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Virtual Seminar on Climate Economics

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Global Economic Impacts of Climate Shocks, Climate Policy and Changes in Climate Risk Assessment

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Presentation to the Virtual Seminar on Climate Economics, May 5, 2022

Based On

- Fernando R., Liu W. and W. McKibbin (2021) "Global Economic Impacts of Climate Shocks, Climate Policy and Changes in Climate Risk Assessment" Brookings Climate and Energy Economics Discussion Paper, March 31, 2021 and CAMA working paper 37/2021

Overview

- Climate Change and macro
- Modeling Climate Risk
  - The G-Cubed Multi-Country Model
  - Calculating climate and policy shocks
- A policy approach to managing climate risk (CALM mechanism)
- Conclusion

Climate Change

- Both the impacts of climate change (physical risk) and the policy responses to climate change (transition risk) have significant macroeconomic implications

What we explore

- the macroeconomic impacts of physical climate risk due to **chronic climate change** associated with global temperature increases and climate-related **extreme shocks**;
- the macroeconomic effects of climate policies designed to transition to net zero emissions by 2050 (transition risk); and
- the potential macroeconomic consequences of changes in risk premia in financial markets associated with increasing concern over climate events.

G-Cubed Model

G-Cubed

- Hybrid of a dynamic stochastic general equilibrium (DSGE) models (used by central banks) and a computable general equilibrium (CGE) model.

- Models Inter-industry linkages, international trade, capital flows, consumption, and investment.

- Annual macroeconomic and sectoral dynamics

- Captures frictions in labor market and capital accumulation
  - Full employment in the long run but unemployment in the short run
  - Labor mobile across sectors but not regions
  - Sector specific quadratic adjustment cost to physical capital

20 Sectors in each region

1	Electricity delivery	Energy Sectors
2	Gas Extraction and utilities	
3	Petroleum refining	
4	Coal mining	
5	Crude oil extraction	
6	Construction	Non- Energy Sectors
7	Other mining	
8	Agriculture and forestry	
9	Durable goods	
10	Nondurables	
11	Transportation	
12	Services	
13	Coal generation	Electricity Sectors
14	Natural gas generation	
15	Petroleum generation	
16	Nuclear generation	
17	Wind generation	
18	Solar generation	
19	Hydroelectric generation	
20	Other generation	

Variables Modelled

- Macro variables (by country):
  - Real and nominal GDP
  - Real GNP
  - Real private Consumption – aggregate and by sector
  - Real private Investment – aggregate and by sector
  - Private Employment – aggregate and by sector
  - Government spending on goods and services
  - Government spending on labor
  - Real Imports – aggregate and by sector by country of origin
  - Real Exports – aggregate and by sector
  - Trade balance
  - Current Account balance
  - Housing Stock (proxied by household durable capital stock)
  - Households stock of human capital
  - Stock of government debt.

Variables Modelled

- Financial Variables (by country):
  - Policy interest rate (nominal and real)
  - Bond rates 2, 5 ,10 year (nominal), 10 year (real)
  - Nominal and real effective exchange rates
  - Nominal and real exchange rate relative to $US
  - Equity prices by sector
  - Money Supply

Variables Modelled

- Prices (by country):
  - Aggregate price index
  - Consumer price index
  - Consumer price inflation (actual and expected)
  - Produce price inflation (actual and expected)
  - Producer price by sector
    - Commodity prices where sector is a commodity
  - Consumer price by sector
  - Energy price
  - Materials price
  - Nominal wage
  - Housing price (proxied by price of household's purchases of durable goods)

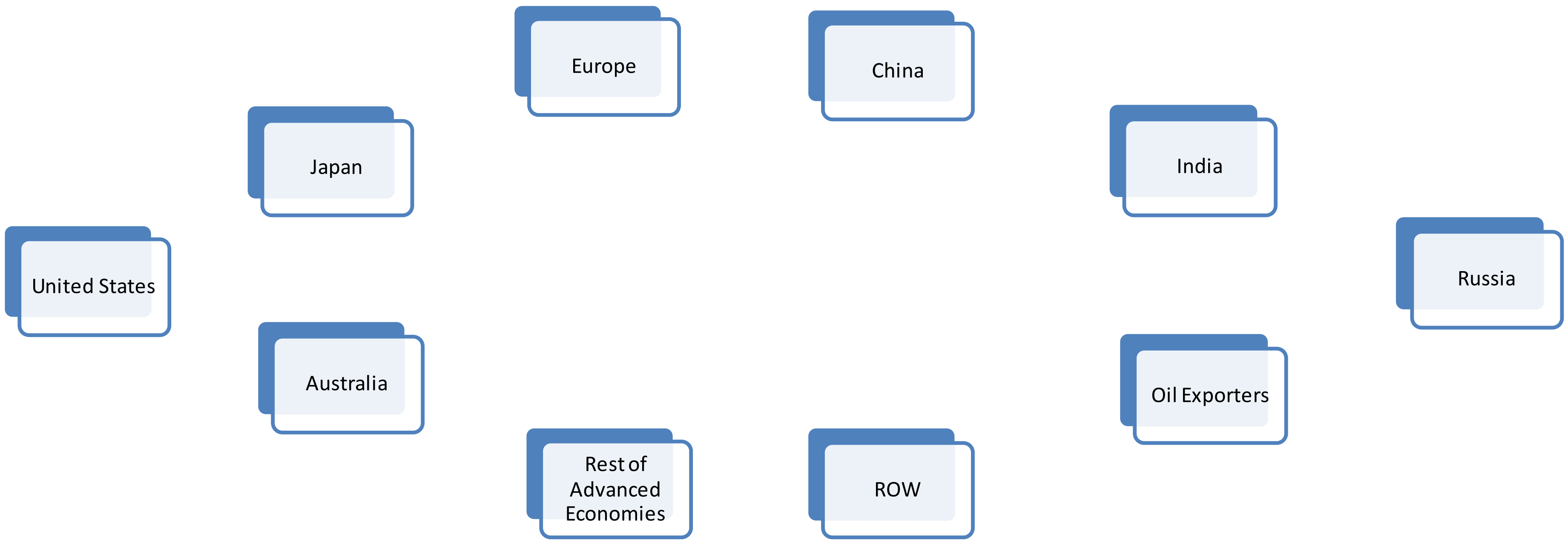
G-Cubed

Modelled

Each country has a fiscal rule for government spending and taxation policy)

Each country has a monetary rule which shows how interest rates are adjusted to trade off various policy target (inflation, output, exchange rates, nominal income)

Version 20J



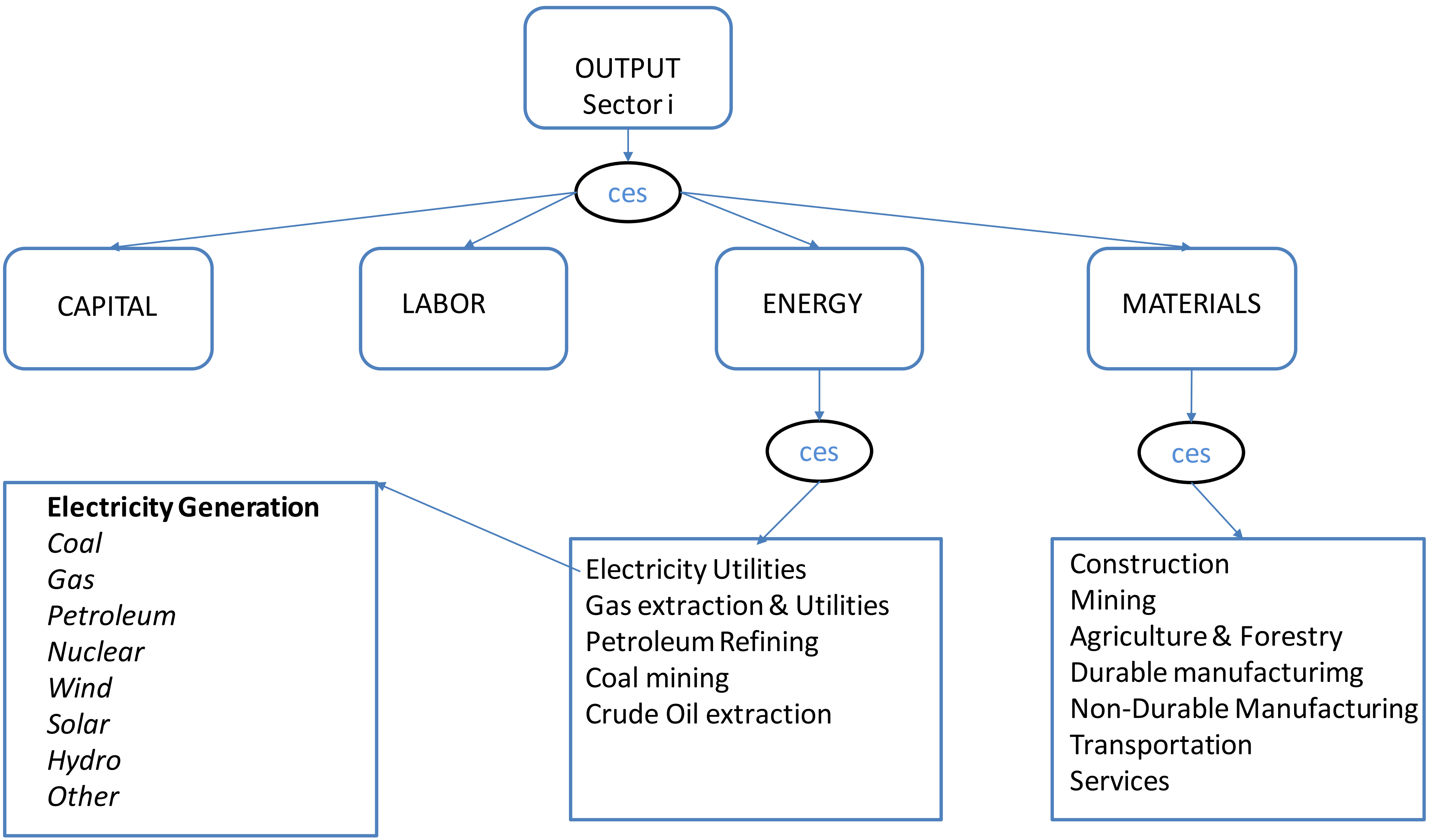
Europe
China
Japan
India
United States
Russia
Australia
Oil Exporters
Rest of Advanced Economies
ROW

