Global Economic Impacts of Physical Climate Risks

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Current Approaches to Modeling Economic Impacts of Climate Change

- Integrated Assessment Models
  - Integrates the socioeconomic interactions with the physical and biological processes of the natural environment.

- Economists' approaches
  - 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)*

- Gaps
  - Lack of developed economic modules.
  - Extensive focus on chronic risks and rarely on extreme risks.
  - Lack of sector representation especially in most of the economic approaches to modelling climate change.
  - Lack of firm-level evidence.

Productivity Impact Pathways of Climate Risks

- Crops*
  - Changes in soil moisture, length, and timing of the growing season
  - Changes in the water-use efficiency and photosynthesis
  - Changes in the quality of water and soil, shifts in weed growth, and disease occurrence
- Livestock & Aquaculture*
  - Impact of extreme heat stress on the physiology, behavior, and movement of the animals, birds, and fish
- Forestry*
  - Changes in growth cycles and resilience to diseases
- Mining & Energy**
  - Changes in the cost of exploration, extraction, production, transportation, and decommissioning
  - Newer opportunities for exploration
  - Higher requirement for cooling water in thermal power plants
  - More frequent maintenance of transmission lines
- Manufacturing & Services***
  - Impact on labor productivity due to changes in temperature
  - Impact on firm capital and infrastructure
  - Substitution of raw materials, altering processes, and retrofitting equipment
  - Changes in procurement patterns
  - Increased cost of production due to reliance on upstream and downstream sectors which are vulnerable to climate risks

References: *US Climate Change Science Program (2008a); Hulme (1996); **Pearce et al (2021); Sun et al (2020); US Climate Change Science Program (2008b); ***Somanathan et al. (2021); Zhang et al. (2017); Hayakawa et al (2015); Kumar & Yalew (2012).

Climate Data & Indicators

- Source
  - Historical Climate Data: Climate Research Unit of the University of East Anglia
  - Projected Climate Data: Earth system model of the Geophysical Fluid Dynamics Laboratory via the Intersectoral Impact Model Intercomparison Project hosted by the Potsdam Institute for Climate Impact Research.
- Resolution: 0.5^0 x 0.5^0
- Historical Observations: 1961 - 2020
- Projections: 2021 - 2100
- Climate Variables: Temperature, Maximum Temperature, Minimum Temperature, Precipitation, Relative Humidity, Wind Speed
- Climate Indicators:
  - Chronic: Mean Temperature and Precipitation
  - Extreme: Extremely Warm and Cold Conditions during the Day and Night, Extremely Dry and Wet Conditions

Firm Data for Empirical Estimations

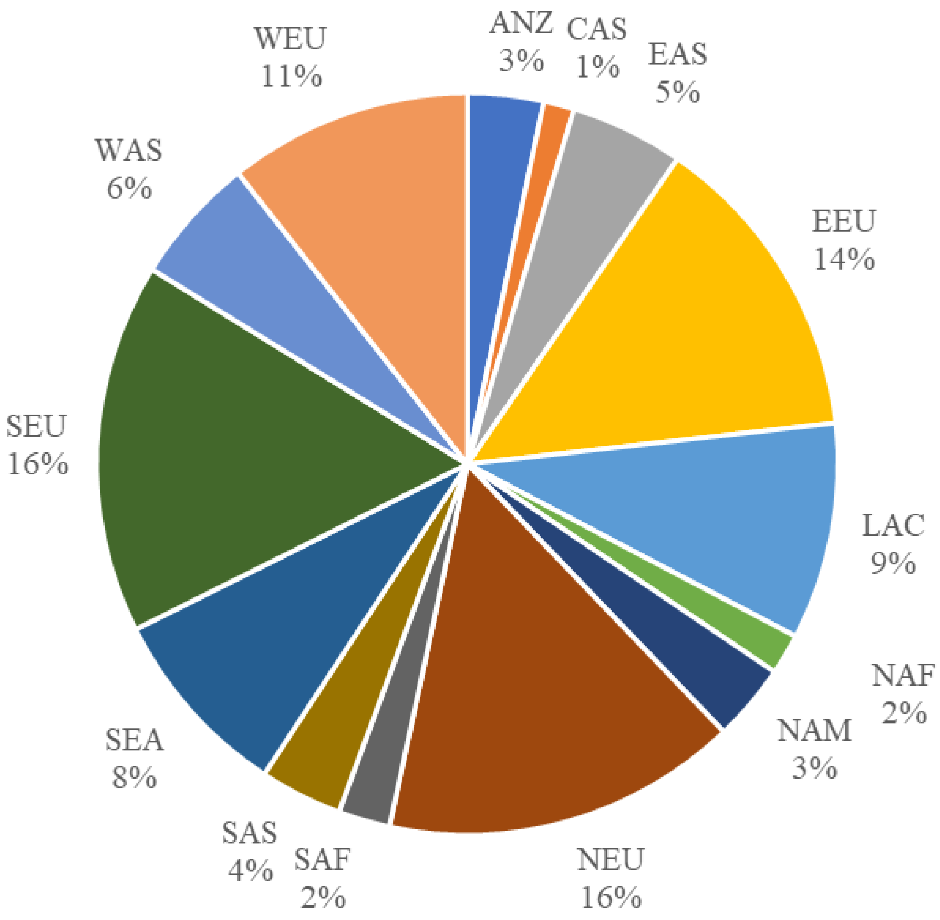
- Cleaned Firm Database:

  Orbis from the Research Department of the IMF

- Total Factor Productivity computation:

  Ackerberg et al. (2015)

- Distribution of the 20,215 (48 countries) across 14 United Nations regions



ANZ – Australia & New Zealand, Melanesia, Micronesia, and Polynesia; CAS – Central Asia; EAS – Eastern Asia; EEU – Eastern Europe; LAC – Latin America and the Caribbean; NAF – Northern Africa; NAM – Northern America; NEU - Northern Europe; SEA – Southeast Asia; SAS – South Asia; SEU – Southern Europe; SAF – Sub-Saharan Africa; WAS – Western Asia; WEU – Western Europe.

