The impact of climate change mitigation policies: Europe and beyond

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Outline

1. Motivation
2. Textual analysis of European Union regulatory news
3. Macroeconomic Impacts of text shocks
4. International Transmission mechanism of climate policies

Motivation

Motivation

- Deteriorating climate crisis and growing concerns on the dangers of climate shocks
  - Policy measures at global scale (Kyoto (1997), Paris agreement (2015))
- Transition to low carbon economy poses challenges and questions:
  - How effective are those policies?
  - Costs and benefits?
  - International transmission of those policies?
- A consensus on the effectiveness in reducing GHG emissions: Martin et al. (2014); Andersson (2019); McKibbin et al. (2017); Rivers and Schaufele (2015)
- The macroeconomic impact is **controversial**

Motivation

- Theoretical models suggest contractionary effects, Goulder and Hafstead (2018) (with \$40 per ton of CO_2 tax, 5% rise per annum)
- Many others do not find any significant impact of climate policies
  - Metcalf (2019): British Columbia carbon tax, DID methods, Canadian provinces (1990-2016)
  - Bernard and Kichian (2021): Also lends support to the previous study, using a VAR analysis.
  - Konradt and Weder di Mauro (2021): No impact on employment and inflation
- Yamazaki (2017): Not much aggregate impact but sectoral shifts in labor market (from "brown" to "green" sectors)
- Recently Känzig (2021) finds significant negative impacts at aggregate and micro level

Aim of this study

1. Analyze textual contents of EU policy reports using:
    - Only regulatory news as a source [Exclude other types]
    - Transition risk vocabulary: [No physical risks], Bua et al. (2022). ▸ Go to Source
    - Derive text surprises: ⇒ Use as an instrument in the proxy SVAR (SVAR-IV)
    - Analyze aggregate macroeconomic impacts
2. Explore international macroeconomic effects using:
    - Climate policy stringencies of 56 countries
    - Bilateral trade weights
    - Analyze macroeconomic impacts within and across countries

Main results

- A **climate text shock** leads to:
  - Decline in GHG emissions
  - A considerable rise in energy prices, but consumer prices go up marginally (Counter acting cost-push and demand channels)
  - Industrial production falls and stock prices lose value
  - Real exchange rates depreciates and bond yields rise!
- **Climate policy stringencies** across countries:
  - Policy measures are effective in reducing CO_2
  - A heterogenous impact profile across countries
  - Direct effects outweigh indirect effects
  - Again, counteracting cost-push (energy prices) and demand channels
  - No country is in isolation: External shocks get more important over time

Textual Analysis of Regulatory Announcements

Textual Analysis

- 355 distinct regulatory announcements, 2010:04 - 2023:01
- Regular text processing
- Calculate *tf-idf* across all documents
- *tf-idf* of transition risks vocabulary are available

Definition

The *tf* - *idf* defines the most representative terms in a given document to be those that appear infrequently overall, but frequently in that specific document, (Gentzkow et al., 2019)