Technology at a point in time

- Each good is produced with a KLEM production technology with CES across KLEM and CES nestings of Energy (E) and Materials (M).

- K is fixed in the current period, L,E and M are variable

- We don’t specify a particular technology but represent technologies by the inputs of KLEM


OUTPUT
Sector i
ces
CAPITAL
LABOR
ENERGY
MATERIALS
ces
ces
Electricity Generation
Coal
Gas
Petroleum
Nuclear
Wind
Solar
Hydro
Other
Electricity Utilities
Gas extraction & Utilities
Petroleum Refining
Coal mining
Crude Oil extraction
Construction
Mining
Agriculture & Forestry
Durable manufacturimg
Non-Durable Manufacturing
Transportation
Services

Baseline without significant Climate shocks or policy

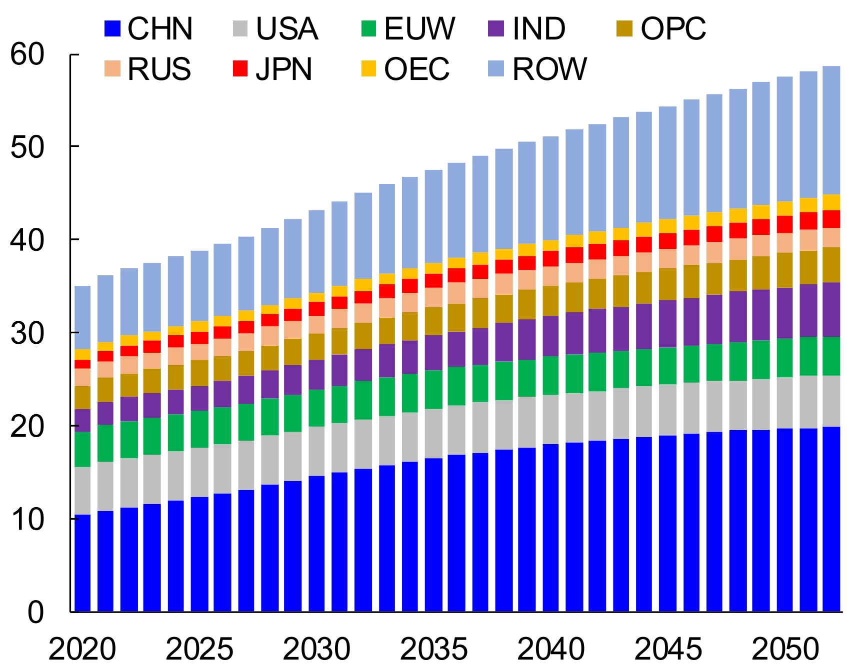
- Using the Groningen Growth and Development 10 sector database, estimate the initial level of productivity in each sector in each economy in 2019.
- Take the ratio of this productivity to the equivalent sector in the United States, which we assume is the frontier.

Baseline without significant climate policy

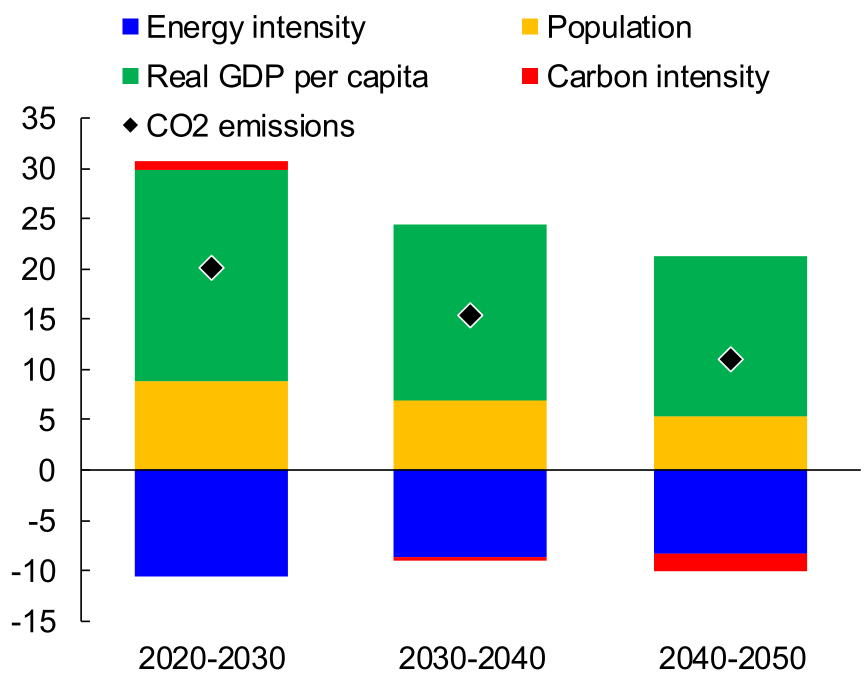
- Given this initial gap in sectoral productivity, and the assumption that each sector in the US has productivity growth of 1.4% per year, use the Barro (2015) catch-up model to generate long term projections of the productivity growth rate of each sector within each country.
- This catchup rate can be varied (over time) if some regions are expected to catch up more quickly to the frontier due to economic reforms (e.g. China) or more slowly to the frontier due to institutional rigidities (e.g. Russia)

Business-as-usual emissions

Business-as-Usual Baseline CO2 Emissions *(Gigatons of CO2)*



Decomposition of the Change in Global CO2 Emissions *(Percent change)*



Source: IMF staff calculations.

Climate Risks

Developing shocks

- physical climate risk due to **chronic climate change** associated with global temperature increases and climate-related **extreme shocks**;
- policies designed to transition to net zero emissions by 2050 (transition risk); and
- the potential macroeconomic consequences of changes in risk premia in financial markets associated with increasing concern over climate events.

Physical Climate risk

- Use four widely used climate scenarios (Representative Concentration Pathways, or RCP)
- identify the physical damage functions due to chronic climate risks. The chronic climate risks include sea-level rise, crop yield changes, heat-induced impacts on labor, and increased incidence of diseases.
- estimate the future incidence of climate-related extreme events, including droughts, floods, heat waves, cold waves, storms and wildfires, based on climate variable projections under the climate scenarios.

Table 1: RCP Scenarios

Scenario	Description
RCP 2.6	The peak in radiative forcing at ~3 W/m^2 (~490 ppm CO2 eq) before 2100 and then decline (the selected pathway decreases to 2.6 W/m^2 by 2100).
RCP 4.5	Stabilization without overshoot pathway to 4.5 W/m^2 (~650 ppm CO2 eq) at stabilization after 2100
RCP 6.0	Stabilization without overshoot pathway to 6 W/m^2 (~850 ppm CO2 eq) at stabilization after 2100
RCP 8.5	Rising radiative forcing pathway leading to 8.5 W/m^2 (~1370 ppm CO2 eq) by 2100.

Source: van Vuuren et al (2011).

Chronic climate change

- Follow the approach of Roson and Sartori (2016) we estimate damage functions at the sectoral level.
- The damage functions we consider in this paper primarily use temperature and precipitation as the climate variables
- We use the projections for the climate variables under the climate scenarios from the model ensemble from 1979 to 2100 to derive the necessary benchmarks and the variations of the future climate variable from the benchmark.
- We then average the variations across the models for a given scenario for a given country.
- Using these variations, we use the damage functions to develop various economic shocks

Extreme Climate Events

- We use data fromThe International Disaster Database, maintained by the Centre for Research on the Epidemiology of Disasters (CRED)
- We focus on two climatological disasters: **droughts and wildfires**, and two meteorological disasters: **extreme temperature events and storms**.
- In addition, despite being classified as a hydrological disaster, we also focus on floods due to the influence of climate variability on hydrological cycle.
- These five extreme climate shocks collectively account for 73% of extreme climate shocks reported by CRED.

