

Global Economic Impacts of Antimicrobial Resistance

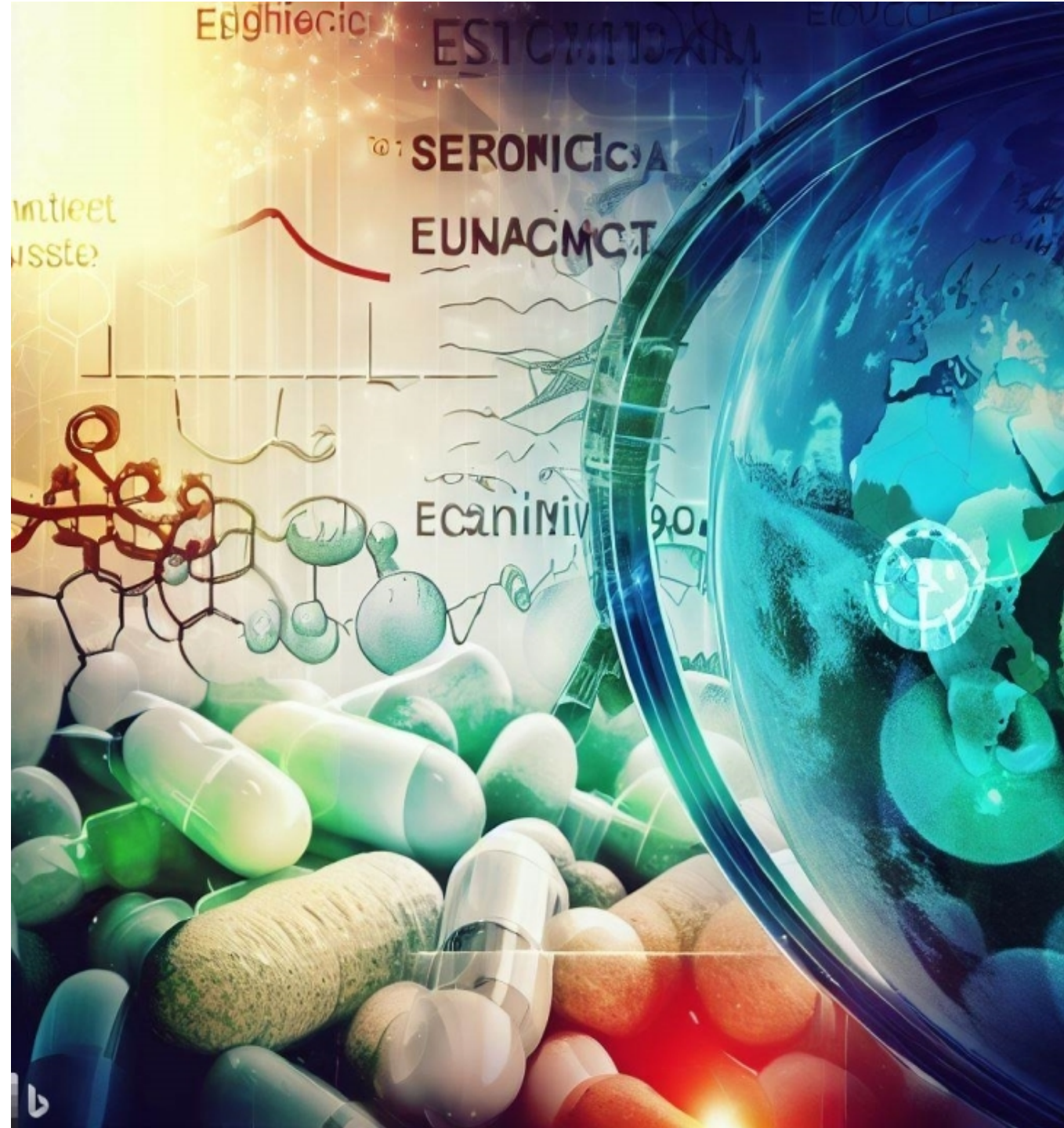
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1. Center for Applied Macroeconomic Analysis,
Crawford School of Public Policy,
The Australian National University
2. ARC Centre of Excellence in Population Ageing Research
3. The Brookings Institution
4. Center for Economic Policy Research

