Dynamic effects of weather shocks on production in European economies

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The effects of climate on the business cycle and the economy
Federal Reserve Bank of San Francisco
November 2-3, 2023

Motivation

- A lot of attention has been devoted in the macro literature to identify the drivers of economic activity both in the long-run and at business cycle frequencies
- In addition to traditional drivers, the literature is now more and more focusing on the role of extreme weather events, given their higher observed frequency and stronger intensity
- Rich literature on the relationships between weather events and economic activity, relying either on theoretical models (IAMs by Nordhaus, 1993) or on empirical models

Motivation

- Looking at the empirical literature, find that relationships between extreme weather events and economic activity are complex and encompass various dimensions:

    1. Endogeneity: what is the direction of the causality?
    2. Horizon-dependence: short run *vs* long run
    3. Geographical heterogeneity: ADVs *vs* EMEs *vs* LICs
    4. Type of weather shock
    5. Sectoral effects and channels of transmission

Motivation

Overall, heterogeneous results as regards the impact of extreme weather on the economy. So, this work focuses on :

1. Impact of weather shocks on short term economic activity (Business cycle)
2. Euro area data, focusing on Germany, France and Italy
3. A new database of weather shocks: cold and heat stresses, droughts, heavy precipitations and intense winds, allowing a comparison across the type of weather shocks
4. Sectoral economic activity from the production side (Manufacturing, Construction, Energy, Services)

What do we do?

- Use a E^3CI database of various types of extreme weather shocks in some European countries (Germany, France, Italy)
- Assess the short-run impact on economic activity through the lens of Impulse Response Functions (IRFs) stemming from a Bayesian SVAR model
- Look at differentiated impacts across sectors / countries of various types of weather shocks (cool, heat, temperatures, wind, droughts)

$$\Downarrow$$

Series of BVARs of the kind:

$$\textit{weather shock}_{i,c} \rightarrow \textit{sector of production}_{j,c} \rightarrow \textit{other macro variables}_c$$

What do we get?

- Large heterogeneity in the results: impact of weather shocks on output are strongly dependent on the nature of the shock and on the country
    1. A cool shock affects positively construction in warm countries
    2. A heat shock affects positively construction in cold countries and negatively in warm countries
    3. Energy production is boosted by cool shocks and cut by heat shocks
    4. No evidence of a significant impact on services
    5. Italy is very sensitive to precipitation shocks while France is overall more resilient than Germany/Italy to weather shocks
- Non-linearities: size of the shock matters, no evidence for business cycle phase differences

Related Papers

- Kim et al. (2021, Richmond Fed WP) study the impact of ACI on the US economy via a ST-VAR. Find that a weather shock reduces industrial production and raises inflation and that the impact has increased overtime.

- Natoli (2022, Bank of Italy WP) finds that unfavorable temperature shocks reduce GDP, consumer prices and interest rates in the US.

- Billio et al. (2021, WP) estimate a panel MS model on EA countries with three weather shocks: temperatures, drought, rainfall. Find strong heterogeneity of effects across countries (North vs South of Europe), France is found to be the most resilient economy.

- Lucidi et al. (2022, WP) document an energy transmission channel of temperature anomalies and find that high temperatures dampen price growth in the EA.

Data on weather shocks

- E^3CI:[1] monthly index on various areas affected by different types of weather-induced hazards. Focus on Germany, France and Italy
- E^3CI is based on ACI, available for North America, and made available by **IFAB**.[2]
- Consists of 5 components, of which the E^3CI is the average:
    1. cold stress
    2. heat stress
    3. drought
    4. extreme precipitation
    5. extreme wind

[1] European Extreme Events Climate Index.

[2] International Foundation Big Data and Artificial Intelligence for Human Development.

