CLIMATE RISKS AND THE GLOBAL ECONOMY

Warwick J. McKibbin

Center for Applied Macroeconomic Analysis
Crawford School of Public Policy, The Australian National University

Centre for Excellence in Population Ageing Research (CEPAR)

The Peterson Institute for International Economics (Washington)

Center for Economic Policy Research (London)

12th South Asia Economic Policy Network Conference on Green Growth in South Asia

Dhaka

30 October 2023

Overview

- Climate Risks and the Global Economy
  - Physical risks: Chronic and extreme risks
  - Transition risks: Climate policies for mitigation
  - Financial risks: Changes in financial risk assessment

Preview of Results

- There are substantial losses to all economies under alternative climate scenarios.
- Losses increase with warming.
- There are substantial adjustments to consumption and investment under climate scenarios.

Key Publications

- Fernando, R., Liu, W. & J., McKibbin, W. 2021. Global economic impacts of climate shocks, climate policy and changes in climate risk assessment. Climate and Energy Economics Discussion Paper. The Brookings Institution, Washington DC.

- Bertram, C, Boirard, A, Edmonds, J, Fernando, R, Gayle, D, Hurst, I, Liu, W, McKibbin, W, Payerols, C, Richters, O & Schets, E. 2022. Running the NGFS scenarios in G-Cubed: A tale of two modeling frameworks. NGFS Occasional Paper, Bank of England, London.

- Fernando, R., Liu, W. & McKibbin, W. 2022. Why climate policy scenarios are important, how to use them, and what has been learned. Brookings Center on Regulation and Markets Policy Brief. The Brookings Institution, Washington DC.

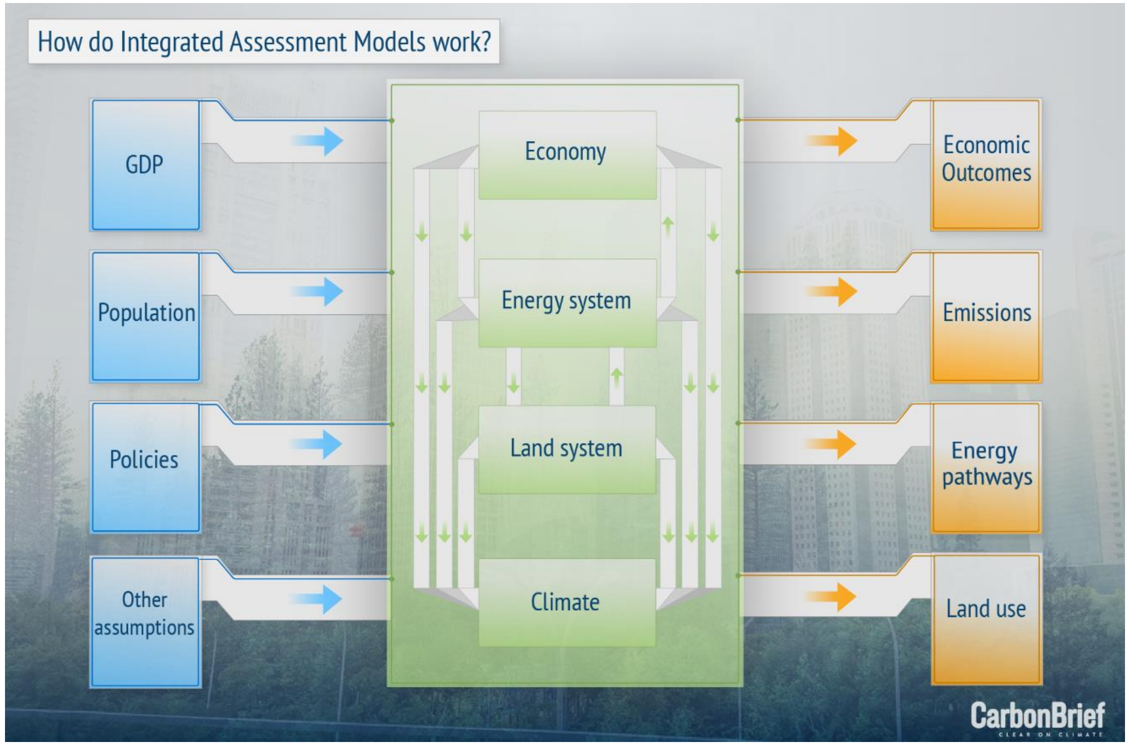
- Fernando, R. 2023. Global economic consequences of physical climate impacts on agriculture and energy. 26^{th} Annual Conference on Global Economic Analysis.

- Fernando, R. & Lepore, C. 2023. Global economic impacts of physical climate risks. The International Monetary Fund, Washington DC.

MODELING ECONOMIC IMPACTS OF CLIMATE CHANGE

Modeling Economic Impacts of Climate Change: Integrated Assessment Models

- Three main classes (Goodess et al. 2003)
  - Cost-benefit Analysis Models
  - Biophysical Models
  - Policy Guidance Models
- Sources of differences
  - Resolution of the human and natural systems and their interactions
  - Elements of the systems
  - How the human and natural systems are thought to evolve



Modeling Economic Impacts of Climate Change: Econometric / economic Models

- Cross-sectional / Panel regressions *(e.g., Kalkuhl and Wenz 2020; Kahn et al. 2019)*
- Structural Vector Auto-Regressive models *(e.g., Gallic and Vermandel 2020)*
- Dynamic Stochastic General Equilibrium models *(e.g., Xu 2021)*
- Computable General Equilibrium models *(e.g., Kompass et al. 2018)*
- Agent-based models *(e.g., Niamir et al 2020)*

Modeling Economic Impacts of Climate Change: Gaps

1. Extensive focus on chronic risks and rarely on extreme risks.
2. Lack of sector representation.
3. Lack of distinction of physical and financial capital in economic models.
4. Lack of focus on macroeconomic implications from changes in financial risk assessment.

MODELING ECONOMIC IMPACTS OF PHYSICAL & FINANCIAL RISKS: THE G-CUBED MODEL

The G-Cubed Model: Overview of Features

- A hybrid DSGE-CGE model
- A global model
- Agents in the model
  - Households
  - Firms (many sectors depending on the model version)
  - Governments
  - Central Banks
- Incorporates heterogeneous agents.
- Features inter-industry linkages via trade, capital flows, consumption, and investment.
- Captures frictions in the labor market and capital accumulation.
- Distinguishes physical and financial capital.
- Comparison of IAMs and G-Cubed:
  - *Bertram, C, Boirard, A, Edmonds, J, Fernando, R, Gayle, D, Hurst, I, Liu, W, McKibbin, W, Payerols, C, Richters, O & Schets, E (2022) 'Running the NGFS scenarios in G-Cubed: A tale of two modeling frameworks', NGFS Occasional Paper, Bank of England, London.*

Source: McKibbin & Wilcoxen 1999; 2013

G-Cubed models are built for purpose

Many sectors (distinguished by number)

Many Countries (distinguished by letter)