- Obtain time series index

Time Series Index of Textual Surprises

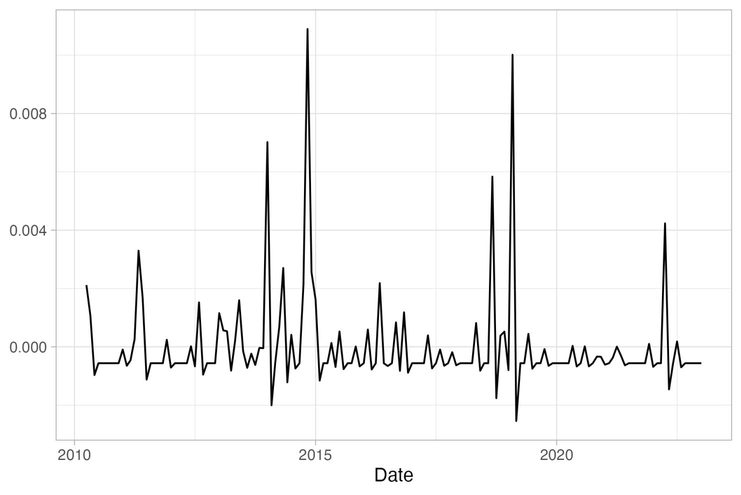

Figure 1: Time Series Index of Textual Surprises

Econometric Framework

- Textual time series index has desirable properties:
  - No auto correlation
  - Not predictable by variables used in estimation
  - No granger causality
- Employ An SVAR-IV, using textual time series index as an **instrument** to uncover the dynamic causal impact of climate policy shocks, Mertens and Ravn (2013); Stock and Watson (2018)

$$y_t = c + A_1 y_{t-1} + A_2 y_{t-2} + \ldots A_p y_{t-p} + \underbrace{u_t}_{B\xi_t} \quad (1)$$

- Given the instrument and VAR results, structural shocks are identified up to sign and scale

Empirical Framework & Data

- 7 key macroeconomic indicators:
  - Energy prices
  - GHG emissions (total)
  - Consumer price index (HICP)
  - Industrial production
  - Government bond rates
  - Stock market index
  - Real exchange rates (ReeR)
- Optimum lag length: 4, (6)
- Estimation sample: 2010:04 - 2022:12

Aggregate macroeconomic impacts

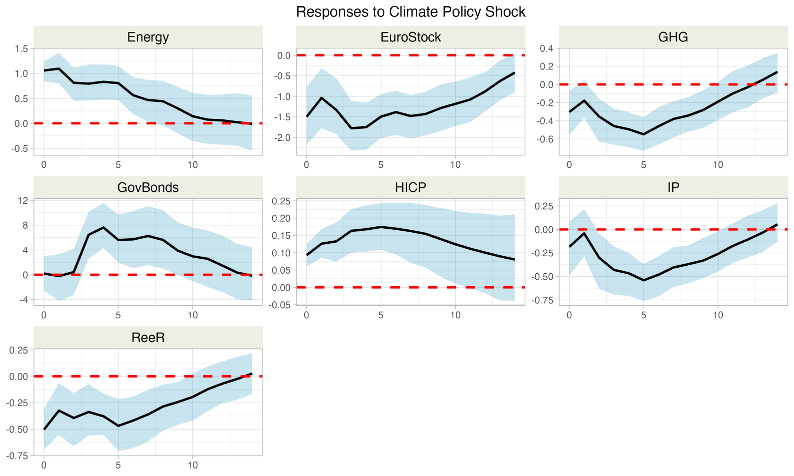

Figure 2: Responses to text shock. Solid line: point estimates, shaded areas represent 90% CI. Std errors are Lenza and Primiceri (2022) COVID-volatility corrected

Weak-IV Robust CI

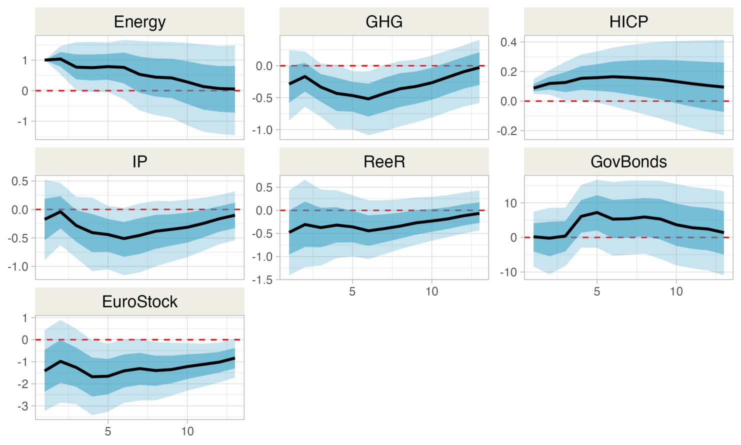

Figure 3: Weak-IV robust std errors. Solide line is point estimate, shaded areas represent 68% and 95% CI.