Data on weather shocks

- The assessment of the components exploits ERA5, the fifth-generation atmospheric reanalysis produced by European Centre for Medium-Range Weather Forecasts
- ERA5 covers the entire Globe on regular latitude-longitude grids at 0.25 x 0.25 degree resolution from January 1950 to the present
- ERA5 is updated daily with a latency of about 5 days allowing a constant update of the components of E^3CI

Data on weather shocks

- weather shocks = Standardized Anomaly Computation wrt reference period 1981-2010
- Example for **Heat Stress**:
  1. On the reference period, for each calendar day, the maximum daily temperatures of a five-days centered window are considered. The 95^{th} percentile among the 150 values (5 days $\times$ 30 years) is computed and taken as threshold.
  2. For each month j and year k, the number of days exceeding the threshold is computed: $HS_{j,k}$.
  3. For each month j, the mean value μ_j^{HS} and the standard deviation σ_j^{HS} of $HS_{j,k}$ are calculated over the reference period. These are used to standardise the Heat Stress:

$$HS_{j,k}^{std} = \frac{HS_{j,k} - \mu_j^{HS}}{\sigma_j^{HS}}$$

Data on weather shocks - Interpretation

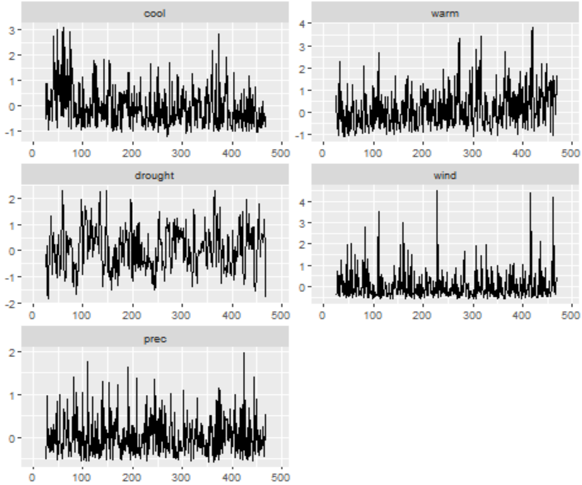
- IRFs will be computed using the 1*sd* normalization, what is 1*sd* of a weather shock computed in this way?

Heat stress in Germany: 4-5 days per month in which the maximum daily temperature exceeds the threshold.Threshold is calendar-day specific and ranges from around 10°C/50°F in January to around 30°C/86°F in July.

Cold stress in Germany: 3-5 days per month in which the minimum daily temperature is below the threshold (around -11°C/12°F in January and 10°C/50°F in July).

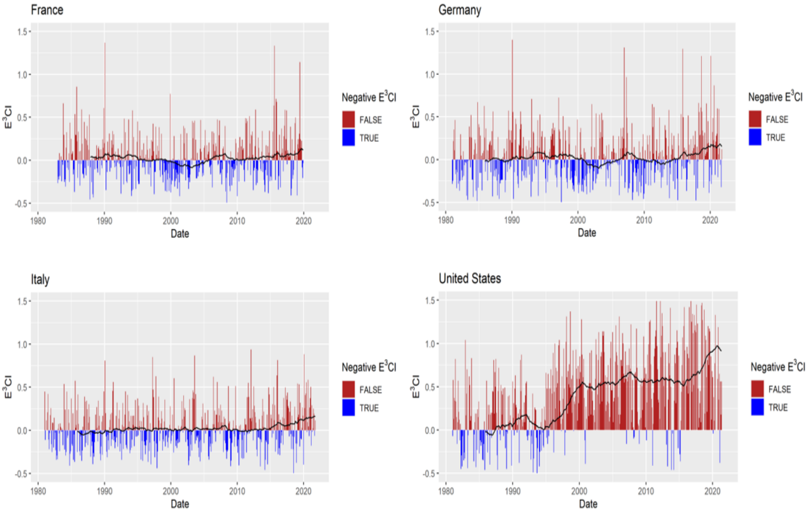
Data on weather shocks

- E3CI components for France



Data on weather shocks

- E3CI for European countries and ACI



Sectoral data

- Monthly data on industrial production, construction production, energy production, and services production, at the division level (annual growth, calendar and seasonally adjusted)
  Sectors are classified following NACE Rev. 2., the "statistical classification of economic activities in the European Community"
  Issue: data from G to N are only available for France

