PIER

PUEY UNGPHAKORN INSTITUTE
FOR ECONOMIC RESEARCH

The Macroeconomic Effects of Climate Shocks in Thailand

Chaitat Jirophat, Pym Manopimoke, Suparit Suwanik

December 28, 2021

Motivation

- Climate change has become an increasing concern for CBs as it poses MP risks *(Batten et al., 2020; Molico, 2019; Bremus et al., 2020; Andersson et al., 2020)*
  - Measuring its quantitative impact is key towards devising appropriate policy responses
- Thailand - a developing country with a hot climate, reliance on the agricultural sector, and a large food component is particularly vulnerable to climate risks *(Buckle et al., 2007; Heinen et al. 2016; Parker, 2018; Acevedo et al., 2018)*
- Limited studies focus on the macroeconomic impacts of climate shocks
  - Thai studies focus on regional output *(Sangkhaphan and Shu, 2019)* or individual crops *(Pipitpukdee et al., 2020, Pakeechai et al., 2020)*
  - International studies are mostly based on cross-country analysis *(Dell et al., 2012; Burke and Tanutama, 2019)*
  - Integrated Assessment models are quite broad and complex *(Gillingham et al., 2015)*

This Paper

- Quantifies and analyzes the macroeconomic impacts of extreme weather events (physical risk) in Thailand over the short to medium run horizons

Table 2: Economic impacts relevant for monetary policy and time horizon for the materialization of climate risks

Type of risk		Economic outcome	Timing of effects
Physical risks from:	Extreme climate events	Unanticipated shocks to components of demand and supply	Short to medium run
	Global warming	Impact on potential productive capacity and economic growth	Medium to long run
Transition risks		Demand/supply shocks or economic growth effects	Short to medium run

Source: Batten et al. (2020)

This Paper (cont.)

Focuses on **output and inflation:**

- Aggregate and disaggregated analysis to sort out channels of transmission
- Investigates country level and cross-regional effects
  - Time-series VAR approach (Buckle et al., 2017; Bremus et al., 2020)
  - Panel ARDL model (Kahn, 2019)
- Considers the impacts of asymmetric and extreme climate conditions (Burke et al. 2015; Kotz et al. 2021; Callahan and Mankin, 2021)

Roadmap

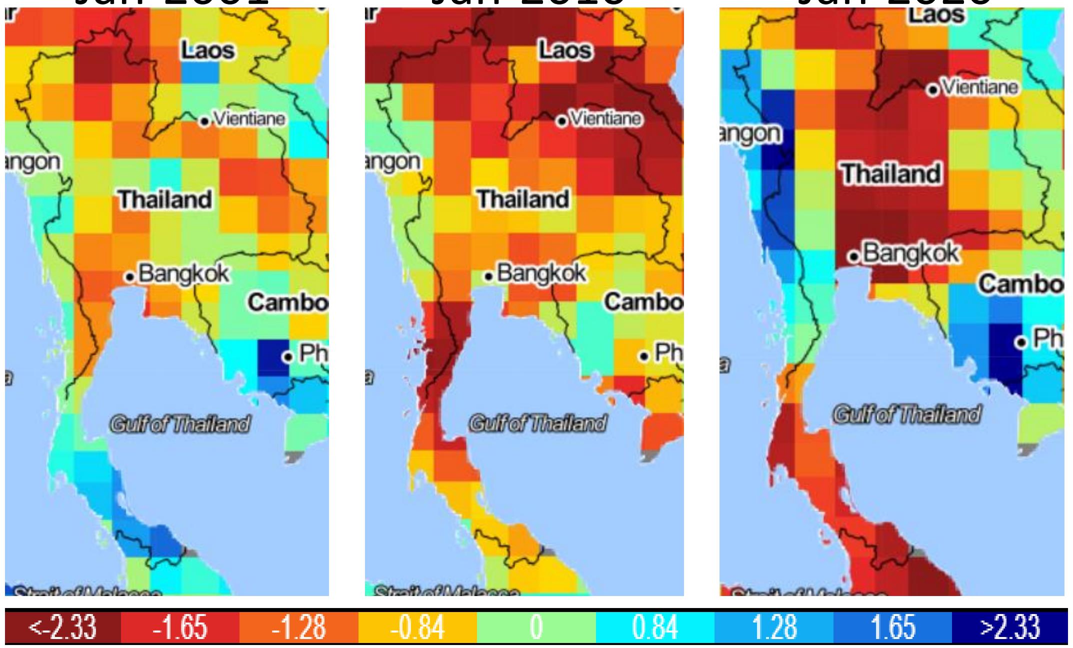
- Introducing the Climate Variable
- Country-level Analysis (VAR model)
- Cross-regional Analysis (Panel ARDL model)
- Key takeaways and Policy Implications

Climate Data

Standardized Precipitation Evapotranspiration Index (SPEI)*

- Measuring cumulative water balance, based on both precipitation (P) and potential evapotranspiration (PET), compared to the norms
- Standardized Index with multi-timescales, from 1 to 48 months

Jan-2001 Jan-2010 Jan-2020



*Source: https://spei.csic.es/

Table B.1. SPEI Drought Classification

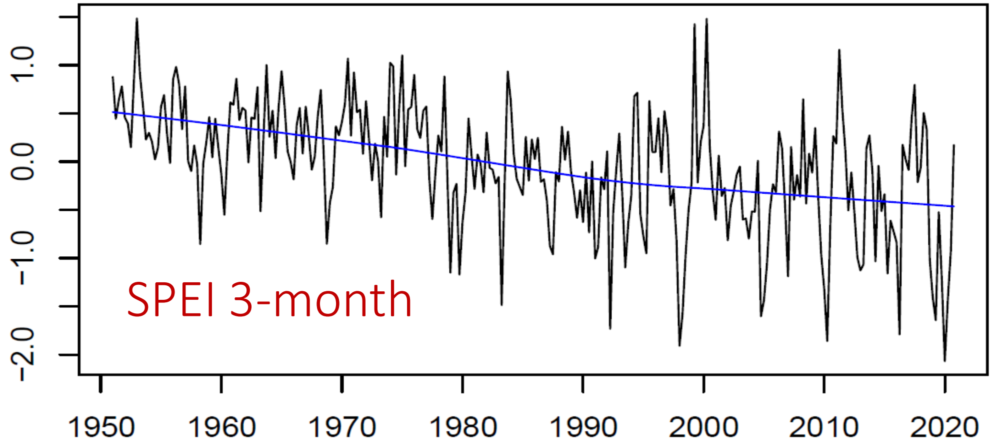
SPEI > 2	Exceptionally moist
1.60 < SPEI < 1.99	Extremely moist
1.30 < SPEI < 1.59	Very moist
0.80 < SPEI < 1.29	Moderately moist
0.51 < SPEI < 0.79	Slightly moist
0.50 < SPEI < 0.50	Near normal conditions
0.79 < SPEI < 0.51	Slightly dry
1.29 < SPEI < 0.80	Moderately dry
1.59 < SPEI < 1.30	Very dry
1.99 < SPEI < 1.60	Extremely dry
SPEI < 2	Exceptionally dry

Source: NOAA's National Centres for Environmental Information

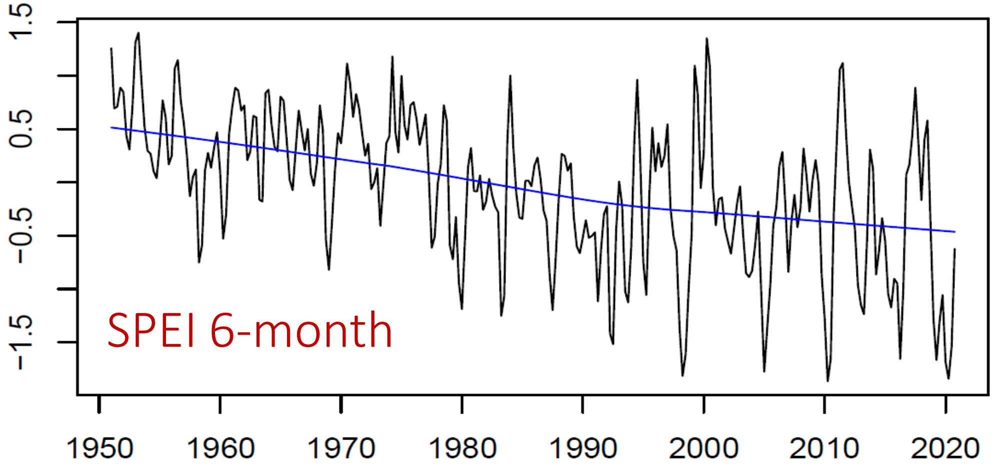
Drier Trend Over Time

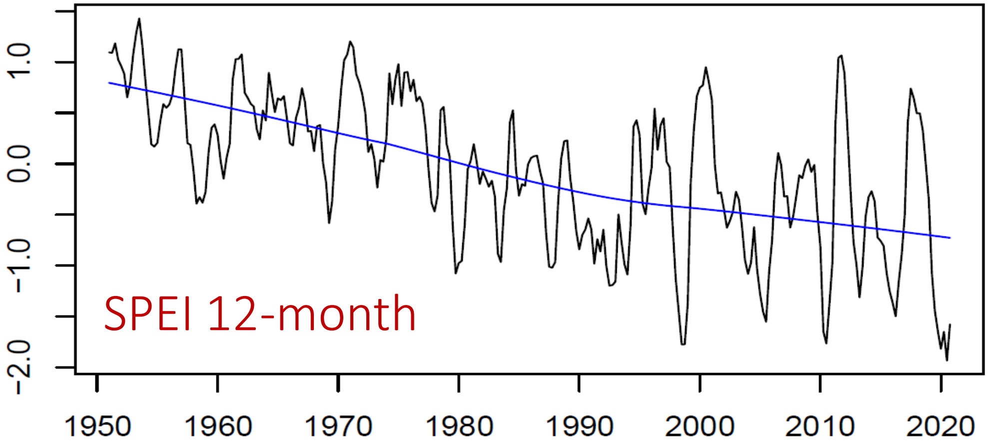
The Mann Kendall trend test shows significant ***negative trends*** in all SPEIs

- ***Drier*** weather conditions overtime



Trend Test	Mann Kendall Test	p-value
SPEI 3 month	-0.3584	0.0000
SPEI 6 month	-0.3783	0.0000
SPEI 12 month	-0.4319	0.0000