Extreme Climate Events

- Using the projections for the climate variables from the model ensemble for the climate scenarios and various approaches drawn from the literature, we approximate the frequency and duration of extreme climate shocks.

Table 2: Approaches to Identifying Extreme Climate Shocks

Extreme Event	Approach	Climate Variables
Drought	Standardized Precipitation Index	Daily Precipitation
Flood	Standardized Precipitation Index	Daily Precipitation
Extreme Temperature (Heat waves & Cold waves)	Heat/Cold Wave Magnitude Index	Daily Maximum/Minimum Temperature
Storms	Probabilistic econometric models	Daily Maximum Temperature
Wildfires	Probabilistic econometric models	Daily Maximum Temperature & Daily Precipitation

Source: Developed by the Authors.

Shocks for Physical climate risk

- Chronic climate change
  - Shocks to sectoral productivity
  - Shocks to labour supply
- Extreme climate events
  - Shocks to sectoral productivity
  - Shocks to labour supply

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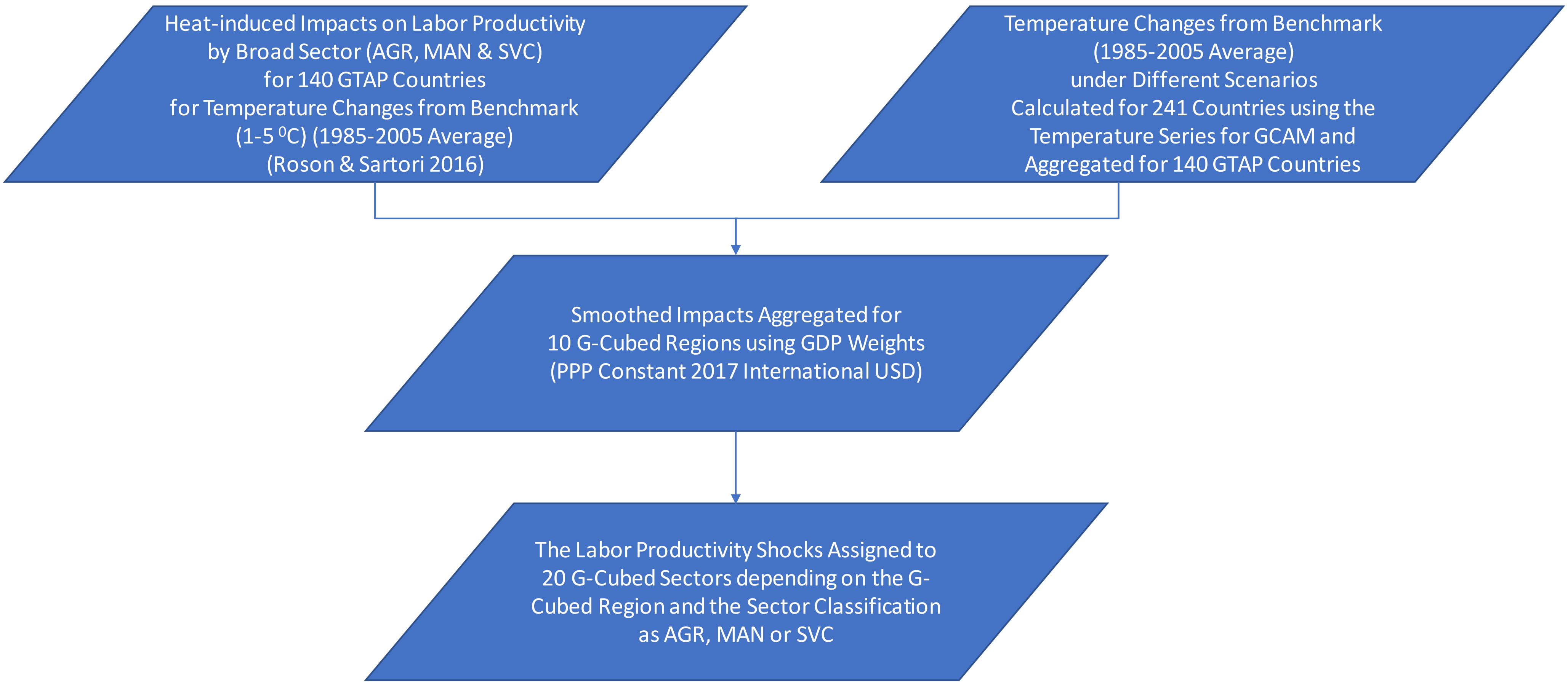
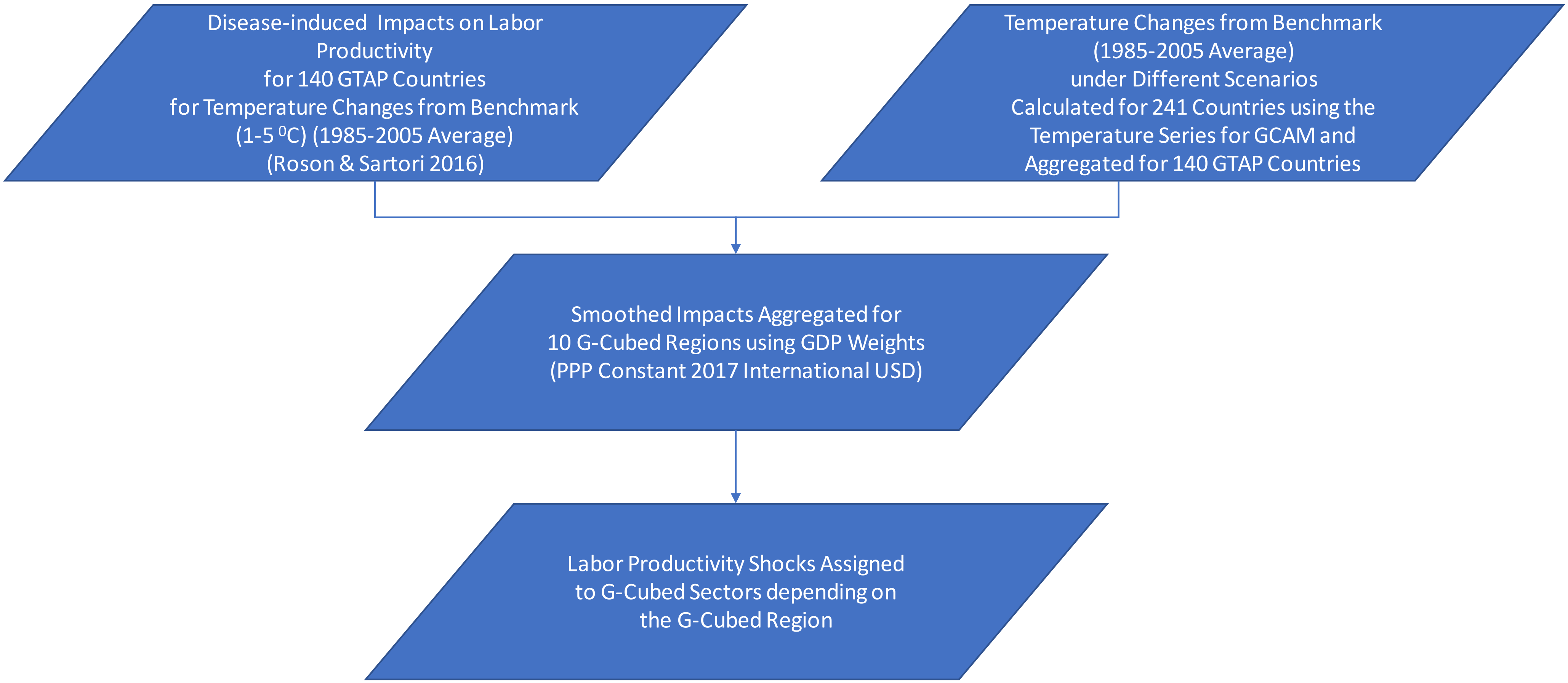
Heat-induced Impacts on Labor Productivity