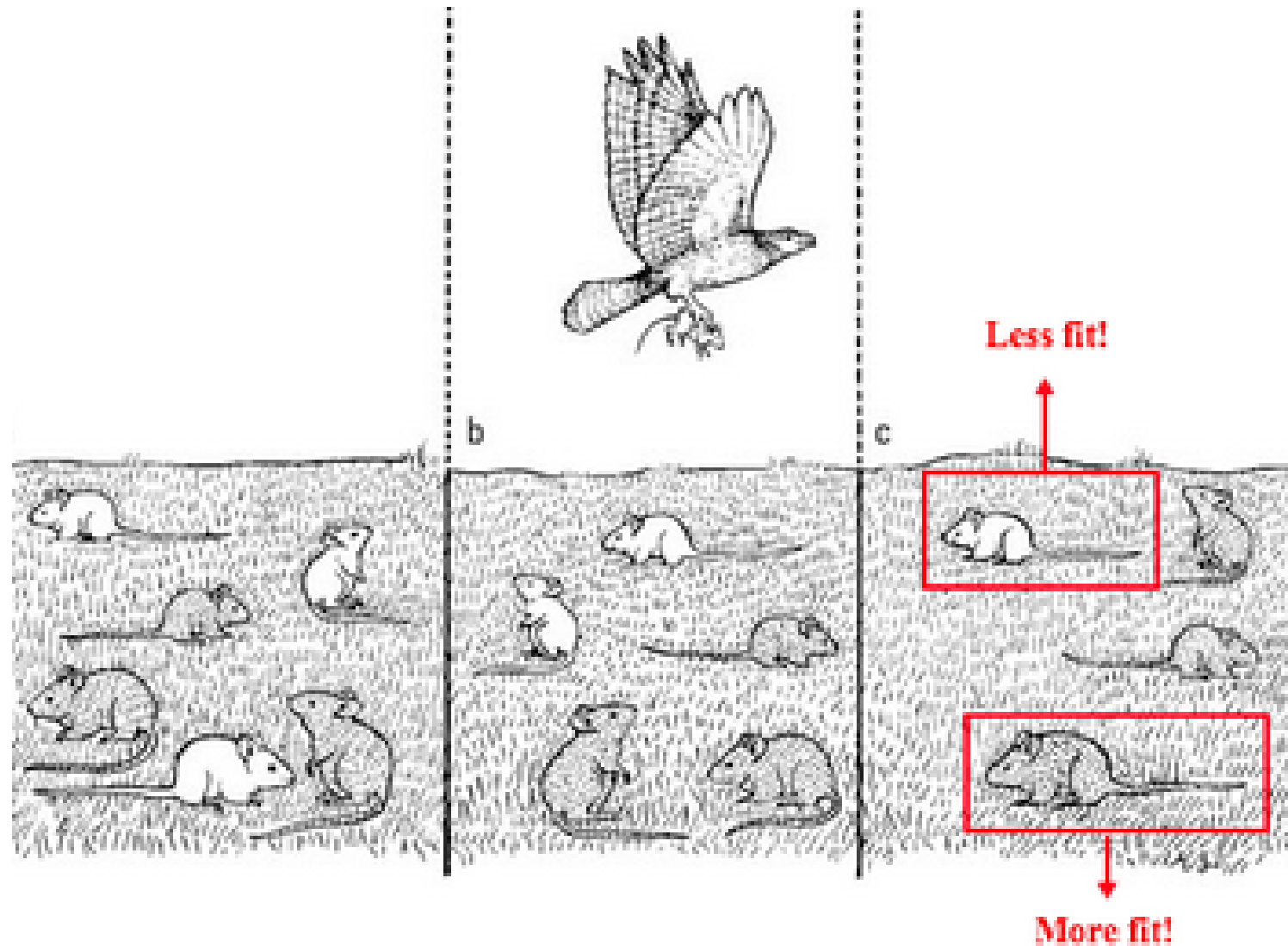
CEPAR International Conference 2023

Sydney, Australia

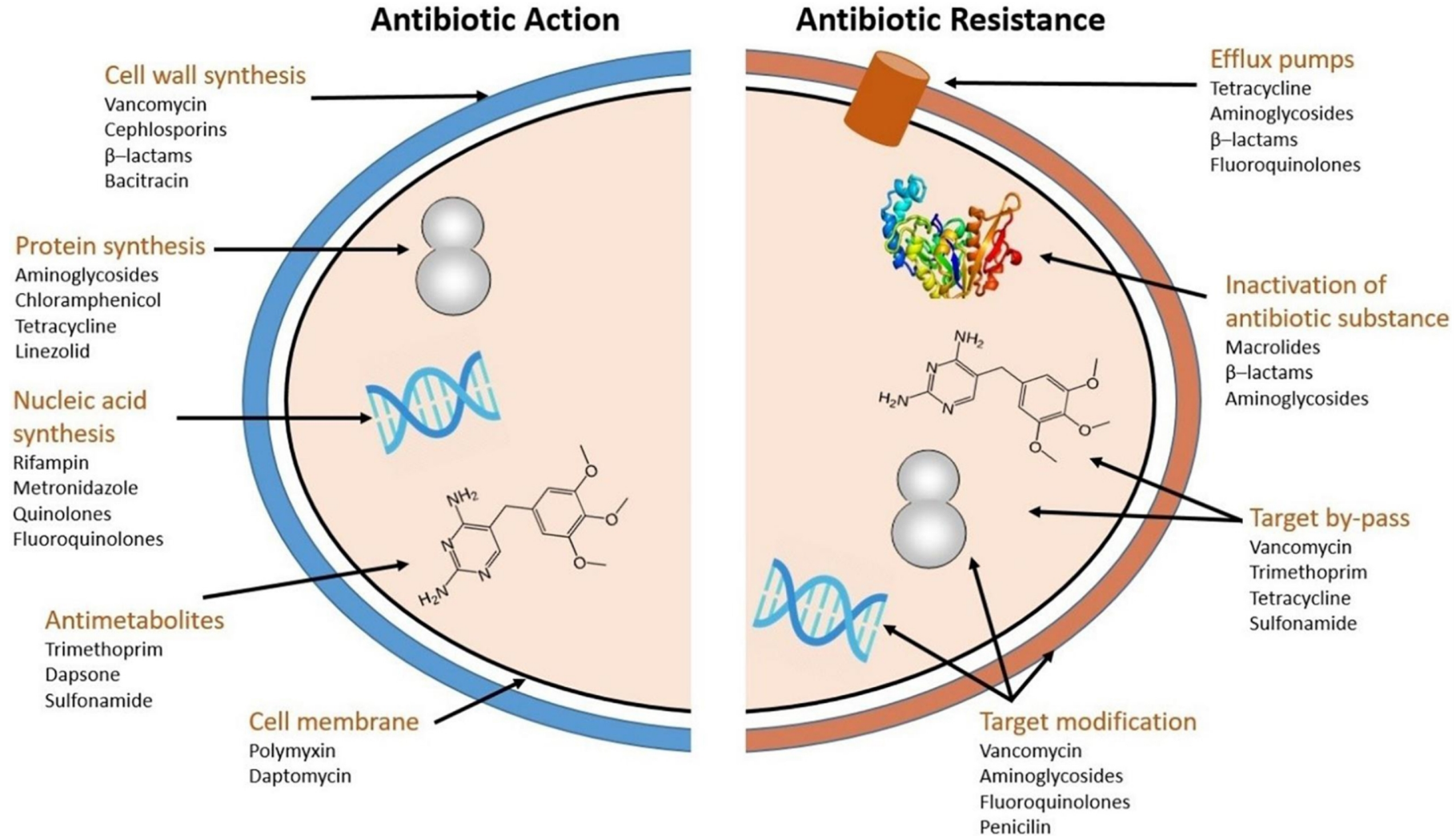
5 July 2023



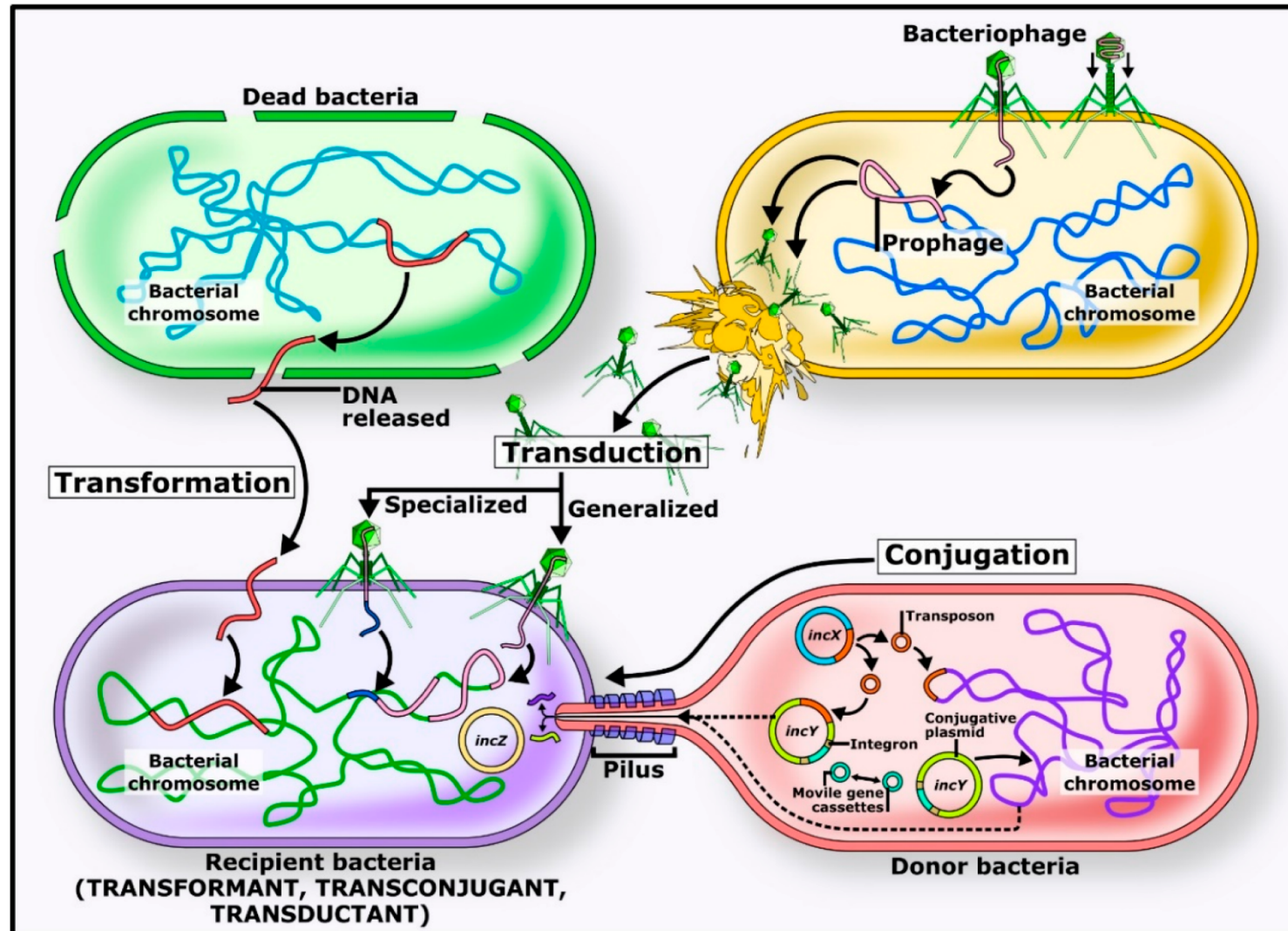
Evolution: Natural Selection



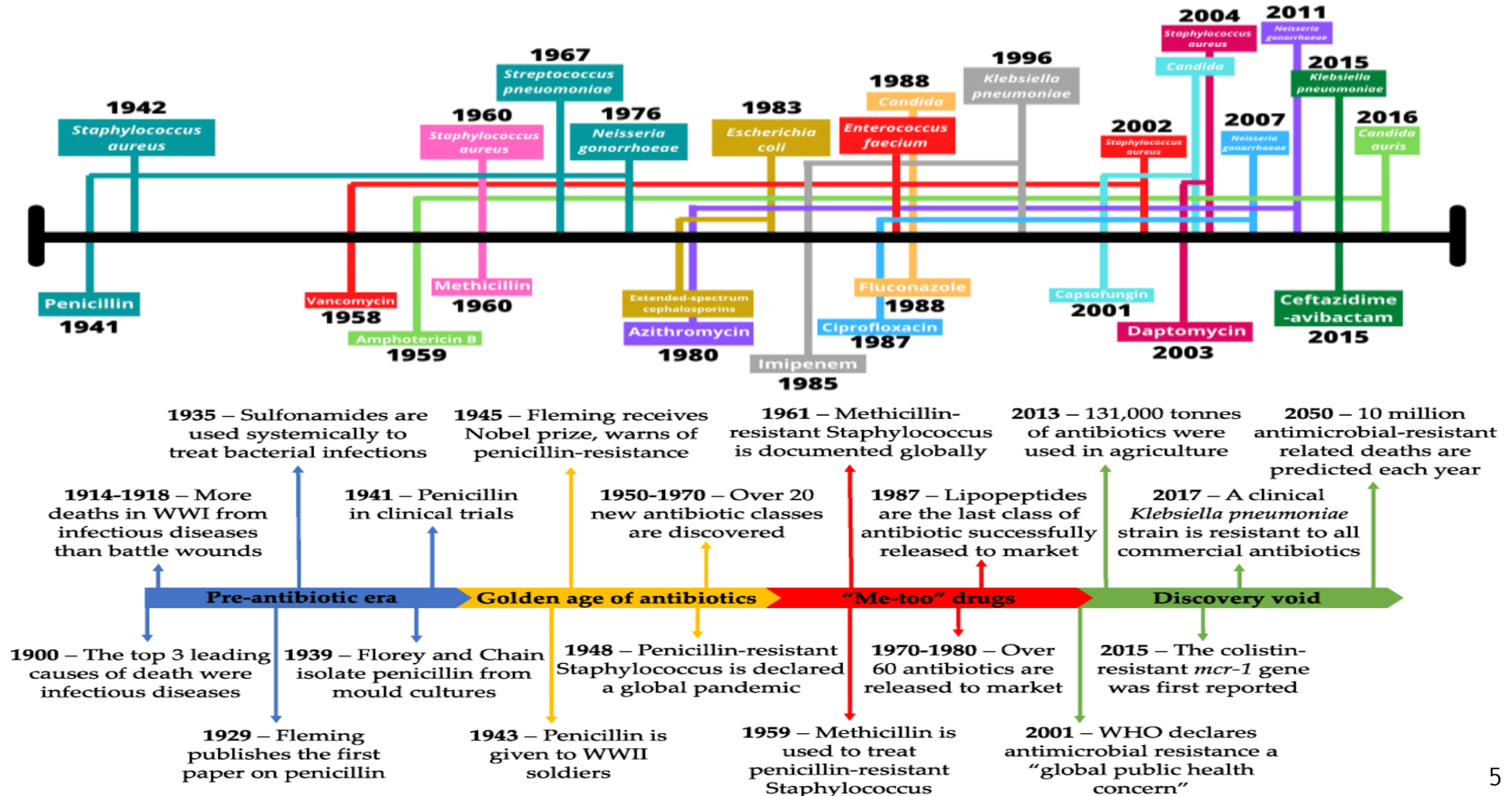