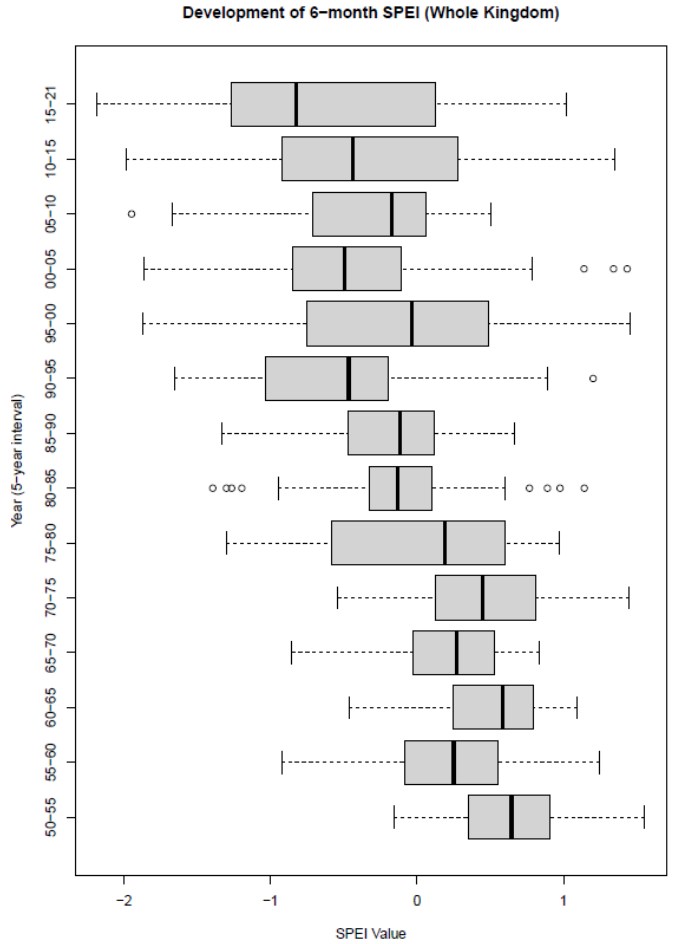


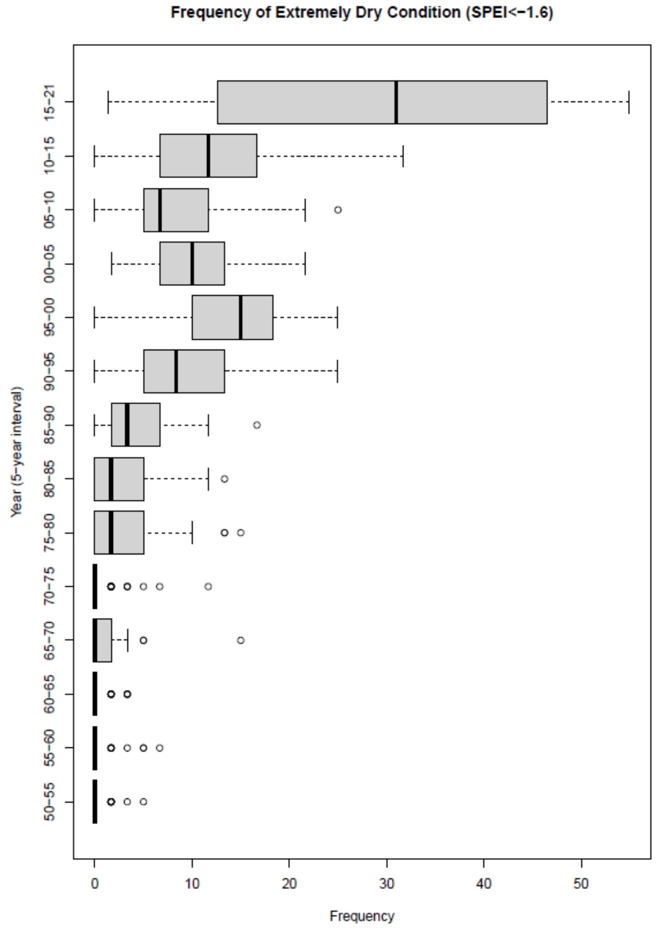


More Volatile and Frequent

Drier weather conditions have become more ***volatile*** overtime

Extremely dry conditions are more ***frequent*** overtime





Climate Data

SPEI 3-, 6-, 12-month indices over 57 grids during 2001-2020

- Cross-sectional aggregation via mean
- Shock construction
  a) **Overall measure** > Absolute value
  b) **Directional Asymmetry** > Positive/Negative Shocks
  c) **Extremity** > SPEI values within a certain threshold

Types of Shocks	1 S.D. Size Equivalent
Absolute Shocks	2019-2020 Drought
Positive Shocks (Wet)	¼ of 2011 Great Flood
Negative Shocks (Dry)	2019-2020 Drought

* Tied to quarterly macroeconomic variables

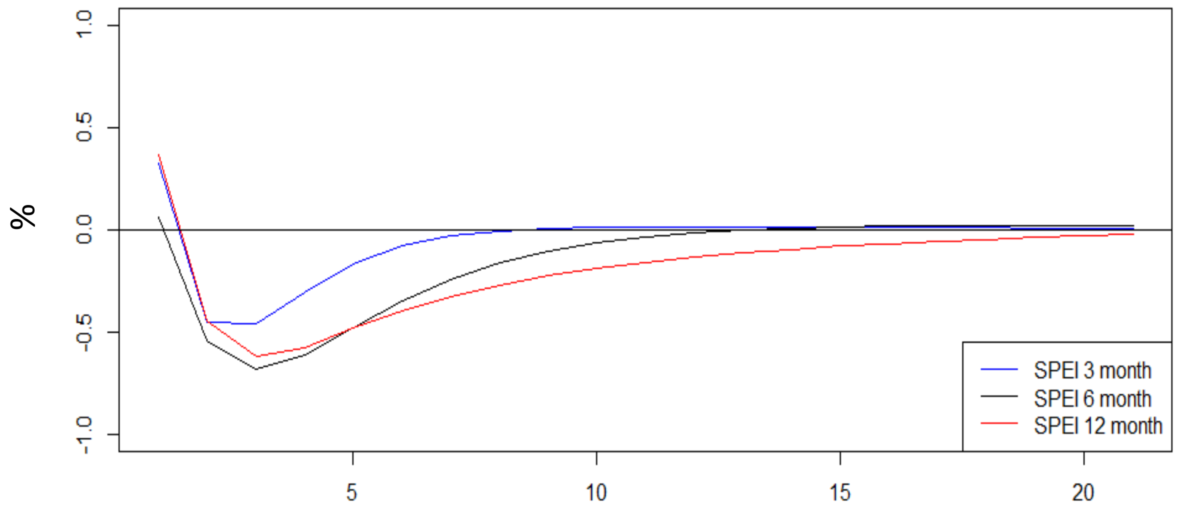
Empirical Methodology

- Vector Autoregression (VAR) model containing:
  - Climate variable [absolute/positive/negative/extremes]
  - Global variables [OECD RGDP growth, VIX index, World Food Price Inflation, Oil Price Inflation]
  - Domestic variables [RGDP growth, CPI inflation, 2 Year govt bond yield, NEER]

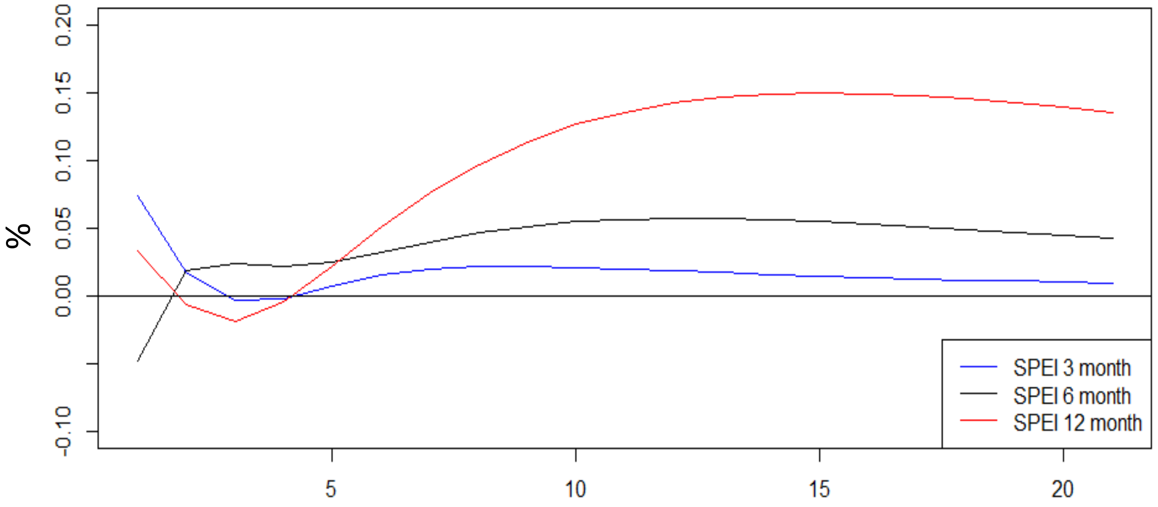
$$\begin{pmatrix} Climate_t \\ Global_t \\ Domestic_t \end{pmatrix} = A_0 + \begin{pmatrix} A_{11} & 0 & 0 \\ 0 & A_{22} & 0 \\ A_{31} & A_{32} & A_{33} \end{pmatrix} \begin{pmatrix} Climate_{t-1} \\ Global_{t-1} \\ Domestic_{t-1} \end{pmatrix} + \varepsilon_t$$

Macro Level Impacts

Climate Shock Impact on Output Growth



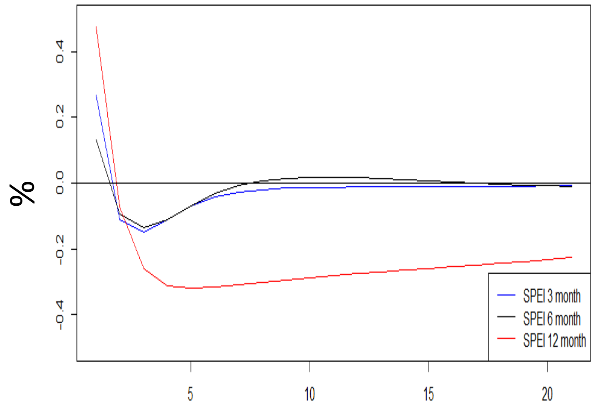
Climate Shock Impact on CPI Inflation



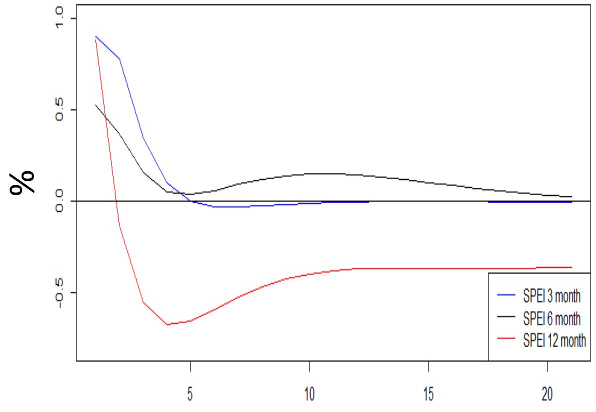
- *Significant contractionary effects on output*
- *Insignificant effects on inflation* (except for SPEI 12 month)
- Persistent climate shocks deliver slightly *larger and long-lasting effects*