Section	
C	*MANUFACTURING*
D	*ELECTRICITY, GAS, STEAM AND AIR CONDITIONING SUPPLY*
F	*CONSTRUCTION*
G	*WHOLESALE AND RETAIL TRADE; REPAIR OF MOTOR VEHICLES AND MOTORCYCLES*
H	*TRANSPORTATION AND STORAGE*
I	*ACCOMMODATION AND FOOD SERVICE ACTIVITIES*
J	*INFORMATION AND COMMUNICATION*
L	*REAL ESTATE ACTIVITIES*
N	*ADMINISTRATIVE AND SUPPORT SERVICE ACTIVITIES*

Macro data for European countries

- Monthly data from January 1990 to December 2019
  - Unemployment rate for each country (source: Eurostat) - seasonally adjusted
  - Harmonized CPI for each country taken in annual growth (source: Eurostat) - YoY growth rates
  - Short-term interest rate for euro area, 3-month Euribor rate (source: OECD)

Modelling

- Modelling is based on a VAR model for each country of the following form:

$$\mathbf{y}_t = a_0 + A_1\mathbf{y}_{t-1} + \cdots + A_p\mathbf{y}_{t-p} + \epsilon_t, \quad \text{with} \quad \epsilon_t \sim N(0, \Sigma)$$

  where y_t contains all the variables

- Bayesian estimation *à la* Giannone et al. (2015), using priors taken from the "normal-inverse-Wishart" family:

$$\beta|\Sigma \sim N(\mathbf{b}, \Sigma \otimes \Omega), \quad \Sigma \sim IW(\Psi, \mathbf{d}),$$

  where **b**, Ω, Ψ and **d** can be expressed as function of the lower-dimensional vector of hyperparameters γ

- Robustness checks and some non-linear exercises have been carried out using Local Projections (Jordà 2005)

Modelling

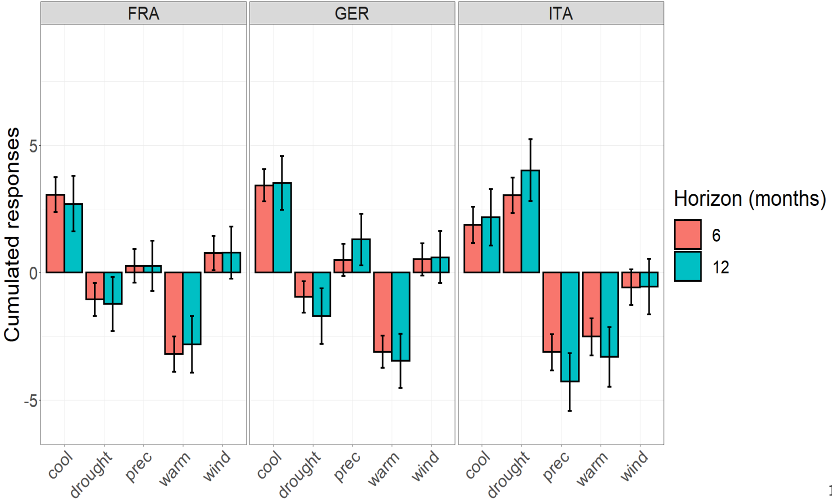
- For **identification**, we use the standard recursive approach (Cholesky decomposition).
- Following Kim et al. (2021), we order the weather variable first
  $\rightarrow$ Any unexpected change in economic variables is assumed to not have any influence on extreme weather events *within the same month*
- But medium-run evolution of economic variables can influence extreme weather shocks

Results

- Results are presented in terms of cumulated IRFs to specific weather shocks after 6 and 12 months
- Results are presented for various types of shocks, as an aggregate weather shock is likely to mask some effects playing in different directions
- We first look at results on 3 specific sectors of production: Energy, Manufacturing, and Construction.