G-Cubed in 2023

G-Cubed (2)
Teaching Model

G-Cubed (6)
Macro,
Demographics
and Growth model

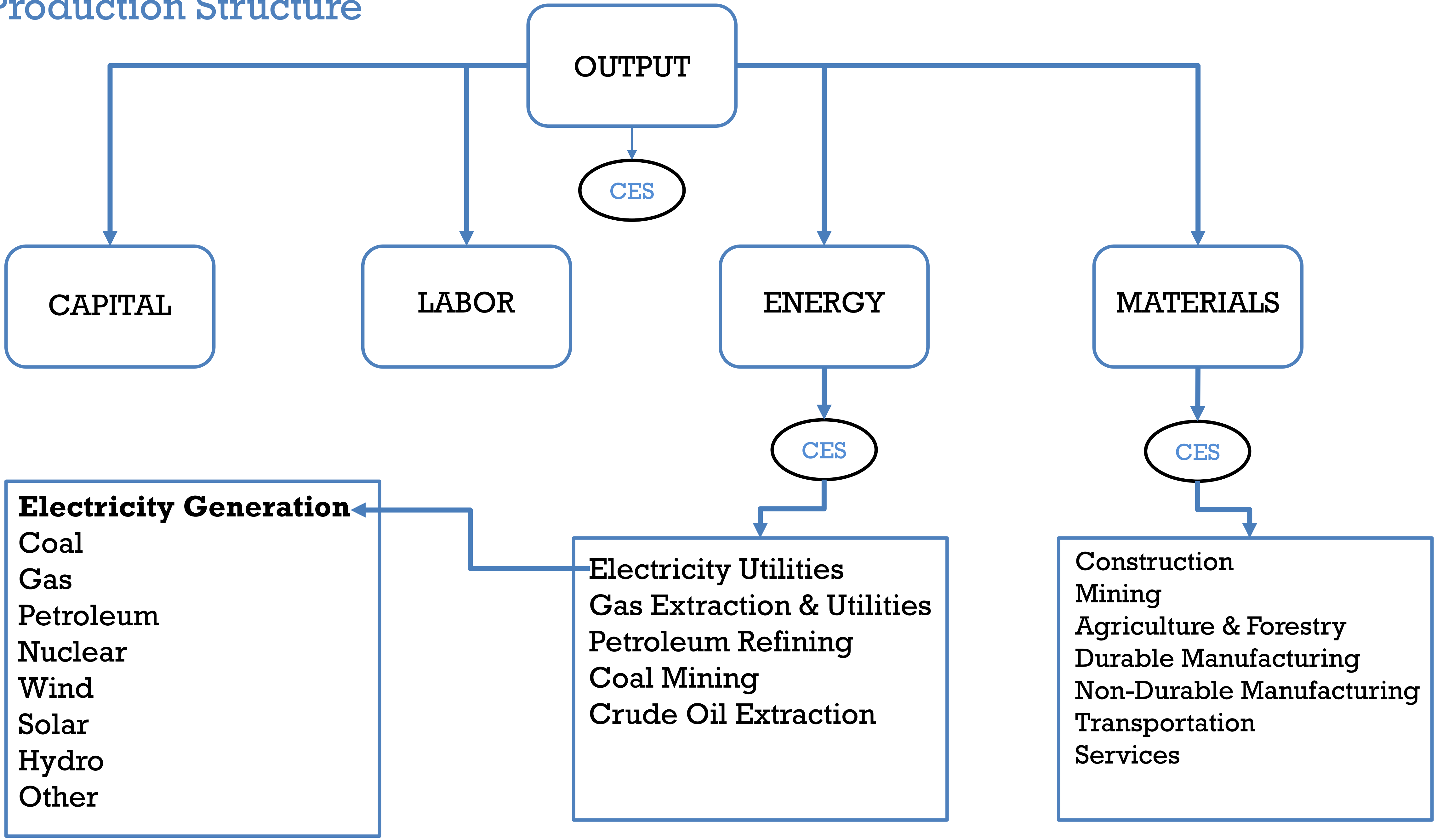
G-Cubed (20)
Climate and
Energy Model

The G-Cubed model: Countries/Regions

Region Code	Region Description
AUS	Australia
CHN	China
EUW	Europe
IND	India
JPN	Japan
OPC	Oil-Exporting Developing Countries
OEC	Rest of the OECD
ROW	Rest of the World
RUS	Russian Federation
USA	United States

Source: G-Cubed Model Version 20J

Production Structure



MODELING ECONOMIC IMPACTS OF PHYSICAL & FINANCIAL RISKS: EMPIRICAL IMPLEMENTATION OF SHOCKS

Climate Impacts on the Economy

- Climate variables impact:
  - Total factor productivity in each sector.
  - Labor productivity in each sector.
  - Risk premium in each sector.
- Incorporate climate shocks through applying damage functions at the sectoral and country level estimated on historical relationships between climate variables and productivity and risk.
- Given damage functions, apply different future climate scenarios into the damage function and generate shocks to feed into the G-Cubed model.

Damage Functions for Chronic Physical Risks

1. Chronic Physical Risks (Roson & Sartori 2016)

Loss of Land due to Sea-level Rise

$$\%\Delta\, Land = \%\Delta\, Land\ by\ 1m\ of\ SLR\ [\propto\ + \beta\ *\ \Delta t\ - Vertical\ Land\ Movement](Year\ - 2000)$$

Variation in Disease Incidence

$$\%\Delta\, Labor\ Productivity = Country - specific\ Coefficient\ *\ \Delta t$$

Damage Functions for Chronic & Extreme Physical Risks

2. Chronic and Extreme Physical Risks

Estimated Model Form for a Given Agriculture/Energy Sector in Country *i* and Year *j*

$$Growth\ in\ Total\ Factor\ Productivity/Production_{i,j} = \beta_0 + \sum_{k=1}^{10} \beta_k * Climate\ Indicator_{k,i,j} + \gamma_i + \delta_j + \varepsilon_{i,j}$$

3. Climate-related Financial Risks

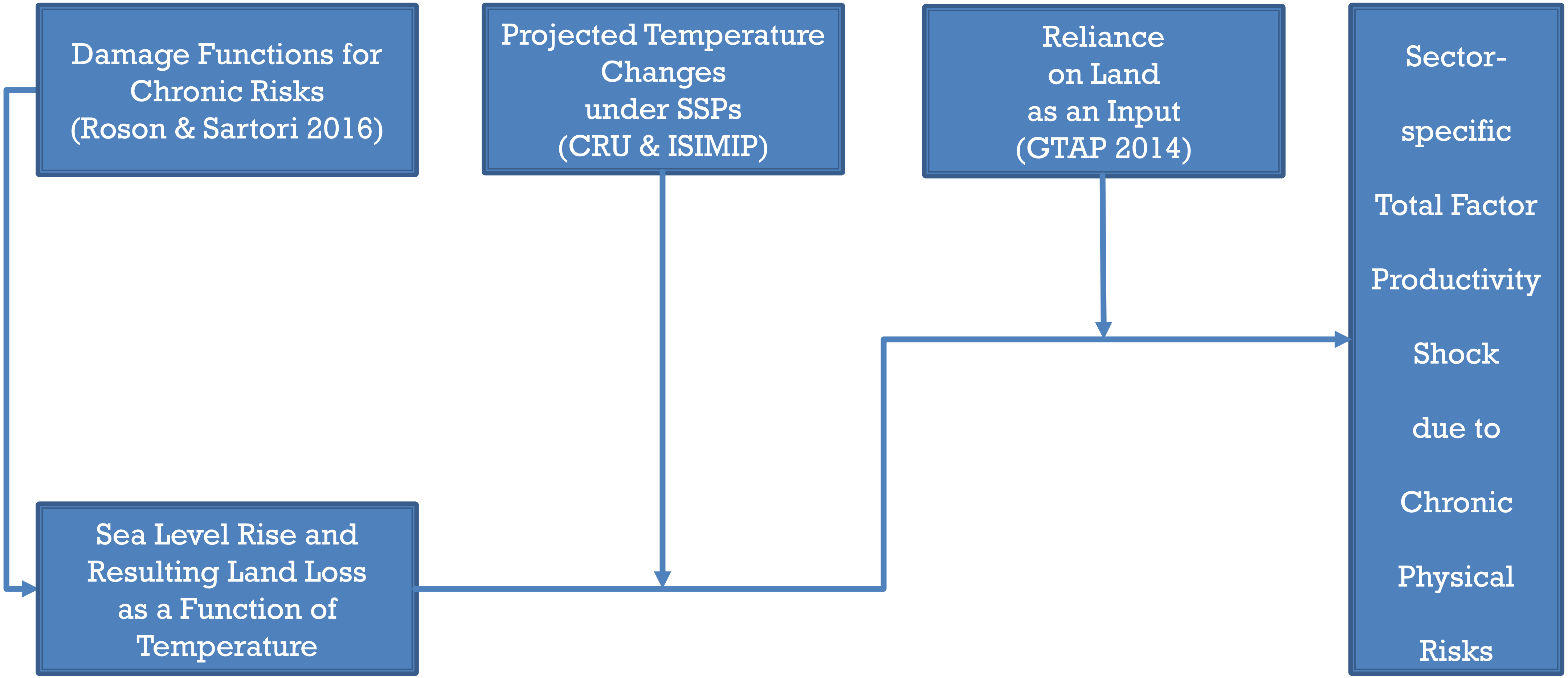
Estimated Model Form for a Given Country *i* in Year *j* for k^{th} Climate Indicator

$$Changes\ in\ Equity\ Risk\ Premia_{i,j} = \beta_0 + \beta_k * Climate\ Indicator_{k,i,j} + \beta_h * X_{i,j} + \gamma_i + \delta_j + \varepsilon_{i,j}$$

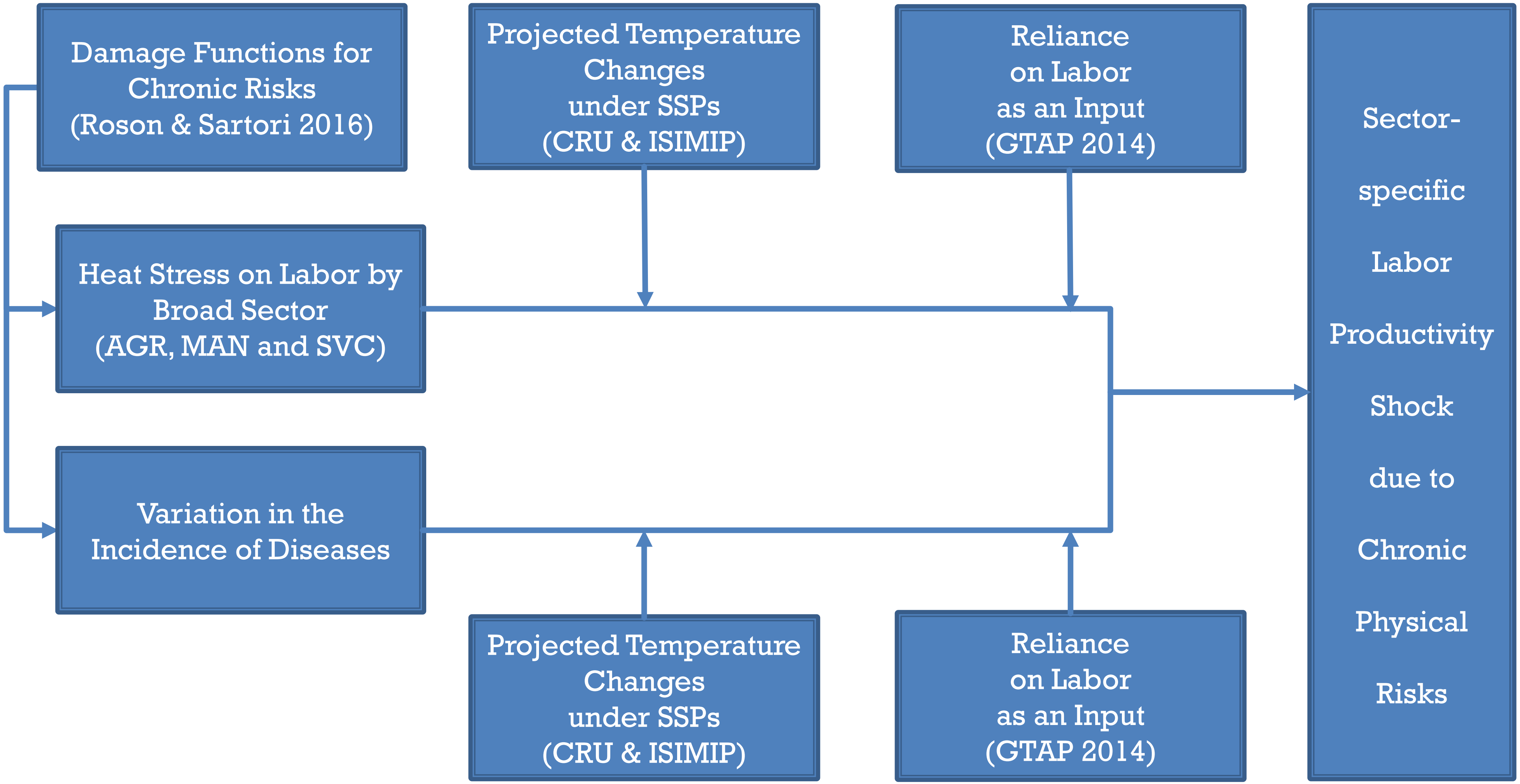
Climate Indicators: Change in mean temperature, precipitation, relative humidity, extreme maximum and minimum temperature changes during the day and night, and extremely dry, wet, and windy conditions.