Aggregate macroeconomic impacts

A text shock leads to:

- A decline in total GHG emissions
- An immediate sharp rise in energy prices
- A fall in industrial production, stock prices
- Depreciation of real exchange rates
- Relatively low impact on consumer prices (HICP)
  - Counteracting channels:
  - Cost-push vs demand factors: Overall impact is moderately positive.

International transmission mechanism

International transmission

- Theoretical justification: Tighter policies lead to change in trade structures, relocation of industries and alter competitiveness (*Pollution Haven hypothesis*)
- Althammer and Hille (2016) : There might be at least short run impacts
- Shed light on the impact of transmission of channel
- No country is in isolation: Risks might spread within and across countries via trade and financial linkages
  - The impact on a particular country can be amplified or dampened
- A compact representation of the world economy is possible via GVAR, Chudik and Pesaran (2016) for applications

Framework

Use BGVAR: Combination of individual country models via trade links

$$x_{it} = a_{i0} + a_{i1}t + \sum_{j=1}^{p_i} \alpha_{i,j} x_{i,t-j} + \sum_{j=0}^{q_i} \beta_{i,j} x^*_{i,t-j} + \sum_{j=1}^{I_i} \gamma_{ij} d_{t-j} + u_{it} \tag{2}$$

where:

- x_{it}: a particular variable for country i at time t, $x_{i,t-j}$ is its lags
- $x^*_{i,t-j}$ is corresponding *foreign* variable, constructed using bilateral trade weights

$$x^*_{it} = \sum_{j=0}^{N} w_{ij} x_{ij} \tag{3}$$

- d_{t-j} is a global variable (oil), t is deterministic time trend, $a_{i0}, a_{i1}, \alpha_{i,j}, \beta_{i,j}, \gamma_{ij}$ are respective parameters.
- Bilateral trade weights are the average of last three years in the sample

Empirical Framework & data

- Climate Change Performance Index (CCPI), developed by Germanwatch, a in collaboration with the New Climate Institute.
- CCPI is a convenient measure of policy stringency, Atanasova and Schwartz (2019)
  - Based on four main pillars and 14 different indicators: Emissions, Renewable Energy, Energy Efficiency, and Overall Climate Policy
- Available from 2005 covering 57 countries
- Emissions
- Other variables follow from GVAR literature: Short and long term interest rates, consumer prices, exchange rates, equity prices, GDP from IFS

Prior & Identification Strategy

- A flexible prior: Stochastic search and variable selection (SSVS) is used as a benchmark
- Sign restrictions on the identifying matrix
- Take advantage of empirically documented studies and our textual shock for exact identification scheme
- Report the impulse responses closest to the median value, Fry and Pagan (2011)

Table 1: Identification scheme of structural shocks

Shock	y	CO2	EQ	pi	ER	LR	SR
Climate Policy	↓	↓	↓	.	.	.	.