Disease-induced Impacts on Labor Productivity



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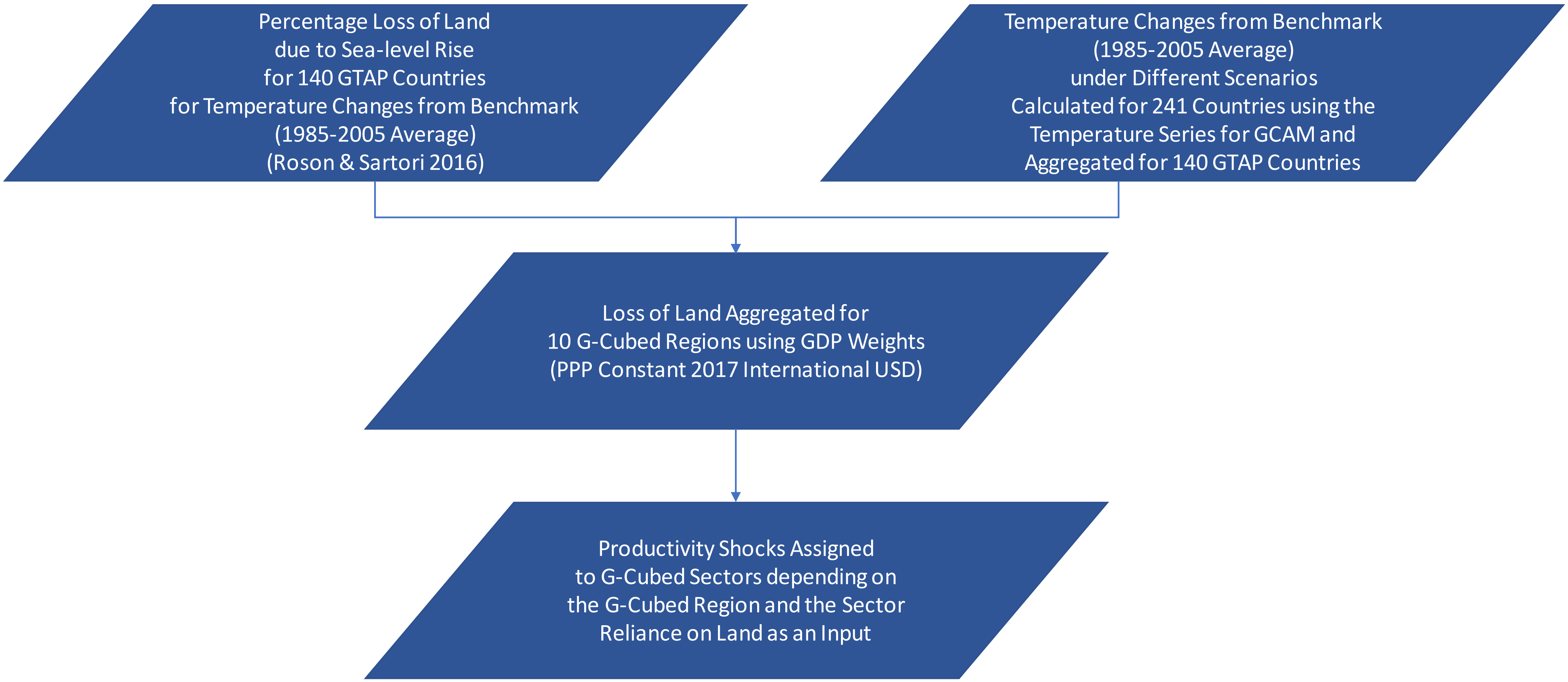
Sea-level Rise Impacts on Sector Productivity



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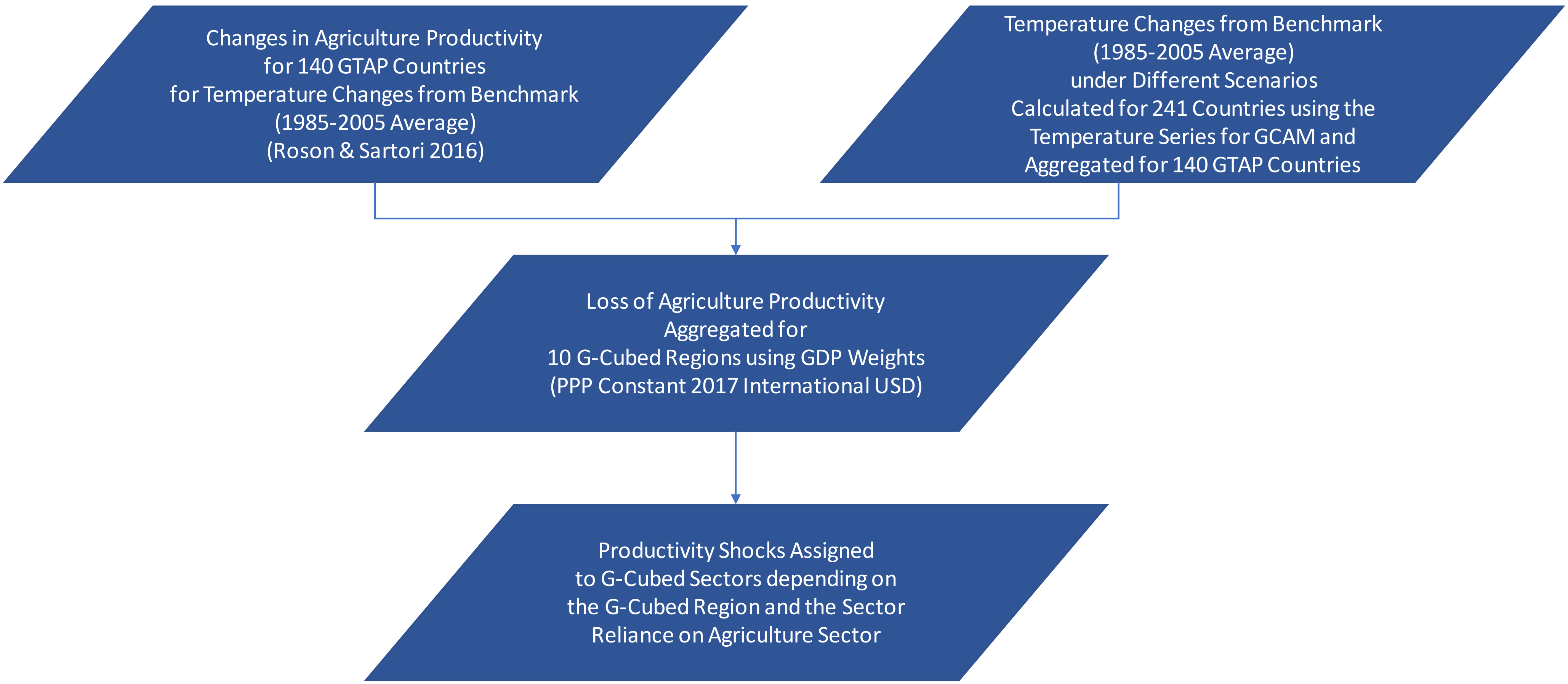
Impacts on Agriculture Productivity and Spill over Impacts to other Sectors



Results for RCP4.5

Table 10: Percentage Deviation from Baseline GDP by Decade under RCP 4.5

Model Region	2021-2030	2031-2040	2041-2050	2051-2060	2061-2070	2071-2080	2081-2090	2091-2100
AUS	-0.74	-0.63	-0.76	-0.79	-0.97	-1.02	-0.81	-1.19
CHI	-2.42	-2.72	-2.67	-3.68	-4.05	-4.02	-5.14	-5.64
EUW	-1.10	-1.10	-1.11	-1.16	-1.21	-1.23	-1.19	-1.24
IND	-1.15	-1.36	-1.72	-2.31	-3.29	-2.97	-3.08	-3.56
JPN	-1.55	-2.03	-2.95	-3.74	-4.69	-4.31	-5.84	-5.11
OPC	-2.08	-2.83	-3.39	-4.00	-4.18	-4.27	-4.05	-4.03
OEC	-1.40	-1.23	-1.08	-0.95	-1.05	-1.05	-1.02	-0.93
ROW	-3.56	-3.53	-3.83	-4.23	-4.59	-4.76	-4.66	-4.96
RUS	-1.72	-1.98	-1.79	-1.93	-2.42	-2.06	-2.21	-2.48
USA	-0.49	-0.65	-0.76	-0.98	-1.13	-1.12	-1.15	-1.31

Source: Results from G-Cubed Model Simulations.