Impacts of Climate Risks on Sectoral Productivity

- Panel regressions coupled with machine learning algorithms

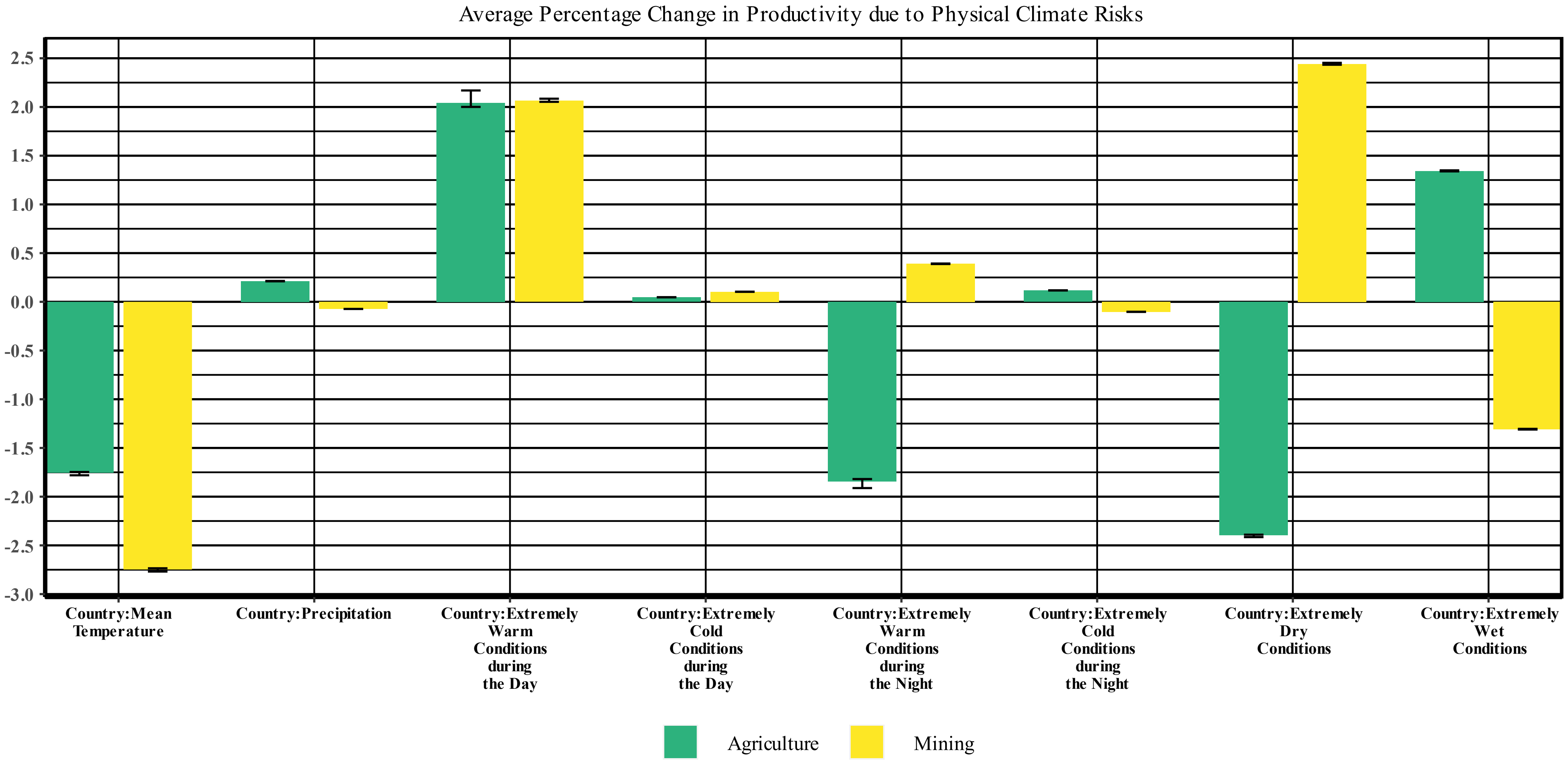
$$Growth\ in\ Firm\ TFP_{i,j,k,l} = \beta_0 + \beta_{GDP} * GDP\ Growth_{j,l} +$$

$$\sum_{n=1}^{8} \gamma_n * Country - level\ Climate\ Indicator_{j,l} +$$

$$\sum_{m=1}^{8} \delta_m * Firm - level\ Climate\ Indicator_{i,l} + \theta_j + \vartheta_k + \varepsilon_{i,j,k,l}$$

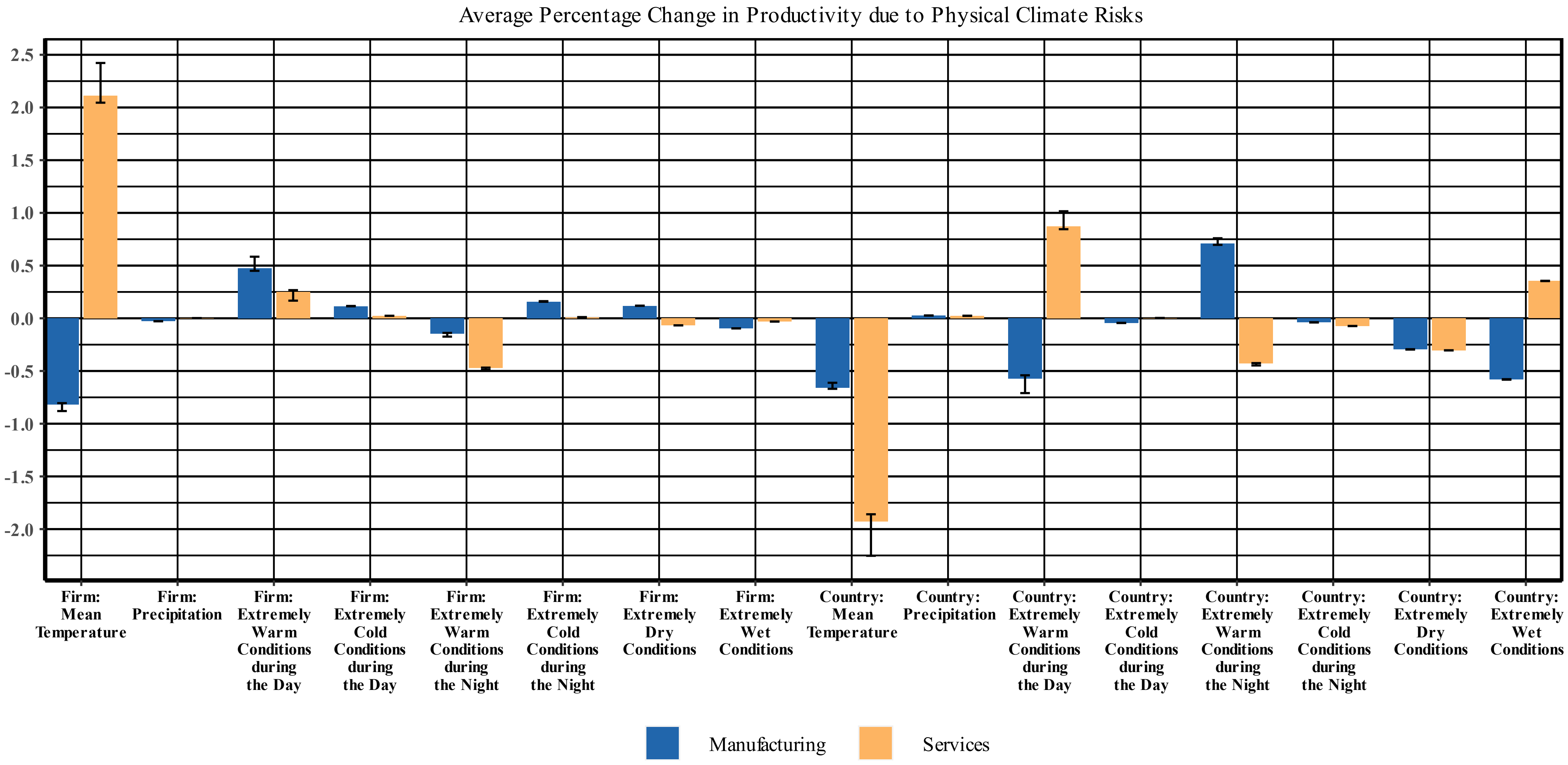
- θ_j: Region-specific fixed-effects;
- ϑ_k: Year-specific fixed-effects.