γ_i: Country Fixed Effects; δ_j: Year Fixed Effects; $X_{i,j}$: Additional Controls (Lagged GDP Growth, GDP per capita, Current Account Balance, Public Debt to GDP Ratio, US Bond Returns, VIX Index)

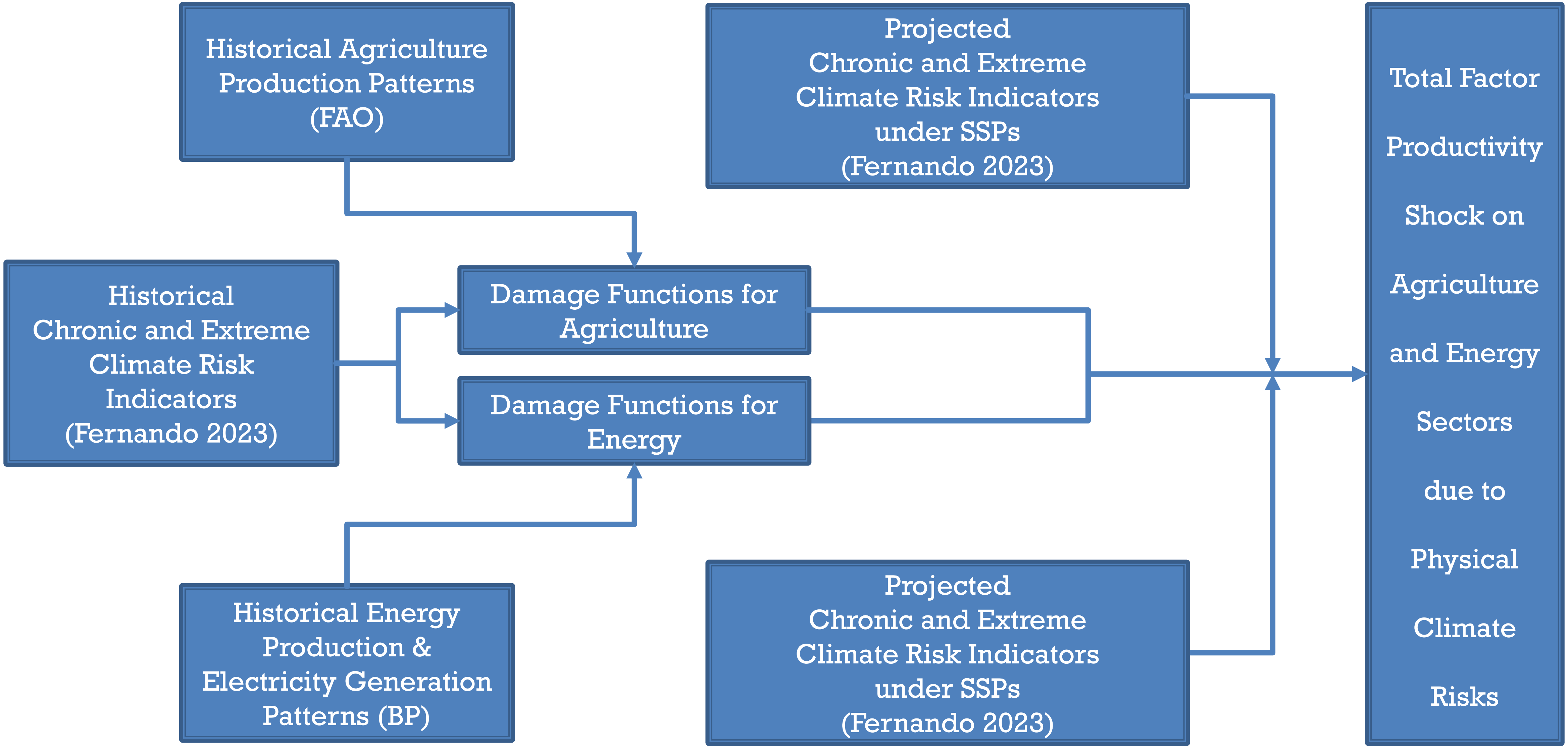
Modeling the Economic Impacts of Physical Climate Risks: Chronic Risks on Total Factor Productivity



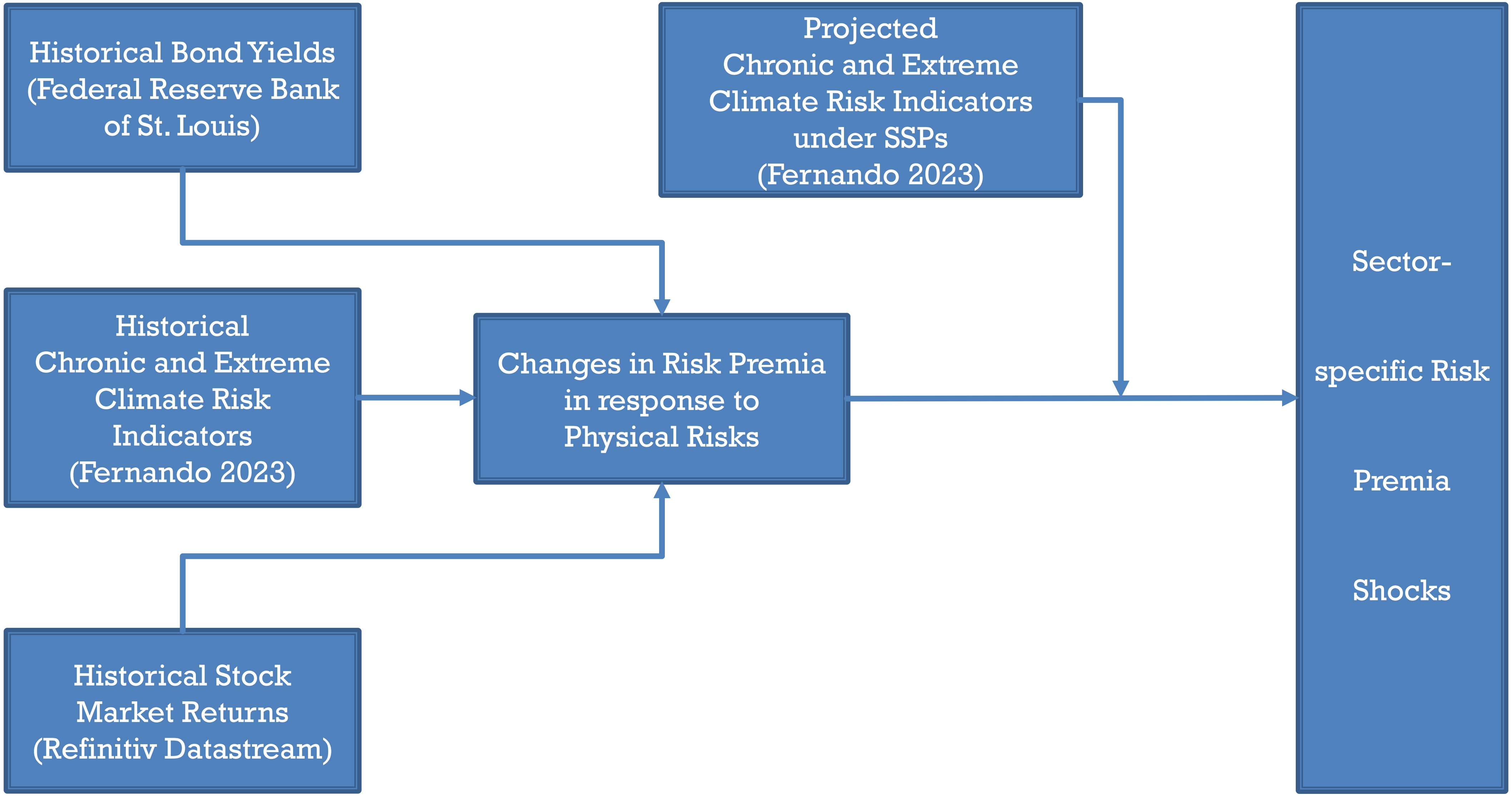
Modeling the Economic Impacts of Physical Climate Risks: Chronic Risks on Labor Productivity



