# Global Inflation Dynamics in the Face of Climate Change: A Unified Approach Using the Climate Condition Index (CCI)

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# Motivation I:

- In recent decades, the growing impact of climate change has emerged as a pressing global concern
- Climate change particularly affects agriculture—a critical sector that significantly influences inflation dynamics, especially in emerging economies

Previous studies have utilized various climate indicators:

- ✓ Rainfall (Odongo, Misati, Kamau, & Kisingu, 2022)
- ✓ Climate disasters (Parker, 2018)
- ✓ Climate change news index (Zhang, 2023)
- ✓ Temperature (Köse & Ünal, 2022), to examine their individual impacts on inflation

However:

- ✓ none of these indicators can fully capture the complexity of climate change alone
- ✓ none of these studies have a comprehensive structural understanding of the connection between climate change and inflation

# Motivation II:

**Consequently, we are interrogating:**

1. **With which transmission channel climate change can affect inflation?**
2. **What is climate change, and which variables indicate it?**
3. **Can we quantify the impact of climate change on inflation?**

## Outline:

1. The scope of our study
2. Building a theoretical context of climate change impact transmission on inflation
3. Generating a novel Climate Condition Index (CCI)
4. Investigating the historical relation between inflation and climate change
5. by a Vector Error Correction Model (VECM)

## The scope and method of our study

1. Focusing on the theoretical context of climate change impact transmission on inflation

- Inspired from:
  - ✓ Friedrich & Selcuk (2022), which examined the impact of globalization and digitization on inflation
  - ✓ Blair (1974); Weiss (1966); Weber & Wasner (2023), which focuses on price-setting behavior transmission

  we discuss the role of climate change on marginal cost and also inflation elasticity to marginal cost through:
  - ✓ productivity
  - ✓ slope parameters
  - ✓ markup dynamics

2. Focusing on the generation of unique climate change indicator

- Benefiting from:
  - the long-run relationship between inflation and five essential climate indicators:
    - ✓ cloud coverage, temperature, precipitation, wet day frequency, and vapor pressure

3. Focusing on quantifying the climate change impact on inflation
   - Based on VECM estimations

## Contributions and Findings

- We propose a Climate Condition Index that characterizes both short- and long-run change in climate conditions
- We find that approximately 77% of analyzed countries are significantly affected by climate change:
  - ✓ 3 out of 39 countries significantly benefit from climate change
  - ✓ 27 countries witness significant inflationary climate impulses
- In response to climate change:
  - ✓ inflation in middle-income countries negatively affected is almost 4 times higher than in high-income economies
  - ✓ inflation in food-importing countries negatively affected is two times higher than in exporter ones

# Conceptualizing *Climate Change* as a determinant of **Inflation**

# Inflation formation – NKPC I

Firms' periodic profit maximization problem can be expressed as follows (Holmberg, 2006):

$$max_{P_{it}} E_t \sum_{j=0}^{\infty} (\beta\theta)^j V_{t,t+j} \left[ \frac{P_{it}}{P_{t+j}} Y_{it+j} - \frac{MC_{it+j}}{P_{t+j}} Y_{it+j} \right] \quad (1)$$

, where

$\theta$ is the probability of the firm not being allowed to change the price in each period,

$\beta^j V_{t,t+j}$ is the stochastic discount factor,

$P_i$ is the nominal price,

$Y_i$ is output,

$MC_{it+j}$ is the firm's marginal cost.

The log-linearized solution for this optimization is:

$$p_{it} = (1 - \beta\theta)[mc_{it}^r + p_t] + \beta\theta E_t p_{it+1} \quad (2)$$

, where

$mc_{it}^r$ is real marginal cost.

# Inflation formation – NKPC II

The real marginal cost can be derived from:

$$Y_t = A_t K_t^{1-\alpha} N_t^{\alpha} \quad (3)$$

, where A identifies technology, K denotes capital, N is labor, and 0<α<1

as below:

$$mc_{it}^{r} = \frac{1}{(1-\alpha)}(w_t + l_t - p_t - y_t) \quad (4)$$

, where

$w_t$ is log nominal wages

$l_t$ is log labor

Replacing real marginal cost in Equation 2 and denoting inflation rate as $\pi_t \equiv p_t - p_{t-1} = \Delta p_t$, we obtain inflation as:

$$\pi_{it} = (1 - \beta\theta)\left[\frac{1}{(1-\alpha)}\Delta(w_t + l_t - p_t - y_t) + \pi_t\right] + \beta\theta E_t \pi_{it+1} \quad (5)$$