Antimicrobial Resistance: Acquisition



Antimicrobial Resistance: Horizontal Gene Transfer

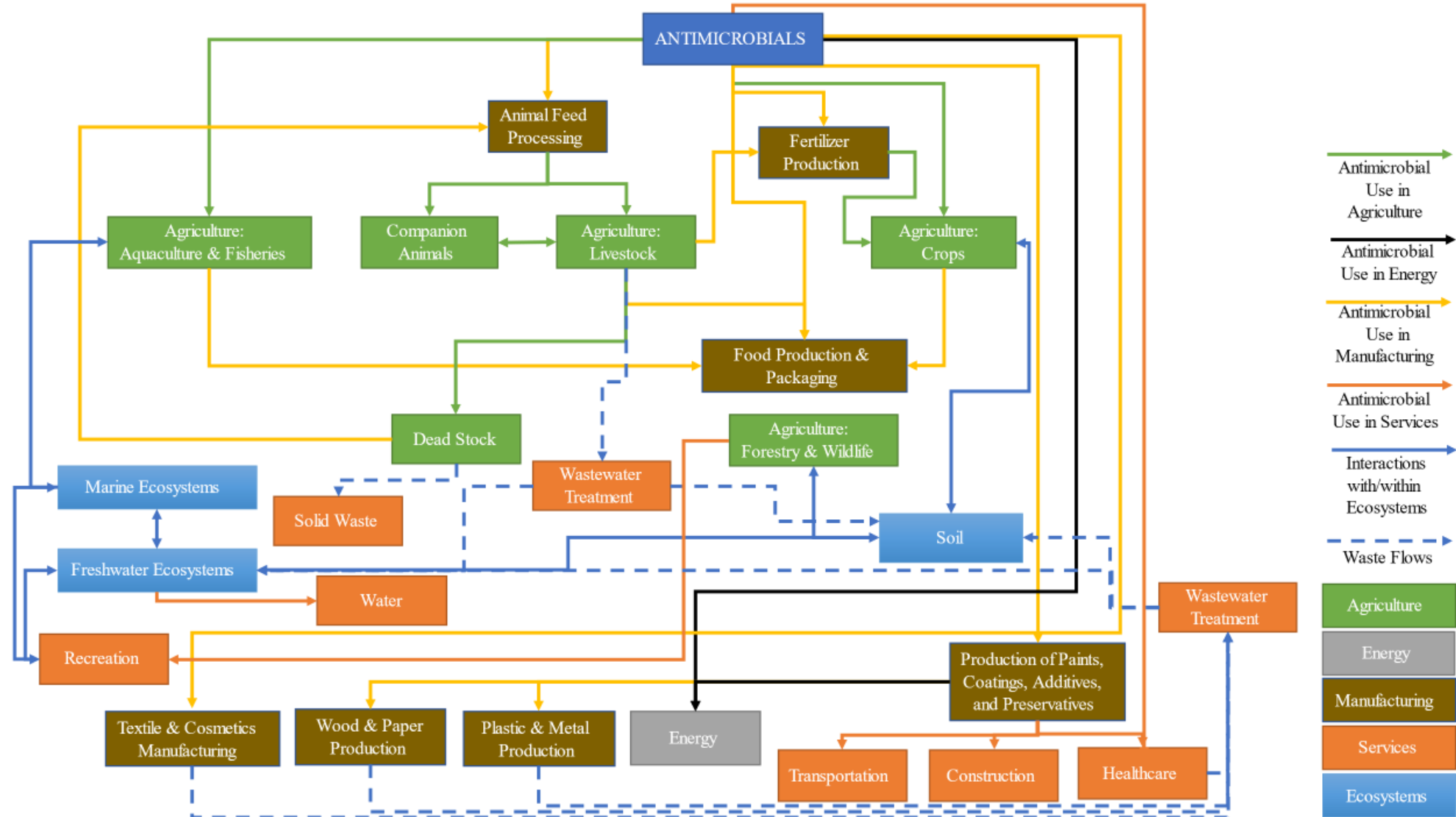


Timeline: Antimicrobial Discovery vs. Resistance



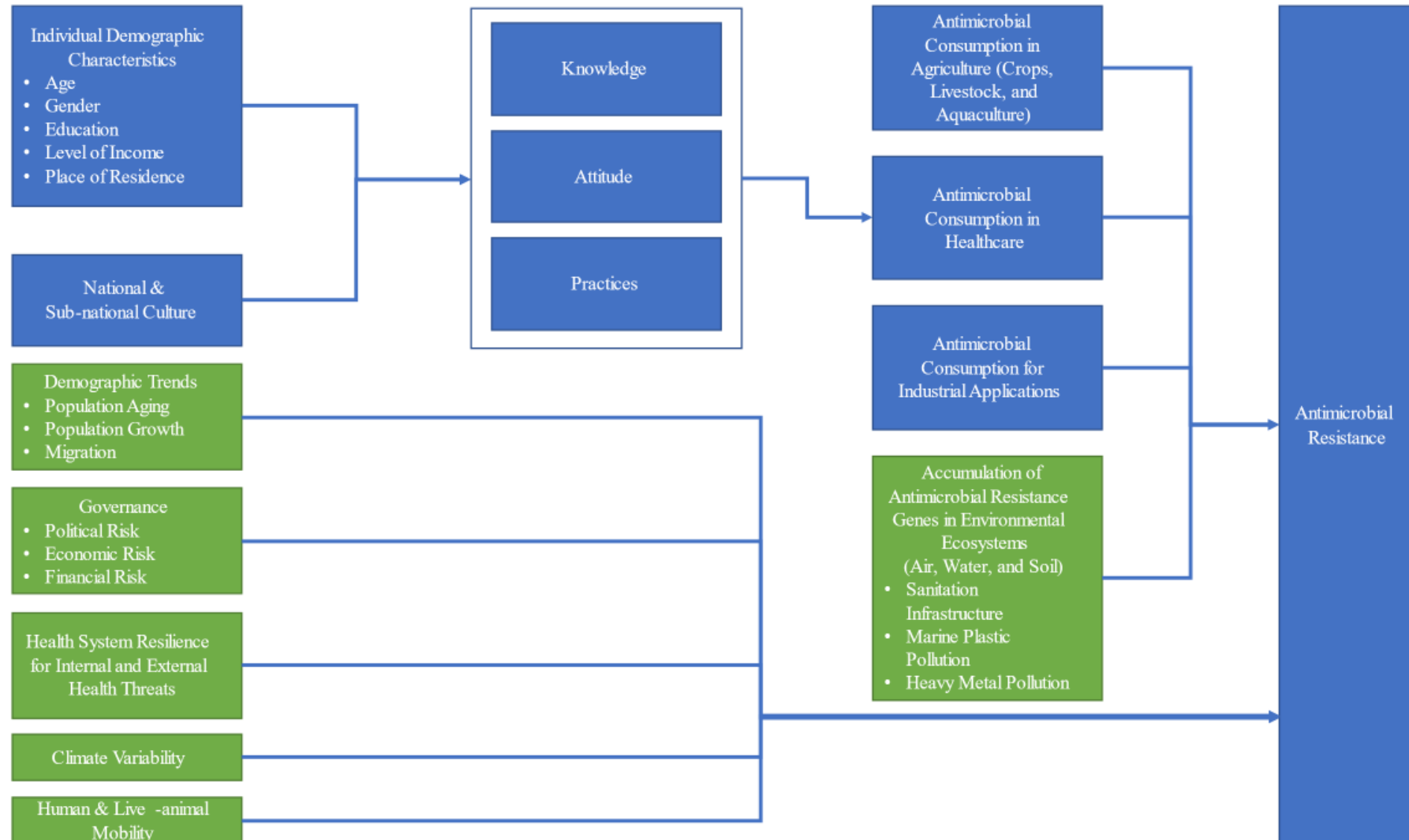
Source: LGC Standards (2022); Browne (2020).