Baseline Results: US

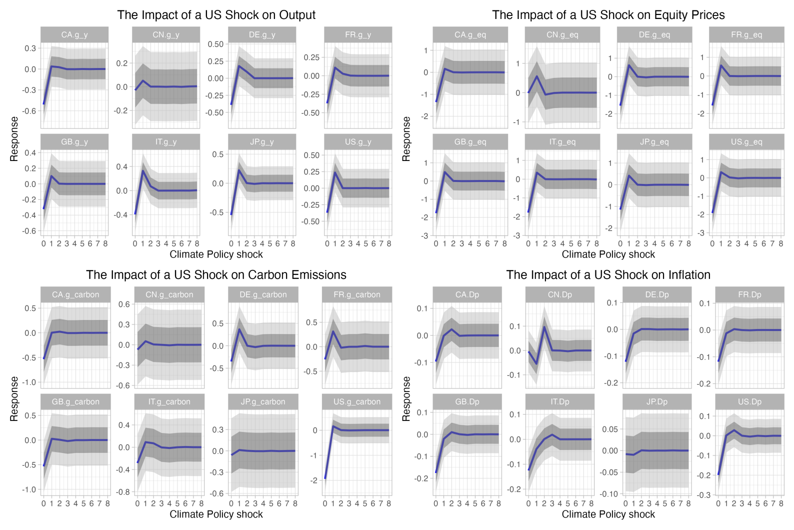

Figure 4: Impulse Responses to Climate Policy Shock in the United States

Baseline Results: DE

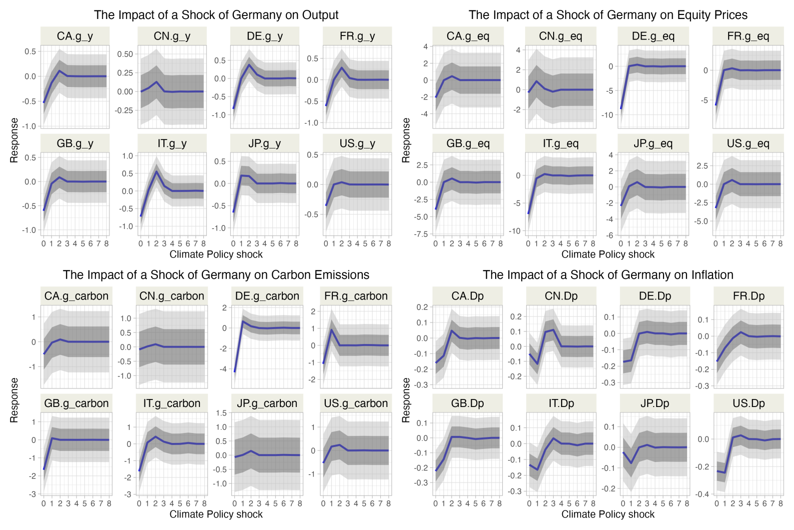

Figure 5: Impulse Responses to Climate Policy Shock in Germany

Baseline Results: Emissions

- Policy shocks can be obtained for any country: The overall results convey the same message:
- Policy measures are effective in tackling the emissions (across all countries)
- Each country experiences the largest fall of following its own policy shock but also affected indirectly by other countries.
  - Ex: In USA, emissions fall by as much as 2% (direct) and emissions in other countries at most by 0.5% (indirect)
- In general, US has largest impact on other countries, in line with monetary policy literature, Feldkircher et al. (2015)
- Germany and UK have reasonable impact on European countries

Baseline Results: Economic Impacts

- A heterogeneous impact profile due trade channel, financial interdependencies
- US has marked influence on Canada, UK, Mexico but almost no influence on Norway, Greece etc.
- Equity prices are mostly affected
  - Fast transmission through markets
- Similar to the emissions, direct effects outweigh the indirect effects
- Germany, France and UK have notable impact on Europe.

Baseline Results: Economic Impacts

- The impact on output is relatively small, 0.5% in the impact year and further decay in the next years
- Consumer prices requires a **careful** reading:
  - **Demand channel:** Reduction in income levels, financial constrains, fewer savings $\Rightarrow$ Downward pressure on consumer prices
  - **Cost-push channel:** Rise in energy prices (more than 1% in the impact year and further increases in the next years)
  - Net effect depends on strength of those channels