Results for RCP4.5

Table 14: Percentage Deviation in Sector Outputs from 2021-2050 under RCP 4.5

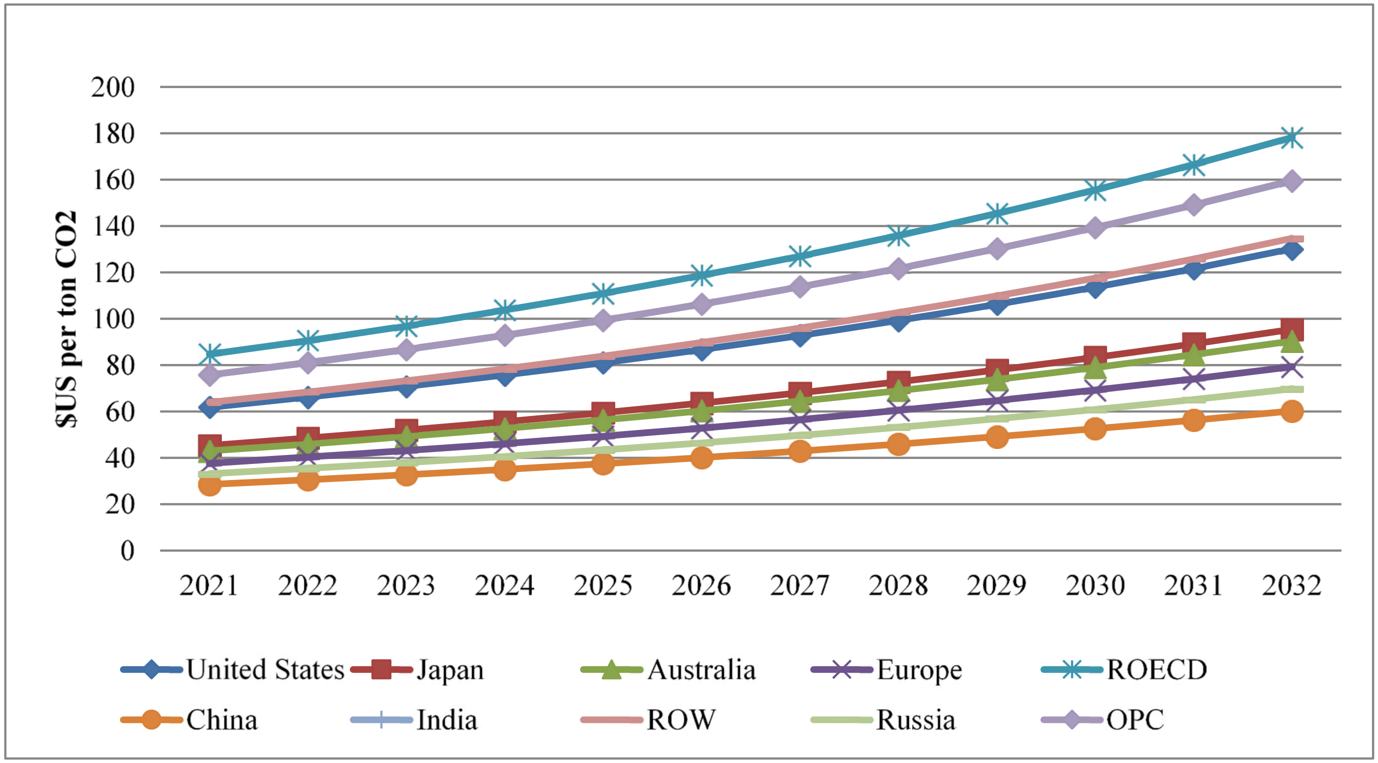
Sector	AUS	CHI	EUW	IND	JPN	OPC	OEC	ROW	RUS	USA
Electricity delivery	-2.78	-4.13	-5.03	-2.03	-4.18	-5.50	-6.00	-7.46	-4.78	-2.53
Gas extraction and utilities	-0.19	-2.75	-0.25	-1.27	-3.92	-2.01	-0.39	-1.95	-0.44	-0.25
Petroleum refining	-1.05	-3.49	-1.75	-1.94	-2.81	-2.72	-1.25	-3.67	-2.06	-1.03
Coal mining	-0.31	-3.48	5.24	-1.59	-2.66	-2.55	-0.09	-1.97	-0.67	1.55
Crude oil extraction	-2.22	-1.47	-2.52	-2.02	-8.68	-2.63	-1.65	-4.21	-3.69	-0.75
Construction	-1.60	-3.70	-1.78	-1.91	-8.16	-5.36	-1.98	-6.25	-3.34	-1.55
Other mining	-2.62	-2.94	-2.41	-2.77	-6.48	-3.29	-3.56	-4.64	-3.33	-3.22
Agriculture and forestry	-4.00	-5.22	-5.96	-2.46	-8.10	-5.86	-5.84	-8.93	-5.50	-3.61
Durable goods	-1.84	-3.15	-2.30	-1.87	-5.21	-3.68	-2.63	-5.22	-2.90	-1.64
Nondurable goods	-2.20	-4.13	-2.58	-1.92	-4.03	-3.89	-3.41	-5.91	-3.08	-1.46
Transportation	-0.41	-1.94	-0.67	-1.06	-1.59	-1.49	-0.99	-2.09	-1.31	-0.60
Services	-0.08	-0.96	-0.22	-0.59	-0.76	-1.07	0.00	-1.25	-0.56	-0.22

Source: Results from G-Cubed Model Simulations.

Transition Risk

- Impact of achieving net zero emissions by 2050 using country specific carbon taxes.
- Different to the IMF WEO results (using the same model) which have a package of policies including green infrastructure in addition to the carbon tax
  - Carbon taxes are bigger when they have to do all the abatement