Antimicrobial Resistance: Epidemiology



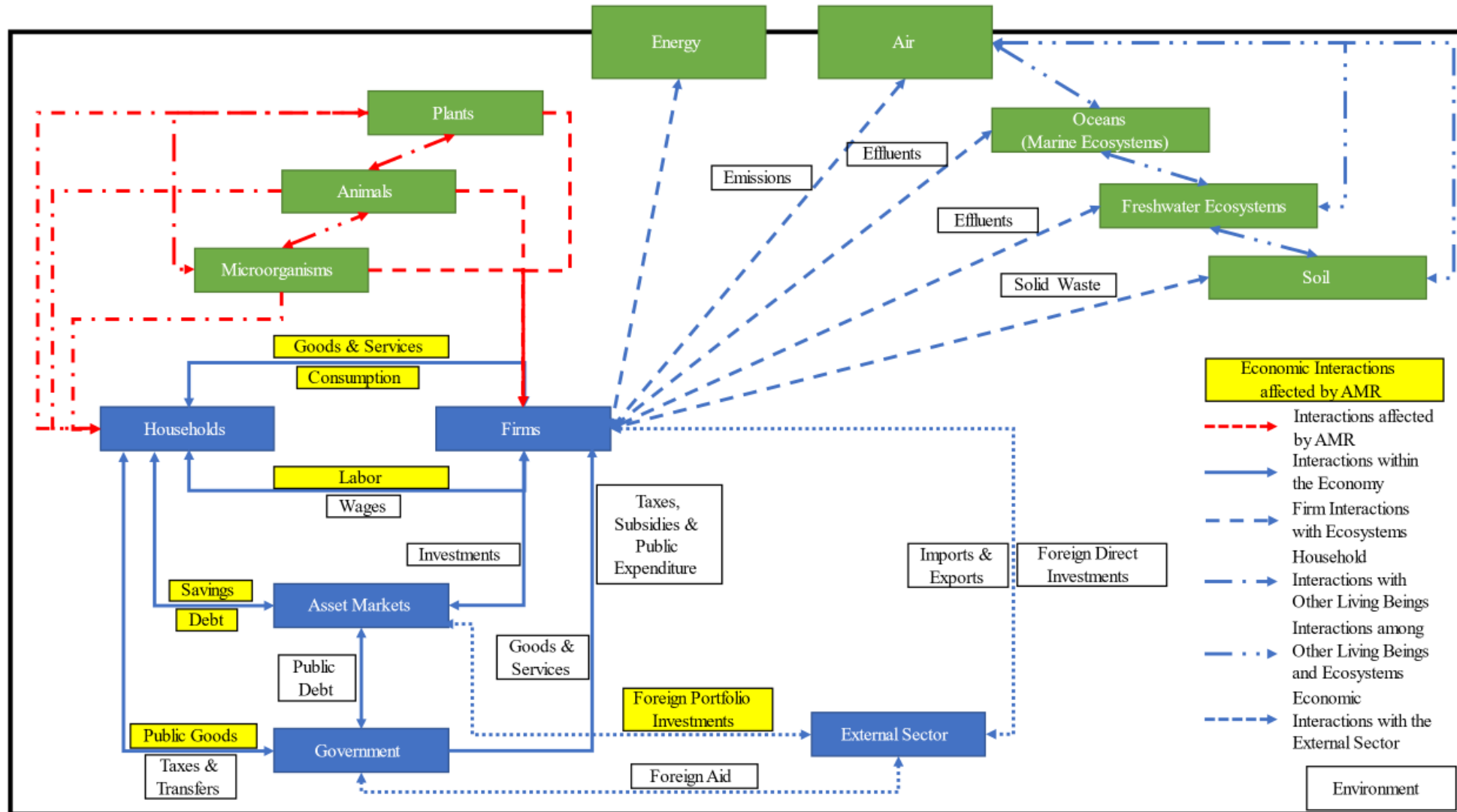
Source: Fernando & McKibbin (2022); Linton (1977).

Antimicrobial Resistance: Factors affecting AMR



MODELING ECONOMIC IMPACTS OF AMR

Conceptualizing Economic Impacts of AMR



Modeling the AMR Effects on Labor Productivity

Changes in Labor Productivity due to Mortality and Morbidity from AMR-related Diseases

(Mortality - Deaths, Morbidity - Disability-adjusted Life Years)

Modeling the Evolution of AMR-related Diseases

Modeling the Evolution of AMR

Modeling the Evolution of AMR-related Diseases

AMR-related Disease Group from the Global Burden of Disease Studies (IHME)	Corresponding Disease Group in the Global Burden of Bacterial Antimicrobial Resistance Study (IHME 2022)
1 Acute hepatitis	Bloodstream infections
2 Bacterial skin diseases	Bacterial infections of the skin and subcutaneous systems
3 Chlamydial infection	Gonorrhoea and chlamydia
4 Diarrheal diseases	Diarrhoea
5 Encephalitis	Meningitis and other bacterial central nervous system infections
6 Endocarditis	Endocarditis and other cardiac infections
7 Gonococcal infection	Gonorrhoea and chlamydia
8 HIV/AIDS	Bloodstream infections
9 Invasive Non-typhoidal Salmonella (iNTS)	Typhoid fever, paratyphoid fever, and invasive non-typhoidal Salmonella
10 Lower respiratory infections	Lower respiratory infections and all related infections in the thorax
11 Meningitis	Meningitis and other bacterial central nervous system infections
12 Tuberculosis	Tuberculosis
13 Typhoid and paratyphoid	Typhoid fever, paratyphoid fever, and invasive non-typhoidal Salmonella
14 Urinary tract infections and interstitial nephritis	Urinary tract infections and pyelonephritis

Modeling the Evolution of AMR-related Diseases

Data:

Diseases:

Global Burden of Diseases (IHME 2022)

Population:

UN Population Prospects (UN 2019)

GDP: World Bank (2022)

Sociodemographic Index: IHME (2022)