Upon this point, it is assumed that firms "set prices as a constant markup over current marginal cost" (Holmberg, 2006, p. 3)

# Inflation formation – PKPC

However, markup may change due to several factors during the transition path to steady state or equilibrium

Consequently, the price formation problem can be expressed as Weintraub's model as below:

$$P = K\frac{WL}{Y} \quad (6)$$

, where

$W$ is nominal wage
$L$ is labor hours
$K$ is average markup

Differentiating Equation 6 in a logarithmic form, we obtain inflation similar to Equation 5 without the expected inflation term:

$$\pi = \Delta k + \lambda(\Delta w + \Delta l - \Delta y) \quad (7)$$

, where $\Delta k$ denotes the change in the markup and $\lambda$ would expected to be one (Dutkowsky & Gianturco, 1986).

# Climate change and Inflation formation

**NKPC:**

$$\pi_{it} = (1 - \beta\theta)\left[\frac{1}{(1-\alpha)}\Delta(w_t + l_t - p_t - y_t) + \pi_t\right] + \beta\theta E_t \pi_{it+1} \quad (5)$$

**PKPC:**

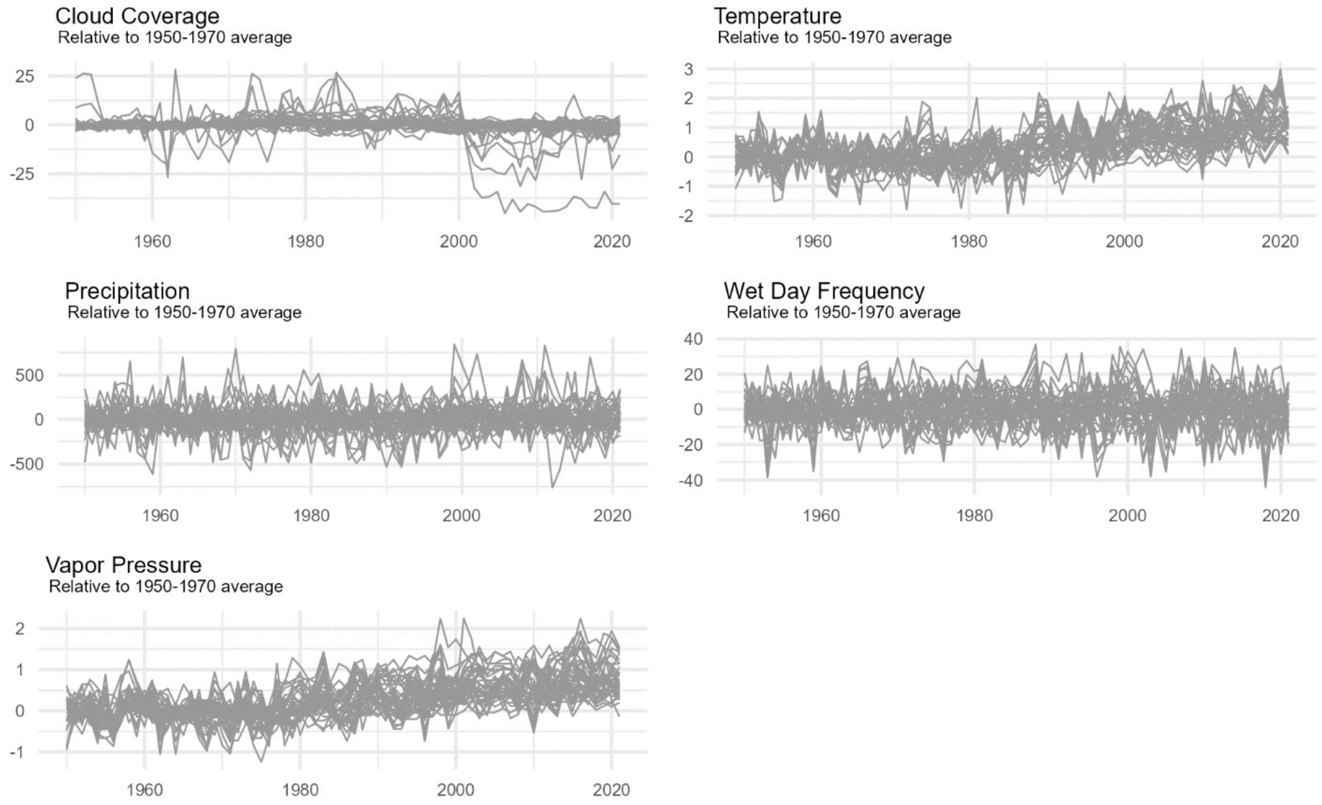
$$\pi = \Delta k + \lambda(\Delta w + \Delta l - \Delta y) \quad (7)$$

