

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

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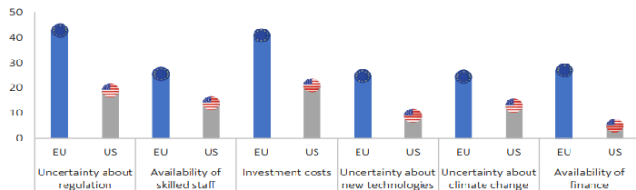


**Sustainable Economy**  
National Research Programme

# 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
- ▶ **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 the last 40 years:
  - ▶ unpredictability of legislative process
  - ▶ unexpected revision or rollback of regulations
  - ▶ legal challenges / awaiting for court decision
- ▶ How does environmental policy uncertainty relate to **clean investments**?
  - ▶ 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) → if investments are irreversible, firms delay their investments when faced with policy uncertainty
- ▶ **Empirical literature on policy uncertainty**
  - ▶ macroeconomics
    - ▶ Baker et al (2016): economic policy uncertainty leads to reduced investments and employment and heightened stock price volatility
  - ▶ environmental economics
    - ▶ Dorsey (2019): uncertainty around 2005 CAIR rules → increased compliance costs by \$124 million due to delayed investments
- ▶ **Text-as-data methods in economics**
  - ▶ Gentzkow and Shapiro (2010); Tobback et al (2018)

# 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*
- ▶ 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

# Outline

Data and Methodology

Evaluation

The Index

Investments in clean markets  
Firm-level

Conclusions

## Data and Methodology

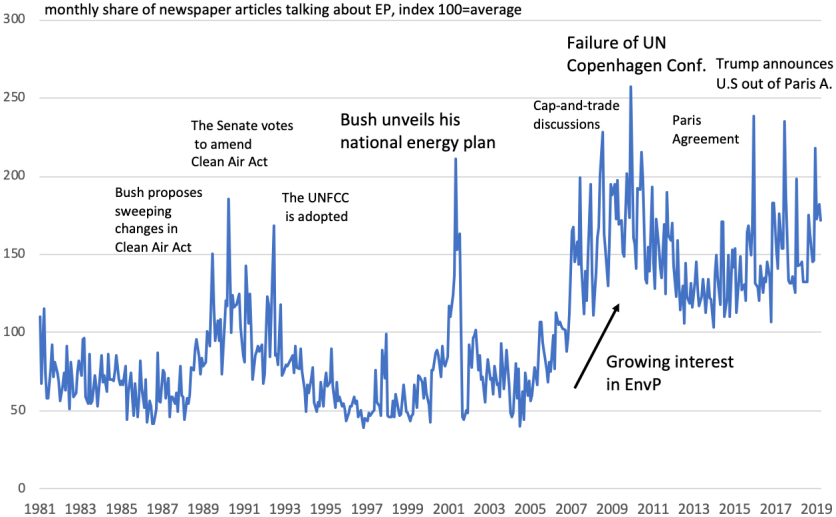
## Step 1: Identifying relevant EnvP articles

### 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 Index](#)



# EnvP articles (scaled by total news volume)



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 (e.g. uncertain impact of climate change, technology uncertainty)
- ▶ 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 classified 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	arpaes	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