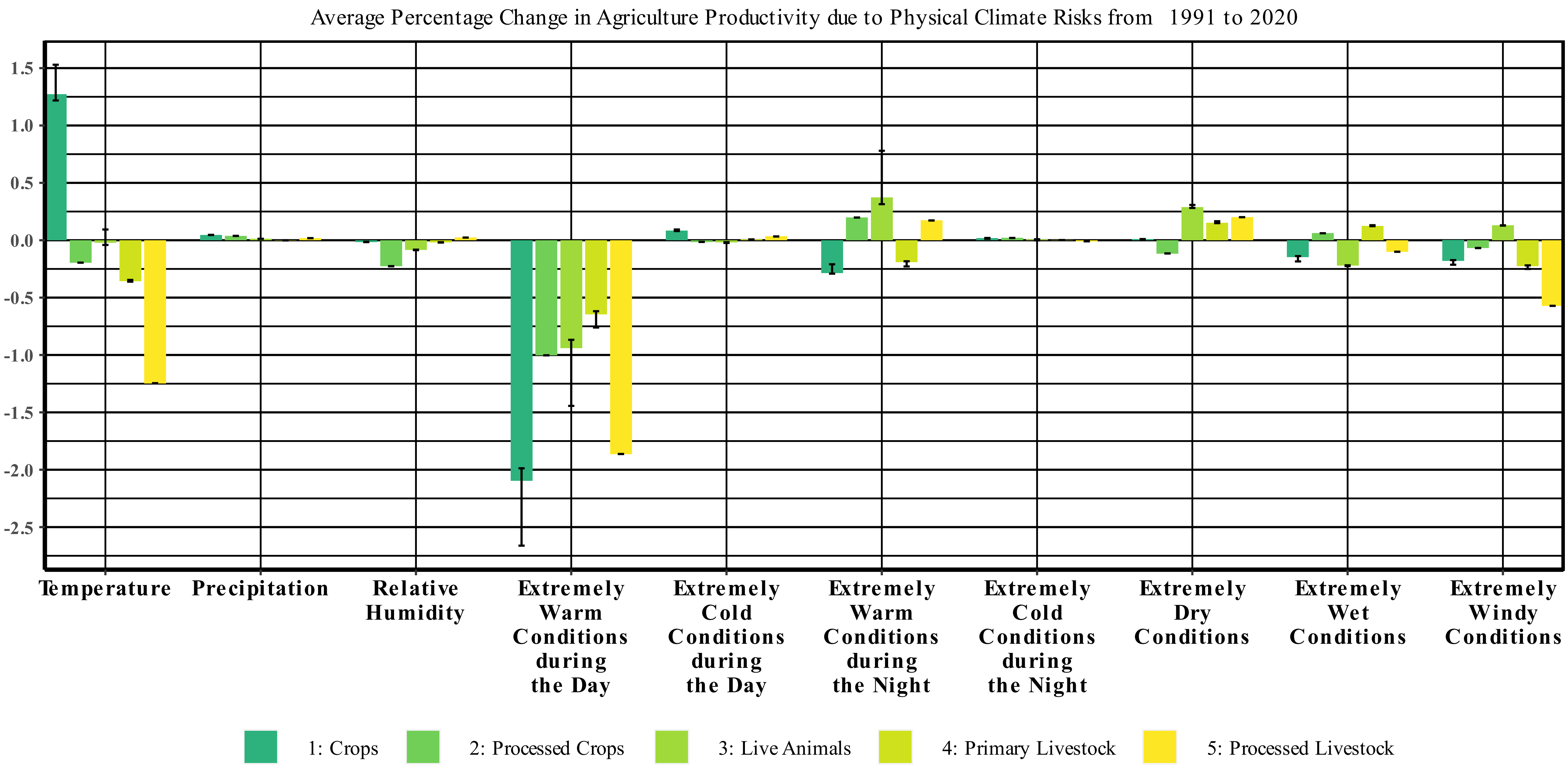
Modeling the Economic Impacts of Physical Climate Risks: Extreme Risks on Total Factor Productivity



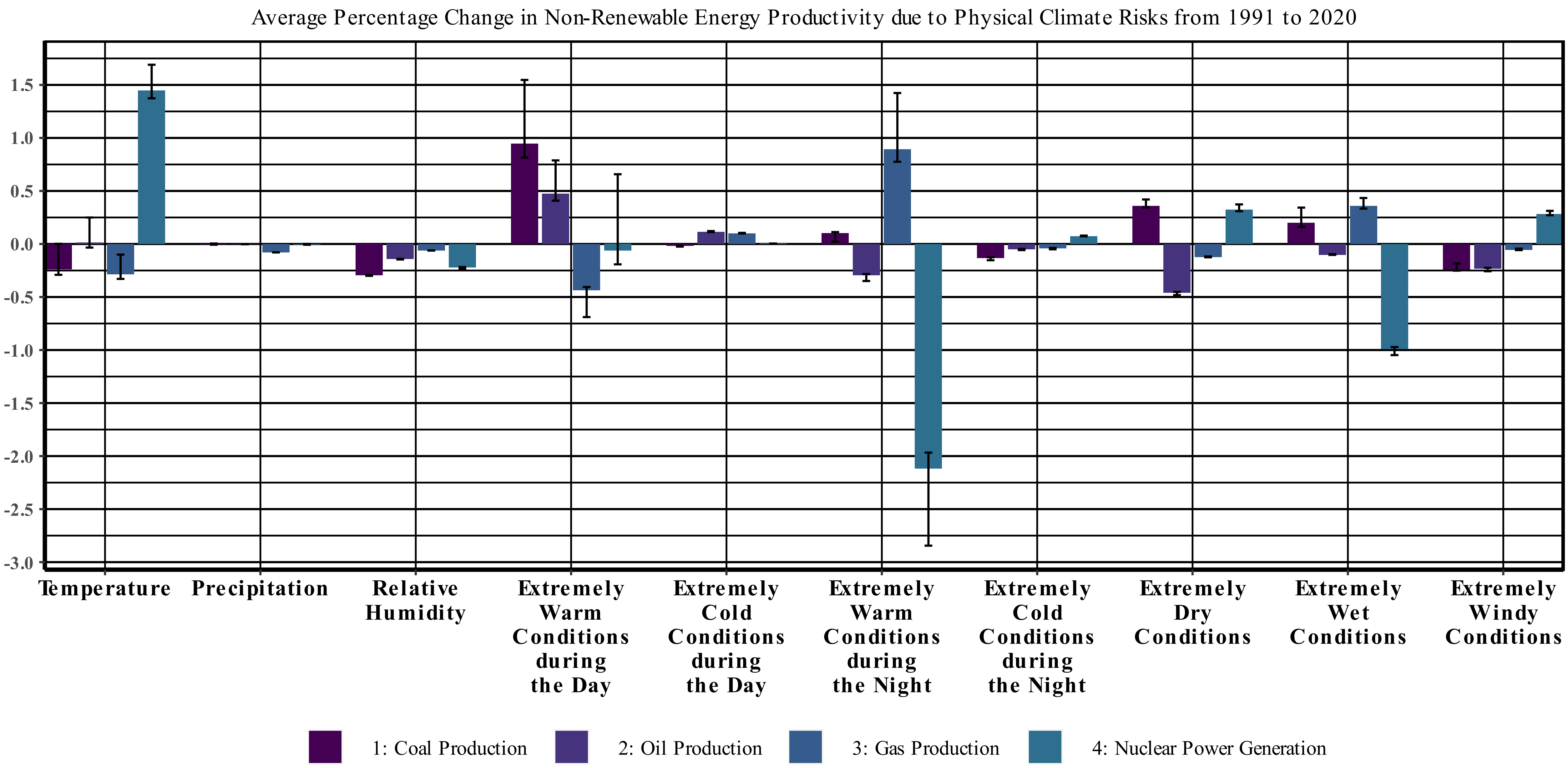
Modeling the Economic Impacts of Financial Risks: Changes in Risk Premia