*Growth in Disease Measures*_{*i,j*}

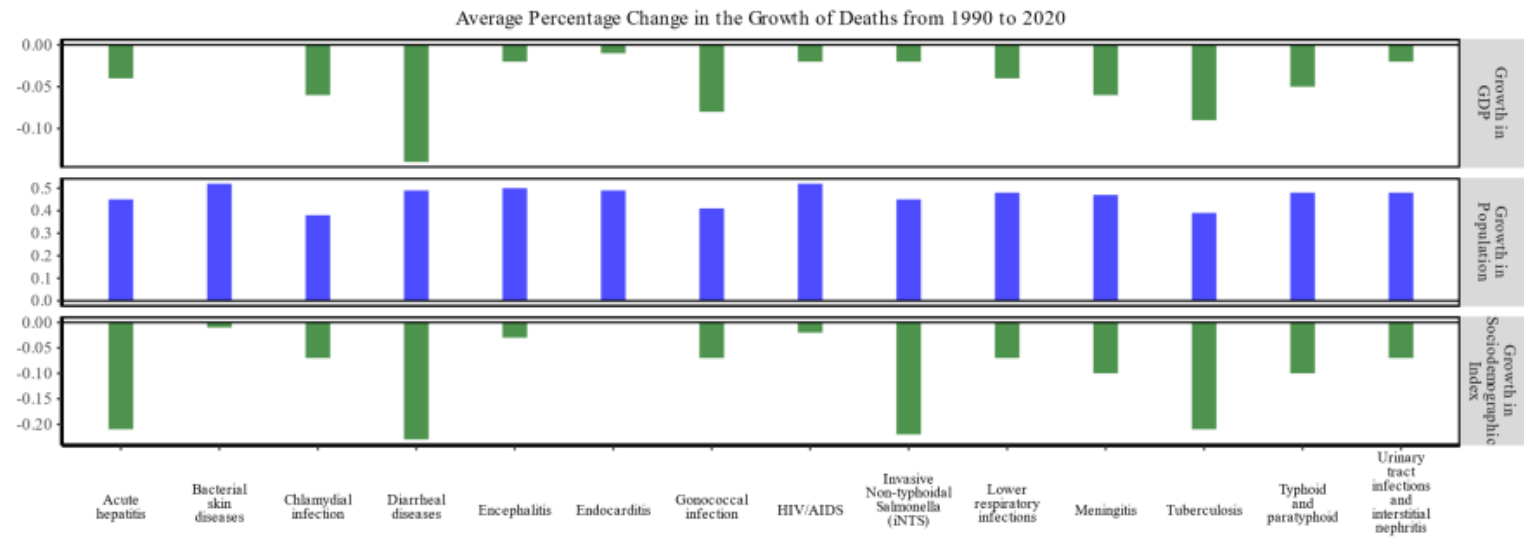
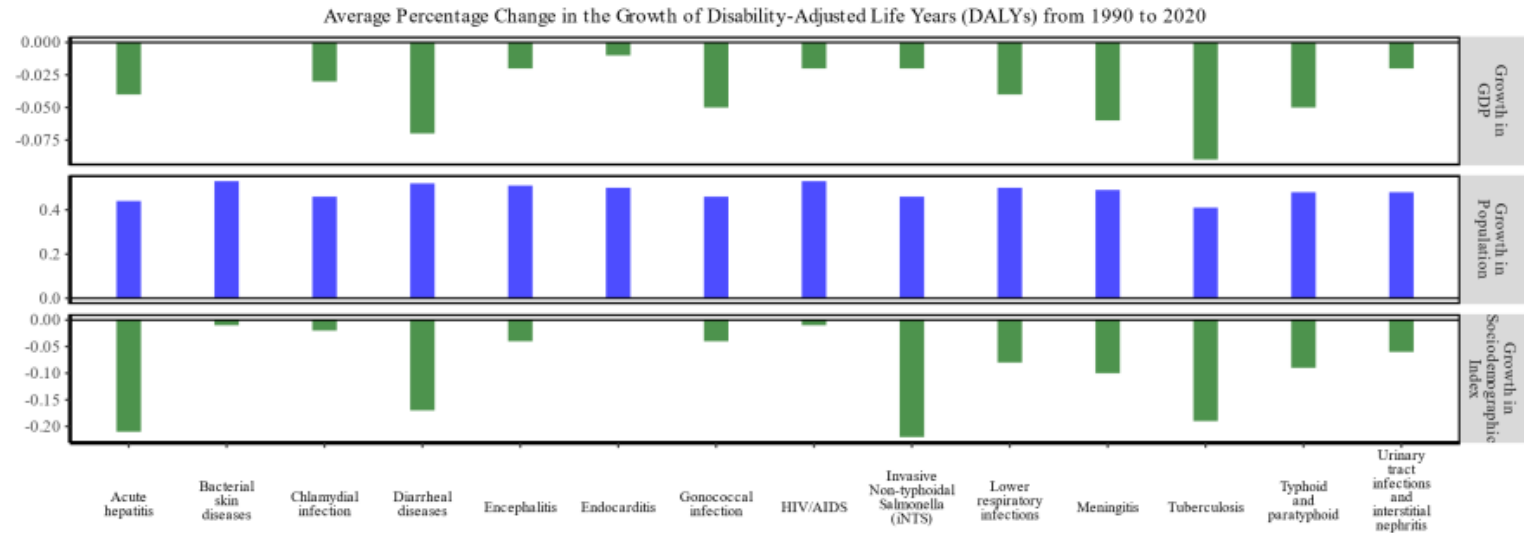
$$= \beta_0 + \beta_{GDP} * \text{Growth in GDP}_{i,j}$$

$$+ \beta_{GP} * \text{Growth in Population}_{i,j}$$

$$+ \beta_{GSDI}$$

$$* \text{Growth in Sociodemographic Index}_{i,j}$$

$$+ \text{Country}_i + \text{Year}_j + \varepsilon_{i,j}$$



Modeling the Evolution of AMR

- As a function of:
 1. Growth in Antimicrobial Consumption
 2. GDP Growth
 3. Growth in Old-age Dependency Ratio
 4. Growth in Climate Indicators

- Seven pathogens:
 1. *Acinetobacter spp.*
 2. *Enterococcus faecalis*
 3. *Enterococcus faecium*
 4. *Escherichia coli*
 5. *Klebsiella pneumoniae*
 6. *Pseudomonas aeruginosa*
 7. *Streptococcus pneumoniae*

- Data: European Centre for Disease Prevention and Control

Modeling the Evolution of AMR

Data:

AMR Rates: ECDC (2022)

Antimicrobial Consumption:

ECDC (2022)

Population Data:

UN Population Prospects (2019)

GDP: World Bank (2022)

Sensitivity of AMR to

Population Ageing

$$\text{Growth in } AMR_{i,j} = \beta_0$$

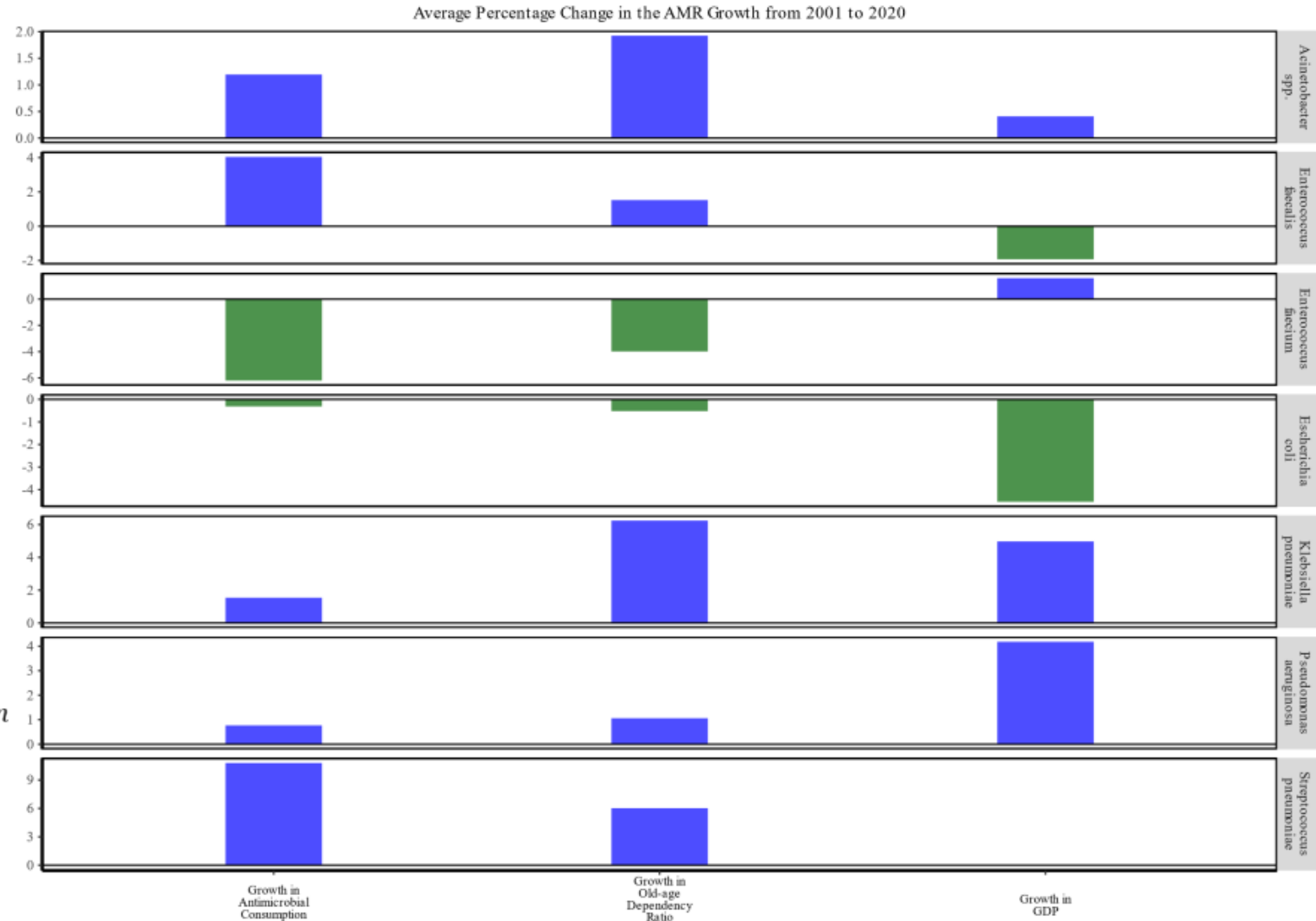
$$+ \beta_{AMC}$$

* Growth in Antimicrobial Consumption

$$+ \beta_{GDP} * \text{Growth in } GDP_{i,j}$$

$$+ \beta_{GDR} * \text{Growth in Dependency Ratio}_{i,j}$$

$$+ \text{Country}_i + \text{Year}_j + \varepsilon_{i,j}$$



Modeling the Evolution of AMR (Contd.)