1. Climate change increases marginal costs through productivity
2. A new inflation determinant that is not accounted previously may increase the inflation elasticity to marginal cost (Friedrich & Selcuk 2022), $\frac{(1-\beta\theta)}{(1-\alpha)}$ in Eq. 5 or $\lambda$ in Eq. 7:
   - ✓ $\theta$ *(probability of the firm not being allowed to change the price in each period)* will decrease in response to common climate change costs to all agricultural producers:
     - ✓ "*firms can safely increase prices since they have a mutual expectation that all market players will do the same*" (Weber & Wasner, 2023, p. 190)
3. Climate change may increase markups, $\Delta k_t$ in Equation 6:
   - ✓ when faced with unique costs for all companies, firms increase the nominal markup more than the costs (Blair, 1974; Weiss, 1966; Weber & Wasner, 2023)

# Generating *Climate Change* indicator

# Climate Condition Index (CCI)

## Climate variables




## Index generation methods

- An equally weighted index
  - × assigning equal importance to all climate variables
- Principal Component Analysis (PCA)
- A model-based weighted sum
  - ✓ Is an importance based, where the focus dependent variable is inflation
  - × Eliminates trends in the data when utilized stationary models
  - ✓ Preserve trends when utilized in level terms such as VECM
  - ✓ Deal with multidimensional relations among climate variables

# Before proceeding with VECM

- ✓ We check the existence of **cointegration relations** using the Johansen procedure for each country separately
- ✓ We select the **appropriate lag order** by utilizing the Hannan-Quinn criterion (HQ)
- ✓ To ensure the stability of model parameters, following Calza, Gartner, and Sousa (2021), we detect **structural break points** in the parameters of VECM by breakpoint Chow test

# Model

$$\Delta x_t = \theta x_{t-1} + \sum_{l=1}^{p-1} \Gamma_l \, \Delta x_{t-l} + \delta det_t + \; dum_t^{dis} + dum_t^{sb} + \varepsilon_t$$

where:

- $\Delta x$ is the vector x variables' (cumulative price level, cloud coverage, precipitation, temperature, vapor pressure, and wet day frequency) first differences,
- $\theta$ is the cointegrating relationship coefficient matrix,
- $\Gamma$ is the lags of differenced variables' coefficient matrix,
- $det$ is a vector of deterministic terms,
- $\delta$ its corresponding coefficient matrix,
- $dum^{dis}$ is climate-related natural disaster (drought, storm, flood, landslide, wildfire, extreme temperature, fog, glacial lake outburst) frequency dummy variables,
- $dum^{sb}$ is structural break dummy,
- p is the lag order of the model, and $\varepsilon$ is an error term.