Results: Energy

- Energy production (electricity, gas, steam and air conditioning supply) is significantly negatively affected by heat shocks in all countries and positively by cold shocks

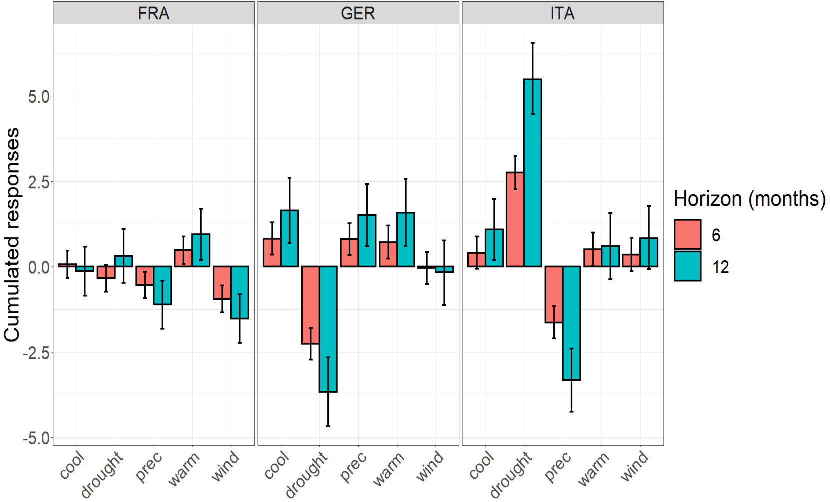


Results: Manufacturing

- More resilience of France to the various shocks
- In Germany, large negative impact of drought shock while other shocks have slightly significant positive effects
- In Italy, strong sensitivity to precipitations, while droughts tend to generate positive impact
- Overall results are quite heterogeneous, depending on the country of interest (in line with Billio et al., 2020)

Results: Manufacturing

- Response of Manufacturing to various types of shocks

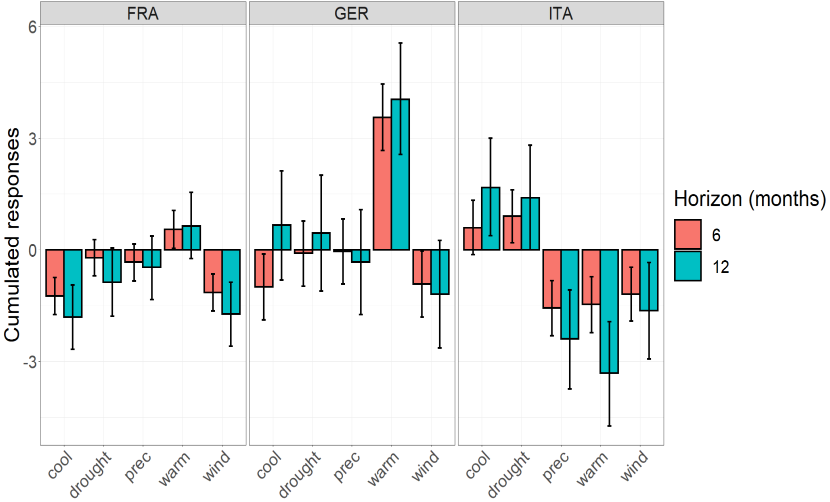


Results: Construction

- A given shock does not affect countries in the same direction (exception for wind)
- Temperatures:
  1. a cool shock: positive effect in Italy, but negative effect in France
  2. a heat shock: strongly positive effect in Germany but strongly negative in Italy
- Impact on construction seems to depend on the latitude of the countries as it is an outdoor economic activity