Data:

AMR Rates: ECDC (2022)

Antimicrobial Consumption:

ECDC (2022)

Climate Indicators:

Fernando (2023) based on

GFDL ESM (ISIMIP 2022)

GDP: World Bank (2022)

Sensitivity of AMR to Physical Climate Risks

$$\text{Growth in } AMR_{i,j} = \beta_0$$

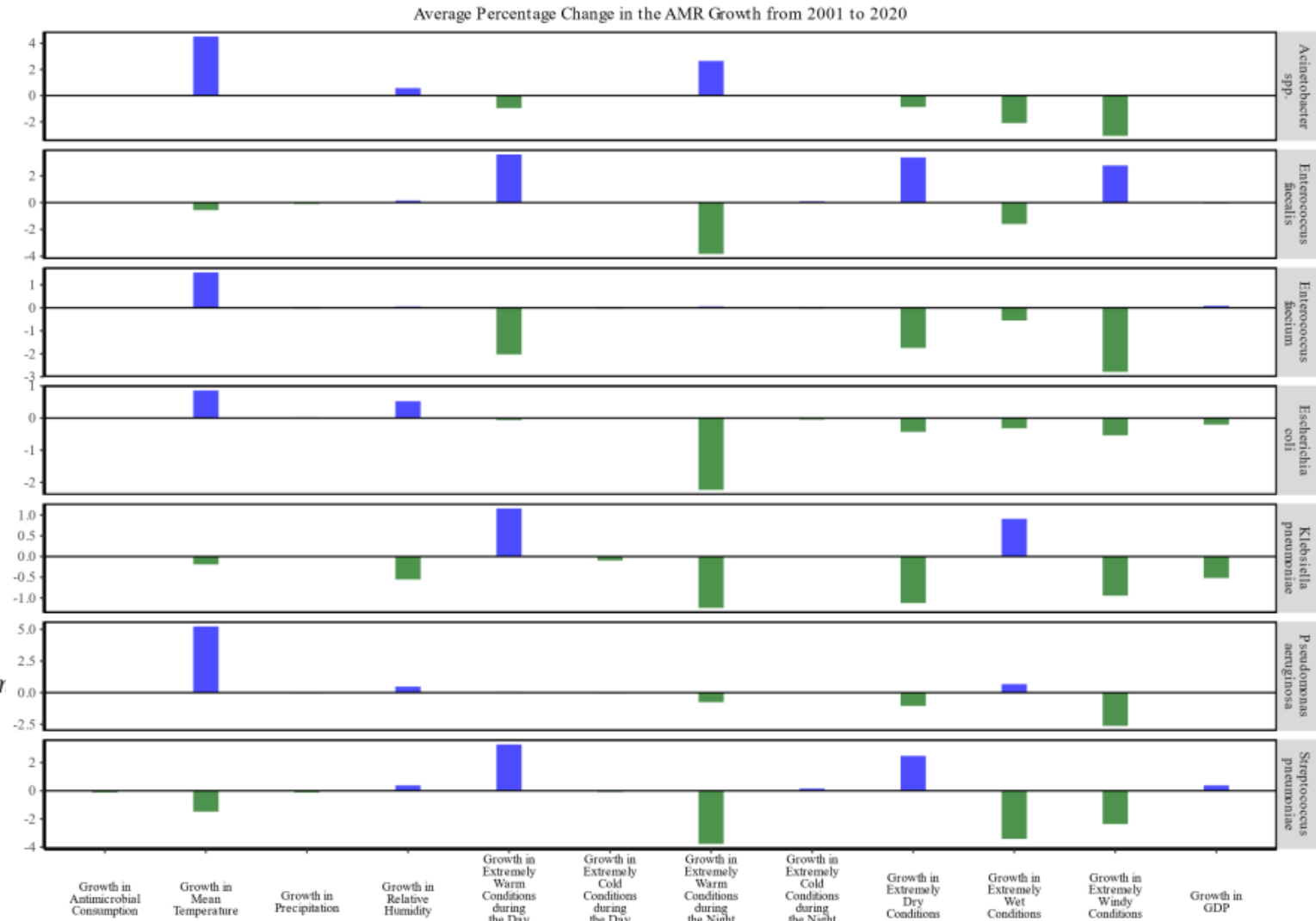
$$+ \beta_{AMC}$$

$$* \text{Growth in Antimicrobial Consumption}$$

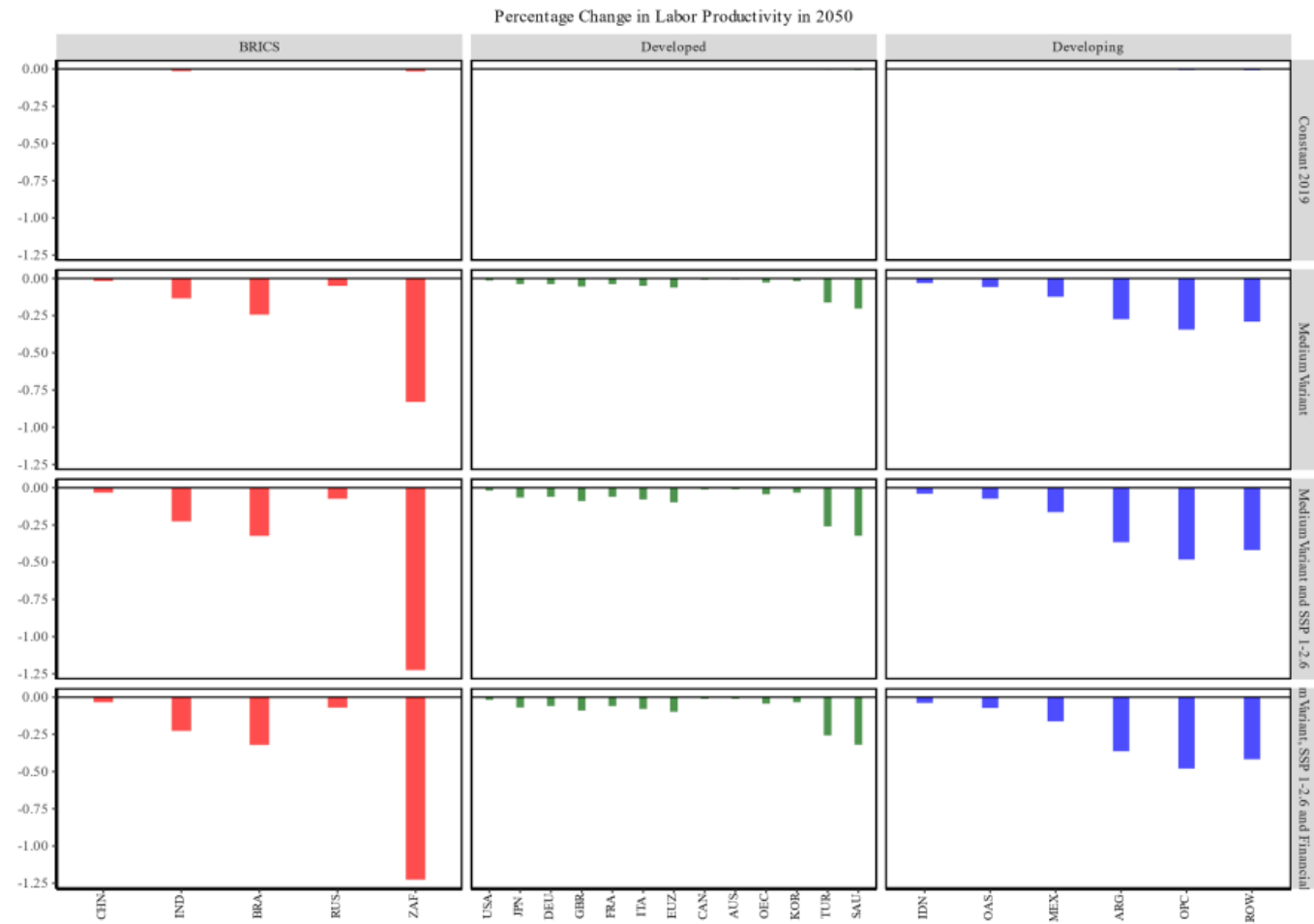
$$+ \beta_{GDP} * \text{Growth in } GDP_{i,j}$$