Impacts of Climate Risks on Sectoral Productivity (Contd.)



Source: Fernando & Lepore 2023.

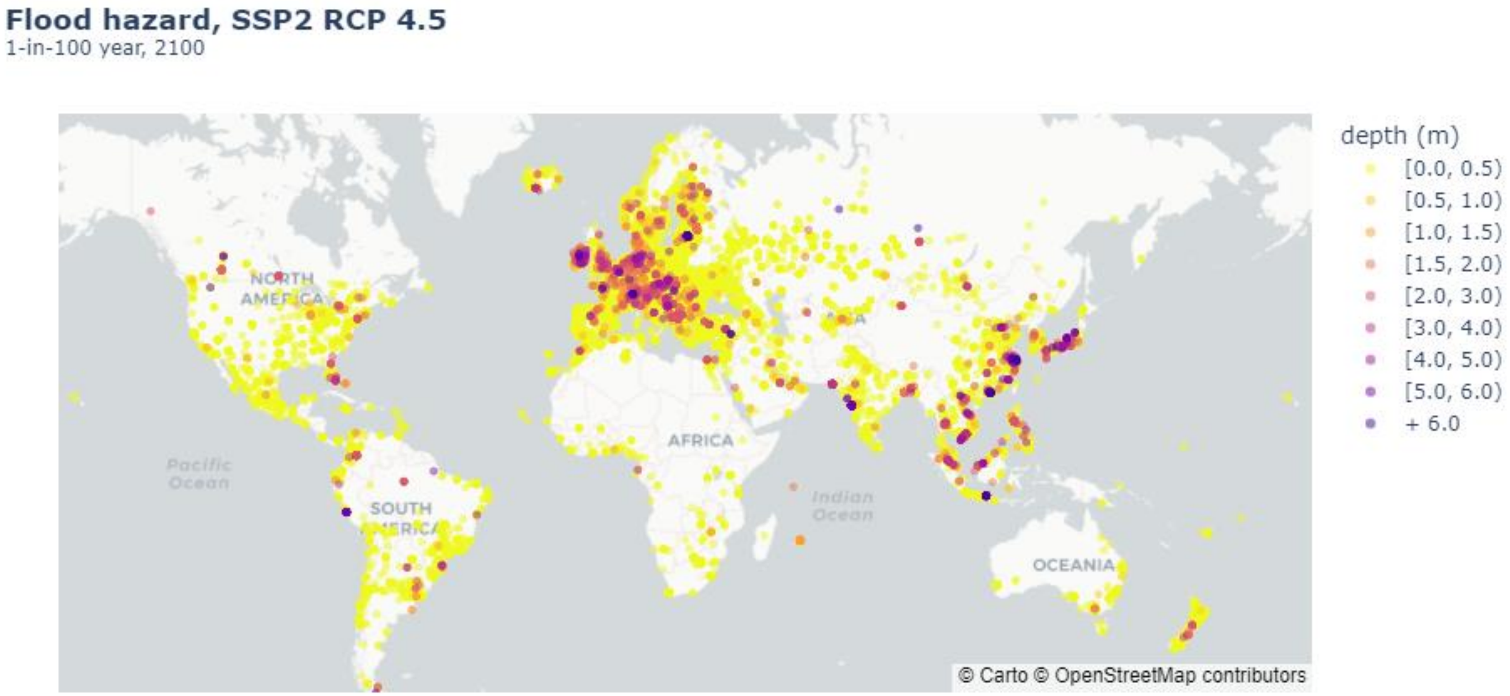
Impacts of Climate Risks on Sectoral Productivity (Contd.)



Source: Fernando & Lepore 2023.

Impacts of Floods on Sectoral Capital

- Data
    - Exposure of firms to floods under different return periods (10, 20, 50, 100, 200, and 500) under different SSPs
    - Source: Jupiter Intelligence
    - Damages for different asset classes for 214 countries for different continents: Huizinga et al (2017)



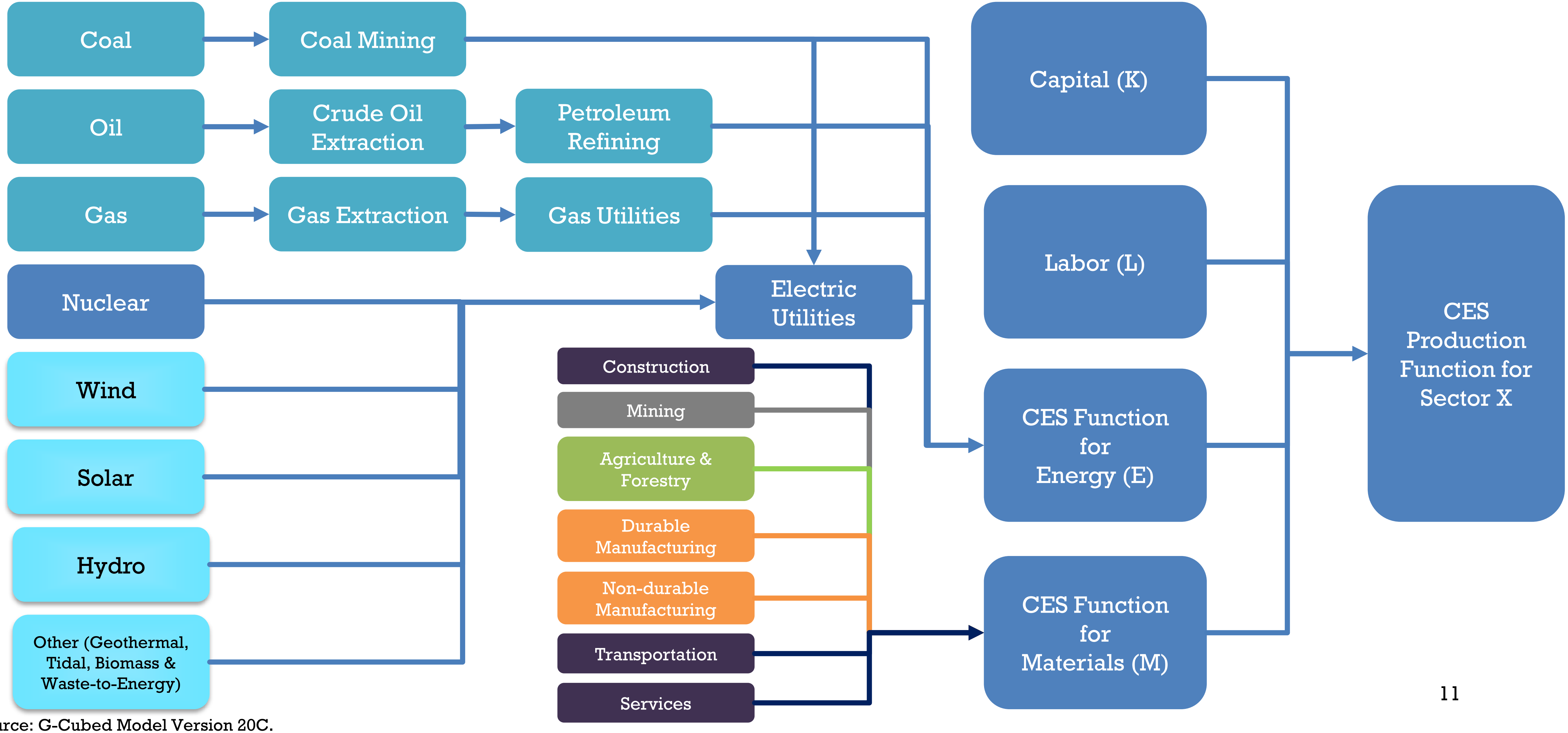
Source: Fernando & Lepore 2023.