Results: Construction

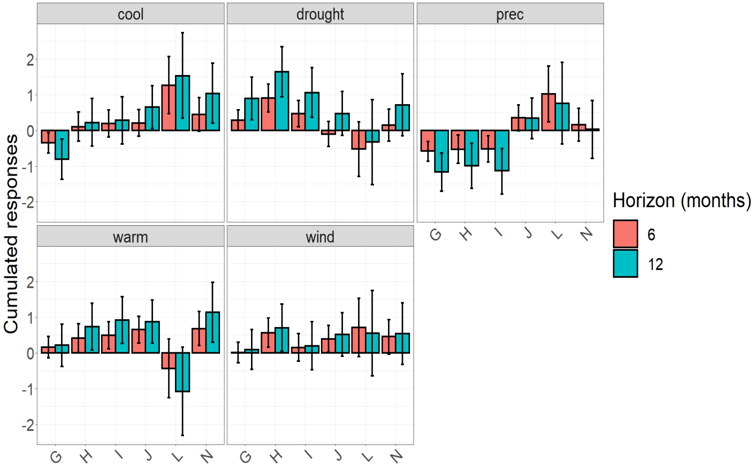
- Response of Construction to various types of shocks



Results: Services

- Services include:
  1. G: whole and retail trade,
  2. H: Transportation and storage,
  3. I: Accomodation and food services ,
  4. J: Information and Communication, Real estate,
  5. N: Administrative and support services
- Unfortunately, data for services is only available for France (Eurostat)
- Overall, relatively **low impact** on the service sector (in line with Acevedo et al., 2020)

Results: Impact on services

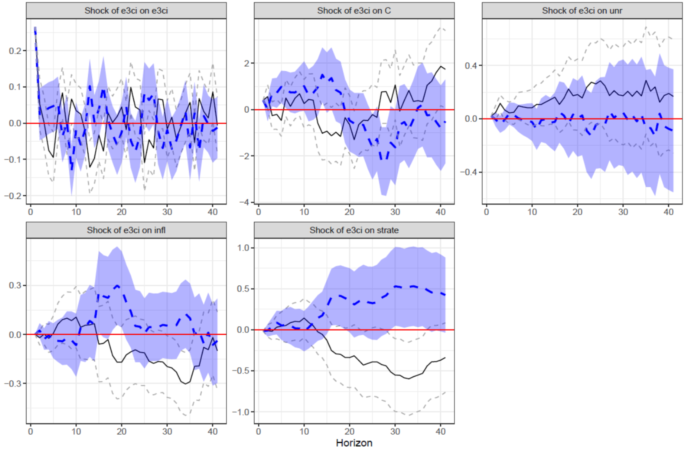


Results: Non-linearities

- One type of non-linearity that we explore is the dependence to the size of the shock: a large shock might have disproportionate effects compared to a small shock (Burke et al., 2005, Nature)
- We use lagged weather shock (aggregate E3CI) as transition variable in a non-linear LP framework and compute IRFs using Manufacturing as output variable: blue line corresponds to high regime (large shock) and dark line to low regime (small shock)
- Main result: a large shock leads to a disproportionate response of inflation, leading to monetary policy tightening. Less evidence for construction and energy.

Results: Non-linearities

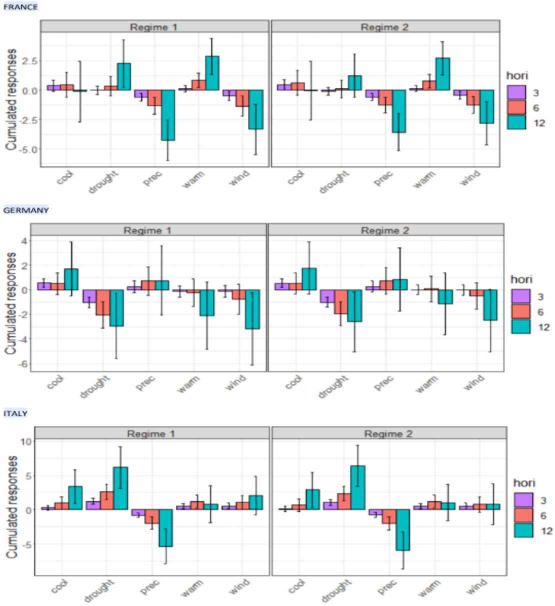
- IRFs to E3CI non-linear shock with Manufacturing as output (Italy)



