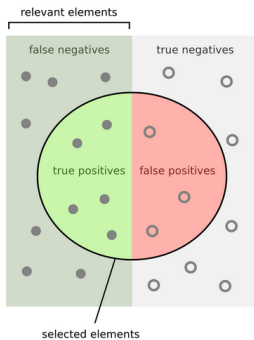
Source: `https://en.wikipedia.org/wiki/Precision_and_recall`.

A glimpse into our SVM's decision rule

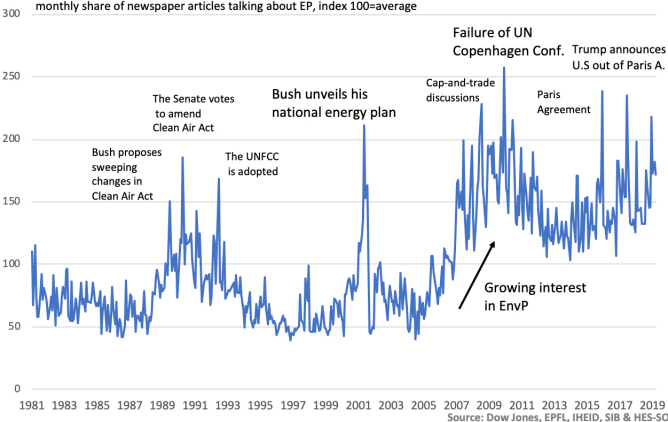Table: Top discriminating keywords for predicting our EnvP index according to the trained SVM classifier.

Word	Weight	Word	Weight	Word	Weight
energy	3.16	crist	1.34	volkswagen	1.09
emission	3.06	air	1.33	refrigerator	1.08
environmental	2.95	ethanol	1.32	utility	1.07
epa	2.24	global warming	1.32	cleanup	1.06
solar	2.17	coal	1.30	federal	1.05
obama	2.05	climate	1.26	car	1.00
clean	1.89	regulation	1.24	penalty	0.99
pollution	1.83	program	1.18	house	0.98
waste	1.67	renewable	1.17	bannon	0.98
warming	1.62	reef	1.15	bill	0.98
recycle	1.47	protection	1.14	mercury	0.97
power	1.45	climate change	1.12	electric	0.96
global	1.38	env. protection	1.10	gasoline	0.94
standard	1.36	clean air	1.10	environment	0.94

Articles with highest SVM score

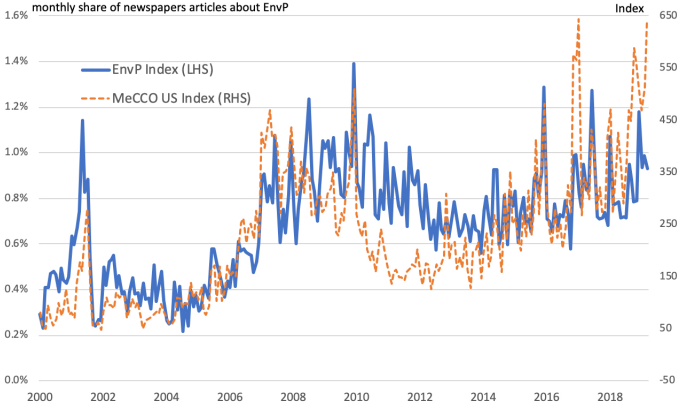| Title	Date	Score	Newspaper	Excerpt
Environment — Handicapping the Environmental Gold Rush	Oct 29, 2007	3.55	Wall Street Journal	"The green stampede is on. As a global economy powered by cheap fossil fuel comes under intense pressure to change, corporate executives are racing to stay ahead of the tectonic shift in their world. From Capitol Hill to California and Brussels to Beijing, multinational companies are stepping up their lobbying [...]"
In Texas, clean energy set to boom	Jan 10, 2016	3.54	Dallas Morning News	"While Texas has long been the top state for oil and gas, much more is going on here. In electricity, cleaner-burning natural gas plants are pushing out coal faster than in the rest of the nation, and that's before the next air pollution regulations kick in."
Obama Flies to the Nevada Desert to Promote Solar Energy	Aug 25, 2015	3.53	New York Times	"While promoting the benefits of all renewable energy, including wind power, the president focused largely on solar energy, part of an increasingly intense effort to counter global warming by instituting policies to reshape the nation's energy industry."
New rule targets pollution from coal	Aug 2, 2015	3.49	Washington Post	"The Obama administration will formally adopt an ambitious regulation for cutting greenhouse-gas pollution on Monday, requiring every state to reduce emissions from coal-burning power plants and putting the country on a course that could change the way millions of Americans get their electricity."
Environmentalists, Industry Air Differences on Pollution	Oct 17, 1999	3.48	Washington Post	"As a result, environmental groups are pressing states and Congress for specific environmental protections against increased pollution, financial incentives for energy efficiency and renewable energy, and federal pollution guidelines to be part of the overall deregulatory effort."