The G-Cubed Model: Overview of Features

- A hybrid DSGE-CGE model
- A global model (7 countries and 4 regions)
- Agents in the model
  - Households
  - Firms (Agriculture, Mining, Energy, Durable & Non-durable Manufacturing, Services)
  - Governments
  - Central Banks
- Heterogeneous agents
- Inter-industry linkages, trade, capital flows, consumption, and investment
- Captures frictions in the labor market and capital accumulation
- 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 2013; 1999.

The G-Cubed Model: Sectors



Source: G-Cubed Model Version 20C.

G-Cubed Baseline & Scenarios

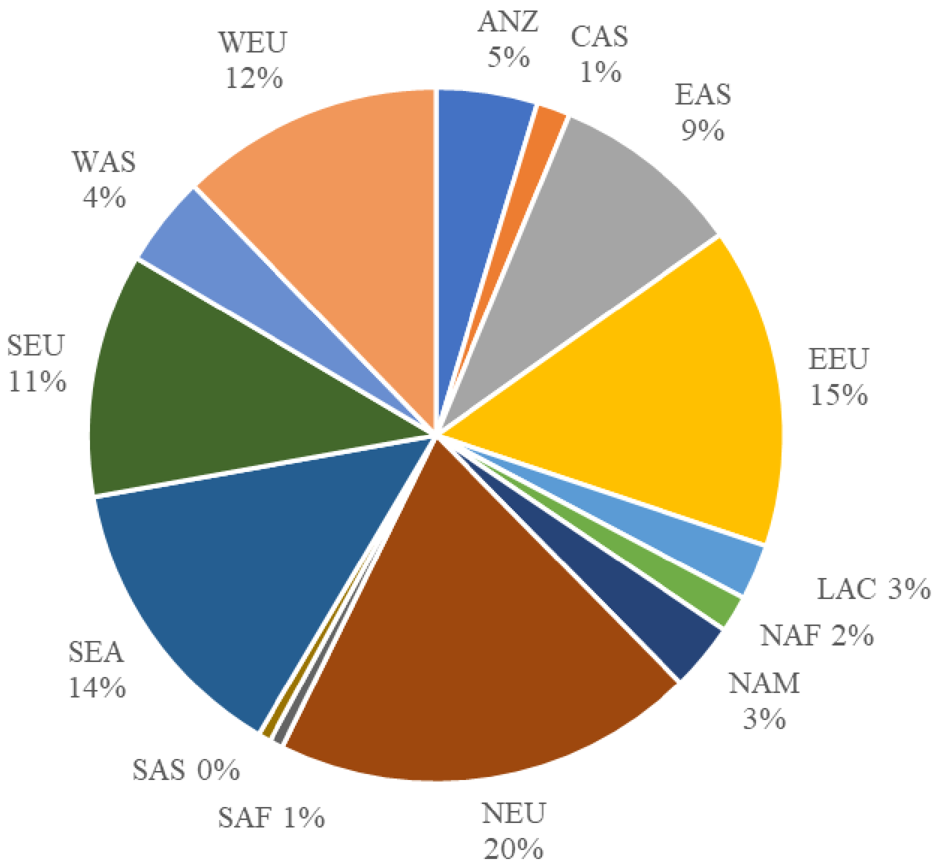
- G-Cubed Baseline: Driven by sectoral productivity growth rates.
- Sectoral Productivity Growth = f (Labor Productivity Growth, Labor Force Growth)
- No additional climate shocks (both climate risks and policies) in the baseline other than those already in place by 2018.
- Shocks are normalized relative to 2020 for the Shared Socioeconomic Pathways (SSPs).

Shared Socioeconomic Pathways

SSP	Scenario	Estimated Global Warming		
		2041-2060 (^{0}C)	2081-2100 (^{0}C)	Range: 2081-2100 (^{0}C)
SSP 1-1.9	Very low GHG emissions: CO_2 emissions reduced to net zero around 2050	1.6	1.4	1.0 – 1.8
SSP 1-2.6	Low GHG emissions: CO2 emissions reduced to net zero around 2075	1.7	1.8	1.3 – 2.4
SSP 2-4.5	Intermediate GHG emissions: CO_2 emissions around current levels until 2050, then falling but not reaching net zero by 2100	2.0	2.7	2.1 – 3.5
SSP 3-7.0	High GHG emissions: CO_2 emissions double by 2100	2.1	3.6	2.8 – 4.6
SSP 5-8.5	Very high GHG emissions: CO_2 emissions triple by 2075	2.4	4.4	3.3 – 5.7

Firms for Projections

- Non-financial Firms
- Firm Financial Data: Bureau van Dijk Orbis database
- Top 1,000 firms in each IMF member country, reporting financial data after 2018, by total asset value.
- Locations of the firms
  - Company addresses: Orbis database
  - Geocoding: Moody's Data Analytics
- Distribution of the 59,554 (147 countries) across 14 United Nations regions