$$+ \sum_{l=1}^{10} \beta_l * \text{Climate Indicator}_{l,i,j}$$

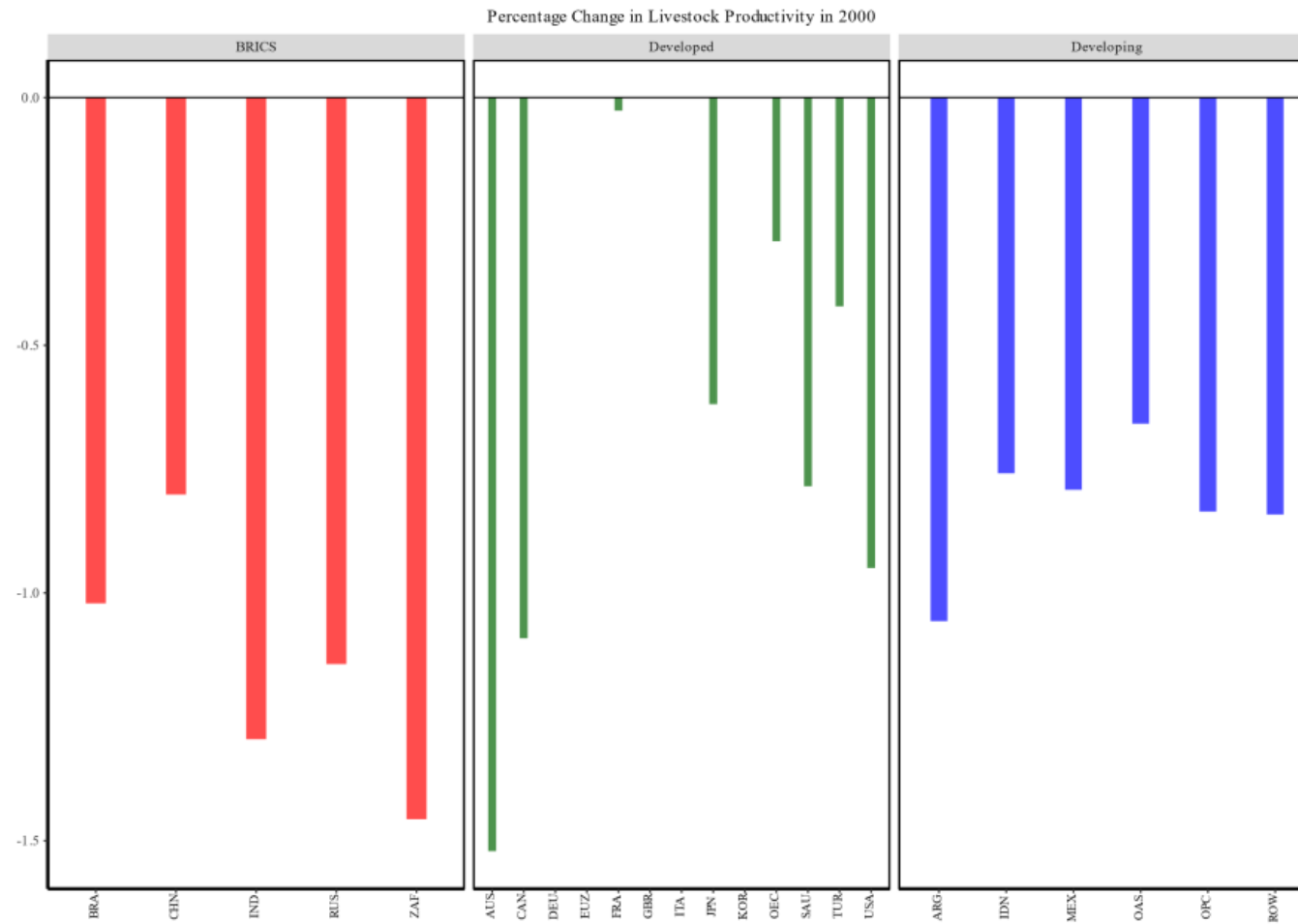
$$+ \text{Country}_i + \text{Year}_k + \varepsilon_{i,j}$$



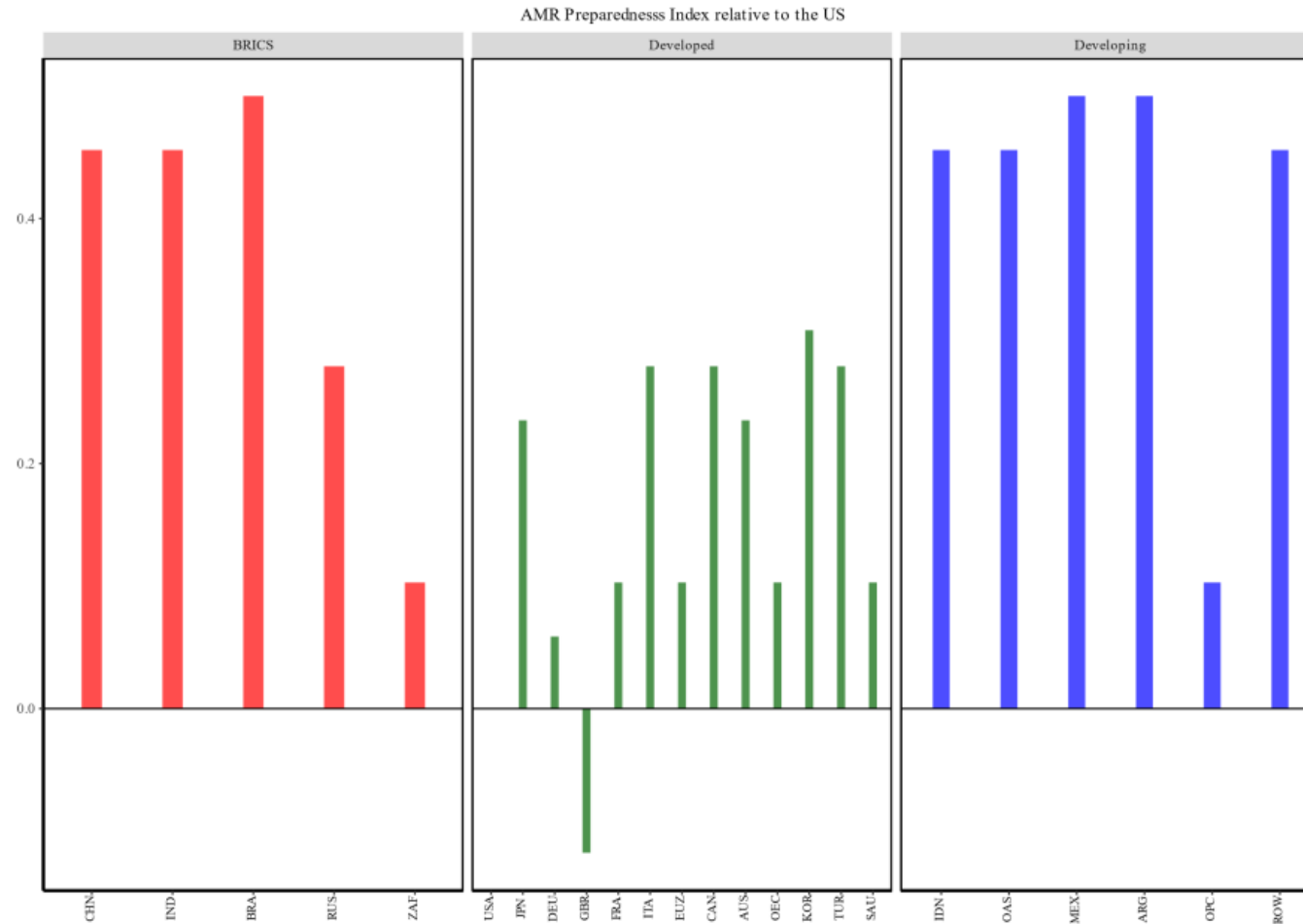
Modeling the AMR Effects on Labor Productivity