Expenditure Side

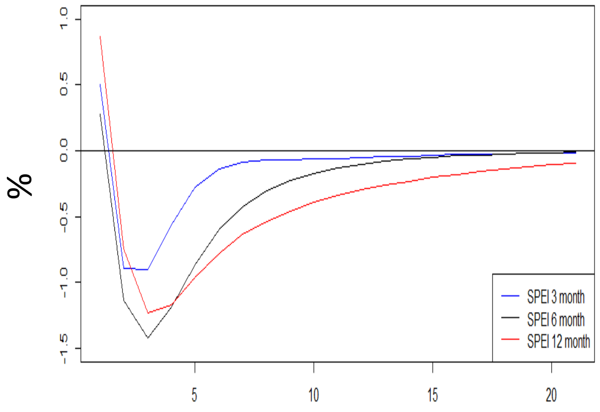
Consumption



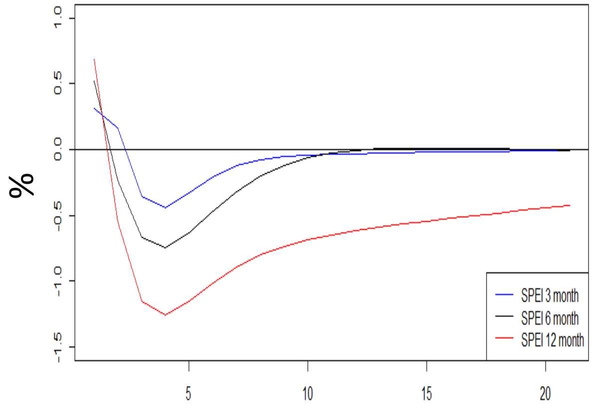
Investment



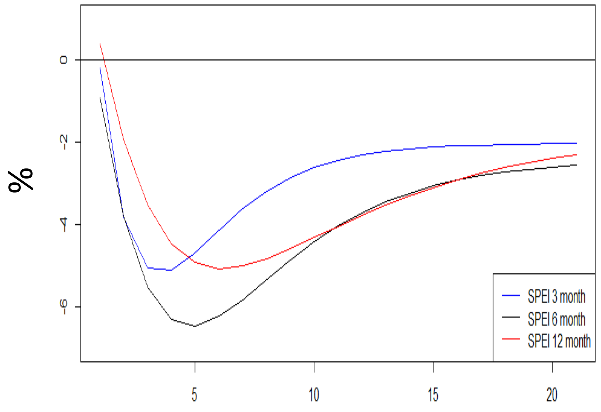
Exports



Imports



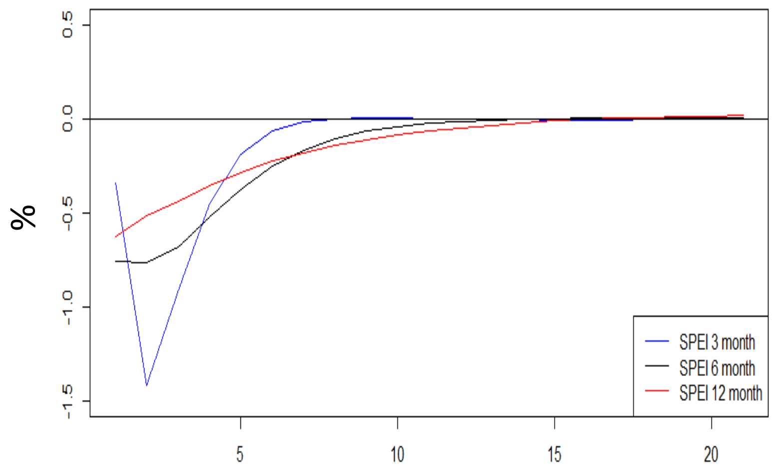
Exports of Service



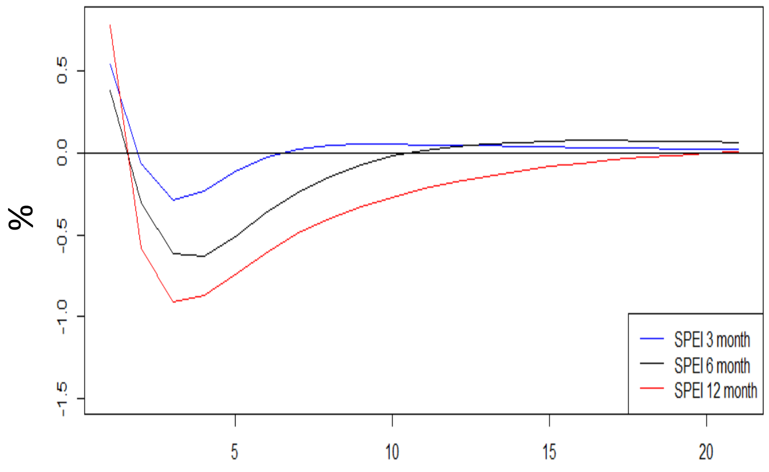
- *All components are negatively affected* by climate shocks
- Most affected is *exports*, especially *exports of services*

Sectors of Production

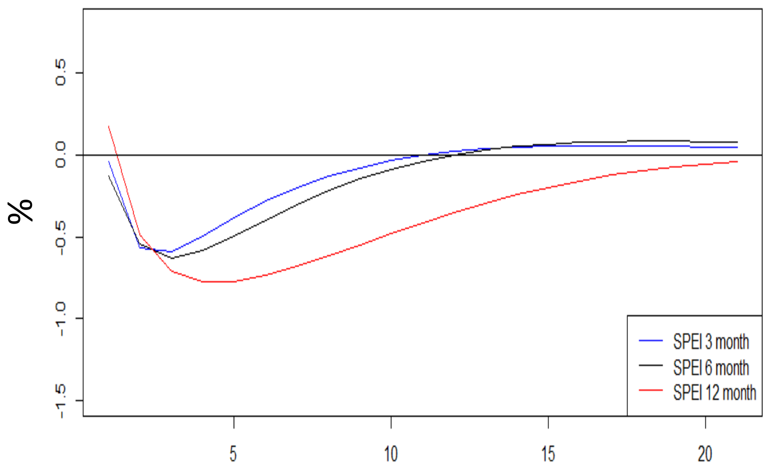
Agriculture [8.63% of GDP]



Industrial [30.39% of GDP]



Service [60.98% of GDP]



- *All major sectors are negatively affected* by climate shocks
- The *agriculture sector* is most affected by non-persistent climate shocks