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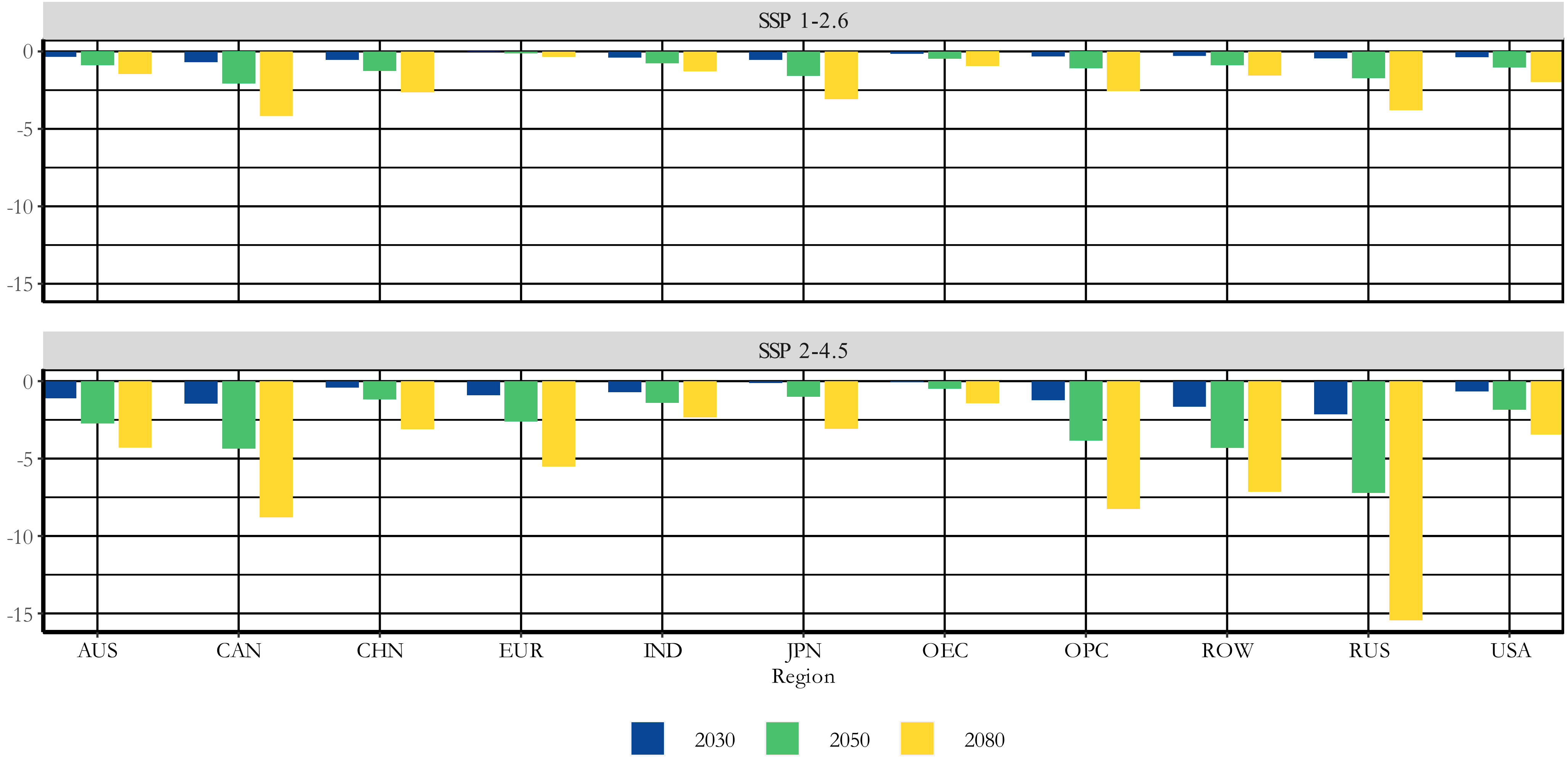
Results: Real GDP: Percentage Deviation from the Baseline

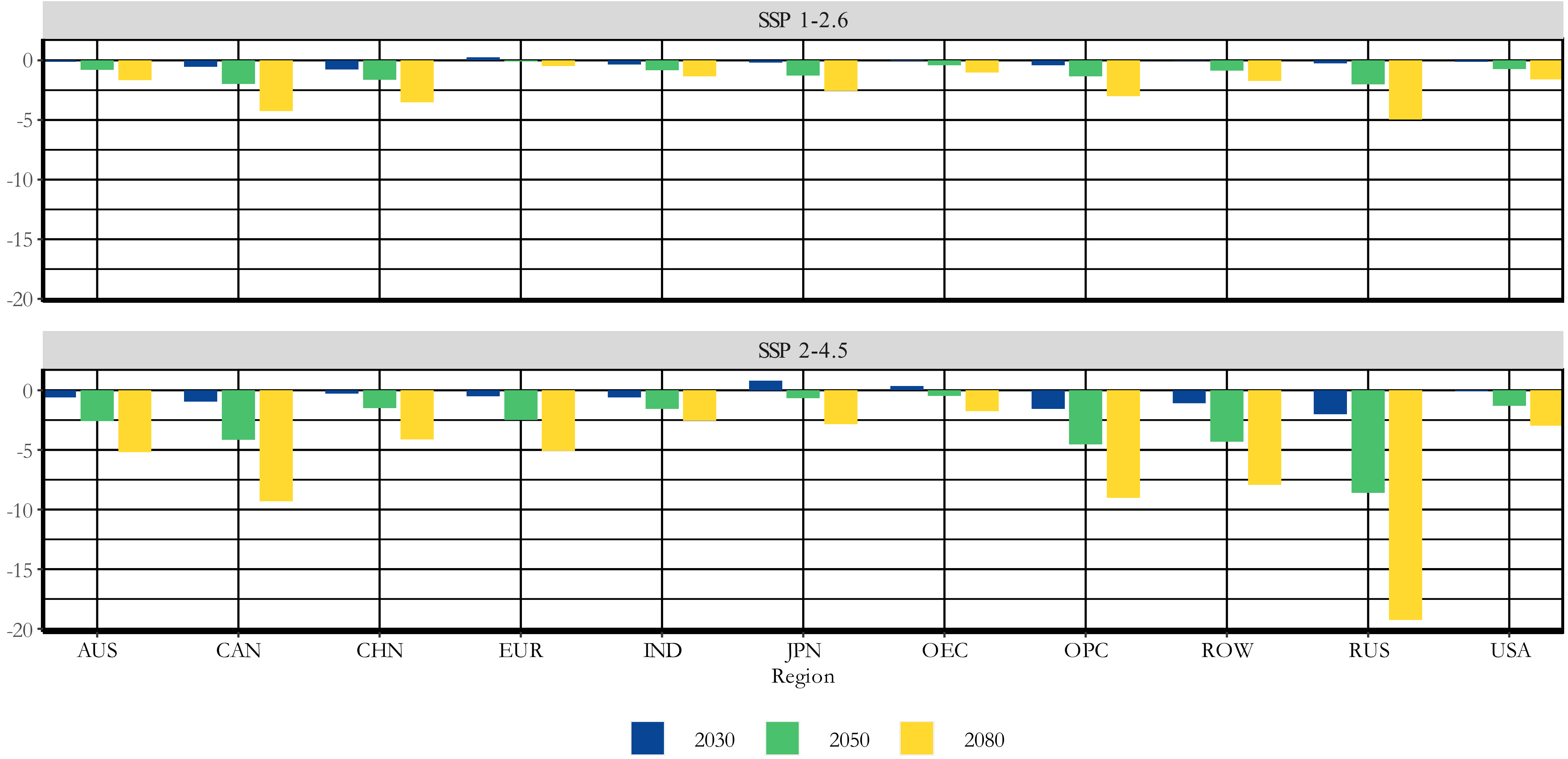


Source: Results from G-Cubed Simulations.