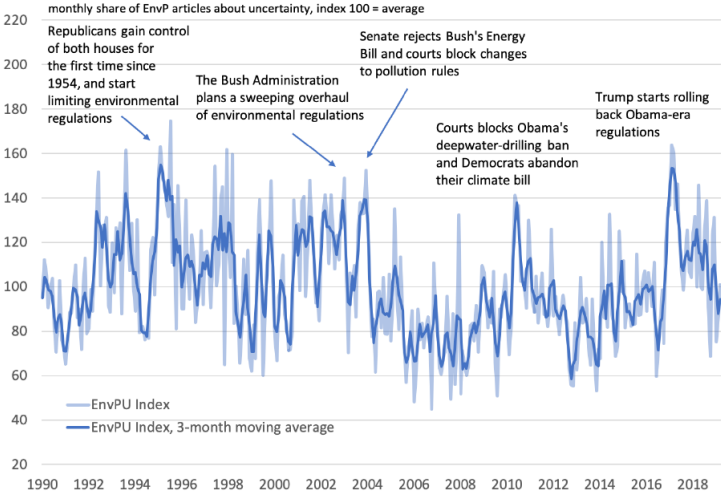
# Evaluation

# Newspaper articles with highest SVM-score

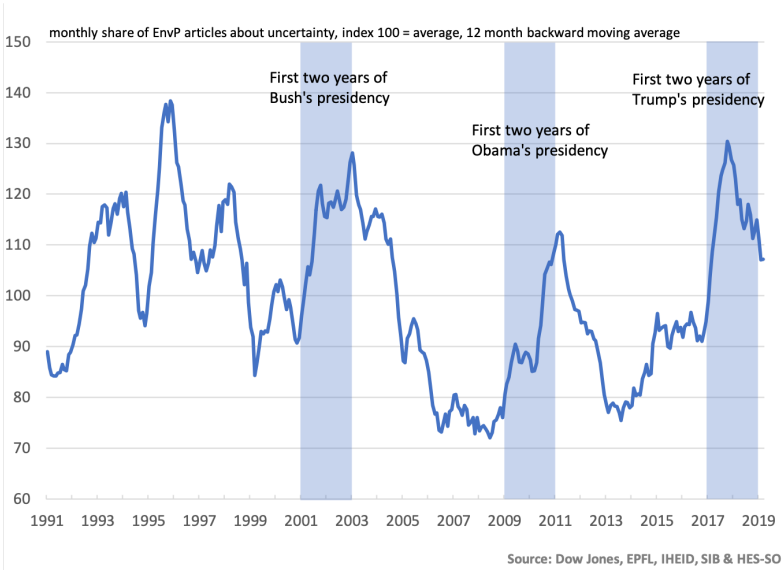
Title	Date	Score	Newspaper	Excerpt
Trump officials deploy court tactic to reverse Obama rules	Apr 18, 2017	2.14	Washington Post	"[...] President Trump has signed executive orders with great fanfare and breathed life into a once-obscure law to nullify numerous Obama-era regulations. But his administration is also using a third tactic: Going to court to stop federal judges from ruling on a broad array of regulations that are being challenged [...]"
Court Rebuffs Trump's Effort To Halt Obama Methane Rule	Jul 4, 2017	2.07	New York Times	"[...] a federal appeals court ruled on Monday that the EPA cannot suspend an Obama-era rule to restrict methane emissions [...] The ruling signals that the Trump administration's efforts to simply delay environmental and public health actions are likely to face an uphill battle in the courts and require a more painstaking process"
Rule-Making Process Could Soften Clean Air Act	Sep 21, 1991	2.07	Washington Post	"As the Senate neared passage of the new Clean Air Act last year, the Bush administration was pushing hard for inclusion of a special provision easing expensive pollution control requirements for electric utilities. [...] Administration efforts for the provision were rebuffed three times [...]"
23 Environmental Rules Rolled Back in Trump's First 100 Days	May 3, 2017	1.93	New York Times	"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."
Texas leads climate rules attack	Jan 11, 2011	1.86	Dallas Morning News	"Texas has filed nearly a dozen legal challenges of EPA regulations over the past year, mostly over climate-change rules. [...] Environmental groups say they expected that some states and business groups would continue to fight carbon limits, even after the Supreme Court's decision [...]"

## The Index

# EnvPU Index (scaled by EnvP)



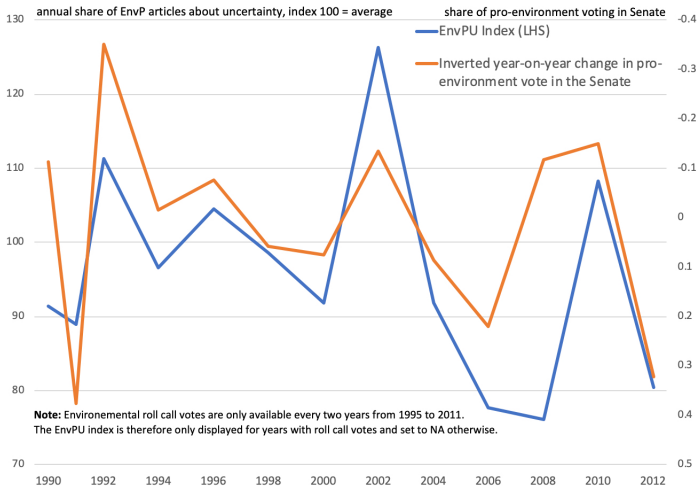
# EnvPU and political transitions





# 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



# Further validation

## 1. Comparison with

- ▶ naive index (uncertain\*) [▶ Here](#)
- ▶ dictionary-based methods (uncertainty thesaurus) [▶ Here](#)