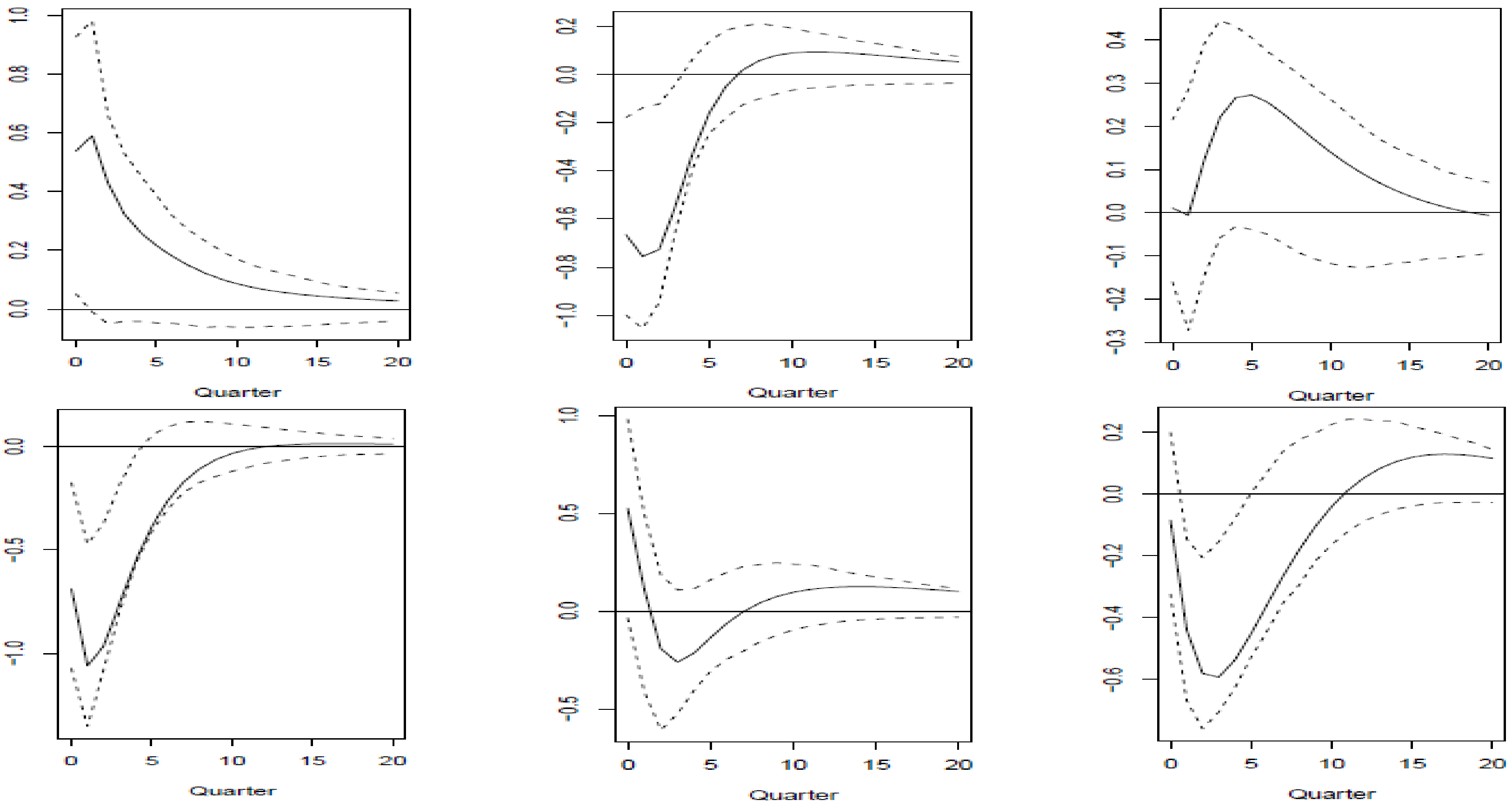
Directional Asymmetry

- Evidence of directional asymmetry is very pronounced in all major sectors

Agriculture | Industrial | Service

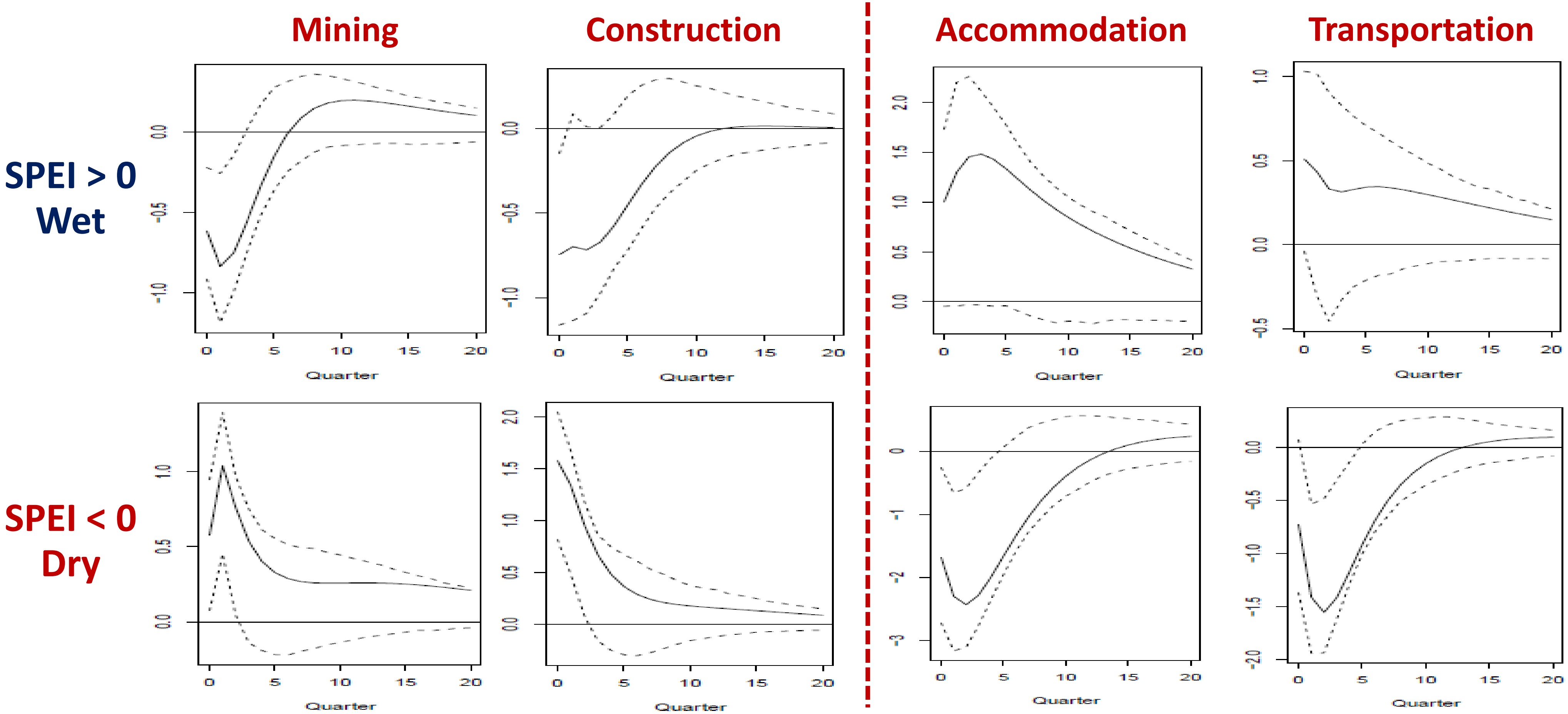
SPEI > 0 (Wet)

SPEI < 0 (Dry)



Directional Asymmetry

- Those related to outdoor activities benefit during dry periods
- Those related to tourism services significantly contract during dry periods



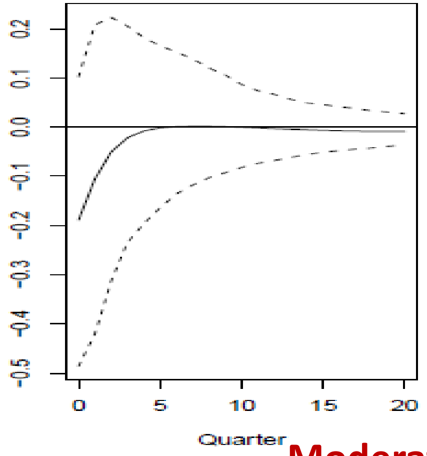
Extreme Climate Conditions

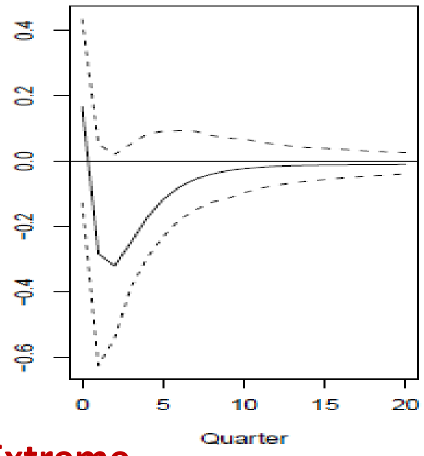
- Impact increases with extremity, especially in the agriculture sector