GDP Losses from Climate Risks

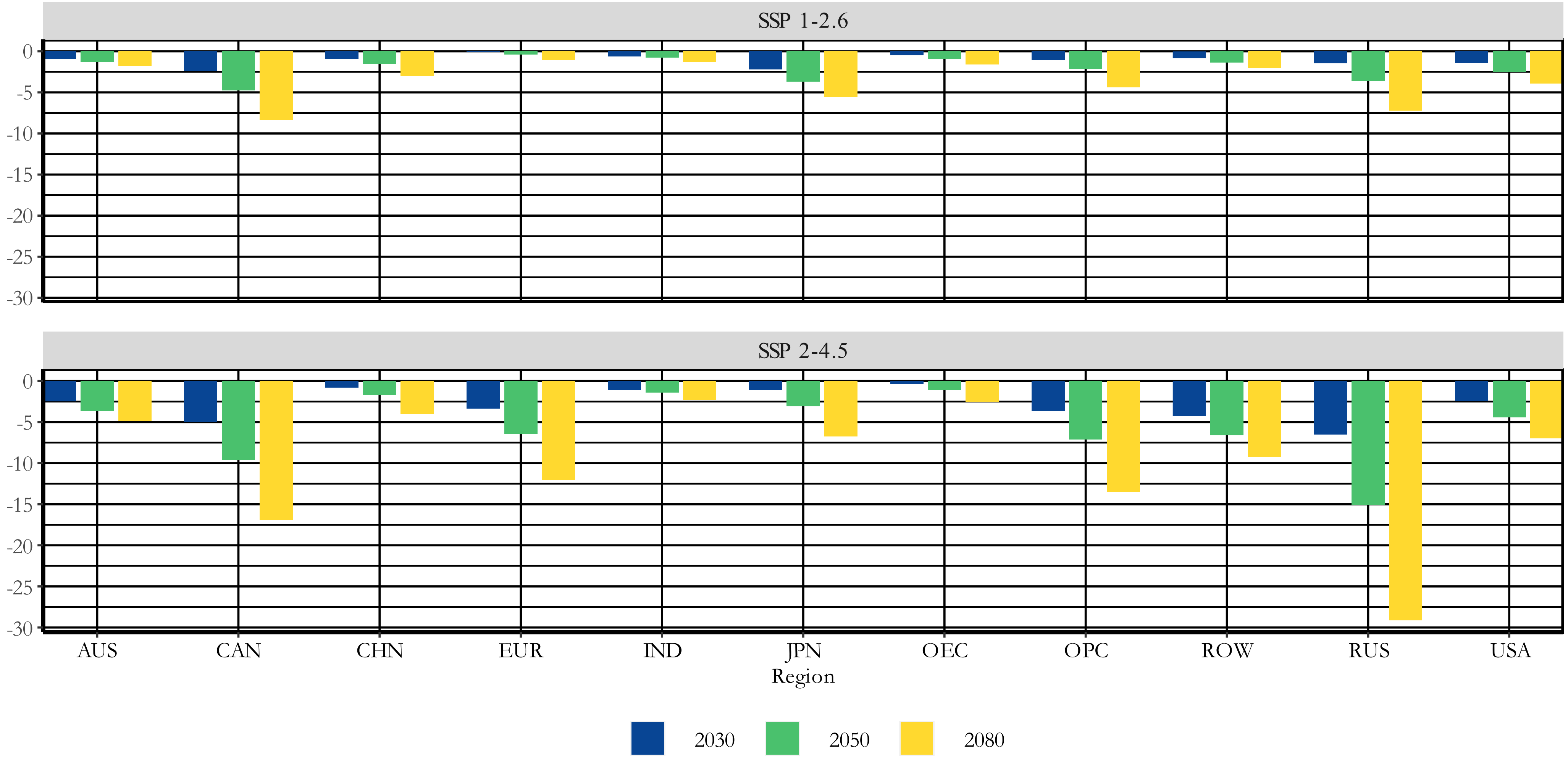
Study	Risks	Scenario	Focus	Horizon	Unit	Estimates
Fernando (2023)	Chronic and Extreme Risks	SSP 1-2.6 SSP 2-4.5 SSP 5-8.5	World	2100	$US Trillion in GDP per annum	-2.0 -6.5 -15.0
Fernando & Lepore (2023)	Chronic and Extreme Risks	SSP 1-2.6 SSP 2-4.5	World	2100	$US Trillion in GDP per annum	-2.4 -7.1
Fernando et al. (2021)	Chronic and Extreme Risks	RCP 2.6 RCP 4.5 RCP 6.0 RCP 8.5	World	2100	$US Trillion in GDP per annum	-3.8 -6.9 -7.9 -13.8
Kahn et al. (2019)	Chronic and (some) Extreme Risks	RCP 2.6 RCP 8.5	World World	2100 2100	% Loss in GDP per capita	0.58% to 1.57% 4.44% to 9.96%
Kompas et al. (2018)	Chronic Risks	2 ^{0}C 3 ^{0}C 4 ^{0}C	World	2020 - 2100	$US Trillion in GDP per annum	-5.6 -9.6 -23.2
Roson & van der Mensbrugghe (2010)	Chronic Risks	5.2 ^{0}C	World	2100	Average % Change in GDP	+3.5% to -12%
Hsiang et al. (2017)	Extreme Risks	2 ^{0}C 4 ^{0}C	USA	2080 - 2099	% Loss in GDP per annum	0.5% 2.0%
Narita et al. (2010)	Storms		World	2100	% Loss in GDP	0.006%

Consumption: Percentage Deviation from the Baseline



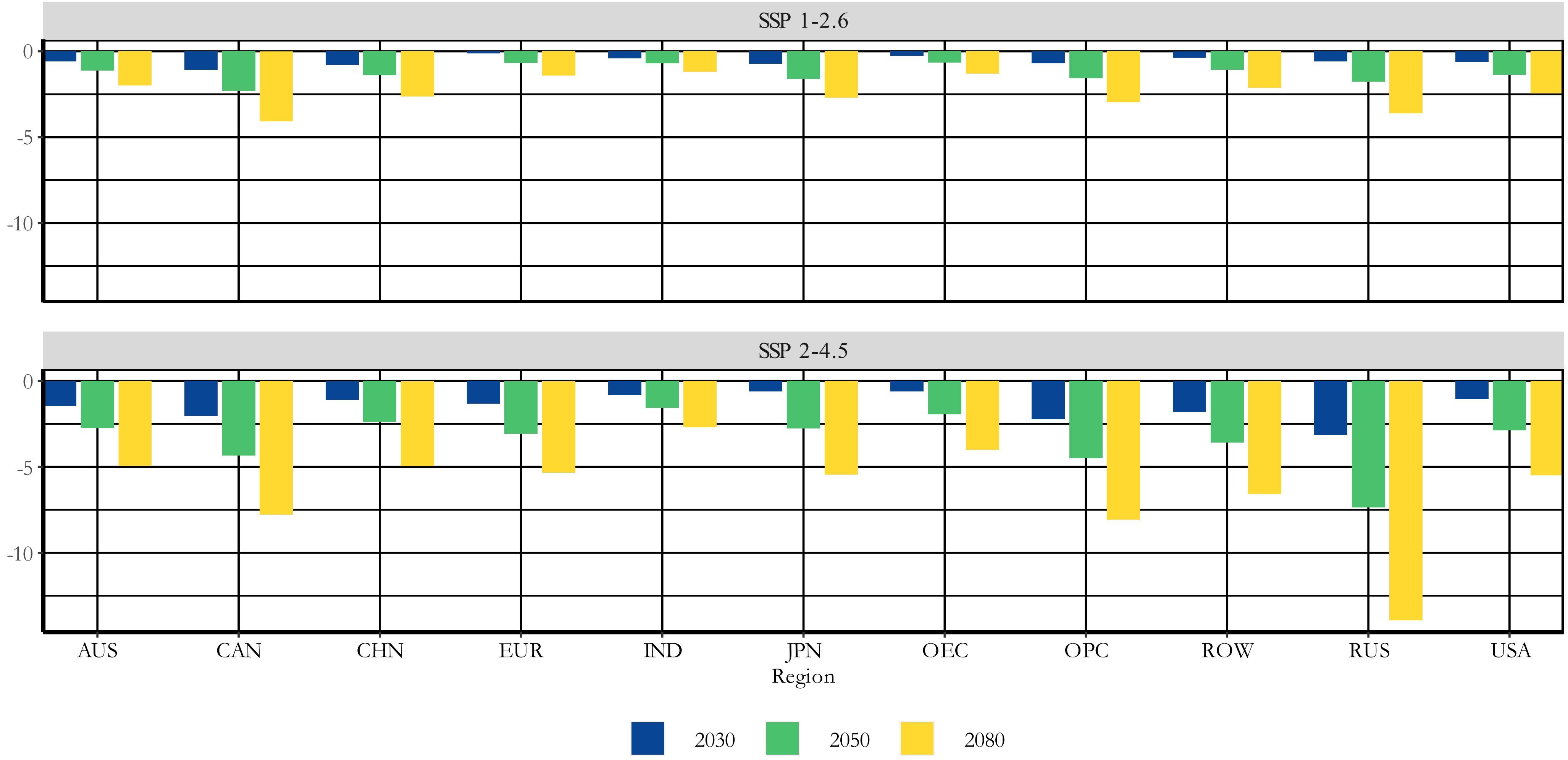
Source: Results from G-Cubed Simulations.