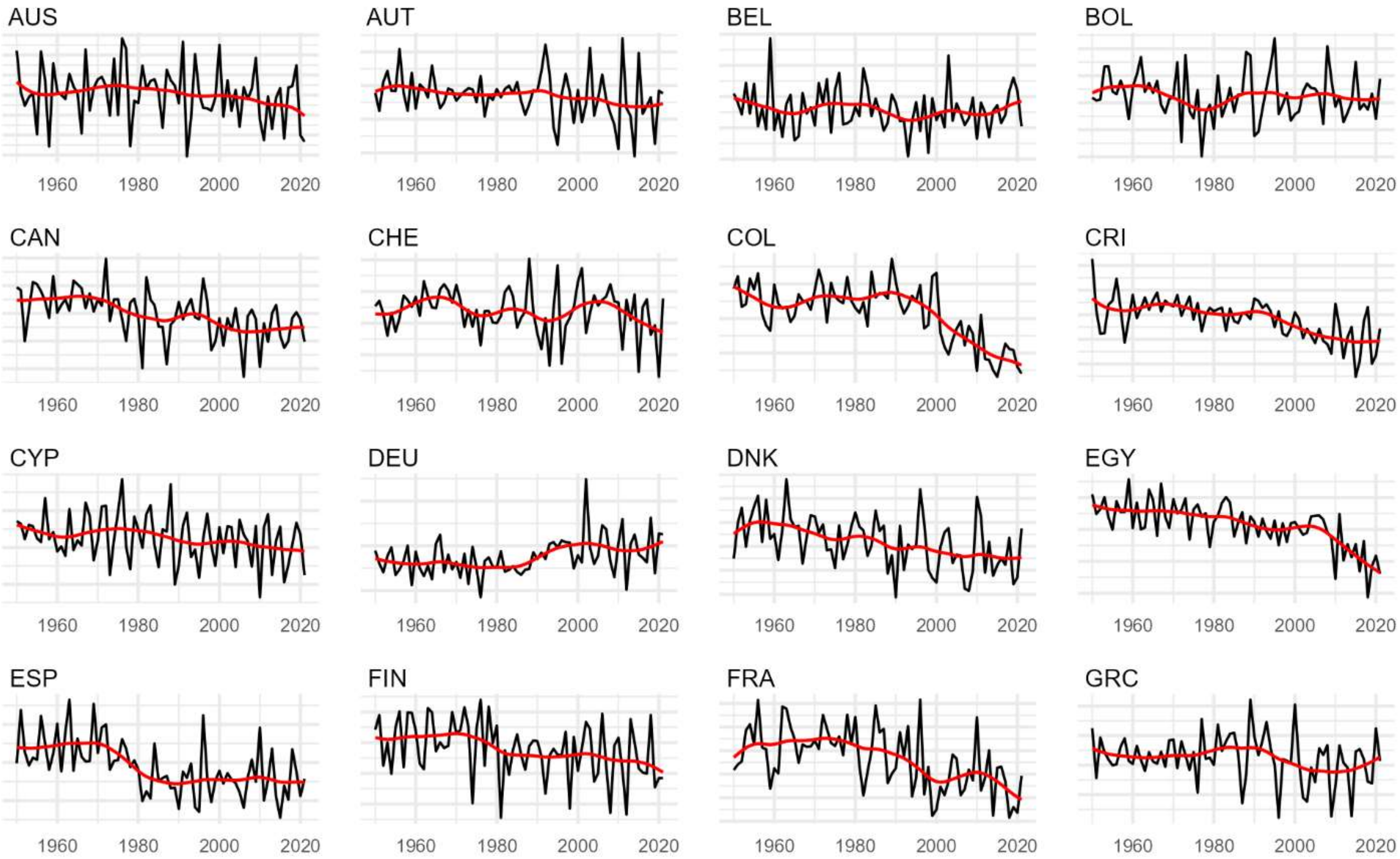
The coefficient matrix $\theta$ can be written as:

$$\theta = \alpha\beta'$$

where:

- $\alpha$ is the speed of convergence to equilibrium,
- $\beta$ is the long run cointegration (or equilibrium) coefficient matrix that is used to generate the CCI.