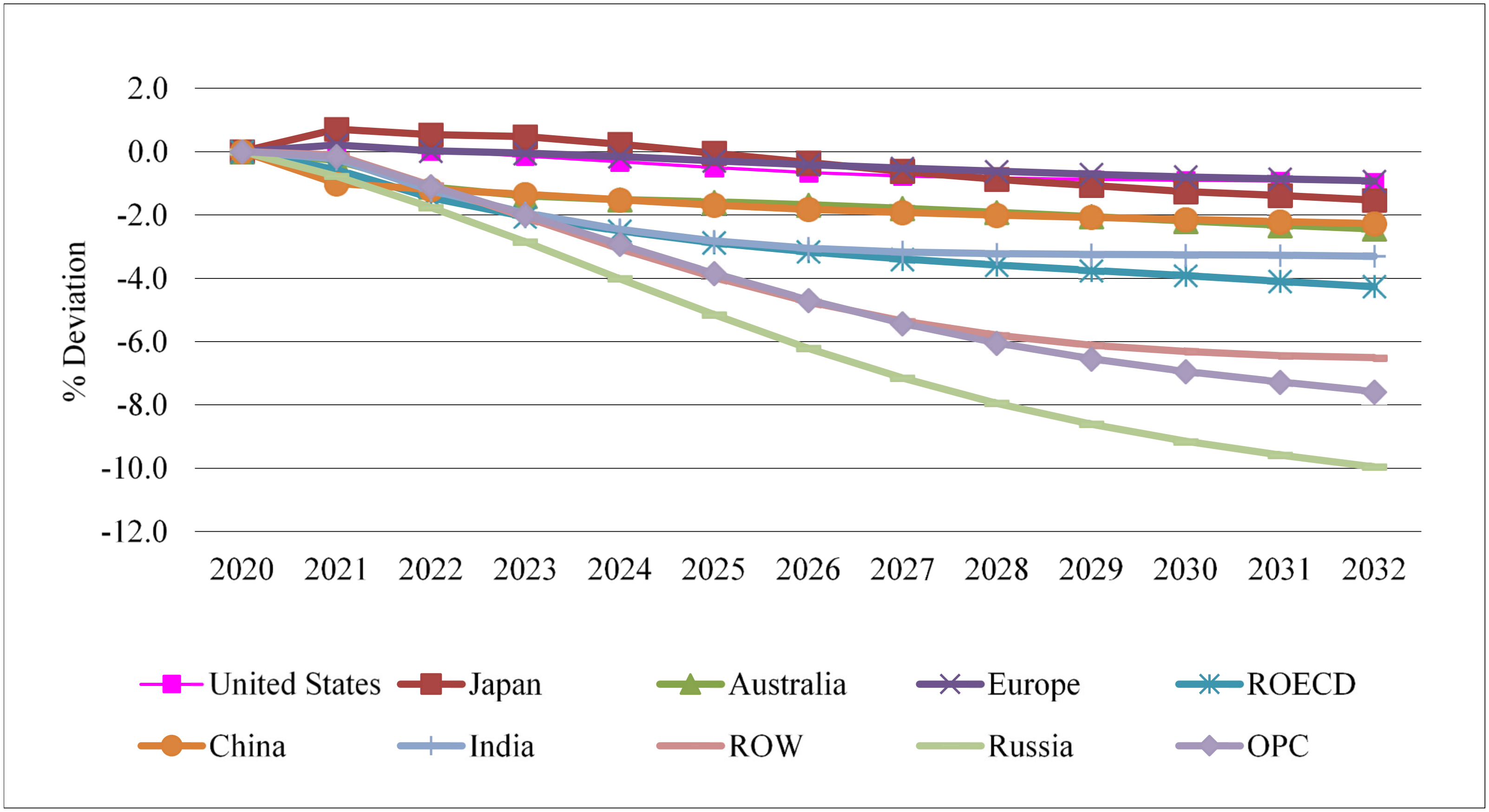
Figure 2: Carbon Tax per Unit of CO2



Key point

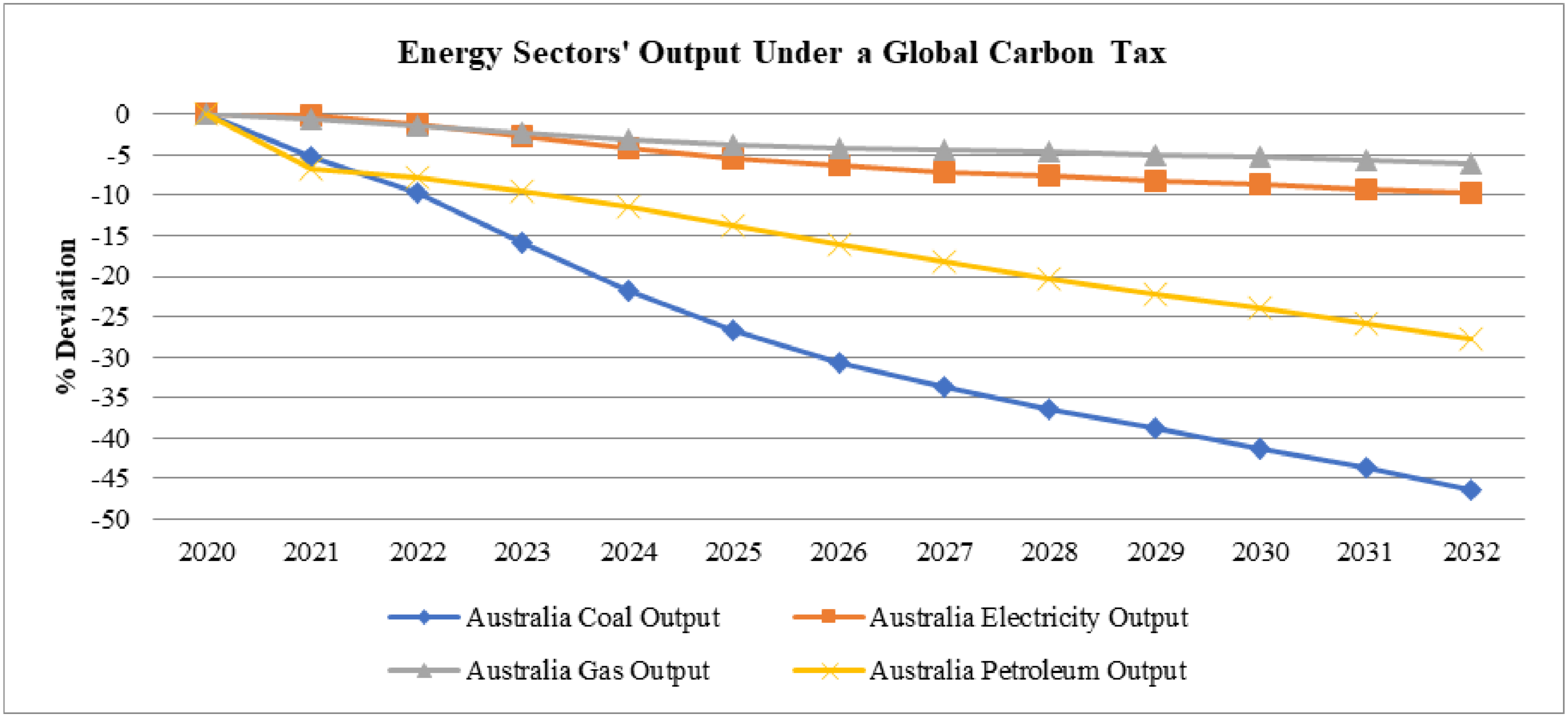
- Very different GDP impacts across countries for same proportional reduction in emissions
- Effort is not captured by the size of the emission reduction.

Figure 3: Global Change in GDP (2021-2032)

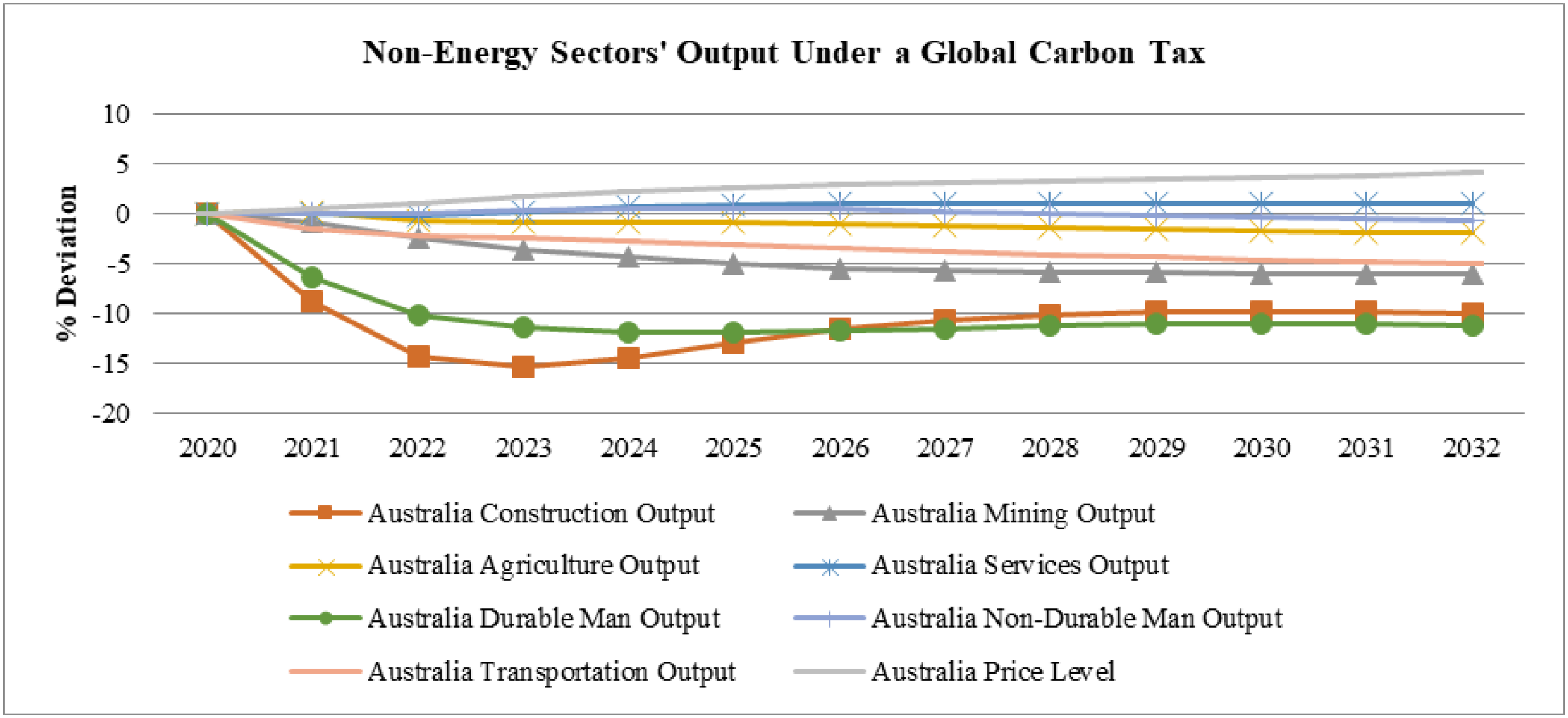


- Very different sectoral impacts within each country for same reduction in emissions