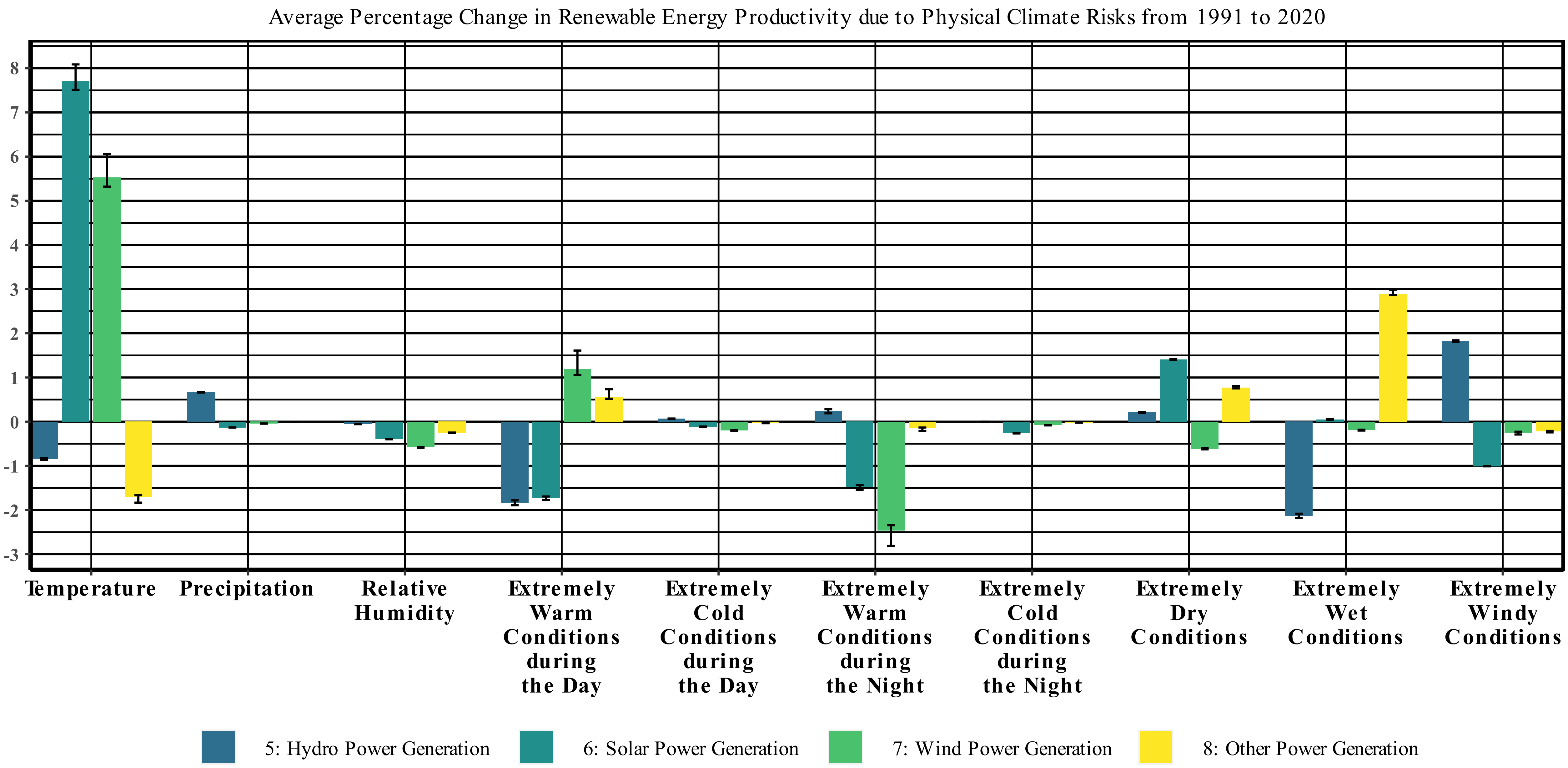
RESULTS FROM EMPIRICAL DAMAGE FUNCTIONS



Source: Fernando (2023).



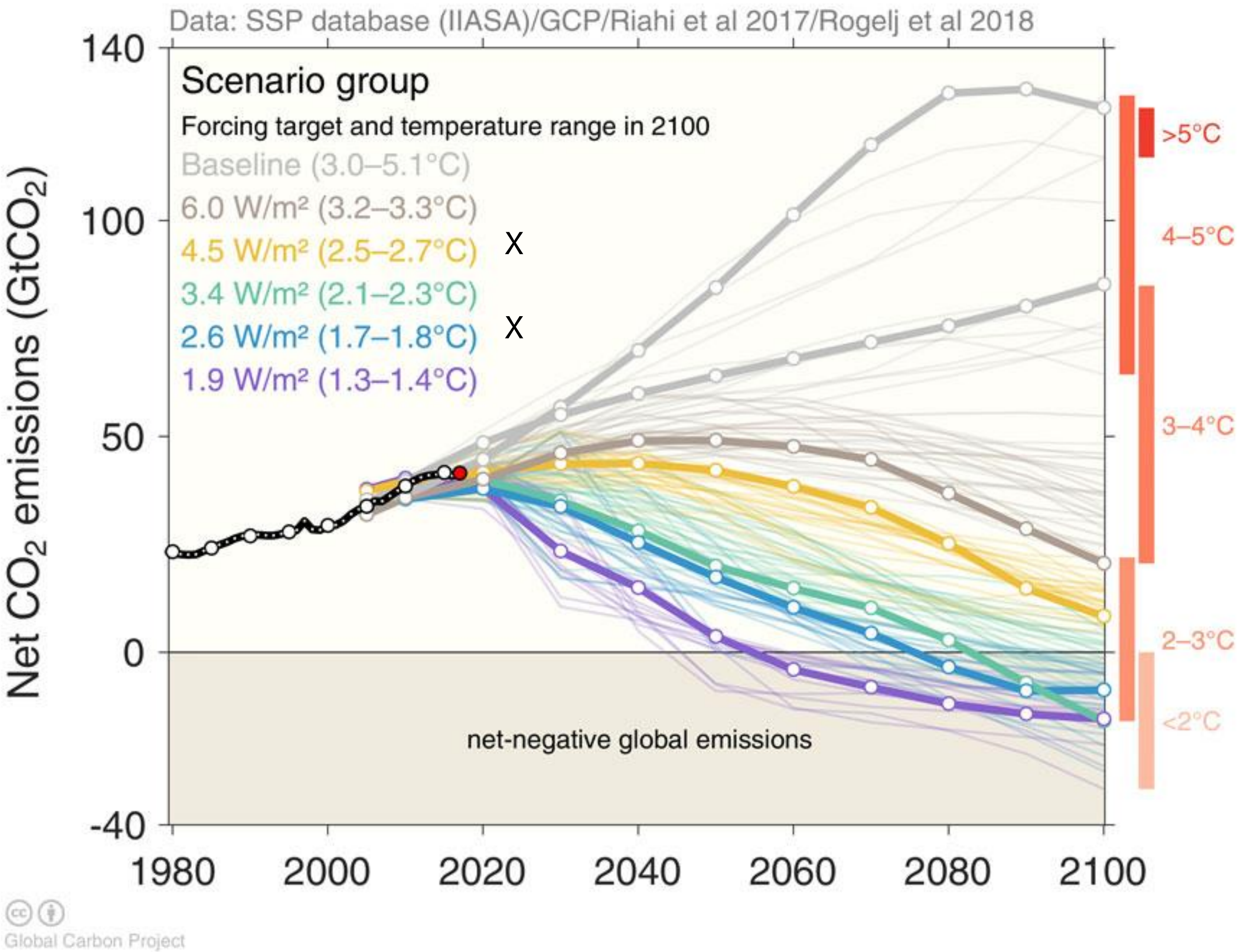
Source: Fernando (2023).



Source: Fernando (2023).