Decomposition of Structural Shocks: External vs Internal Shocks

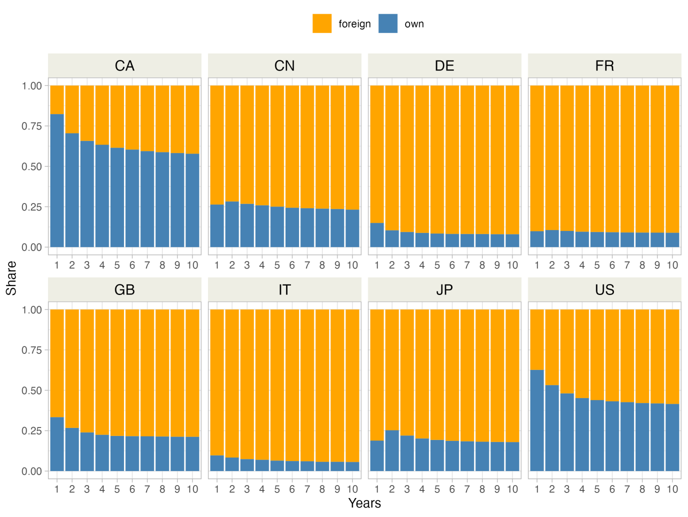

Figure 6: Generalized FEVD: External vs Domestic Shocks

Decomposition of Structural Shocks: External vs Internal Shocks

- No country is in isolation: They might affect each other through financial linkages and trade channels, Kose et al. (2003).
- Decompose the total variance of shocks into internal vs external shocks
- US and Canada have largest share attributable to their own policy shocks than external shocks
- External shocks gain importance overtime
- This is in a way similar to the transmission of monetary policy shocks, Feldkircher et al. (2015).

Robustness Controls

The baseline results are robust to:

- Trade weights: Construct the trade weights using all observations in the sample, not only the last three years
- Prior specifications: Apply Normal-Gamma & Minnesota prior
- Exclude expert views (20%)

Summary & Further Research

- Climate policy shocks are effective in reducing emissions
- **This does not come without a cost though:** short to medium term impacts on key indicators:
  - A marked increase in energy prices
  - Consumer prices rise only marginally (Opposite forces)
  - IP falls and stock prices lose value
  - Depreciation in real exchange rates and jumps is government bond yields
- **There might be long run positive impacts through rise in patents and innovation**: (Further research)
- Transmission channel also plays a key role
  - Each country & its trade partners play a role in reducing emissions and causing economic costs
  - Direct effects are larger than the indirect effects.
  - External shocks get more important over time

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Appendix

Prior in detail

Rewrite (2)

$$x_i = Z_i \Pi_i + \varepsilon_i \tag{4}$$

$\Psi = vec(\Pi_i)$ as the coefficient vector. The starting point is the natural conjugate prior:

$$\begin{aligned}
\Psi_i | \Sigma_{\varepsilon i} &\sim N(\underline{\Psi}_i, \Sigma_{\varepsilon i} \otimes \underline{V}_i) \qquad (5)\\
\Sigma_{\varepsilon i} &\sim IW(\underline{S}_i, \underline{v}_i) \qquad (6)
\end{aligned}$$

$\underline{\Psi}_i$ and $\underline{V}_i$ stand for the mean and variance of the prior distribution. The prior mean, Ψ_i, follows a multivariate Gaussian process, and the prior variance is assigned the inverse Wishart distribution. What is more, $\underline{v}_i$ is the degrees of freedom for the variance-covariance matrix $\Sigma_{\varepsilon i}$ and $\underline{S}_i$ serves as a scale matrix.

Prior in detail

The prior mean of the random walk is characterized using the following process;

$$\Psi_{ij} = \begin{cases} \alpha_{i,j} & \text{the first lag of endogenous variable i in equation j} \\ 0 & \text{otherwise} \end{cases} \tag{7}$$

where the prior mean is denoted by $\alpha_{i,j}$, which is then set to 1 to for a random walk process. This is simplified as in global model as

$$x_t = x_{t-1} + \eta_t$$

where the variance-covariance matrix of η_t in the global model, ε_t, is *block-diagonal*, that is, the i^{th} block equals the prior expectation of $\Sigma_{\varepsilon i}$.