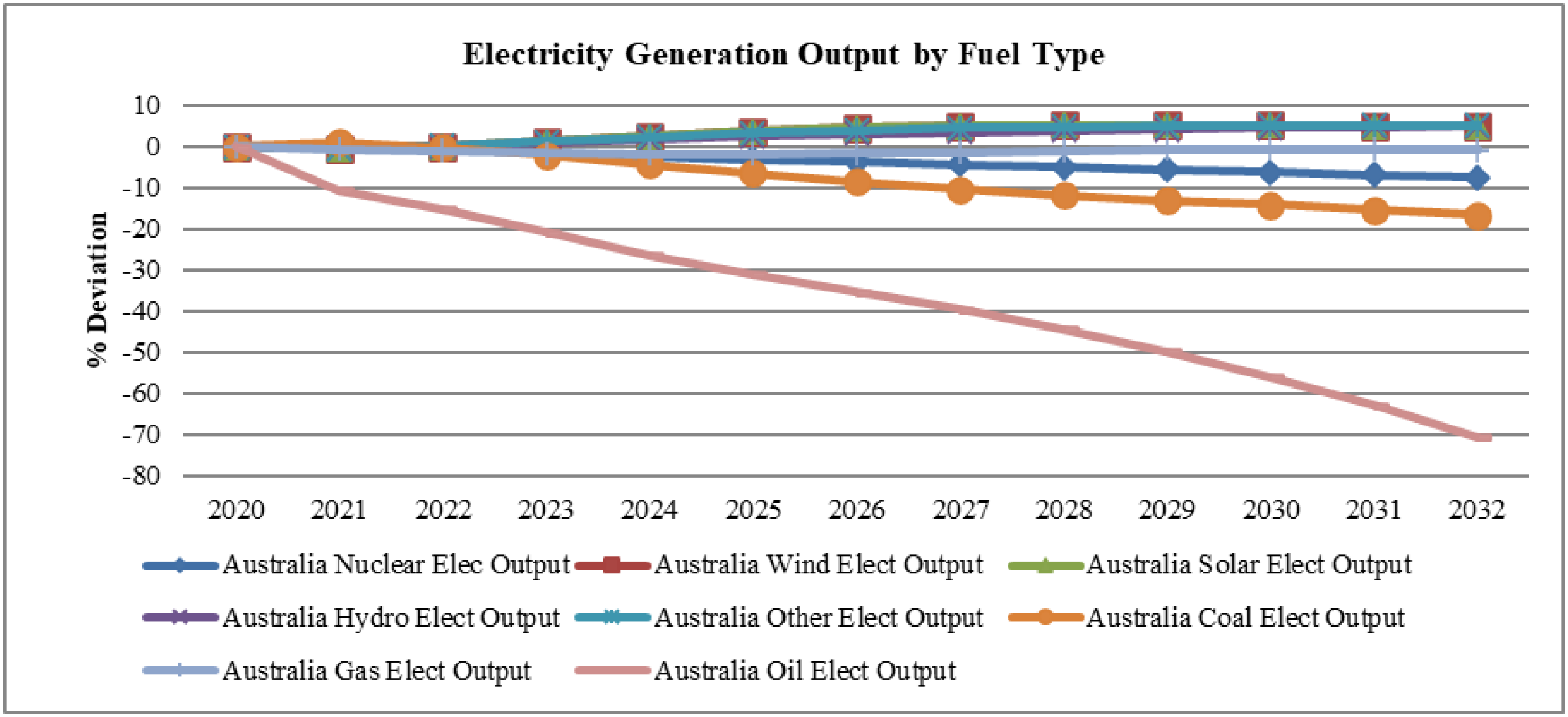
Sectoral Results Australia



Sectoral Results Australia



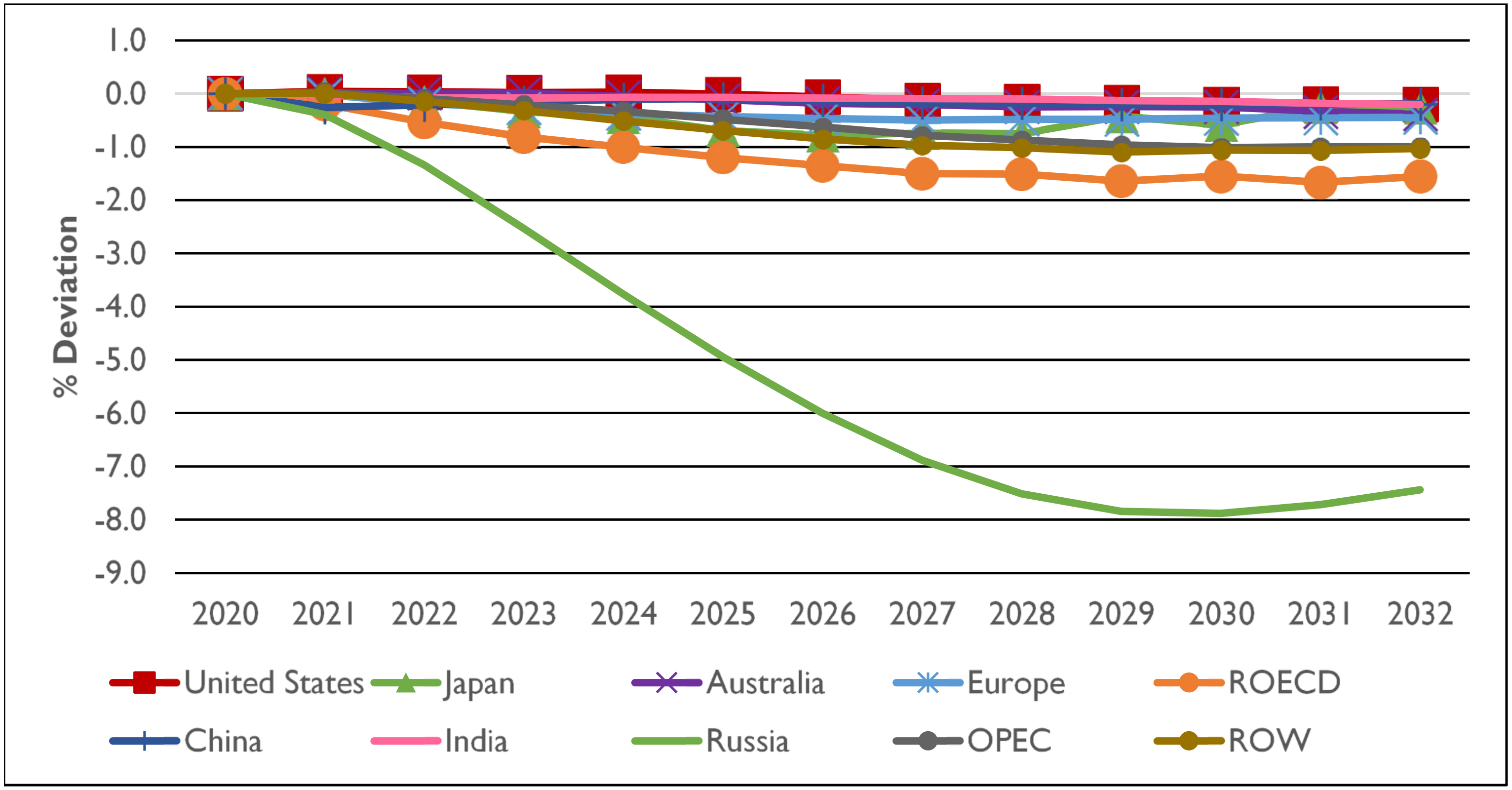
Sectoral Results Australia



Changes in risk premia

- We calculate shocks to financial risk premia based on relationships between historical climate shocks and changes in financial market risk premia.
- We apply these shocks to risk premia under the RCP scenarios and find that the cost of rising risk premia can be of a magnitude consistent with historical experience