General EnvP Index

monthly share of newspaper articles talking about EP, index 100=average

Bush proposes sweeping changes in Clean Air Act

The Senate votes to amend Clean Air Act

The UNFCC is adopted

Bush unveils his national energy plan

Cap-and-trade discussions

Failure of UN Copenhagen Conf.

Paris Agreement

Trump announces U.S out of Paris A.

Growing interest in EnvP

Source: Dow Jones, EPFL, IHEID, SIB & HES-SO

▸ Comparison between our index and Mecco index   ▸ Back

EnvP versus MECCO Index

monthly share of newspapers articles about EnvP

Index

EnvP Index (LHS)

MeCCO US Index (RHS)
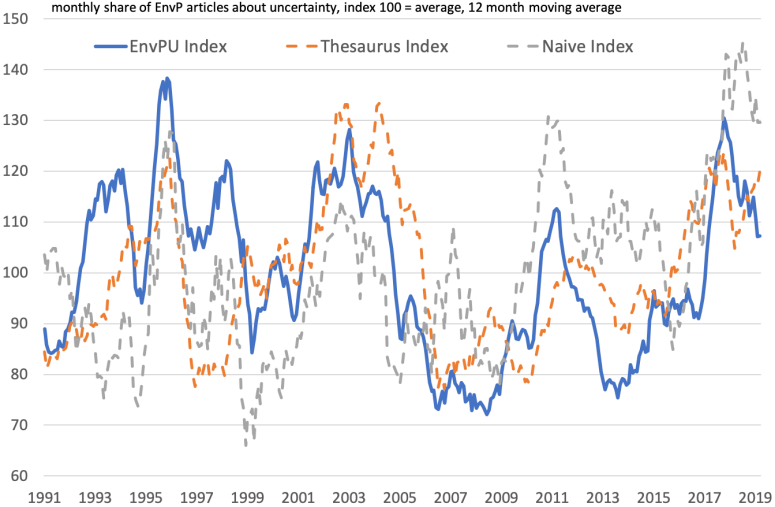
Source: Dow Jones, EPFL, IHEID, SIB & HES-SO

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How we code EnvPU

An article is coded as EnvPU $= 1$ if there is:

- ▶ a clear reference to *current* environmental policies.
- ▶ uncertainty about the timing of environmental policies.
- ▶ uncertainty about an important detail about the policy design.
- ▶ a lack of political will and commitment for environmental policies.
- ▶ uncertainty about the enforcement of environmental policies.
- ▶ a risk of a sudden reversal/discontinuation of current environmental policies (also due to legal challenges)
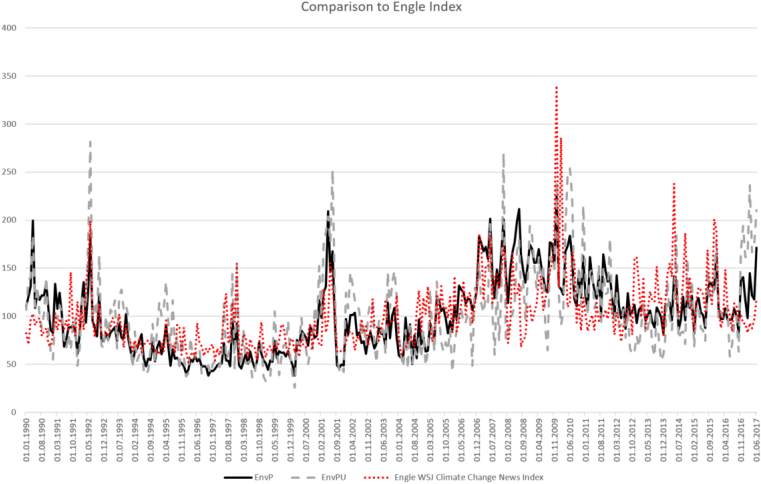- ▶ ...

EnvPU and benchmark indices

monthly share of EnvP articles about uncertainty, index 100 = average, 12 month moving average

EnvPU Index — Thesaurus Index — Naive Index

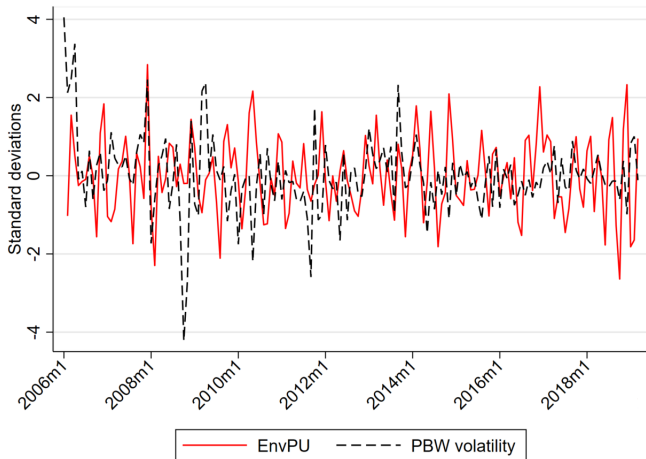Source: Dow Jones, EPFL, IHEID, SIB & HES-SO

EnvP and EnvPU versus Engle Index

Comparison to Engle Index

The correlation between EnvPU and volatility in renewable-energy ETF market value demand volatility is very low (¡10%)

Source: Datastream. • Back

Variables and Cholesky ordering

Table: Baseline VAR clean stocks

Variables	Version used	Cholesky ordering
Our EnvP policy index	2m MA of the std. returns	1
Our EnvPU policy index	2m MA of the std. returns	2
US West Texas Intermediate crude oil spot price	Std. volatility of returns	3
Federal funds effective rate	Std. returns	4
NYSE Arca Technology Stock Index	Std. volatility of returns	5
WilderHill Clean Energy ETF market value	Std. volatility of returns	6

No time trend; 1 lag.

Regression equation

$$r^e_{i,t=m} = \beta_1 \epsilon^{EnvP}_{t=m} + \beta_2 \epsilon^{EnvPU}_{t=m} +$$
$$\left(\beta_3 + \beta_4 \epsilon^{EnvP}_{t=m} + \beta_5 \epsilon^{EnvPU}_{t=m} \right) \text{EnvPU exposure}_{i,t=y} +$$
$$\beta_6 \text{Firm controls}_{i,t=y} + \gamma_i + \gamma_{t=m/y} + \varepsilon_{i,t=m}$$

Additionally drop observations (e.g. Kruse et al., 2020)

▶ with negative equity or sales values (so that firms in financial distress do not drive results).

▶ where growth in total assets was larger than 100% in absolute value (to exclude M&A's and other corporate reorganizations).

Robustness (GR share)

Continuous GR share

Robustness (GR share)