Investment: Percentage Deviation from the Baseline



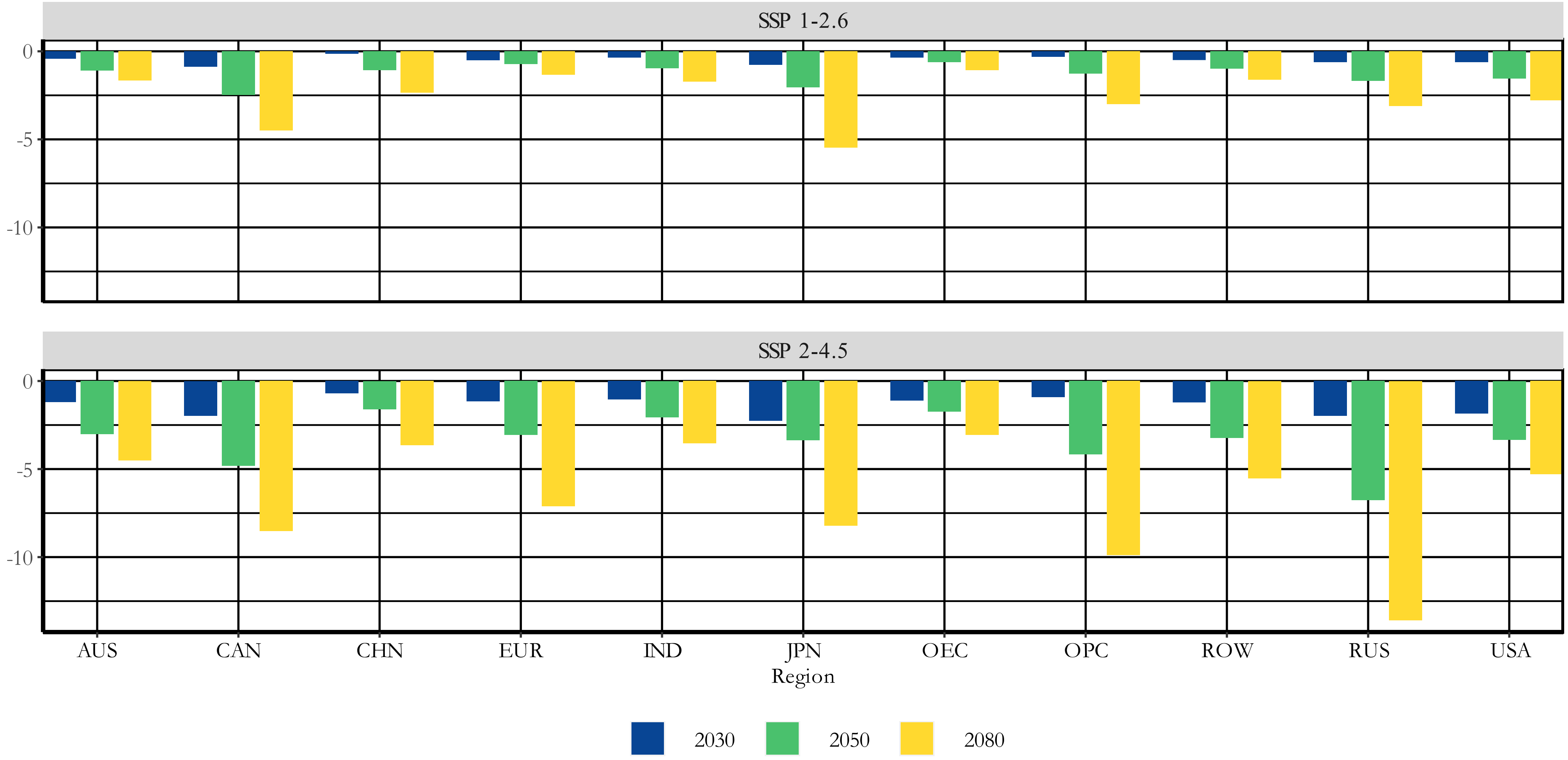
Source: Results from G-Cubed Simulations.

Imports: Percentage Deviation from the Baseline



Source: Results from G-Cubed Simulations.

Exports: Percentage Deviation from the Baseline



Source: Results from G-Cubed Simulations.

Agriculture Output: Percentage Deviation from the Baseline

Source: Results from G-Cubed Simulations.