# Climate Condition Index



# Estimating *Climate Change* impact on Inflation

## Regional results:

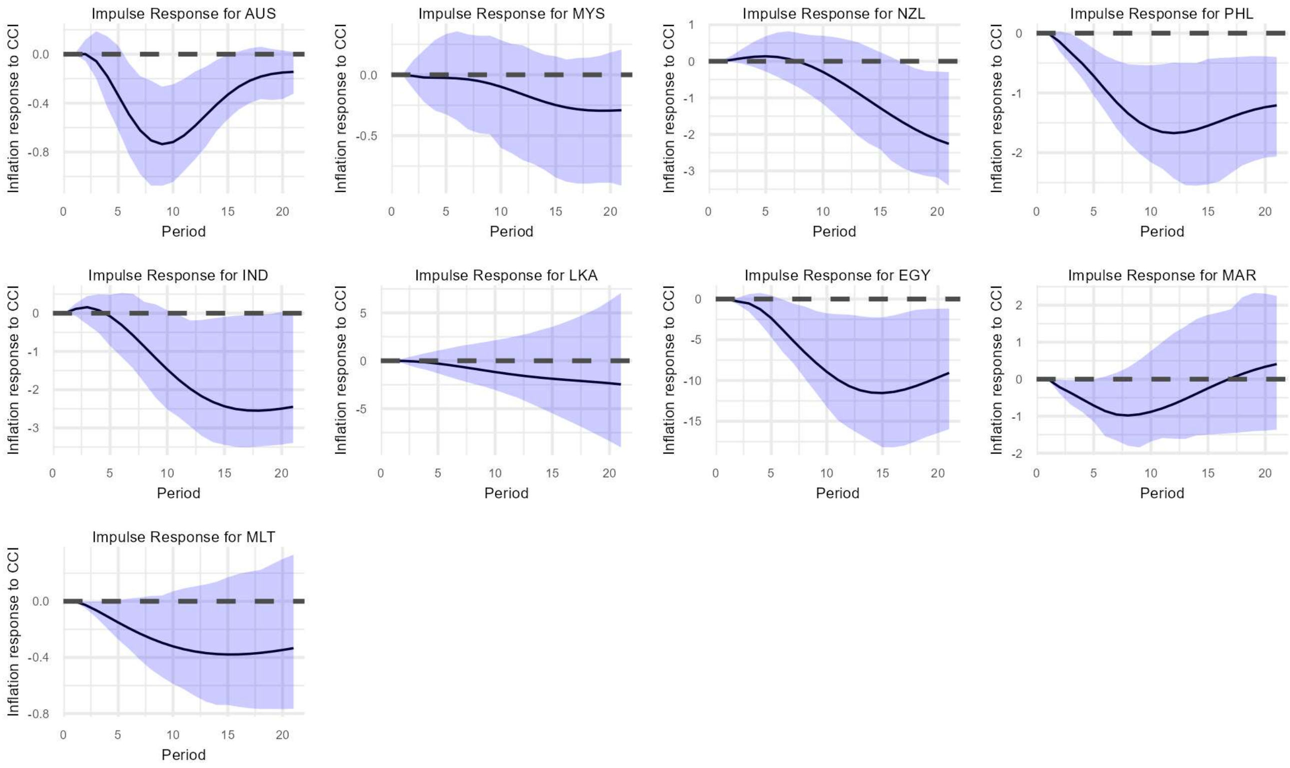
**Short-run impact:**
Malta and Morocco

**Mid-run impact:**
Australia and India