## 2. Human audit on 900 articles over 2008-2011 period [▶ Here](#)

## 3. Liberal vs. conservative newspapers [▶ Here](#)

## Investments in clean markets (firm-level)

# EnvPU and investments in clean markets

- ▶ How does our measure of environmental policy uncertainty relate to investments in clean firms?
  - ▶ venture capital investments
  - ▶ stock market price volatility
- ▶ 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
- ▶ Validation exercise → our EnvPU index has a meaningful association with clean investments

# 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)	(2)	(3)
	Funded (Q+1)	Funded (Q+1)	Amount (Q+1)
EnvPU index	0.000957** (0.000475)	0.000960** (0.000475)	0.0241** (0.0116)
EnvPU x Cleantech	-0.00352*** (0.00121)		
EnvPU x Cleantech excl. Energy		-0.00159 (0.00116)	-0.0734** (0.0294)
EnvPU x Clean Energy		-0.00338*** (0.00122)	-0.0703** (0.0316)
EnvP index	-0.00366*** (0.000807)	-0.00370*** (0.000807)	-0.0345* (0.0196)
EnvP x Cleantech	0.00516*** (0.00102)		
EnvP x Cleantech excl. Energy		0.00272*** (0.000982)	0.0565* (0.0314)
EnvP x Clean Energy		0.00501*** (0.00106)	0.0729*** (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
R <sup>2</sup>	0.006	0.006	0.119

Table presents results of an OLS regression. The sample period is January 1998 to March 2019. The dependent variable in Columns (1), and (2) is a dummy variable that indicates whether firm  $i$  received VC funding next quarter. In Column (3), the dependent variable is the logarithm of the amount received, conditional on having received funding. The news indices are standardized to a mean of zero and unit standard deviation. Other controls include age, oil price, a time trend, GDP and the fed fund rate. Standard errors are clustered at the company level. Standard errors are in parentheses. \*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

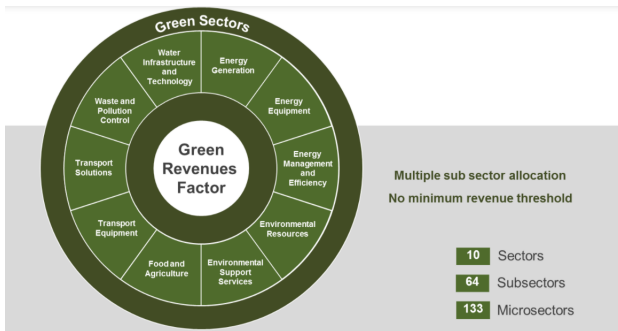
A one SD increase in EnvPU in the next quarter is associated with a decrease of 0.3 pp in the probability of receiving VC funding (4% decrease in avg probability)

▶ Robustness

# 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)	(2)	(3)	(4)	(5)	(6)	(7)
	Log volatility	Log volatility	Log volatility	Log volatility	Log volatility	Log volatility	Log volatility
EnvPU × AVG GR share	0.0050** (0.0024)			0.0050** (0.0024)			
EnvP × AVG GR share	0.0006 (0.0018)			0.0010 (0.0018)		0.0020 (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)		0.0100*** (0.0030)		
EnvP × Pre-sample GR share			-0.0017 (0.0016)		-0.0013 (0.0017)		0.0010 (0.0019)
EPU × AVG GR share				-0.0067*** (0.0015)			
EPU × Pre-sample GR share					-0.0081*** (0.0024)		
Naive EnvPU × AVG GR share						0.0013 (0.0022)	
Naive EnvPU × Pre-sample GR share							0.0045 (0.0032)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	39955	39955	17869	39955	17869	39955	17869
Firms	438	438	158	438	158	438	158
R <sup>2</sup>	0.65	0.65	0.6401	0.65	0.64	0.65	0.64

The table presents results of an OLS regression. Standard errors are clustered at the firm level. The dependent variable corresponds to the natural logarithm of the annualized monthly volatility of daily log returns. Firm controls include size as the natural logarithm of market capitalization, profitability as return on assets and leverage as total debt over total equity. The EnvP innovations and EnvPU innovations correspond to the residuals from an AR(7) and AR(3) process, respectively, and are standardized to a mean of zero and unit standard deviation. The green revenue share (GR share) is standardized in the same way. The recession associated with the Global Financial Crisis is excluded. Standard errors are in parentheses. \*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