Results: Non-linearities

- One of the results from Billio et al. (2022) is evidence of non-linearity wrt to the business cycle: stronger impact of weather shock when low phase of the business cycle
- We test this hypothesis by using past Manufacturing Production as transition variable
- Fail to reject the null as IRFs in both regimes are similar in terms of amplitude
- Similar results hold with other proxies of the business cycle as the European Commission indexes (ESI) stemming from surveys

Results: Non-linearities



Conclusions

- First attempt to assess the impact of weather shock on aggregate economic activity and production sectors in main European countries through the lens of a SVAR model
- Use a new innovative database of extreme weather events for 5 types of shocks: heat, cool, precipitation, wind and drought
- Evidence of significant impact on output (manufacturing, construction, energy), but strong heterogeneity in the results with dependence to the type of the shock and the country
- No clear impact on the production of services
- Evidence of non-linearity to the size of the shock for manufacturing, leading to monetary policy reaction when large shocks occur

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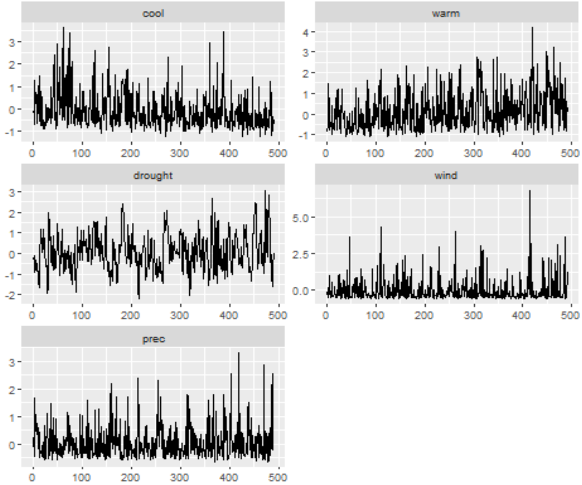
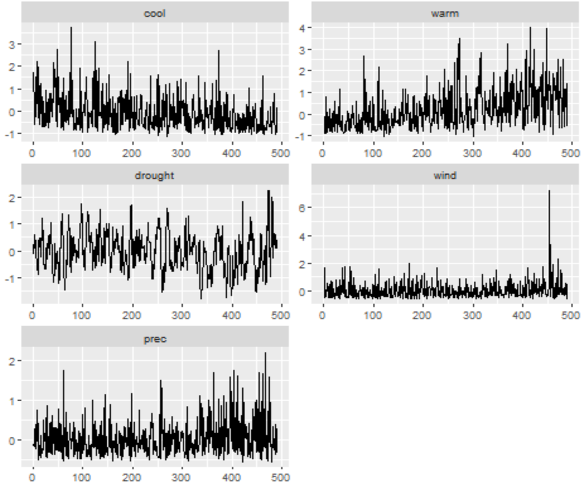
Data on weather shocks