The key point which leads to different specifications in prior models follows from how the prior variance, $\underline{V}_{ij}$, is handled, Sims and Zha (1998)

Prior in detail

- The conjugate priors, which impose the same degree of shrinkage across all blocks (equations)
- The SSVS, introduced by George et al. (2008) to the VAR models, allows a flexible shrinkage across different endogenous variables by mixing Normal distributions on each coefficient of VARX* models

$$\Psi_{ij}|\delta_{ij} \sim (1-\delta_{ij})N(0,\tau_{0j}^2) + \delta_{ij}N(0,\tau_{1j}^2) \tag{8}$$

δ_{ij} is a binary random variable for the parameter j in model i. It is 1 if included in a country model and 0 otherwise. Normal distribution with $\delta_{i,j} = 0$ is coupled with a small value of τ_{0j}^2 to force the parameters in the model towards zero. The prior variance of the distribution for $\delta_{ij} = 1$, τ_{1j}^2, rather gets a larger value. This large value implies an uninformative structure for a particular parameter.

Prior in detail

Specify prior more compactly, following Feldkircher et al. (2015). Define m (scalar) such that;

$$m_{ij} = \begin{cases} \tau_{0j}, \text{if } \delta_{ij} = 1 \\ \tau_{1j}, \text{if } \delta_{ij} = 0 \end{cases} \tag{9}$$

All m_{ij} are further collected in a $v_i \times v_i$ square matrix D_i. The diagonal elements of D_i follows from m_{ij}, that is, $D_i = diag(d_{i1}, d_{i2}, ..., d_{iv_i})$. The prior structure then will be as follows:

$$\begin{aligned} \Psi_i | D_i &\sim N(0, \underline{R}_i) && (10) \\ \Sigma_{\varepsilon i} &\sim IW(\underline{S}_i, \underline{v}_i) && (11) \end{aligned}$$

where $\underline{R}_i = D_i D_i$, and $\Sigma_{\varepsilon i}$ is the usual IW prior with hyperparameters $\underline{v}_i$ and $\underline{S}_i$, degrees of freedom and the scale matrix respectively.

Hyperparameters

Let variable enter the model equally likely. (The probability of inclusion for each variable is 0.5). Following George et al. (2008), I set $\tau_{0j} = 0.1 s_j$ and $\tau_{1j} = 10 s_j$ in (8) where s_j is the standard error of a coefficient j in the country model ($VARX^*$). The hyperparameters for IW are $\underline{S}_i = 10 I_k$, $v_i = k_i$.

For other prior types, default values are used.

Estimation: Gibbs Sampler

- First, Ψ_i is drawn from the full conditional posterior, which is distributed normally.
- Secondly, δ_{ij} is drawn from the Bernoulli distribution.
- Lastly, $\Sigma_{\varepsilon i}$ is drawn from Inverse Wishart (IW) distribution.
- The same process is repeated many times and then the initial draws are discarded (burn-in).

Sign Restrictions: Details

Following Dees et al. (2007), pre-multiply the 2 with a newly defined matrix $Q_0 = R_0 P_0^{-1'}$ where the R_0 is the restriction matrix and $P_0^{-1'}$ is the lower Cholesky factorization of the variance covariance matrix of initial model, Σ_u. The structural shocks errors are obtained by $v_0 = Q_0 u_t$. The variance covariance matrix is by definition $\Sigma_u = P_0^{-1'} P_0^{-1}$. We seek an appropriate rotation (restriction) matrix R_0 fulfilling $R_0 R_0^{'} = I_k$. The variance covariance matrix of the structural shocks is given by

$$\Sigma_v = R_0 P_0^{-1'} P_0^{-1} R_0^{'} = Q_0 Q_0^{'} \tag{12}$$

The algorithm follows from RUBIO-RAMIREZ et al. (2010). I repeatedly draw orthogonal Q matrices and keep only the ones that fulfill prior sign restrictions.