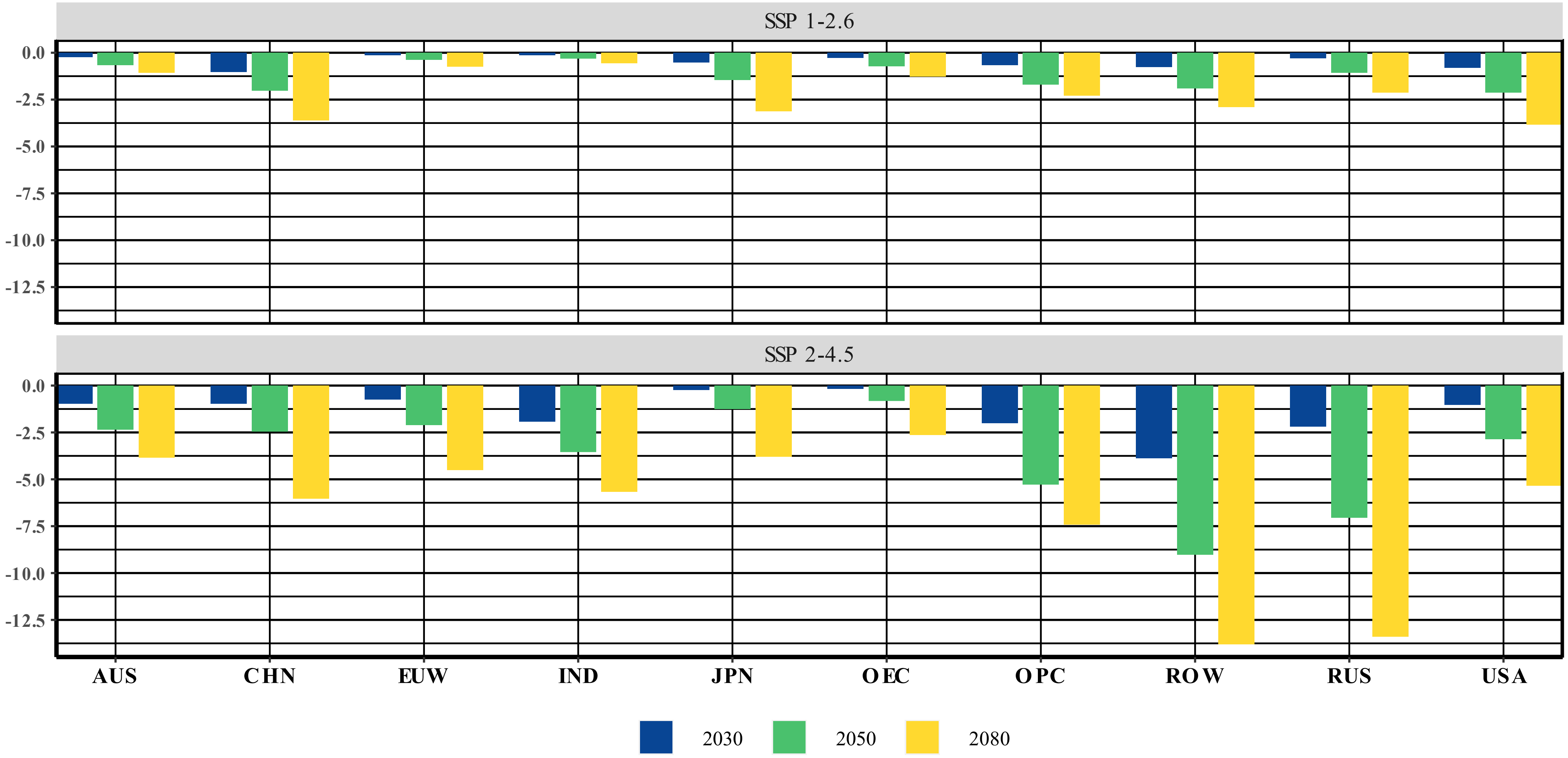
MODELING ECONOMIC IMPACTS OF PHYSICAL RISKS IN G-CUBED

Climate Scenarios: Shared Socioeconomic Pathways



Source: Global Carbon Project

Real GDP: Percentage Deviation from Baseline

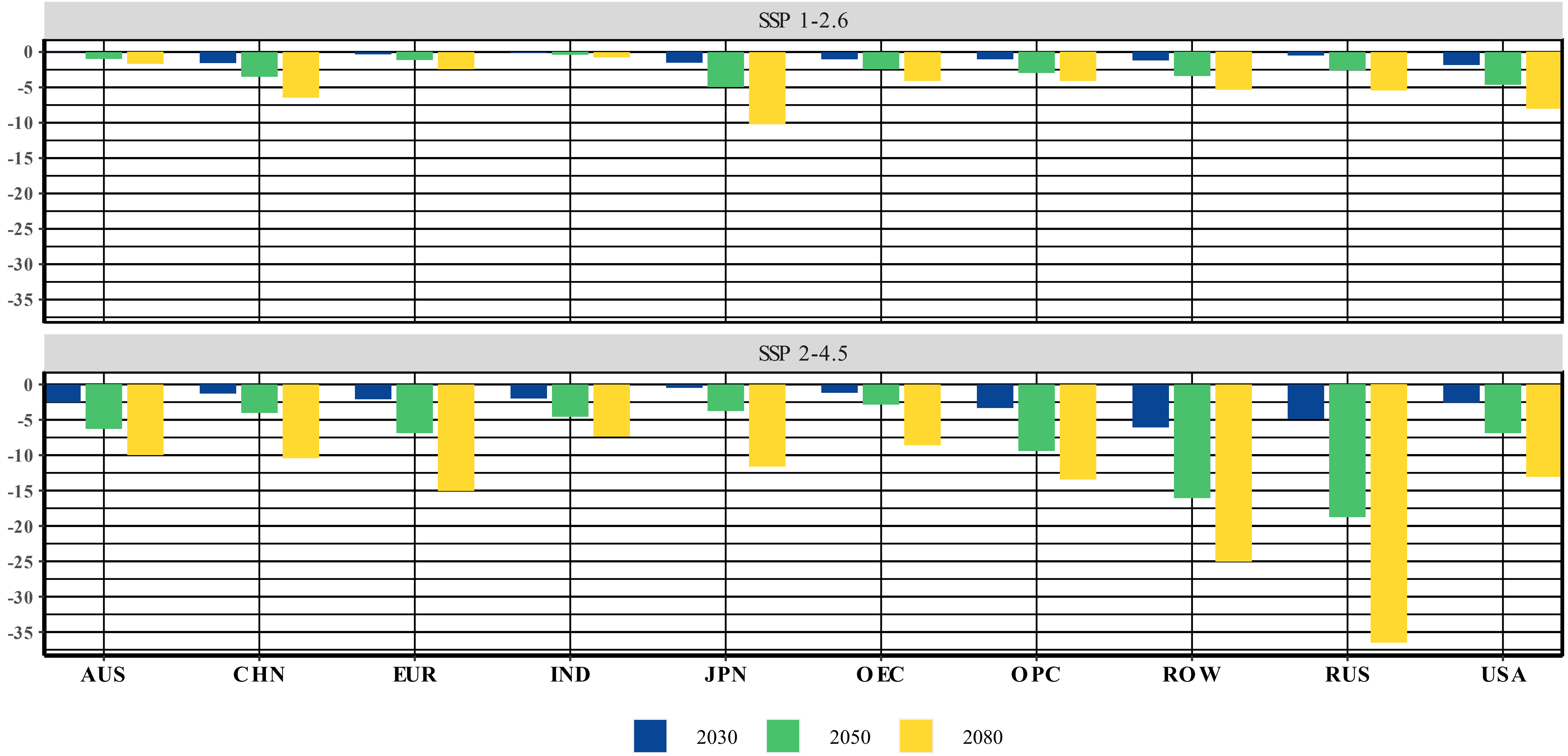


Source: G-Cubed Simulations.

GDP Losses from Climate Risks

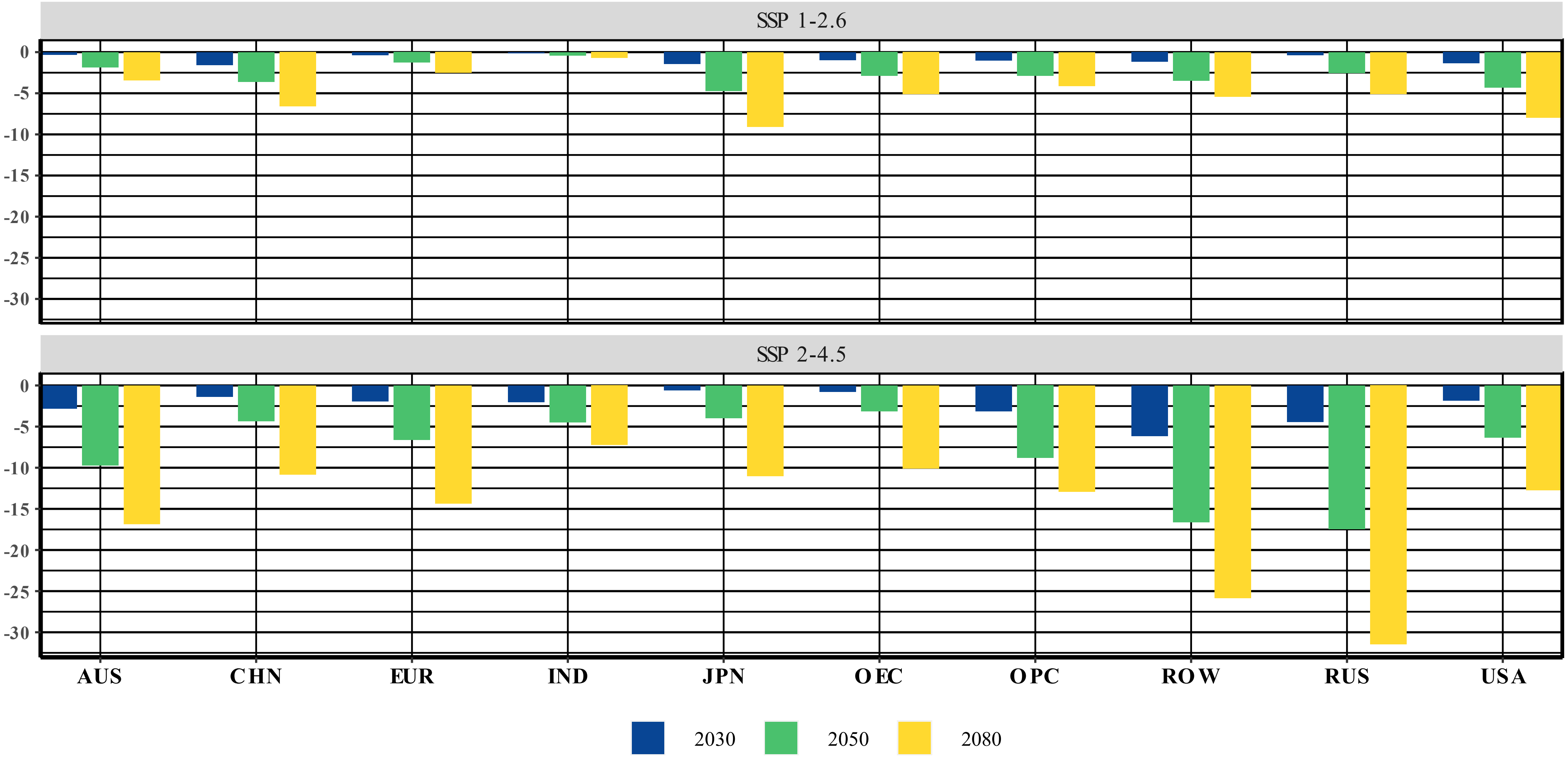
	Study	Risks	Scenario	Focus	Horizon	Unit	Estimates
1	Fernando et al. (2023)	Chronic and extreme risks	SSP 1-2.6	World	2100	$US Trillion in GDP per annum	-5.1
			SSP 2-4.5				-14.5
2	Fernando et al. (2021)	Chronic and extreme risks	RCP 2.6	World	2100	$US Trillion in GDP per annum	-3.8
			RCP 4.5				-6.9
			RCP 6.0				-7.9
3	Fernando & Lepore (2023)	Chronic and extreme risks	SSP 1-2.6	World	2100	$US Trillion in GDP per annum	-2.4
			SSP 2-4.5				-7.1
4	Kahn et al. (2019)	Chronic and (some) extreme risks	RCP 2.6	World	2100	% Loss in GDP per capita	0.58% to 1.57%
			RCP 8.5	World	2100	% Loss in GDP per capita	4.44% to 9.96%
5	Kompas et al. (2018)	Chronic risks	2 ^{0}C	World	2020 - 2100	$US Trillion in GDP per annum	-5.6
			3 ^{0}C				-9.6
			4 ^{0}C				-23.2
6	Roson & van der Mensbrugghe (2010)	Chronic risks	5.2 ^{0}C	World	2100	Average % Change in GDP	+3.5% to -12%
7	Hsiang et al. (2017)	Extreme risks	2 ^{0}C	USA	2080 - 2099	% Loss in GDP per annum	0.5%
			4 ^{0}C				2.0%
8	Narita et al. (2010)	Storms		World	2100	% Loss in GDP	0.006%