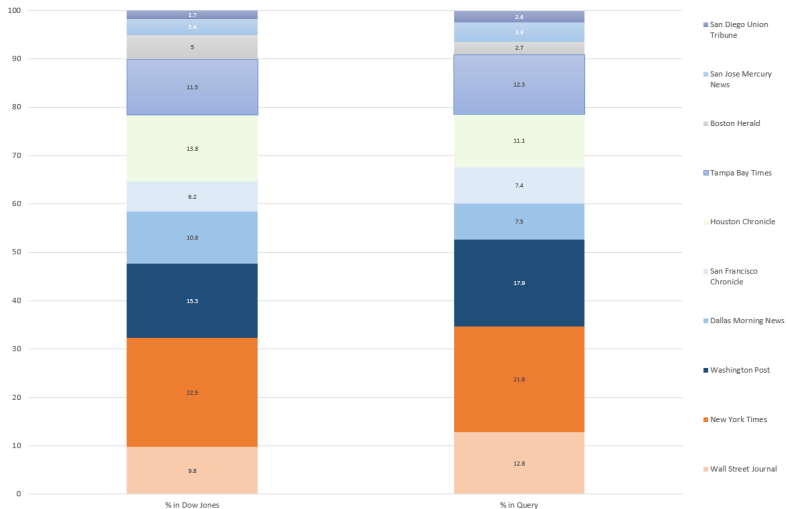
## Conclusions

## Conclusions and next steps

- ▶ News provide a rich dataset covering environmental policies at high frequency and allow to measure perceptions about policy uncertainty in real-time.
- ▶ Novel methods based on text-mining ML algorithms to extract information from news.
- ▶ 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



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# 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.

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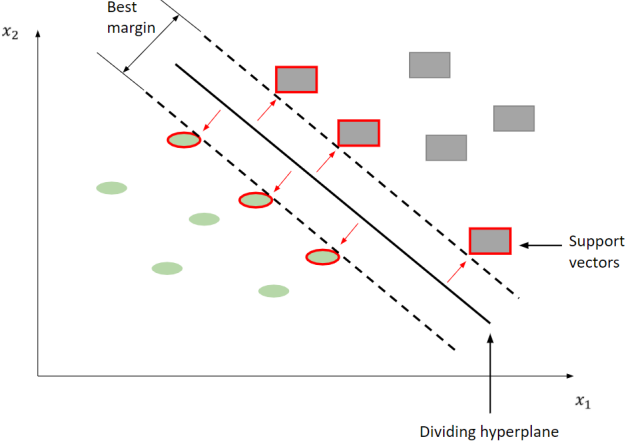
# Our codebook

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	<p>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)</p> <ul style="list-style-type: none"><li>- Article is about local environmental impacts in a very specific geographical area, with some reference to <i>state or federal</i> env/climate policy</li><li>- 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.</li></ul>	

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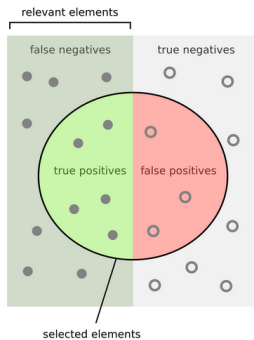
# Support Vector Machines (SVM)

SVM maximizes the distance between the two closest articles on both sides of the decision boundary:





# Precision & Recall



How many selected items are relevant?

$$\text{Precision} = \frac{\text{true positives}}{\text{true positives} + \text{false positives}}$$

How many relevant items are selected?

$$\text{Recall} = \frac{\text{true positives}}{\text{true positives} + \text{false negatives}}$$

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Source: [https://en.wikipedia.org/wiki/Precision\\_and\\_recall](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.