- E3CI components for Germany



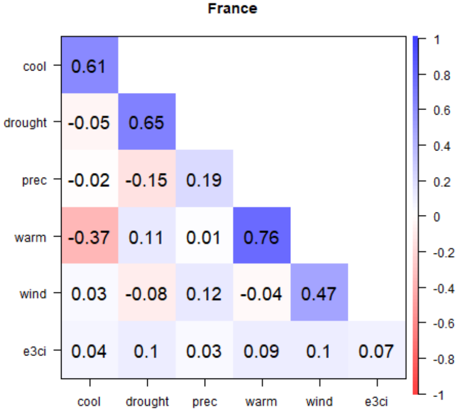
Data on weather shocks

- E3CI components for Italy



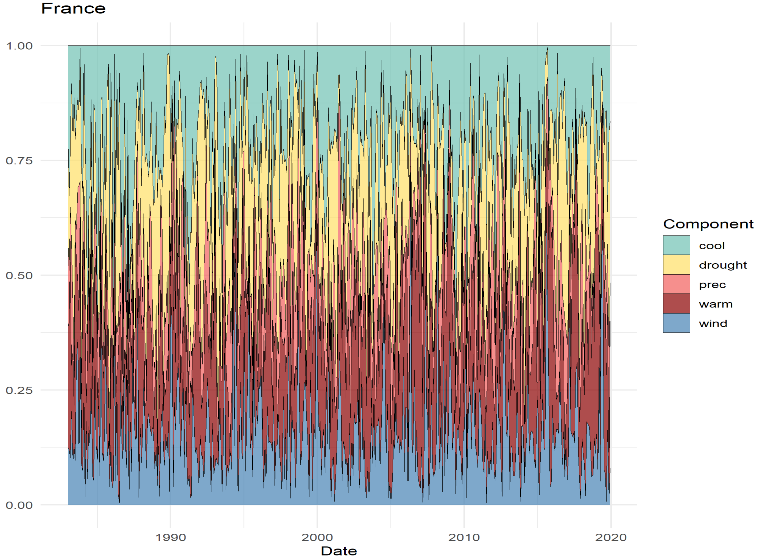
Data on weather shocks

- Variance-covariance matrix of components of E^3CI (Example for France)



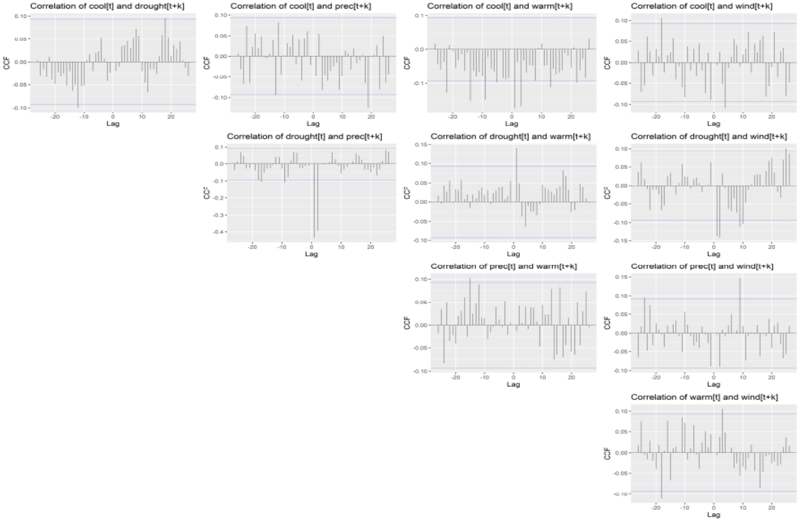
Data on weather shocks

- E3CI contributions of components (Example for France)



Data on weather shocks

- Cross-Correlation between shocks (Example for France)



Cross-country spillovers

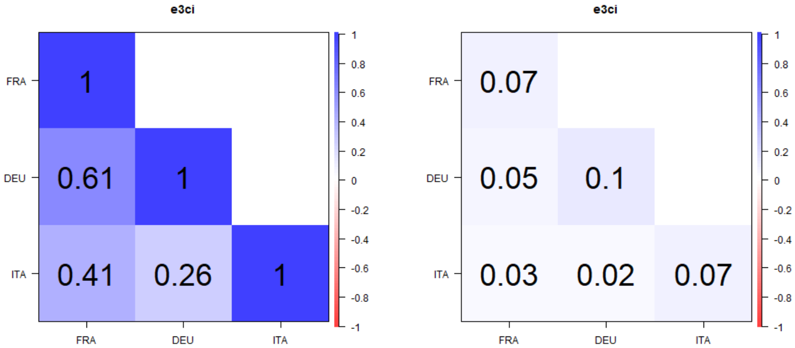
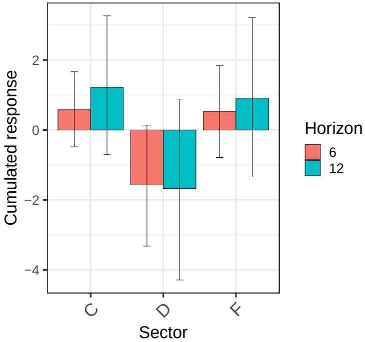