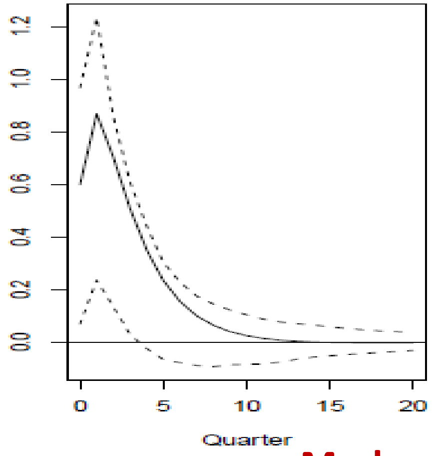
Output

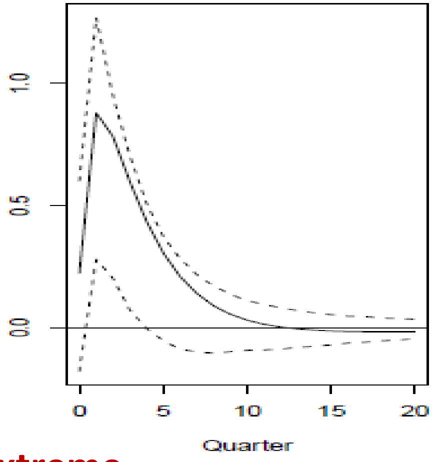
Agriculture

Wet
SPEI > 0









0.8<SPEI<1.59
-1.59<SPEI<-0.8

Moderate to Extreme →

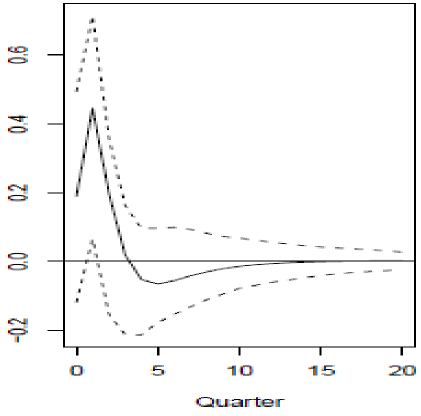
SPEI>1.6
SPEI<-1.6

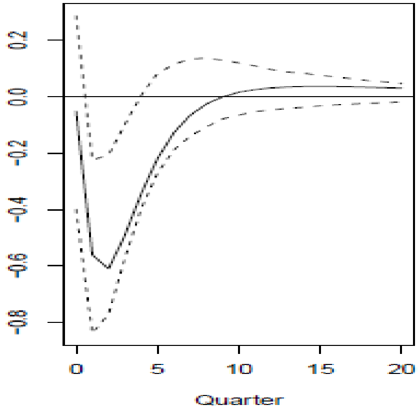
0.8<SPEI<1.59
-1.59<SPEI<-0.8

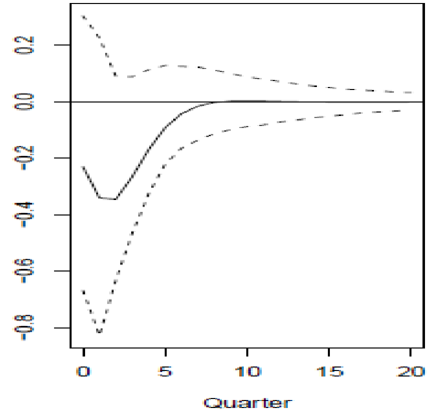
Moderate to Extreme →

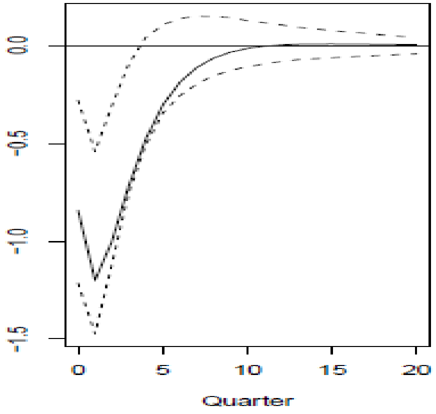
SPEI>1.6
SPEI<-1.6

Dry
SPEI < 0



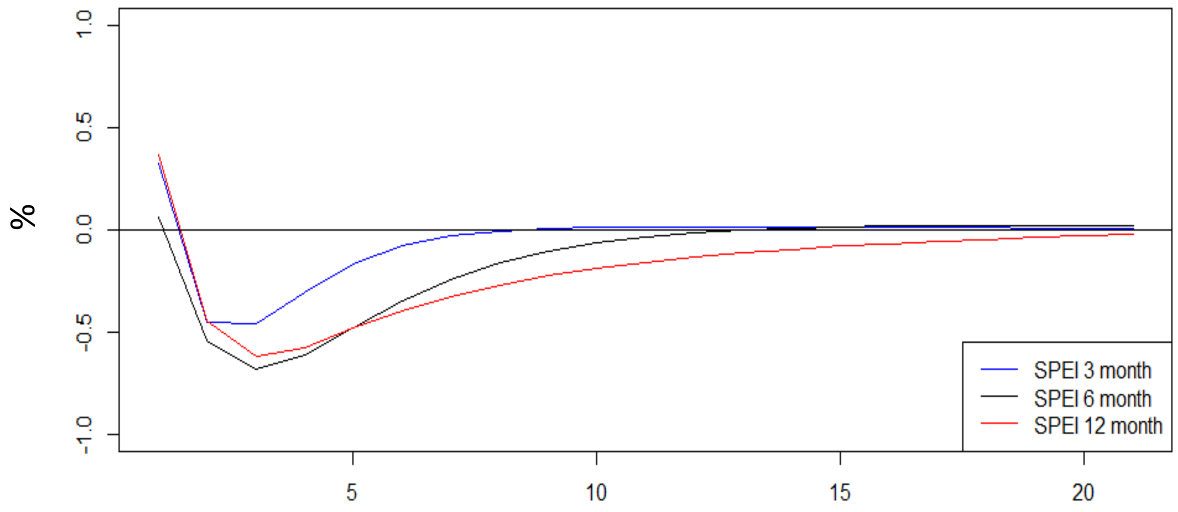




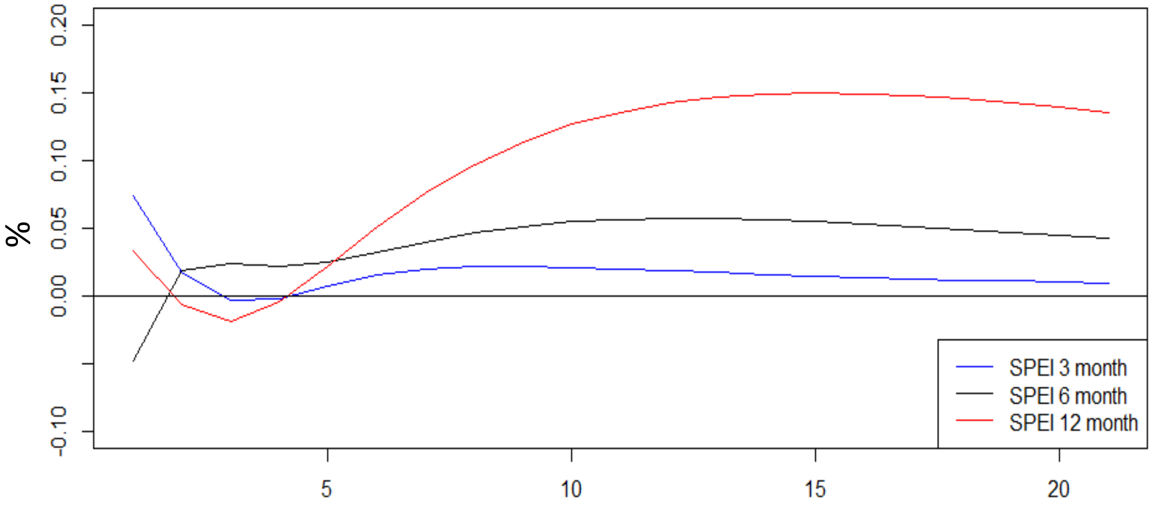


Revisiting: Macro Level Impacts

Climate Shock Impact on Output Growth



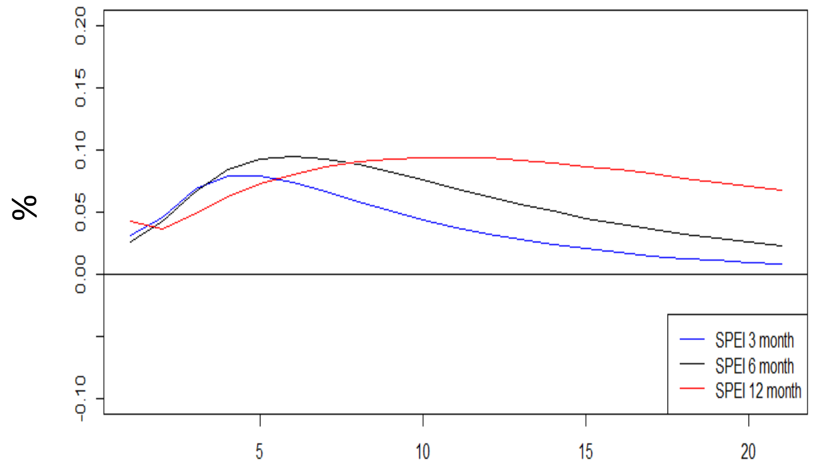
Climate Shock Impact on CPI Inflation



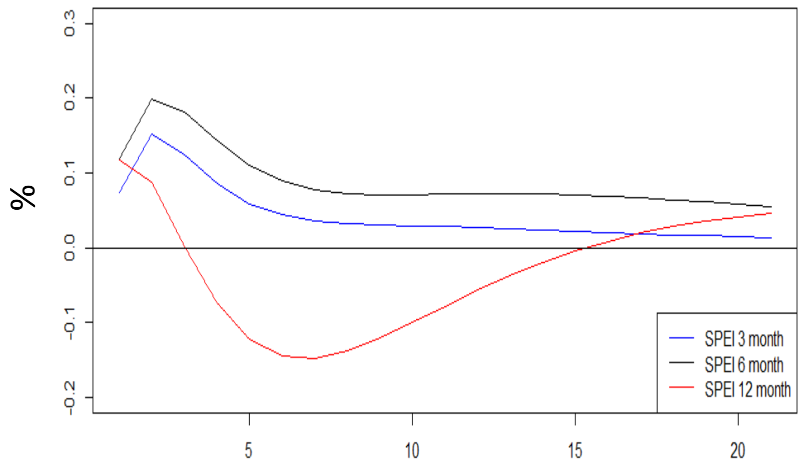
- *Output is contractionary within a year*
- The effect on *inflation* is *insignificant*, but *delivers persistent upward pressures for SPEI 12 month*
- Persistent climate shocks deliver slightly *larger and more persistent effects*

Persistent versus Transitory Effects

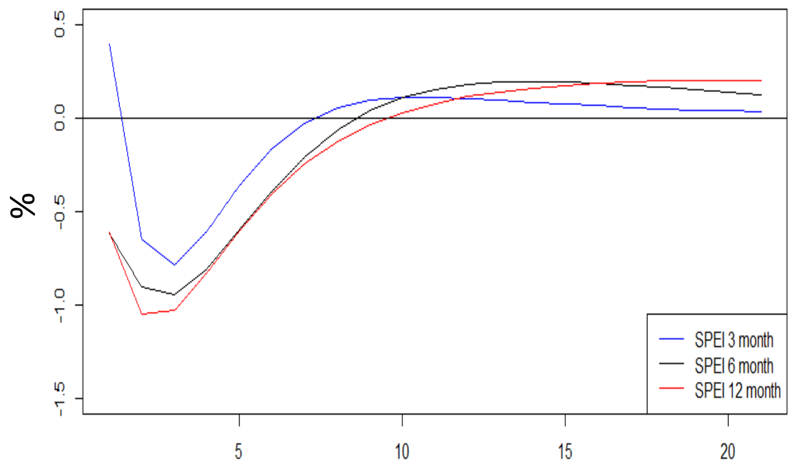
Core



Food

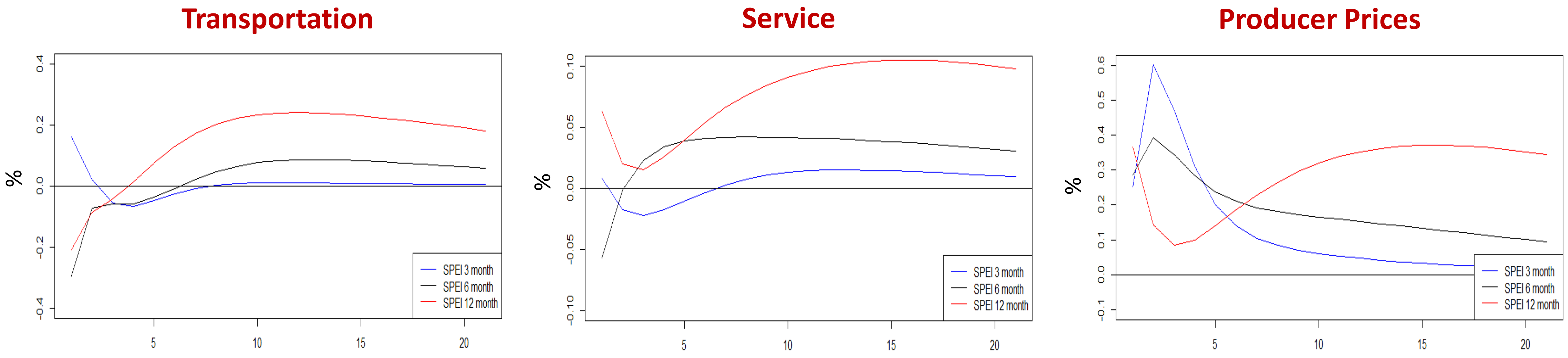


Energy



- Effects on food and energy are in general shorter-lived
- Possible second-round effects on core components in the case of persistent climate events