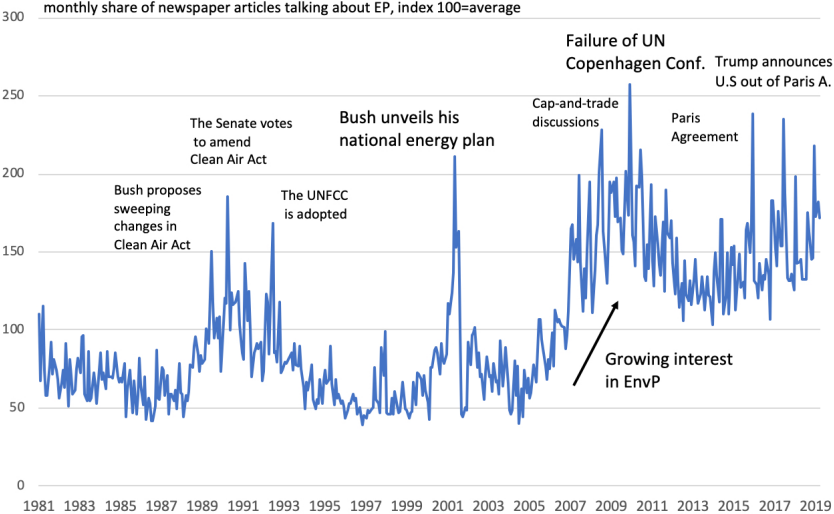
Word	Weight	Word	Weight	Word	Weight
energy	3.16	crist	1.34	volkswagen	1.09
emission	3.06	air	1.33	refrigerator	1.08
environmental	2.95	ethanol	1.32	utility	1.07
epa	2.24	global warming	1.32	cleanup	1.06
solar	2.17	coal	1.30	federal	1.05
obama	2.05	climate	1.26	car	1.00
clean	1.89	regulation	1.24	penalty	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
<i>Environment — Handicapping the Environmental Gold Rush</i>	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 [...]"
<i>In Texas, clean energy set to boom</i>	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."
<i>Obama Flies to the Nevada Desert to Promote Solar Energy</i>	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."
<i>New rule targets pollution from coal</i>	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."
<i>Environmentalists, Industry Air Differences on Pollution</i>	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."

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# General EnvP Index



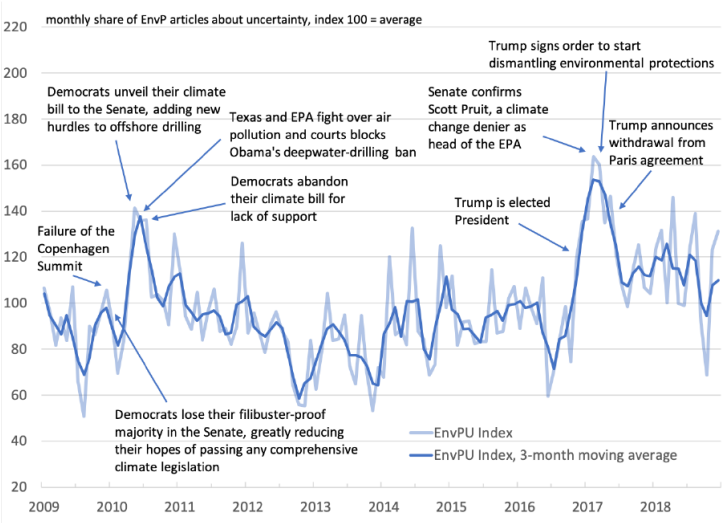
# How we code EnvPU

## An article is coded as **EnvPU = 1** if there is:

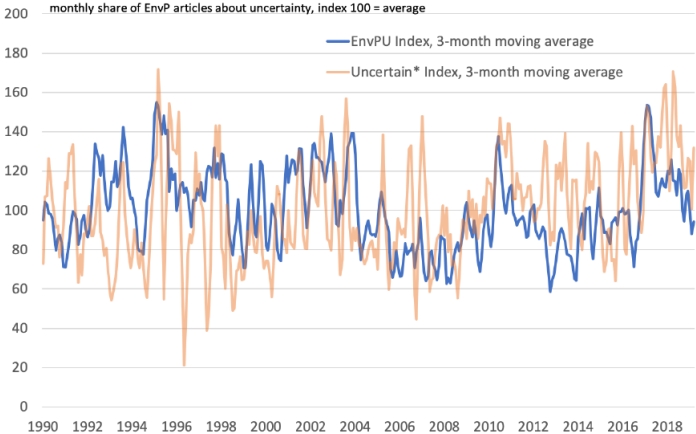
- ▶ a clear reference to *current* environmental policies.
- ▶ uncertainty about the timing of environmental policies.
- ▶ uncertainty about an important detail about the policy design.
- ▶ a lack of political will and commitment for environmental policies.
- ▶ uncertainty about the enforcement of environmental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