**Long-run impact:**
Philippines, Egypt, and New Zealand

**Are not significant:**
Malaysia and Sri Lanka

## Impulse Response of Asia and Middle East & North Africa



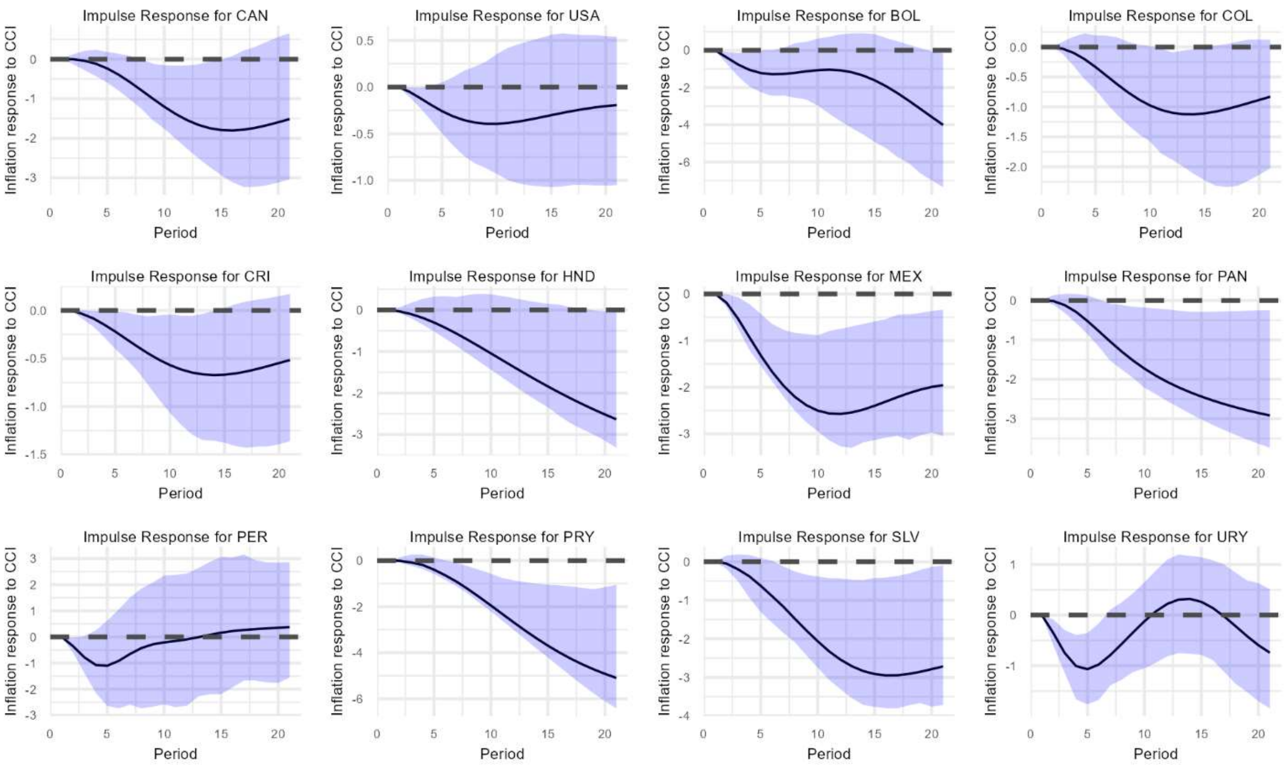
## Regional results:

**Short-run impact:**
USA, Peru, and Uruguay

**Mid-run impact:**
Canada, Colombia, and Costa Rica

**Long-run impact:**
Bolivia, Honduras, Mexico, Panama, Paraguay, and El Salvador

### Impulse Response of Americas



## Regional results:

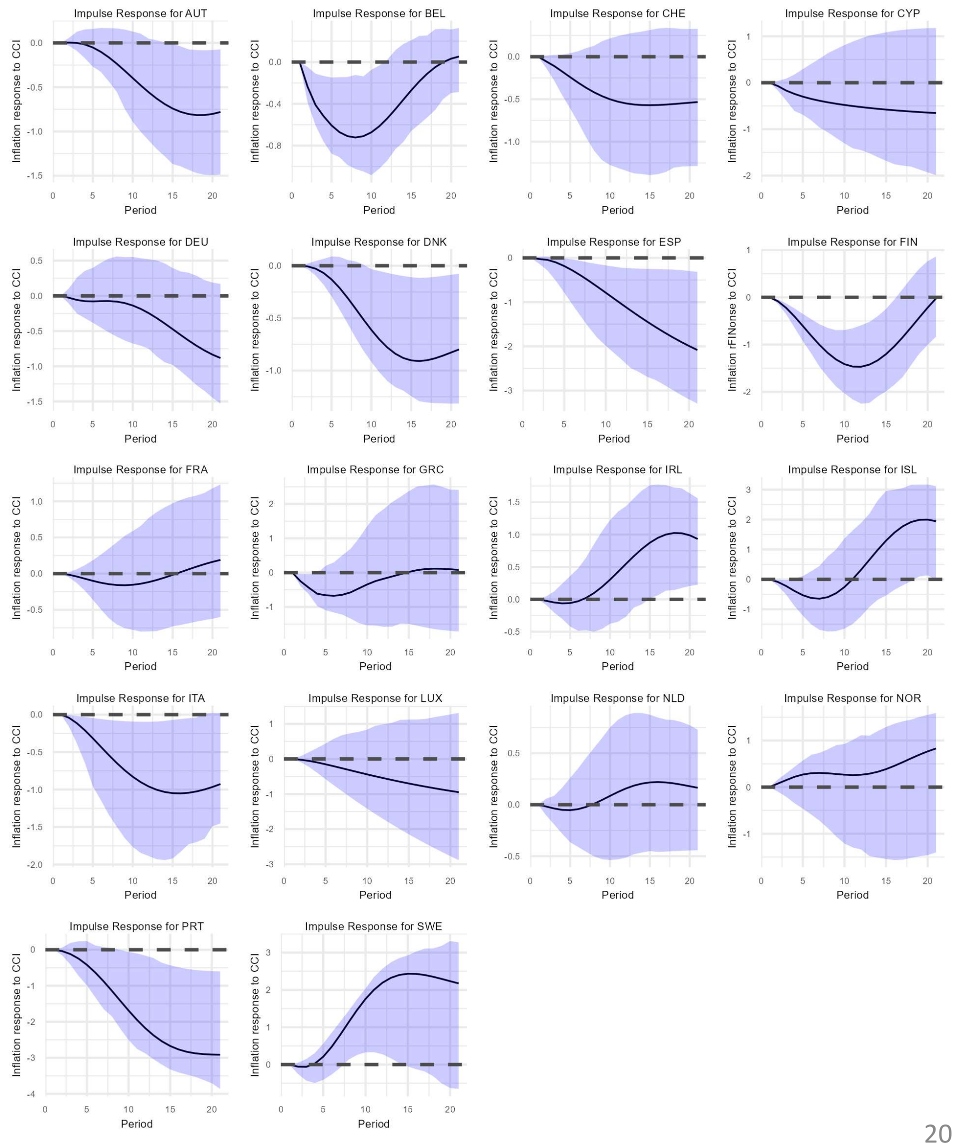
**Short-run impact:**
Greece

**Mid-run impact:**
Belgium, Finland, Italy, and Sweden (deflationary)

**Long-run impact:**
Austria, Denmark, Spain, Portugal,
Ireland (deflationary), and Iceland (deflationary)

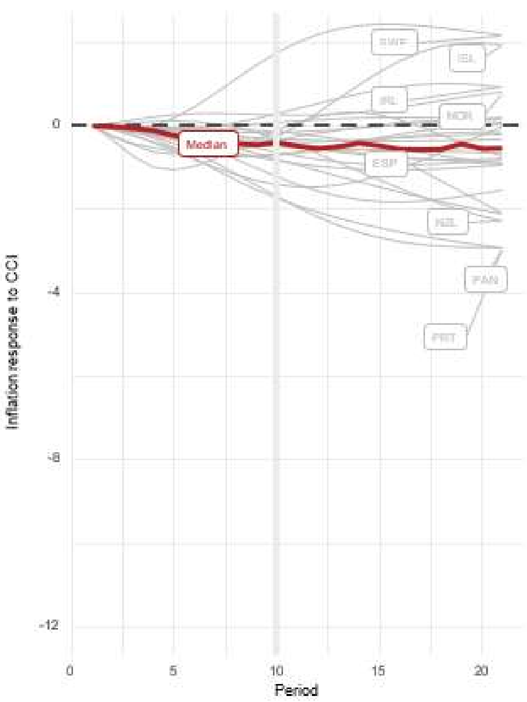
**Are not significant:**
Switzerland, Cyprus, Germany, France, Luxembourg,
Netherlands, and Norway

## Impulse Response of Europe and Central Asia

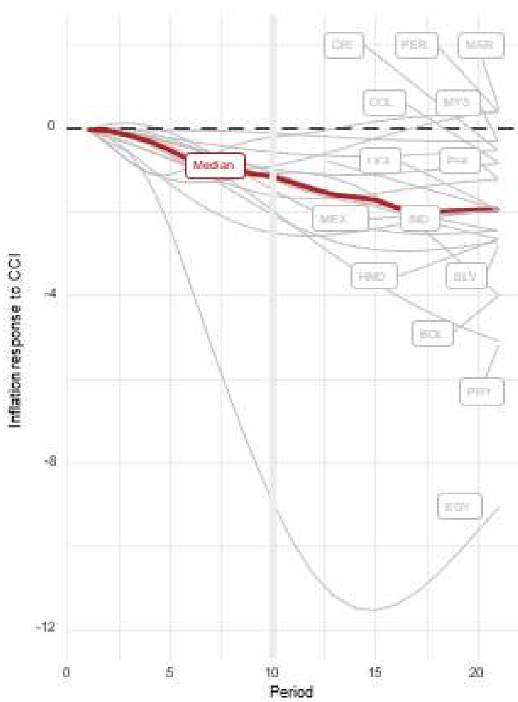


## Group results demonstrating that middle-income countries face nearly four times the negative impact on inflation compared to high-income economies