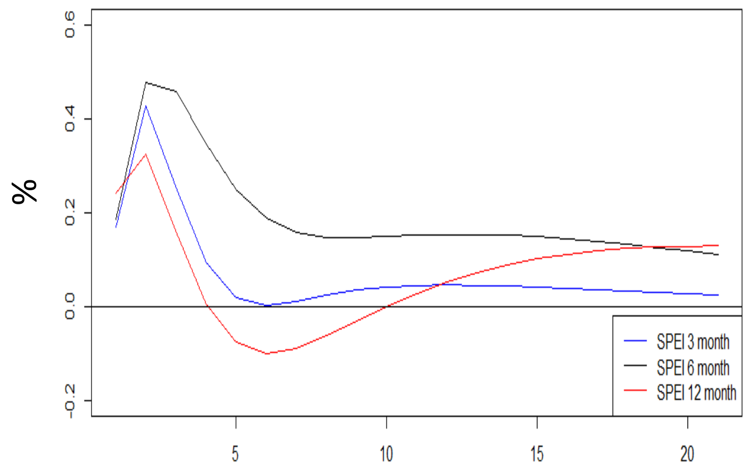
Components with Persistent Effects



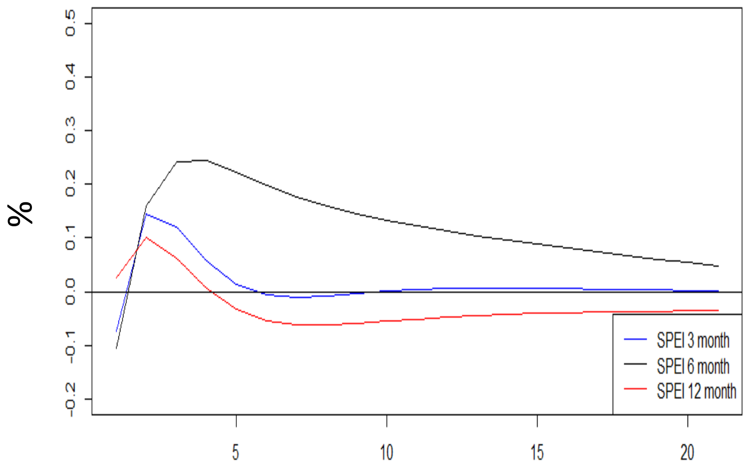
- Transportation and service prices are main contributors
- Climate shocks can also put upward pressure on producer price inflation

Including Vegetables

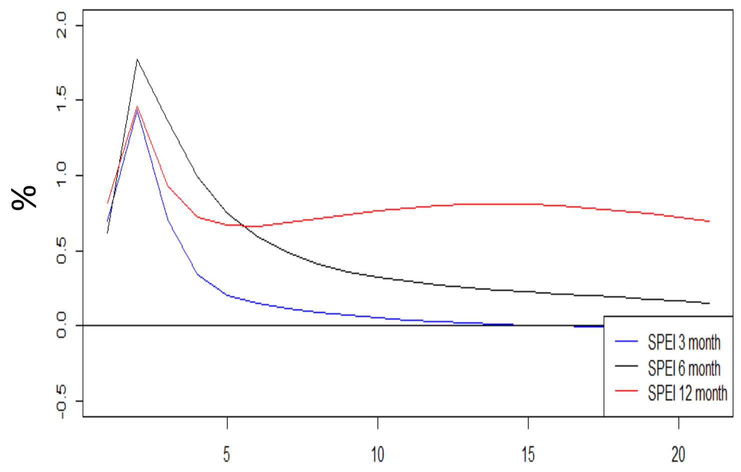
Raw Food



Meat



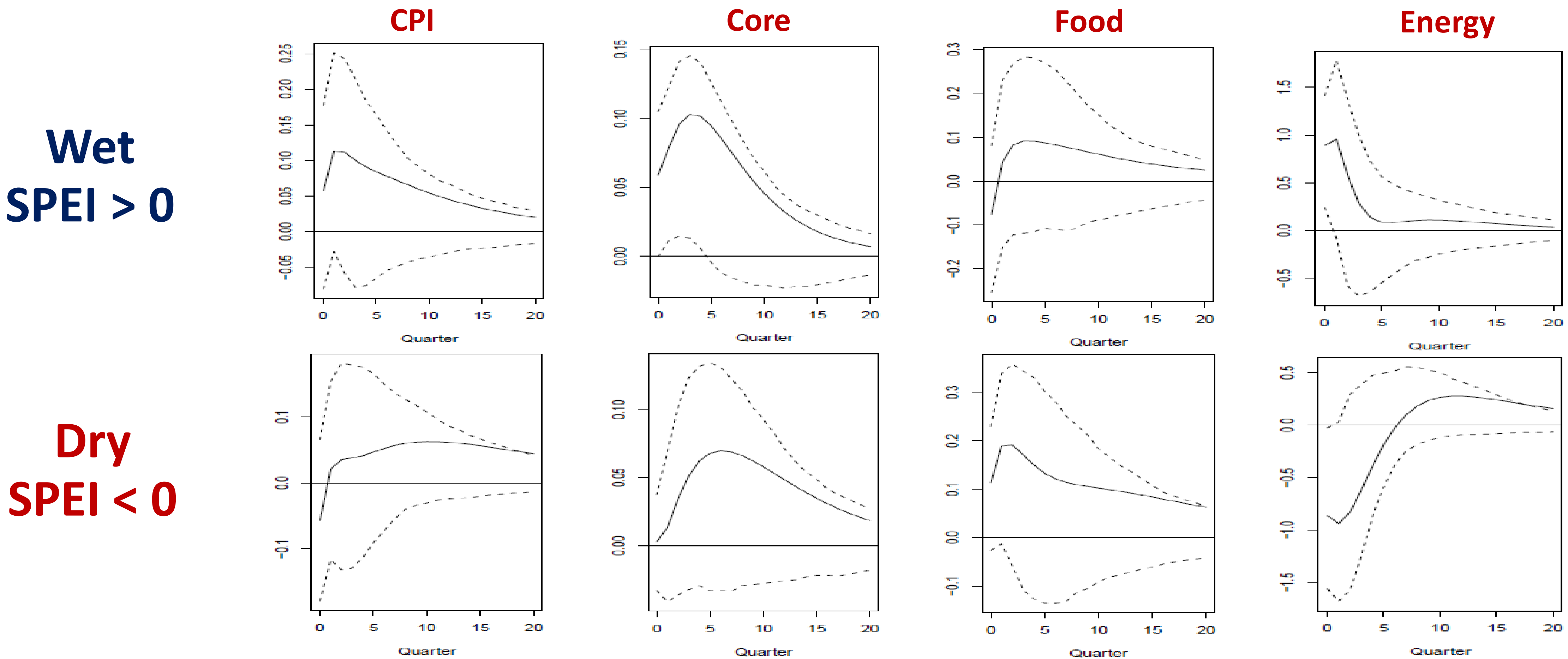
Vegetable



- Significant inflationary pressure from climate shocks on raw food and its components
- Impact of persistent climate events are long-lasting for vegetables

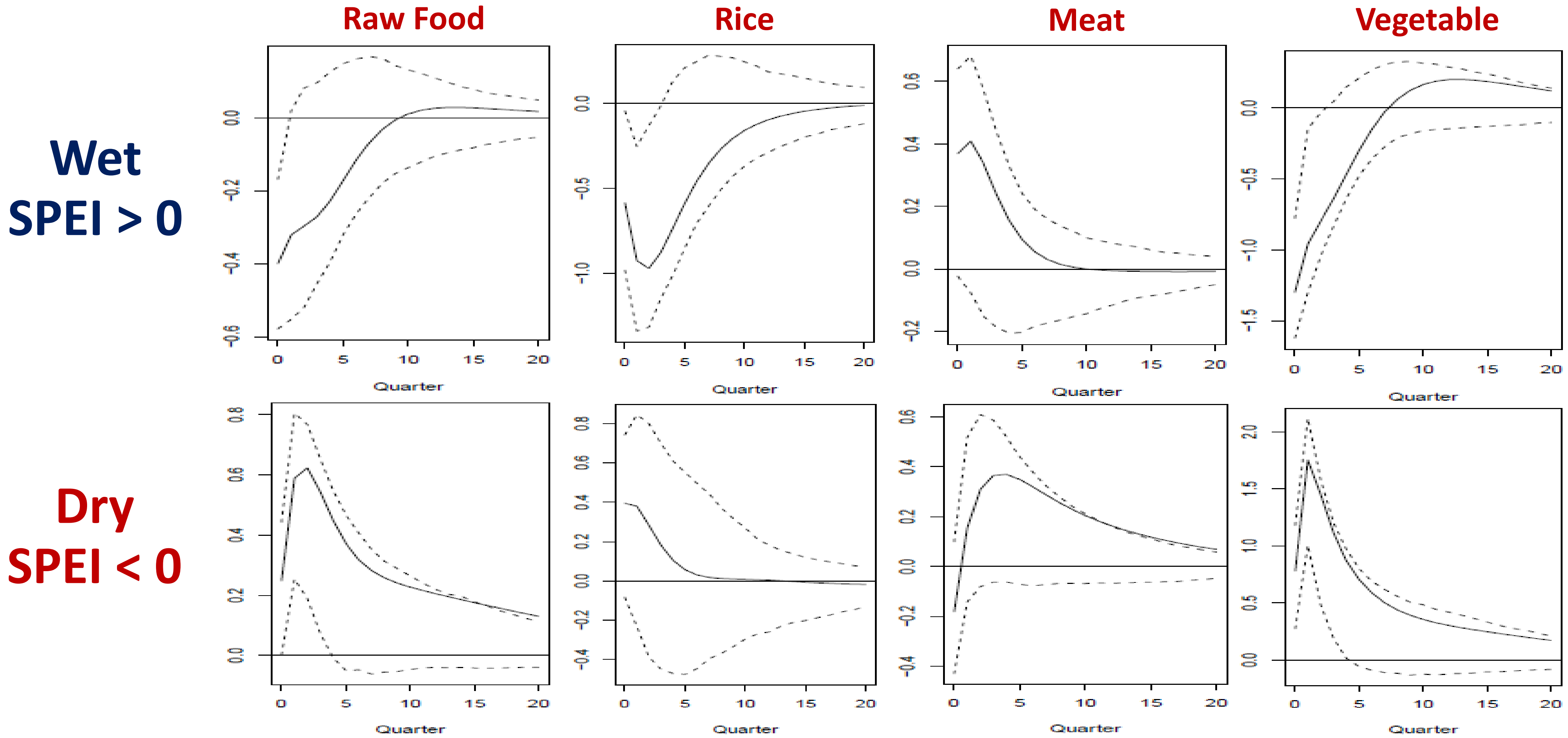
Directional Asymmetry

- Insignificant but differentiated responses to positive/negative climate shocks



Directional Asymmetry

- Directional asymmetry is significant for raw food, especially vegetables

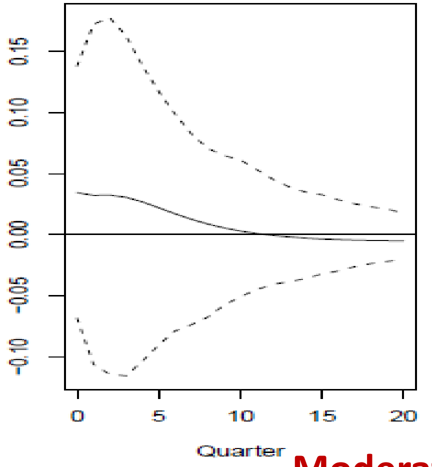


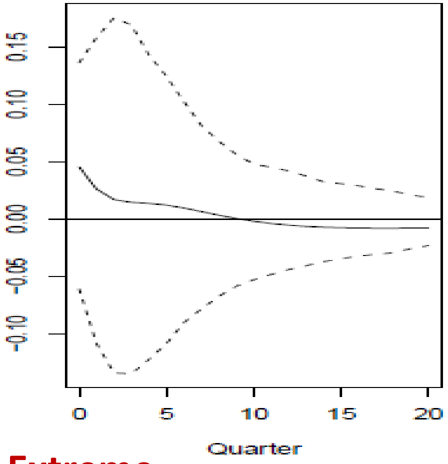
Extreme Climate Conditions

- Unlike output, impact of climate shocks on inflation does not increase with its severity, except for vegetables