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# EnvPU zoomed in

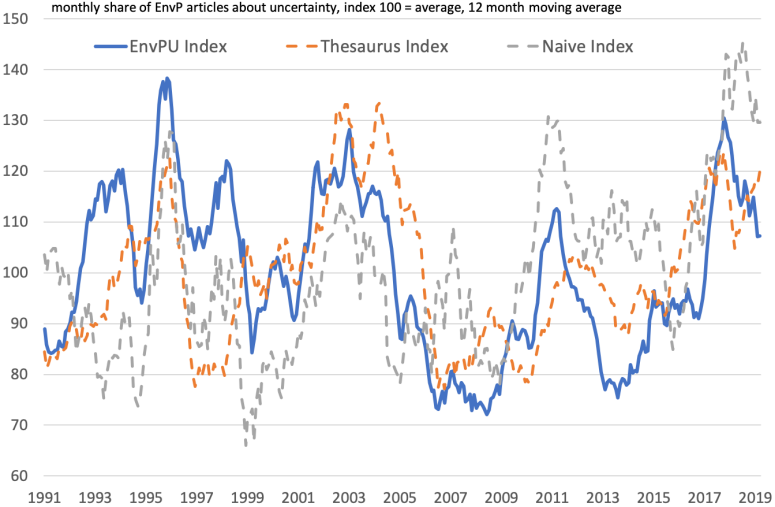


# NaiveEnvPU Index



Precision: 49%; Recall of 8%. [▶ Back](#)

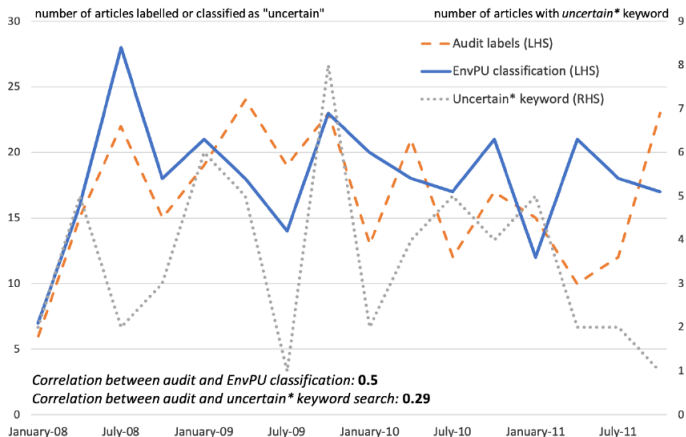
# Thesaurus-based EnvPU Index



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

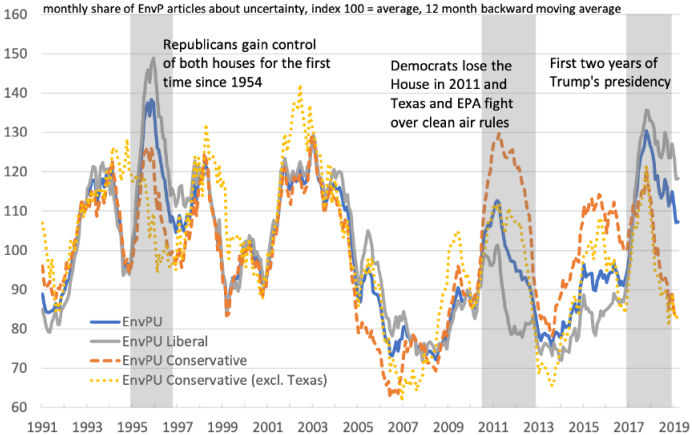


# Human audit



Note: 6 human auditors read and labeled a sub-sample of 925 articles randomly drawn from all the 14,158 published articles over the January 2008-December 2011 period (i.e., around 6.5 percent).

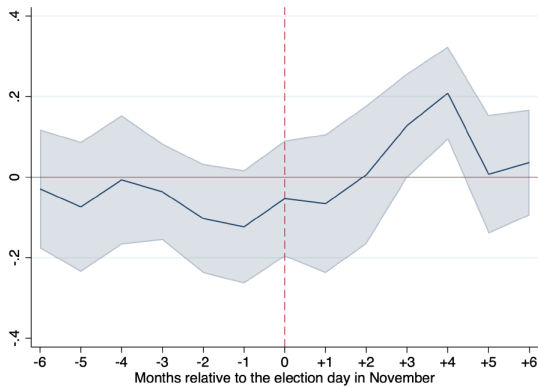
# EnvPU and political slant



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# EnvPU around elections

$$\ln(\text{EnvPU}_t) = \gamma_m + \gamma_c + \sum_{n=-6}^6 \beta_n 1(\text{ElectionMonth}_{t-n} = 1) + \epsilon_t$$



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# 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.

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# Regression equation

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

**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).

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# Robustness (GR share)