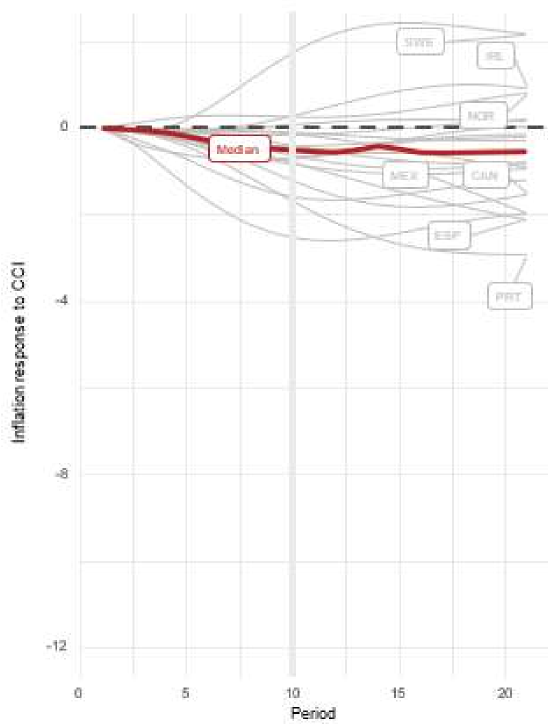
A. Impulse Response for High-income



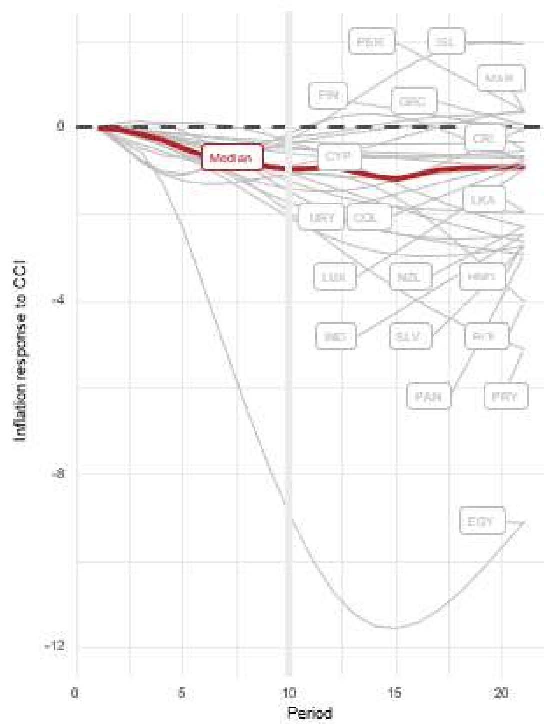

B. Impulse Response for Middle-income




A. Impulse Response for Food Exporters




B. Impulse Response for Food Importers




- ✓ Food importers and middle-income countries are more prone to be affected by worsening climate conditions
- ✓ The impact of climate change is inflationary for up to 10 years for almost all analyzed food importers and middle-income countries

# Contributions and Findings

- We unify five indicative climate variables into a Climate Condition Index (CCI)
- The Climate Condition Index characterizes both short- and long-run change in climate conditions
- We find that approximately 77% of analyzed countries are significantly affected by climate change:
  - ✓ 3 out of 39 countries significantly benefit from climate change
  - ✓ 27 countries witness significant inflationary climate impulses
- In response to climate change:
  - ✓ inflation in middle-income countries negatively affected is almost 4 times higher than in high-income economies
  - ✓ inflation in food-importing countries negatively affected is two times higher than in exporter ones

Thanks for your *attention*

# APPENDIX

# Analyzed Countries

| High-income | | | | Middle-income | | | |
|---|---|---|---|---|---|---|---|
| Abbreviation | Country | Region | Trade status | Abbreviation | Country | Region | Trade status |
| AUS | Australia | East Asia & Pacific | Exporter | COL | Colombia | Latin America & Caribbean | Importer |
| AUT | Austria | Europe & Central Asia | Exporter | CRI | Costa Rica | Latin America & Caribbean | Importer |
| BEL | Belgium | Europe & Central Asia | Exporter | MEX | Mexico | Latin America & Caribbean | Exporter |
| CAN | Canada | North America | Exporter | MYS | Malaysia | East Asia & Pacific | Exporter |
| CHE | Switzerland | Europe & Central Asia | Exporter | PER | Peru | Latin America & Caribbean | Importer |
| CYP | Cyprus | Europe & Central Asia | Importer | PRY | Paraguay | Latin America & Caribbean | Importer |
| DEU | Germany | Europe & Central Asia | Exporter | BOL | Bolivia | Latin America & Caribbean | Importer |
| DNK | Denmark | Europe & Central Asia | Exporter | EGY | Egypt, Arab Rep. of | Middle East & North Africa | Importer |
| ESP | Spain | Europe & Central Asia | Exporter | HND | Honduras | Latin America & Caribbean | Importer |
| FIN | Finland | Europe & Central Asia | Importer | IND | India | South Asia | Importer |
| FRA | France | Europe & Central Asia | Exporter | LKA | Sri Lanka | South Asia | Importer |
| GRC | Greece | Europe & Central Asia | Importer | MAR | Morocco | Middle East & North Africa | Importer |
| IRL | Ireland | Europe & Central Asia | Exporter | PHL | Philippines | East Asia & Pacific | Exporter |
| ISL | Iceland | Europe & Central Asia | Importer | SLV | El Salvador | Latin America & Caribbean | Importer |
| ITA | Italy | Europe & Central Asia | Exporter | | | | |
| LUX | Luxembourg | Europe & Central Asia | Importer | | | | |
| MLT | Malta | Middle East & North Africa | Importer | | | | |
| NLD | Netherlands, The | Europe & Central Asia | Exporter | | | | |
| NOR | Norway | Europe & Central Asia | Exporter | | | | |
| NZL | New Zealand | East Asia & Pacific | Importer | | | | |
| PAN | Panama | Latin America & Caribbean | Importer | | | | |
| PRT | Portugal | Europe & Central Asia | Exporter | | | | |
| SWE | Sweden | Europe & Central Asia | Exporter | | | | |
| URY | Uruguay | Latin America & Caribbean | Importer | | | | |
| USA | United States | North America | Exporter | | | | |

A country is classified as a main food exporter if its share of global food exports exceeds 0.5%.