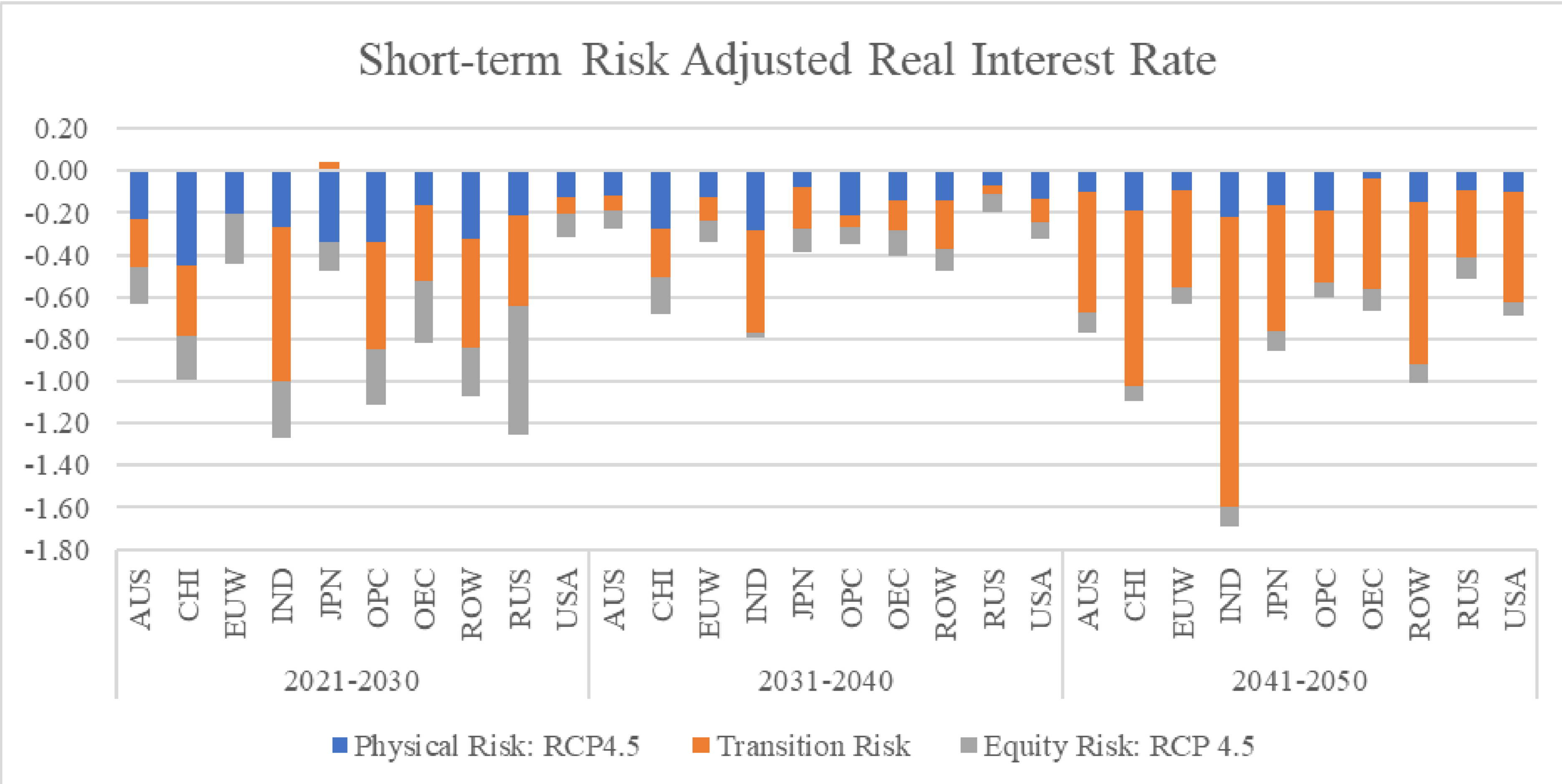
Figure 7: GDP Change under RCP 8.5

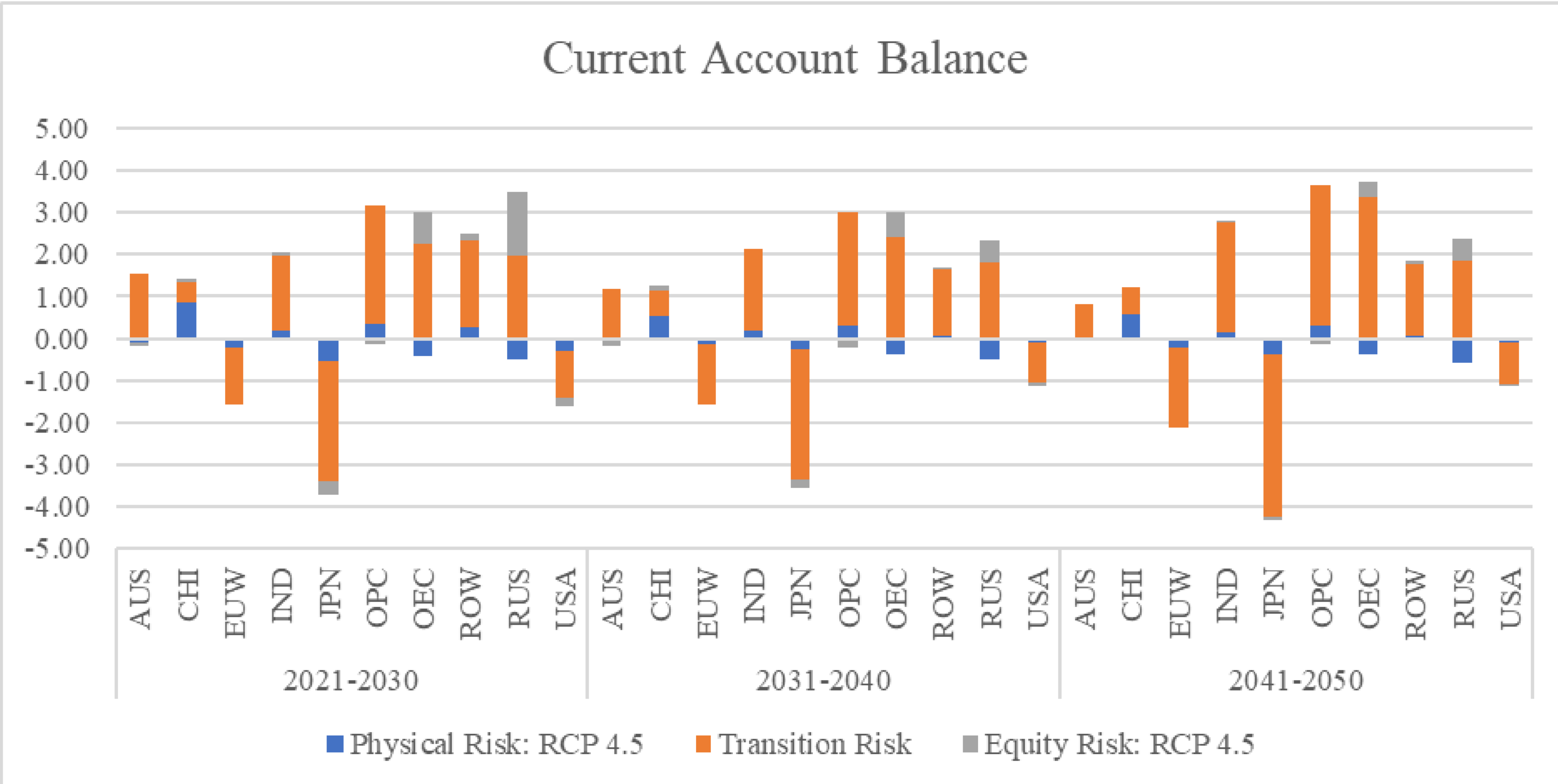


Additional results

R*

Trade flows


Short-term Risk Adjusted Real Interest Rate
0.20
0.00
-0.20
-0.40
-0.60
-0.80
-1.00
-1.20
-1.40
-1.60
-1.80
AUS CHI EUW IND JPN OPC OEC ROW RUS USA
2021-2030
2031-2040
2041-2050
Physical Risk: RCP4.5
Transition Risk
Equity Risk: RCP 4.5


Current Account Balance
5.00
4.00
3.00
2.00
1.00
0.00
-1.00
-2.00
-3.00
-4.00
-5.00
AUS CHI EUW IND JPN OPC OEC ROW RUS USA
2021-2030
AUS CHI EUW IND JPN OPC OEC ROW RUS USA
2031-2040
AUS CHI EUW IND JPN OPC OEC ROW RUS USA
2041-2050
Physical Risk: RCP 4.5
Transition Risk
Equity Risk: RCP 4.5

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CALM

Climate Asset and Liability mechanism
(A Hybrid of carbon taxes and emissions trading)

Warwick McKibbin AO,FASSA
The Australian National University

Draw on policy approaches

- McKibbin W. and P. Wilcoxen (2002) ‘The Role of Economics in Climate Change Policy”, Journal of Economic Perspectives, vol 16, no 2, pp107-129

- McKibbin W. and P. Wilcoxen (2007) “A Credible Foundation for Long Term International Cooperation on Climate Change” in Joseph Aldy and Robert Stavins (eds), Architectures for Agreement: Addressing Global Climate Change in the Post-Kyoto World, Cambridge University Press, pp185-208.

Latest version

- Academy of Social Sciences in Australia (2020) "Efficient, Effective and Fair: Climate Policy in Australia", Discussion Paper June. Academy of Social Sciences in Australia, Canberra.
- https://socialsciences.org.au/publications/efficient-effective-and-fair-discussion-paper/

2 goals

- emitting activities should incur the liabilities for their emissions
- the allocation of the right to emit (an asset), and its price, should be set in a market framework, to achieve the emissions targets at a minimum economic cost.

Core policy design

- Need to manage short term and long term risks separately
- Policy Framework Flexibility in crucial
  - If technological breakthroughs makes it cheaper to reduce emissions more quickly then it should happen
  - If fewer countries take action or costs are higher than predicted, then reduction can should be slowed.

Key issues to balance

- Imposition of the liability would be a cost to existing activities
- Long term emissions prices are an opportunity for innovation and new enterprises

How CALM works

- Combine the best features of emissions trading and carbon pricing
- The government sets an emissions goal of perhaps zero net emissions by 2050 and a path of emission reduction to achieve this.
- A Carbon Bank is created whose role is
  - To record annual emissions of all large polluters
  - To create annual emission certificates equal to the government target
  - To require all large emitters to hold annual certificates (assets) to match their emissions (the liabilities)
  - To bundle emission certificates of each future years into carbon bonds
  - Sell addition certificate into the certificates market at a fixed price to eliminate volatility and cap short term cost.

How CALM works

- The government allocates all carbon bonds at the start of the policy.
- Market are created that trade certificates, carbon bonds and futures markets for trading future certificates.
- This creates a yield curve of carbon prices out to 2050.
- Future carbon prices will drive investment and innovation with a market regulated by the Carbon Bank.

Advantages

- Clear long-term price signals to consumers and firms to reduce emissions through modifying existing activities and undertaking new investment
- Clear market signals pricing new information
- Creates a political constituency to support the continuation of the policy.
- The allocation of carbon bonds would increase the wealth of Australia Households and companies who receive them and can more than offset short term economic costs associated with carbon pricing.

Further information on G-Cubed

www.sensiblepolicy.com