Agriculture Output: Percentage Deviation from Baseline



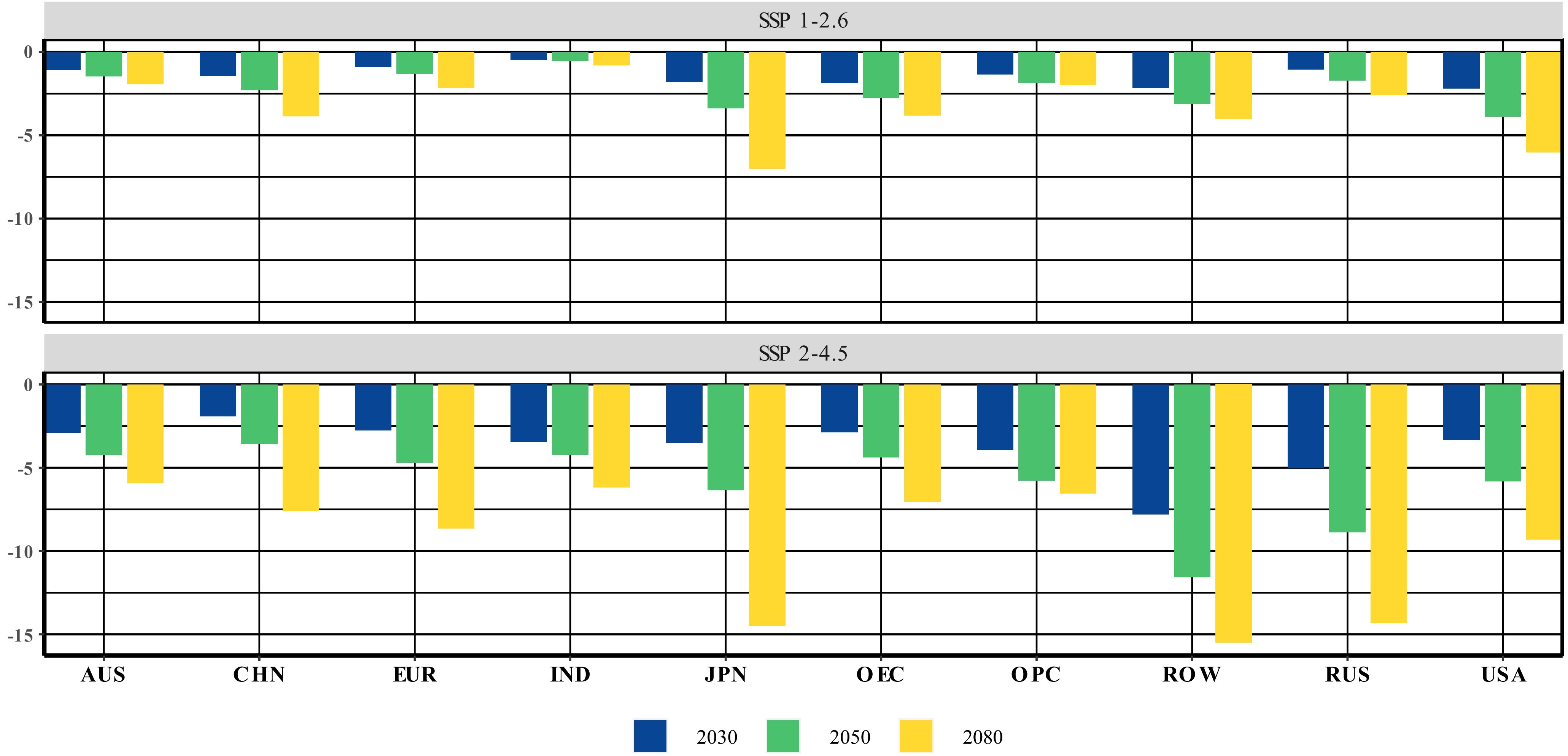
Source: G-Cubed Simulations.

Non-durable Manufacturing Output: Percentage Deviation from Baseline



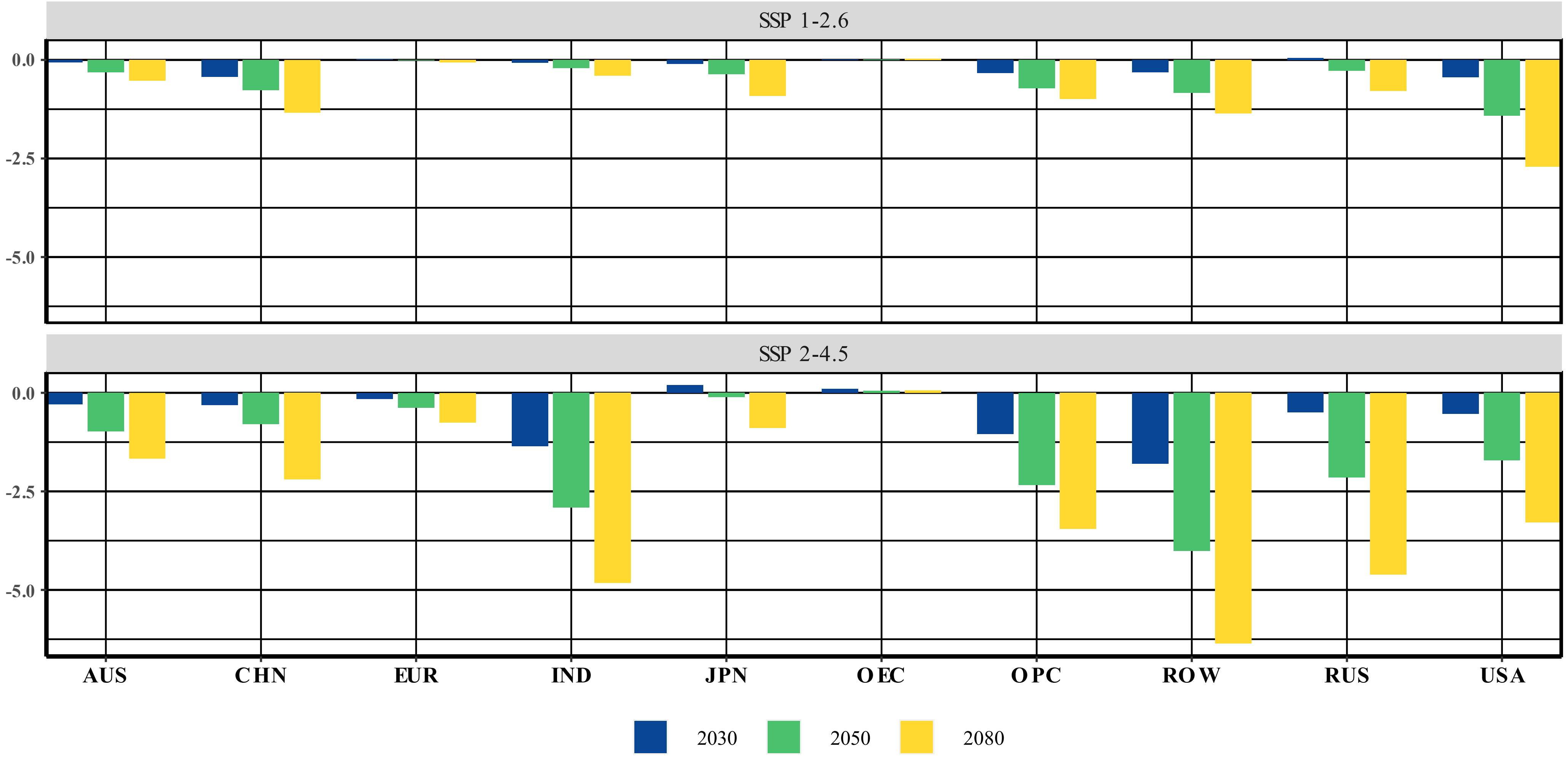
Source: G-Cubed Simulations.

Durable Manufacturing Output: Percentage Deviation from Baseline



Source: G-Cubed Simulations.