Sign Restrictions: Details

Then, I construct the Q matrix which takes the form of

$$Q = \begin{bmatrix} Q_0 & 0 & \dots & 0 \\ 0 & I_{k1} & \dots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \dots & I_{kN} \end{bmatrix}$$

The accompanying equation of the reduced form of GVAR model is multiplied with the Q matrix to obtain the transformed version.

$$Qx_t = Q\alpha_0 + Q\alpha_1 t + QFx_{t-1} + Q\xi_t \tag{13}$$

The (13) provides us with the impulse responses of "identified" macroeconomic shocks.

CCV: Source of Text, Bua et al. (2022)

Year	Source	Title	Transition	Physical
1990	IPCC	IPCC Synthesis Report 1990	115-148p	
1990	IPCC	Climate change: The IPCC Impacts Assessment		Entire
1992	IPCC	Climate change: The IPCC 1990 and 1992 Assessments		87-113p
1999	IPCC	IPCC Special Report: Aviation and the global atmosphere	Entire	
2000	IPCC	IPCC Special Report: Methodological and technological issues in technology transfer	Entire	
2001	IPCC	IPCC Synthesis Report 2001	302-354p	
2001	IPCC	Climate change 2001: Impacts, adaptation and vulnerability		Entire
2005	IPCC	IPCC Special Report: Carbon dioxide capture and storage	Entire	
2005	IPCC	IPCC Special Report: Safeguarding the ozone layer and the global climate system: Issues related to hydrofluorocarbons and perfluorocarbons	Entire	
2007	IPCC	IPCC Synthesis Report 2007	55-70p	
2007	IPCC	Climate change 2007: Impacts, Adaptation and Vulnerability		Entire
2011	IPCC	IPCC Special Report: Renewable energy sources and climate change mitigation	Entire	
2012	IPCC	IPCC Special Report: Managing the risks of extreme events and disasters to advance climate change adaptation		Ch. 2-4
2014	IPCC	IPCC Synthesis Report 2014	75-112p	
2014	IPCC	Climate change 2014: Impacts, adaptation and vulnerability		Part A & B
2018	UNEP FI - Acclimatise	Navigating a new climate. Part 2: Physical risks and opportunities		Entire
2019	IPCC	IPCC Special Report: Global warming of 1.5C	Ch. 2 & 4	Ch. 3
2019	IPCC	IPCC Special Report: Climate change and land		Ch. 1-5
2019	IPCC	IPCC Special Report: The ocean and cryosphere in a changing climate		Entire
2020	IMF – Journal of Macroeconomics	The effects of weather shocks on economic activity: What are the channels of impact?		Entire
2020	McKinsey Global Institute	Climate risk and response: Physical hazards and socioeconomic impacts		Entire
2020	Swiss Re Institute	Natural catastrophes in times of economic accumulation and climate change		Entire

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ACF of Text Surprises

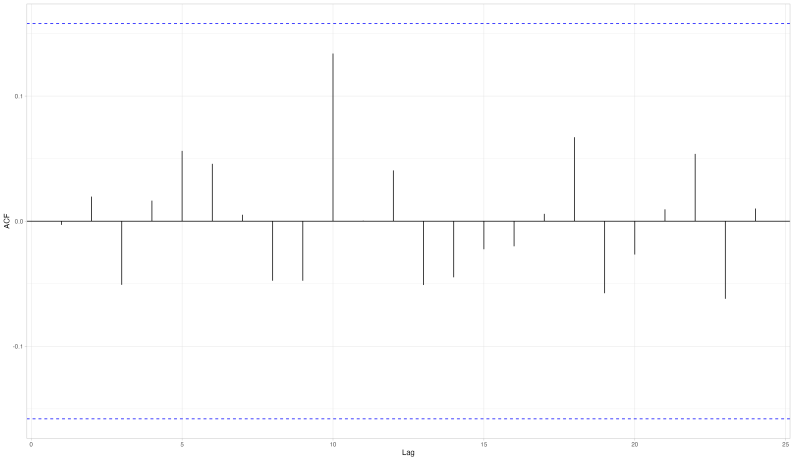

Figure 7: ACF of Text Surprises

Figure 8: The response of energy prices to climate policy shock