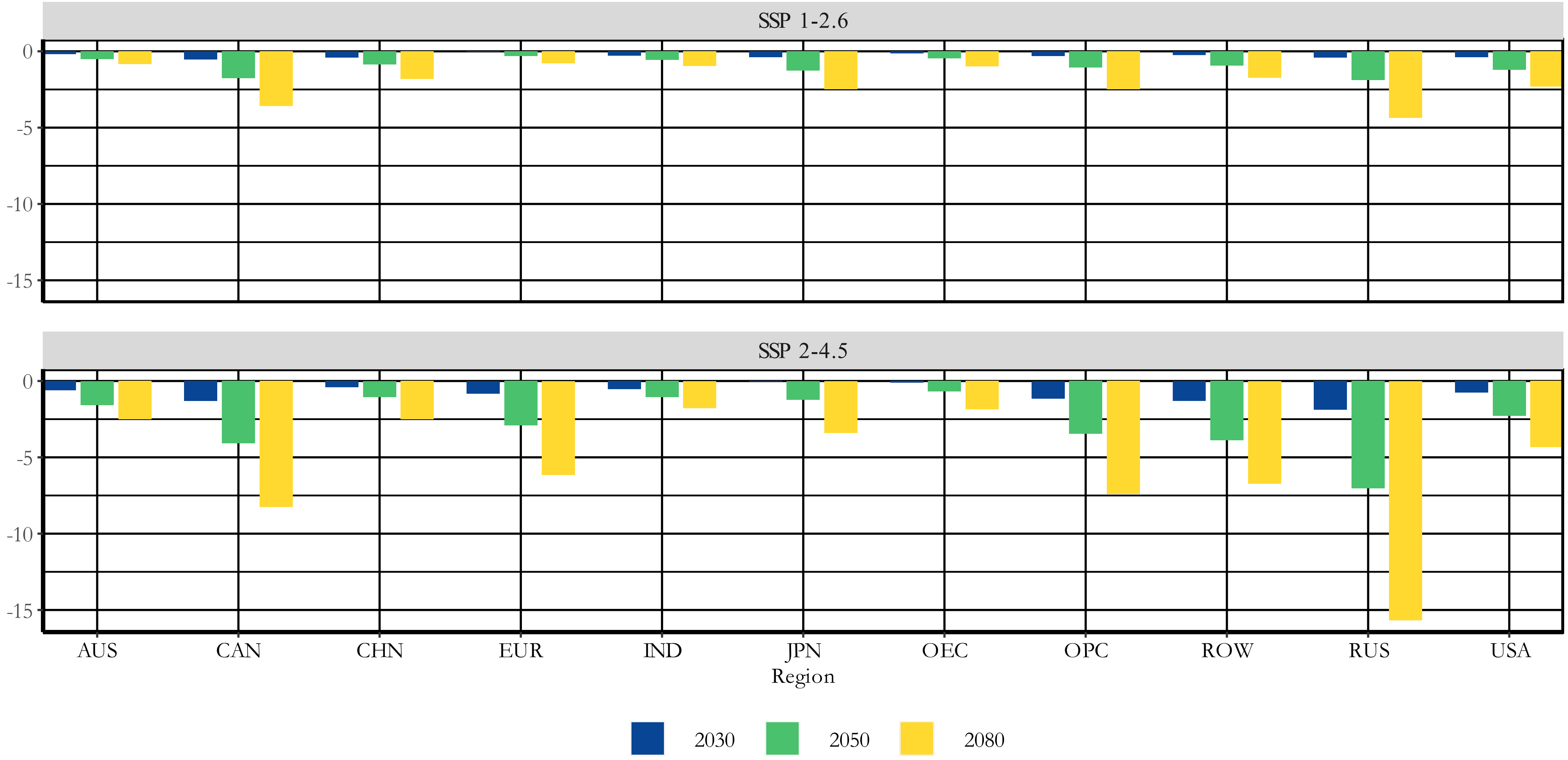
Manufacturing (Consumables) Output: Percentage Deviation from the Baseline

Source: Results from G-Cubed Simulations.

Energy (Petroleum Refining) Output: Percentage Deviation from the Baseline

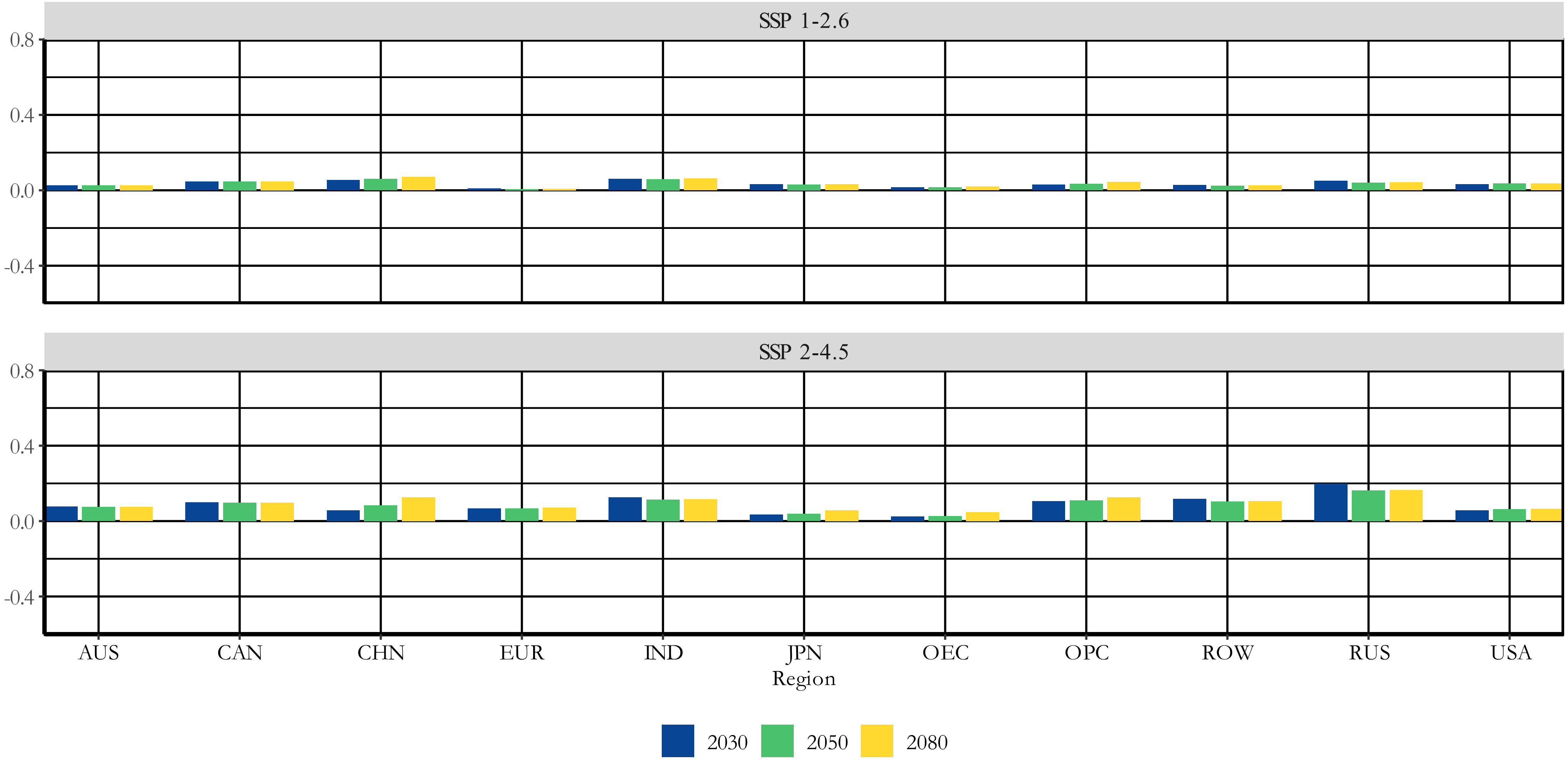
Source: Results from G-Cubed Simulations.

Transportation: Percentage Deviation from the Baseline



Source: Results from G-Cubed Simulations.

Inflation: Percentage Points from the Baseline



Source: Results from G-Cubed Simulations.

Conclusion: Policy Implications

- Assessment of the economic impacts of alternative climate scenarios is imperative to policy making 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 economic consequences of climate change.

- Firm-level analyses of impacts and general equilibrium analyses provide a richer understanding of macroeconomic impact pathways of climate risks.