CPI

Wet
SPEI > 0



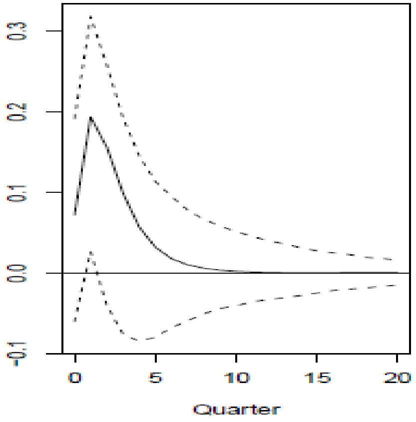


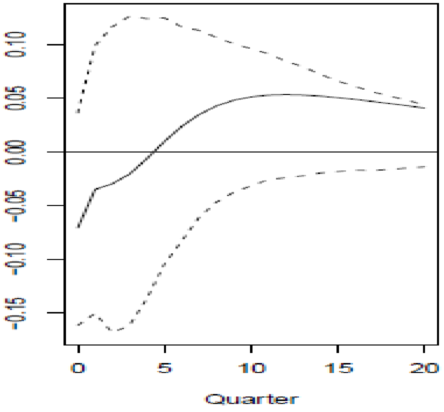
0.8<SPEI<1.59
-1.59<SPEI<-0.8

Moderate to Extreme

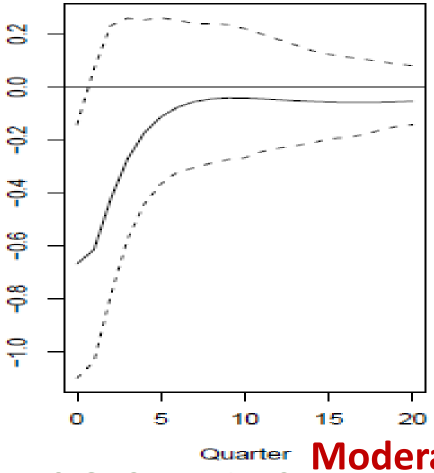
SPEI>1.6
SPEI<-1.6

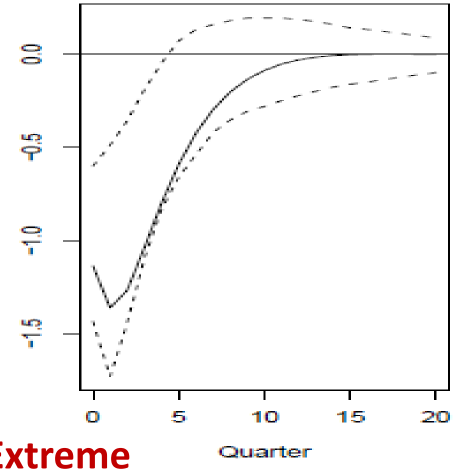
Dry
SPEI < 0





Vegetable

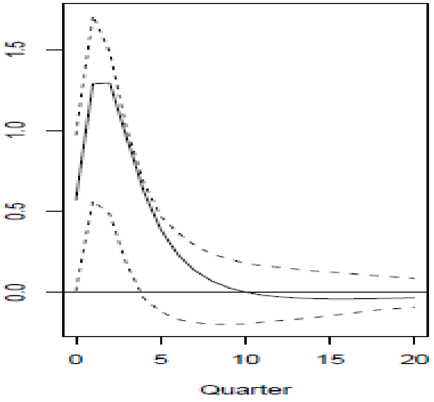


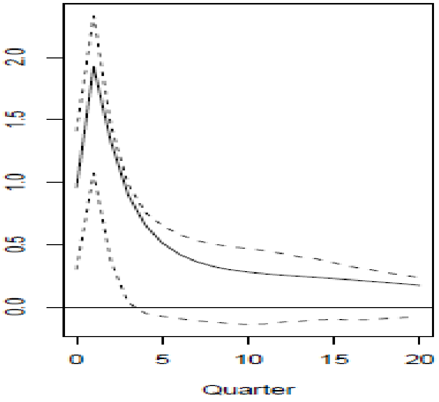


0.8<SPEI<1.59
-1.59<SPEI<-0.8

Moderate to Extreme

SPEI>1.6
SPEI<-1.6





Key Takeaways: VAR analysis

- **Thailand is getting drier and increasingly susceptible to more frequent, and more volatile climate conditions**

- **Climate shocks in general negatively affects output in all key sectors**
  - Mostly act as supply shocks
  - Differentiated sectoral responses
  - Asymmetric and non-linear impacts

- **The impact on inflation are less visible, but can be exceptionally persistent**
  - Potential second-round effects through core components
  - Climate shocks largely affect vegetable prices

Cross-Regional Effects

- Investigate via a panel autoregressive distributed lag model (ARDL) (Kahn et al., 2019)

$$\boldsymbol{\Delta y_{i,t}} = \boldsymbol{\alpha_1 \Delta SPEI_{i,t}} + \boldsymbol{\alpha_2 \Delta SPEI_{i,t-1}} + \boldsymbol{\alpha_3 \Delta SPEI_{i,t-2}} + \boldsymbol{\beta_1 \Delta y_{i,t-1}} + \boldsymbol{\beta_2 \Delta y_{i,t-2}} + \gamma_i + \boldsymbol{a_t} + \boldsymbol{\varepsilon_{i,t}}$$

where $\Delta y_{i,t}$ is the change in log of real GPP per capita in the province i at time t

$\Delta SPEI_{i,t}$ is the difference between the population-weighted 12-month average of SPEI in the province i at time t and t-1

γ_i is the provincial fixed effect

a_t is the time fixed effect

- Estimated by feasible generalized least squares (FGLS) to ensure heteroskedastic-robust results (Bai et al., 2020)

Empirical Methodology

- Investigate directional asymmetry via $\left(\Delta SPEI_{i,t}\right)^{+}$ and $(\Delta SPEI_{i,t})^{-}$
- Quantify medium-run effects (θ) from the estimated short-run coefficients:

$$\Theta = \frac{\sum_{j=1}^{l} \alpha_j}{1-\sum_{k=1}^{p} \beta_k}$$

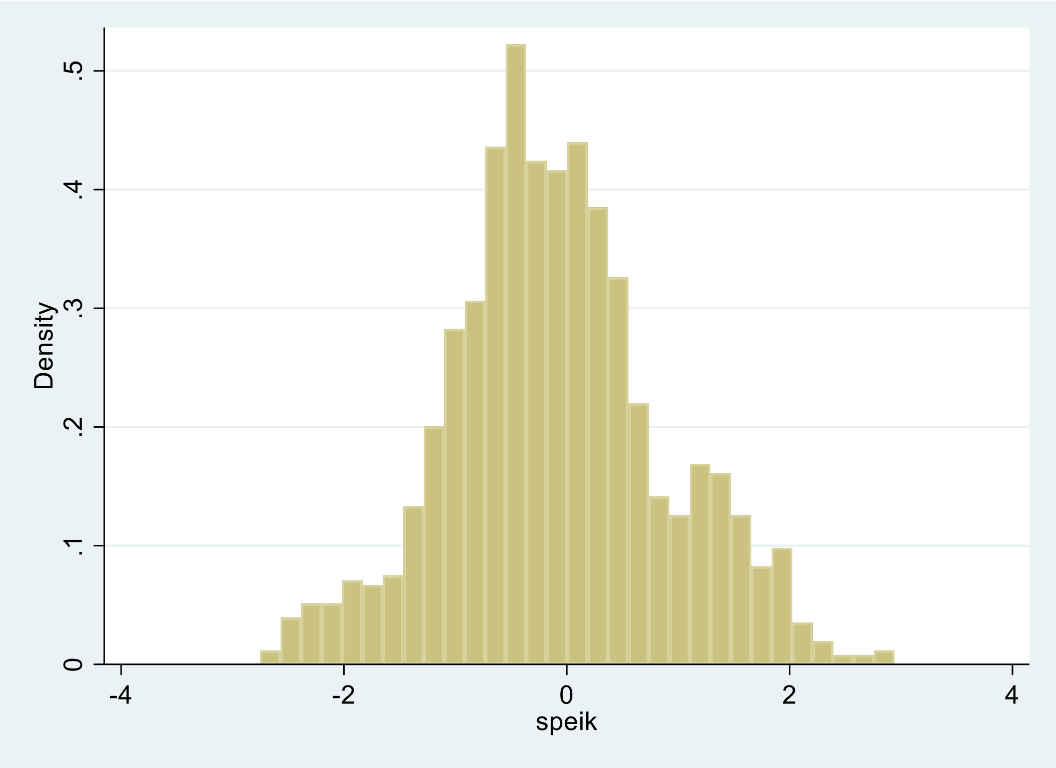
- Incorporate interaction terms to differentiate between the impact on different regions as well as poor vs. rich, agricultural vs. non-agricultural, tourism vs. non-tourism
  - Regional dummy (R_t) corresponds to provinces in Bangkok and Vicinity, Central, North, Northeast, West, East, South
  - Poor province dummy (P_t) constructed based on provinces that have average GPP per capita below or equal to the 25th percentile
  - Agricultural province dummy (A_t) constructed based on provinces that have agriculture proportion more than 5% of GPP on average
  - Tourism province dummy (T_t) is constructed based on provinces that heavily relies on Tourism according to the Ministry of Tourism and Sports

Data

- Our panel regression is restricted to the 2001-2019 period due to the short availability of annual GPP data from NESDB
  - Covers 19 years and 77 provinces
- For consistency with the annual frequency of GPP data, the SPEI index utilized in the panel regression is the 12-month SPEI index
- Analyzing the impact of extreme climate conditions with annual data may not appropriate