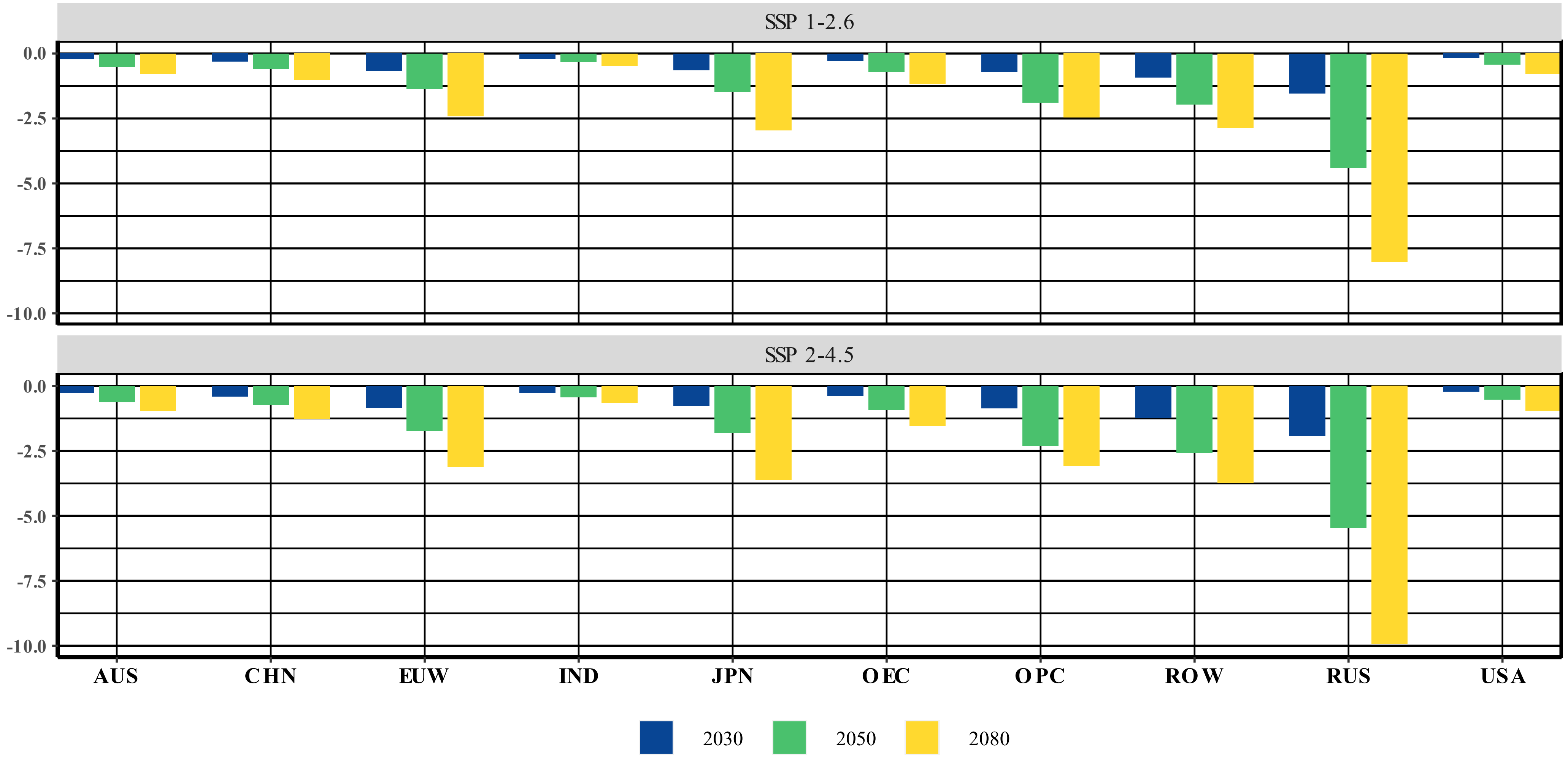
Services: Percentage Deviation from Baseline



Source: G-Cubed Simulations.

MODELING ECONOMIC IMPACTS OF CLIMATE-RELATED FINANCIAL RISKS IN G-CUBED

Real GDP: Percentage Deviation from Baseline



Source: G-Cubed Simulations.

CONCLUSION

Summary of the current research

- Assess the economic impacts of physical and financial climate risks.
- Incorporate both chronic (gradual changes in sea level, disease incidence, heat stress, temperature, precipitation, and relative humidity) and extreme physical risks (representative of droughts, floods, heatwaves, coldwaves, and storms).
- Use existing damage functions for some chronic risks and develop damage functions for agriculture and energy sectors from chronic and extreme risks.
- Estimate the historical responsiveness of financial markets to physical risks.
- Project the changes in productivity and risk premia under two SSPs.
- We also explore transition risks (not in this presentation)
- Illustrate the macroeconomic and sectoral outcomes.

Summary of Results

- There are substantial losses to all economies under alternative climate scenarios.
- Losses increase with warming.
- Effects are heterogenous in the distribution across sectors, countries, and time.
- General equilibrium effects (including the heterogenous agent behavior and price effects) could magnify the impact of the physical shocks.
- Agriculture sector is the most affected, while services are affected the least.

Policy Implications

- Assessment of the economic impacts of alternative climate scenarios is important for policymaking under the uncertainties arising from climate change.
  - *Fernando, R, Liu, W & McKibbin, W (2022) 'Why climate policy scenarios are important, how to use them, and what has been learned', Brookings Policy Brief, the Brookings Institution, Washington DC.*

- Incorporating extreme events/conditions into economic analyses is crucial for understanding the macroeconomic implications of climate change.

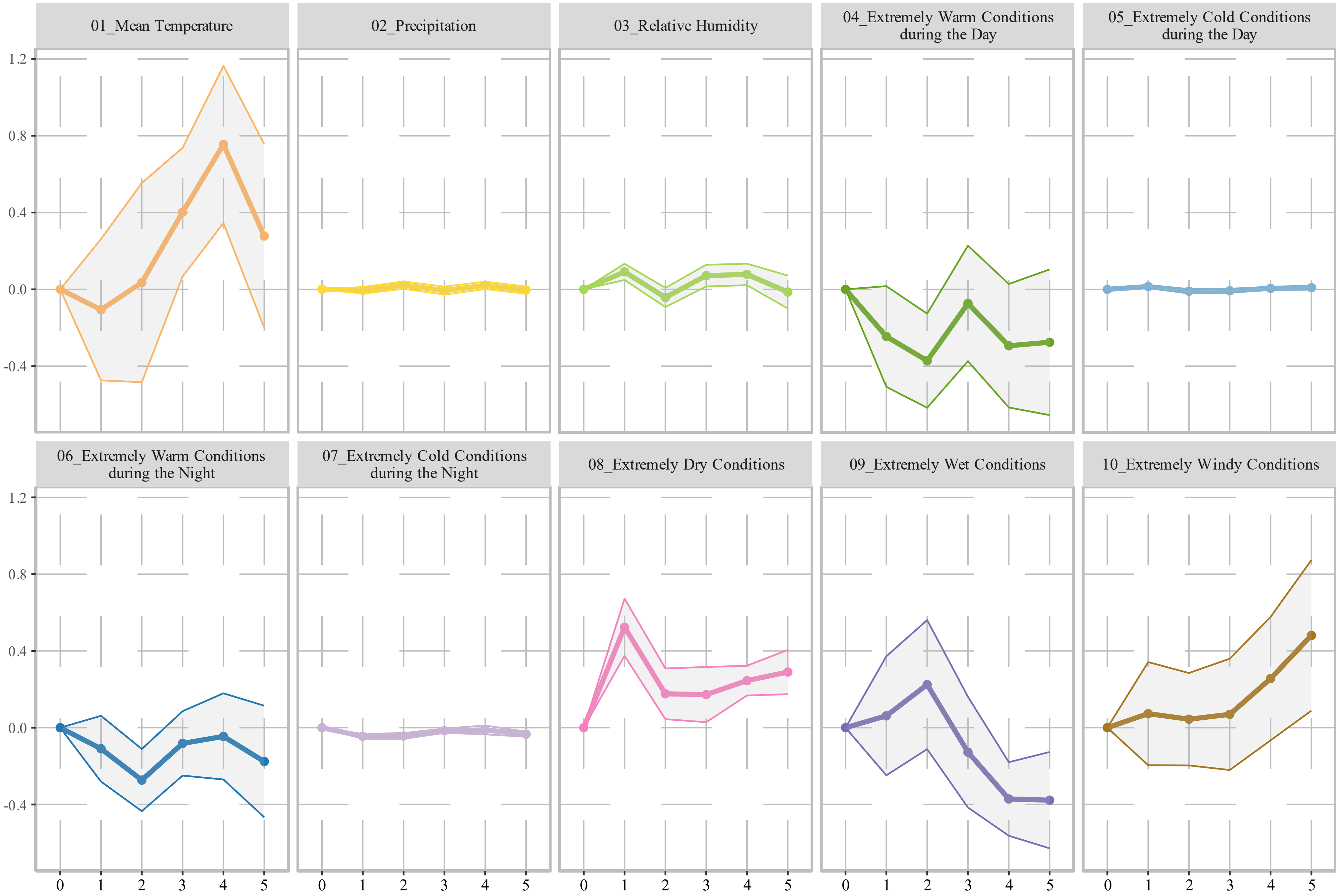
- Financial risks arising from revaluating asset prices in response to physical risks could also be costly.

THANK YOU!

Further Details: www.gcubed.com

ADDITIONAL SLIDES

Persistent Responsiveness of Equity Risk Premia to Physical Climate Risks (Percentage Point Change) [Local Projections]



Source: Fernando (2023).