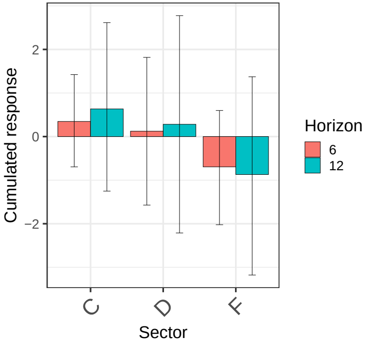
Figure: Correlation (left panel) and variance-covariance (right panel) matrices for the E^3CI across countries.

Cross-country spillovers

- No significant spillovers at the 6 and 12 months horizons (example for France)



German E^{3}CI on French sectors



Italian E^{3}CI on French sectors

Figure: Cumulated responses to a shock in the residual foreign E^{3}CI on domestic sectors.

Modelling

- Robustness checks and some extensions have been carried out using Local Projections (Jordà 2005)
- LPs allow to directly estimate IRFs in a easier way:

$$y_{t+h} = c^h + \beta_h \nu_t + \Gamma \mathbf{x}_t + u_{t+h}^h \qquad \text{for} \quad h = 1, \cdots, H \quad (1)$$

  where ν_t is the shock, $\mathbf{x}_t$ a set of control (lagged) variables including those included into the SVAR. β_h is the response of y at $t+h$ after a shock at t and the IRF is the sequence $\{\beta_h\}_{h=1}^{H}$.

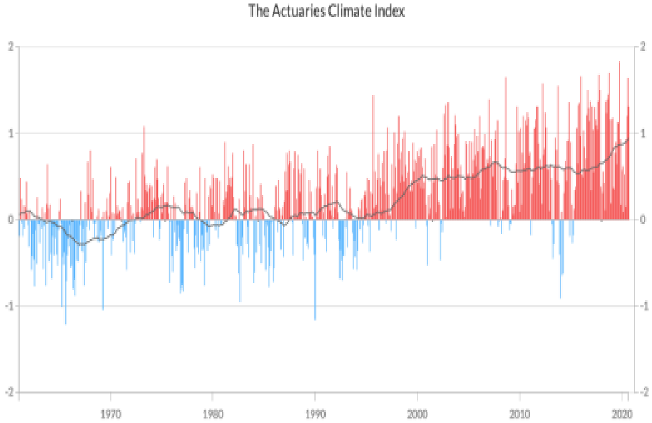
- We also use LPs to integrate non-linearities into the dynamics

Literature review: Kim et al. (2021)

- Most related paper is Kim, Matthes and Phan (2021, Richmond Fed WP) who investigate potential time-varying effects of extreme weather on the U.S. economy over the past 60 years
- Use the monthly Actuaries Climate Index (ACI, provided by American Academy of Actuaries and Canadian Institute of Actuaries) that summarises deviations to the mean of physical and meteorological observations of (i) temperatures (min and max), (ii) rainfall, (iii) drought, (iv) wind speed, and (v) sea level, into a unique measure of extreme weather.

Literature review: Kim et al. (2021)

- ACI aggregate index shows an increase over time since mid-90s



Literature review: Kim et al. (2021)

- Kim et al. (2021) study the impact of ACI on the growth rate of industrial production through the lens of a SVAR model that accounts for standard macroeconomic variables: industrial production, unemployment rate, CPI inflation and short-term interest rate.
- They show by estimating a non-linear time-varying SVAR model that the economic impact of weather shocks has increased overtime.

Literature review: Kim et al. (2021)

- A weather shock reduces industrial production and raise inflation since 1990 (red lines), but not before (blue lines) (source Kim et al., 2021)