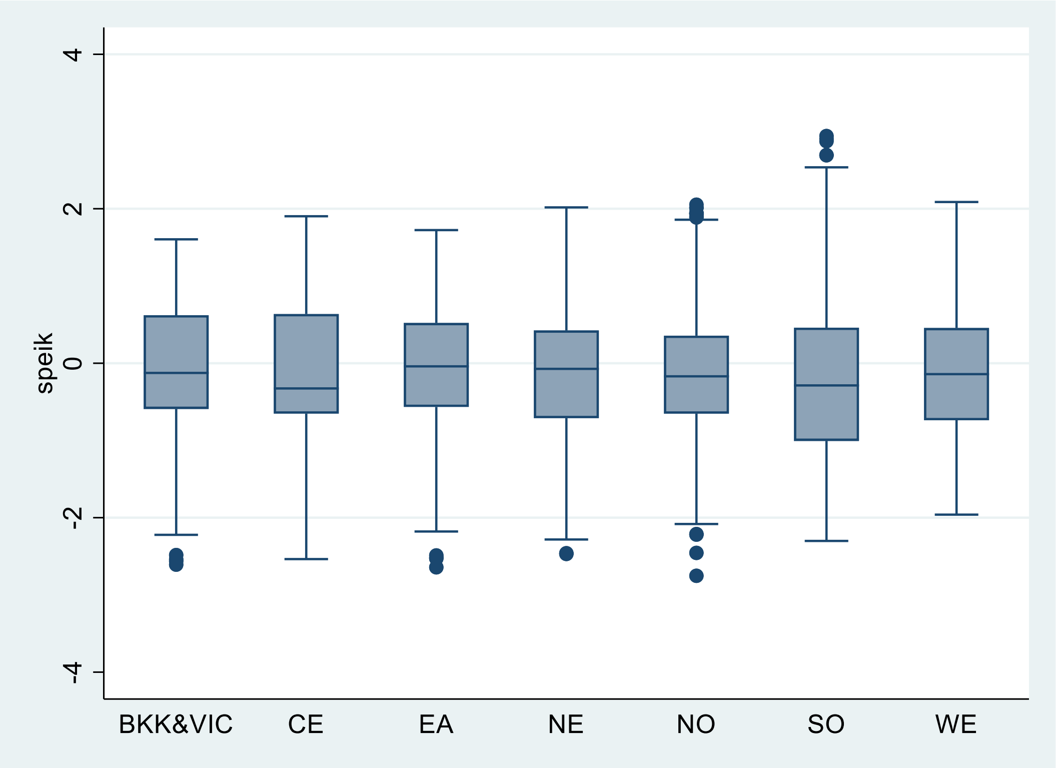
Yearly Changes in SPEI

$SPEI_t - SPEI_{t-1}$, 2001-2019



Obs	Mean	Std. Dev.	Min	Max
1,386	-.0975537	.9718246	-2.752729	2.941706

$SPEI_t - SPEI_{t-1}$ by region, 2001-2019



On average, the change in SPEI reflects
***drier conditions across* all regions**

Regional Impacts

Effects of a change in 12-month average SPEI on Real GPP per capita growth, 2001 - 2019

Dependent Variable is Real GPP per capita growth ($\Delta y_{i,t}$)	**Feasible Generalised Least Squares (FGLS)**			
	(1)	(2)	(3)	(4)
$\hat{\theta}_{\Delta SPEI_{i,t}}$	-0.0237*** (0.0066)	-0.0229*** (0.0064)	-0.0193*** (0.0065)	-0.0229*** (0.0064)
$\Delta y_{i,t-1}$	0.0117 (0.0279)	0.011 (0.0278)	0.0115 (0.0278)	0.0108 (0.0269)
$\Delta y_{i,t-2}$	0.0722*** (0.0269)	0.075*** (0.0269)	0.0777*** (0.0269)	0.0746*** (0.0269)
$\Delta SPEI_{i,t} * \mathrm{N}$	0.0034 (0.0027)	-	-	-
$\Delta SPEI_{i,t} * \mathrm{NE}$	-	0.001 (0.0027)	-	-
$\Delta SPEI_{i,t} * \mathrm{S}$	-	-	-0.0088*** (0.0031)	-
$\Delta SPEI_{i,t} * \mathrm{C}$	-	-	-	0.0022 (0.0047)
No. of Observations	1222	1222	1222	1222

*Notes: 1. Standard errors in parentheses; 2. Time and provincial fixed effects were included (coefficient not reported); 3. Asterisks indicate statistical significance at the 1% (***), 5% (**) , and 10% (*) levels; 4. The long-run effects, θ, are calculated from the OLS estimates of the short-run coefficients; 5. S is a dummy variable for Southern Region (equals to 1, otherwise 0); W is a dummy variable for Western Region (equals to 1, otherwise 0) and B is a dummy variable for Bangkok and Vicinity (equals to 1, otherwise 0)

Regional Impacts

Effects of a change in 12-month average SPEI on Real GPP per capita growth, 2001 - 2019

Dependent Variable is Real GPP per capita growth ($\Delta y_{i,t}$)	**Feasible Generalised Least Squares (FGLS)**		
	(5)	(6)	(7)
$\hat{\theta}_{\Delta SPEI_{i,t}}$	-0.023*** (0.0064)	-0.023*** (0.0064)	-0.0203*** (0.0064)
$\Delta y_{i,t-1}$	0.0091 (0.0278)	0.0162 (0.0278)	0.0125 (0.0277)
$\Delta y_{i,t-2}$	0.0764*** (0.0269)	0.0731*** (0.0268)	0.0733*** (0.0268)
$\Delta SPEI_{i,t} * \mathrm{E}$	0.0071 (0.0044)	-	-
$\Delta SPEI_{i,t} * W$	-	0.0158*** (0.0043)	-
$\Delta SPEI_{i,t} * B$	-	-	-0.011*** (0.0041)
No. of Observations	1222	1222	1222

*Notes: 1. Standard errors in parentheses; 2. Time and provincial fixed effects were included (coefficient not reported);
3. Asterisks indicate statistical significance at the 1% (***), 5% (**) , and 10% (*) levels; 4. The long-run effects, θ, are calculated from the OLS estimates of the short-run coefficients; 5. S is a dummy variable for Southern Region (equals to 1, otherwise 0);
W is a dummy variable for Western Region (equals to 1, otherwise 0) and B is a dummy variable for Bangkok and Vicinity (equals to 1, otherwise 0)

Impacts Based on Characteristics

Effects of a change in 12-month average SPEI on Real GPP per capita Growth, 2001 - 2019

Dependent Variable is Real GPP per capita growth ($\Delta y_{i,t}$)	**Feasible Generalised Least Squares (FGLS)**			
	(a)	(b)	(c)	(d)
$\hat{\theta}_{\Delta SPEI_{i,t}}$	-0.0228*** (0.0064)	-0.0207*** (0.0064)	-0.0282*** (0.0070)	-0.0234*** (0.0064)
$\Delta y_{i,t-1}$	0.0103 (0.0278)	0.0126 (0.0278)	0.0112 (0.0278)	0.0106 (0.0278)
$\Delta y_{i,t-2}$	0.0745*** (0.0268)	0.0791*** (0.0268)	0.0750*** (0.0268)	0.0745*** (0.0269)
$\Delta SPEI_{i,t} * P_t$	-	-0.0074*** (0.0025)	-	-
$\Delta SPEI_{i,t} * A_t$	-	-	0.0063** (0.0031)	-
$\Delta SPEI_{i,t} * T_t$	-	-	-	0.0019 (0.0029)
No. of Observations	1222	1222	1222	1222

*Notes: 1. Standard errors in parentheses; 2. Time and provincial fixed effects were included (coefficient not reported); 3. Asterisks indicate statistical significance at the 1% (***), 5% (**) , and 10% (*) levels; 4. The long-run effects, θ, are calculated from the OLS estimates of the short-run coefficients.

Impacts based on Characteristics (Directional Asymmetry)

Effects of a directional change in 12-month average of SPEI on Real GPP per capita Growth, 2001 - 2019

Dependent Variable is Real GPP per capita growth ($\Delta y_{i,t}$)	Feasible Generalised Least Squares (FGLS)		
	(e)	(f)	(g)
$\hat{\theta}_{\Delta SPEI_{i,t}^{+}}$	-0.0193** (0.0091)	-0.0178** (0.0089)	-0.0336*** (0.0105)
$\hat{\theta}_{\Delta SPEI_{i,t}^{-}}$	0.0156* (0.0084)	0.0082 (0.0083)	0.015 (0.0093)
$\Delta y_{i,t-1}$	0.0126 (0.0269)	0.0009 (0.027)	0.008 (0.027)
$\Delta y_{i,t-2}$	0.0842*** (0.0262)	0.0774*** (0.0262)	0.081*** (0.0263)
$\hat{\theta}_{\Delta SPEI_{i,t}^{+}} * P_t$	-	0.0034 (0.0038)	-
$\hat{\theta}_{\Delta SPEI_{i,t}^{+}} * A_t$	-	-	0.0145*** (0.005)
$\hat{\theta}_{\Delta SPEI_{i,t}^{-}} * P_t$	-	0.0154*** (0.0033)	-
$\hat{\theta}_{\Delta SPEI_{i,t}^{-}} * A_t$	-	-	-0.0024 (0.0042)
No. of Observations	1298	1298	1298

*Notes: 1. Standard errors in parentheses; 2. Time and provincial fixed effects were included (coefficient not reported); 3. Asterisks indicate statistical significance at the 1% (***), 5% (**) , and 10% (*) levels; 4. The long-run effects, θ, are calculated from the OLS estimates of the short-run coefficients.

Key Takeaways: Panel ARDL Analysis

- Panel regression results confirm the contractionary effects of a SPEI change on real activity that may have important regional differences

- Climate shocks tend to affect poor provinces more and agricultural provinces less which also depend on the direction of SPEI change

Conclusion and Implications

- **Extreme weather events can significantly affect business cycles**

    - Arise mostly as supply shocks, although if persistent could feed into demand
    - Large effects through tourism and agriculture
    - Poor provinces and agricultural sectors are most sensitive
    - Ignorance of non-linear and extreme impacts can understate climate risks

→Requires policymakers to react but may face trade-off when dealing with supply shocks

→Being able to predict future climate events and incorporate its impact into macro-models becomes a key challenge

Conclusion and Implications

- **Although relatively small, extreme weather events (especially persistent ones) can have important near-term and longer-term impacts on inflation**
  - Impact on food and energy components are transitory, but with long-lasting impacts on core inflation

→ Need to disentangle temporary versus more persistent effects that may deliver second round effects

→A credible monetary policy framework is key to anchor inflation expectations especially in the face of more frequent and volatile shocks in the future

Further Studies

- Longer term impacts
- Transition risks
- Financial stability
- Endogenous feedback loops