Modeling the AMR Effects on Agriculture Productivity



Modeling the AMR Effects on Changes in Risk Premia



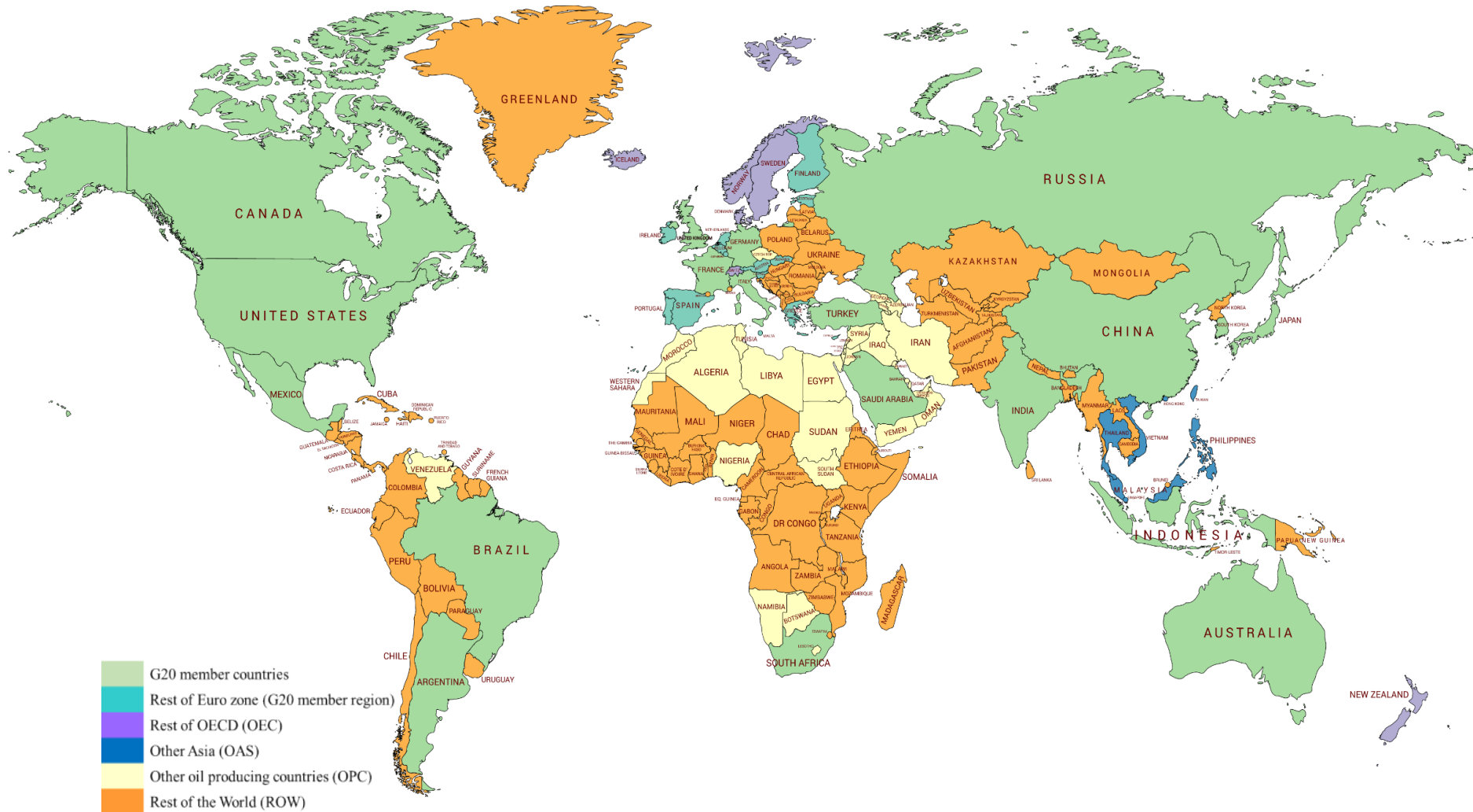
Scenarios

Scenario	Evolution of Diseases	Evolution of Resistance Rates	Evolution of Agriculture Productivity Impacts	Financial Risks
Baseline Scenario		Constant 2019 Resistance Rates.	2000 rates gradually increasing to reach a 20 percent increase by 2100.	
Scenario 1	Evolution as a Function of the Medium Variant.	2019 rates gradually increasing to reach a 20 percent increase by 2100.		
Scenario 2		Resistance Rates as a Function of Medium Variant		
Scenario 3	Evolution as a Function of the Low Variant.	Resistance Rates as a Function of Low Variant	2000 rates gradually increasing to reach a 40 percent increase by 2100.	None.
Scenario 4	Evolution as a Function of the High Variant.	Resistance Rates as a Function of High Variant		
Scenario 5		Resistance Rates as a Function of Medium Variant & SSP 1-2.6		
Scenario 6	Evolution as a Function of the Medium Variant.	Resistance Rates as a Function of Medium Variant & SSP 2-4.5	2000 rates gradually increasing to reach a 60 percent increase by 2100.	
Scenario 7		Resistance Rates as a Function of Medium Variant & SSP 2-4.5		Changes following the AMR Preparedness Index.

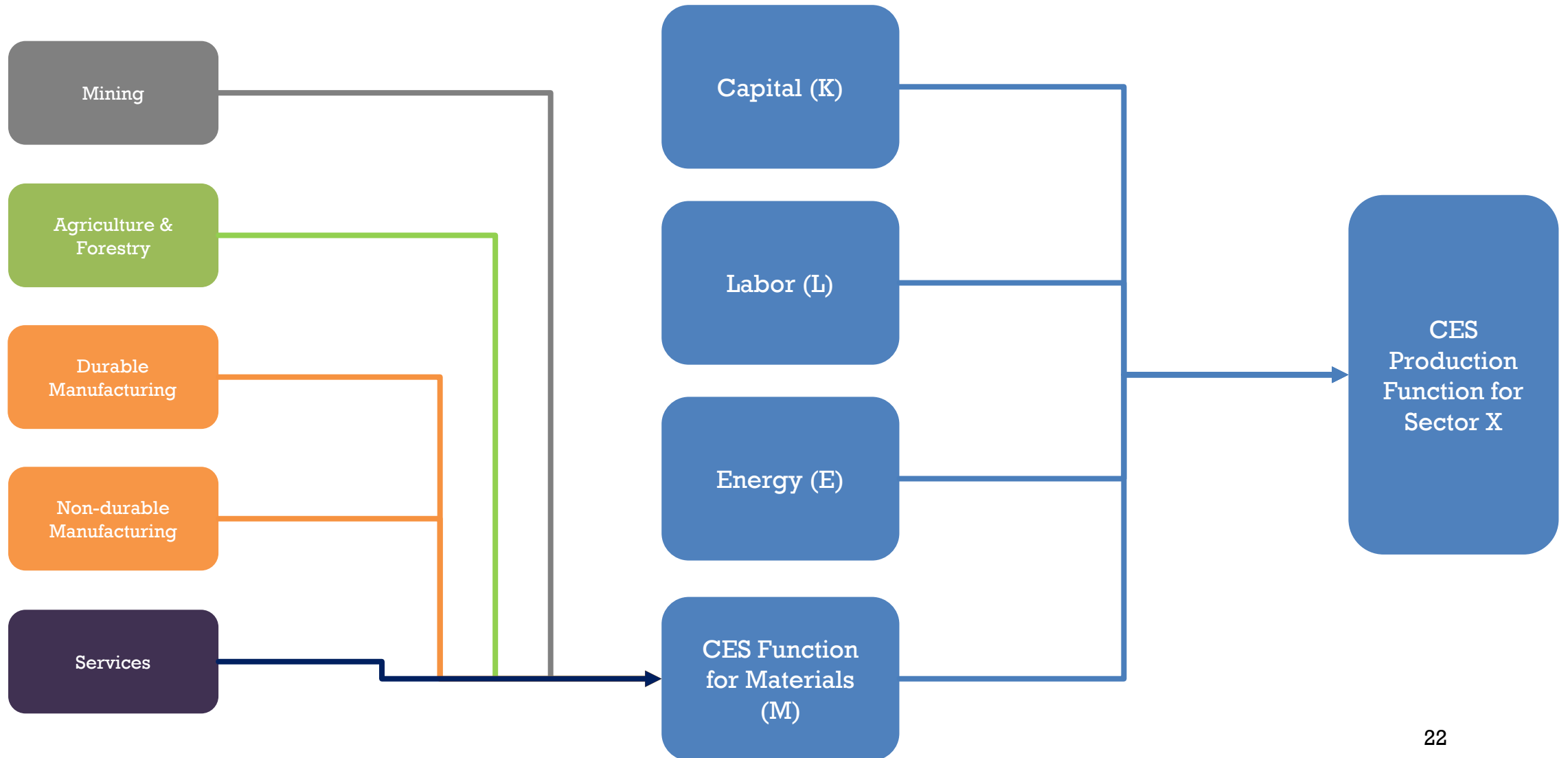
The G-Cubed Model: Overview of Features

- A global, multisectoral, intertemporal general equilibrium model
- A hybrid DSGE-CGE model
- Agents in the model
 - Households
 - Firms (Energy, Mining, Agriculture, Durable Manufacturing, 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

The G-Cubed Model: Countries/Regions

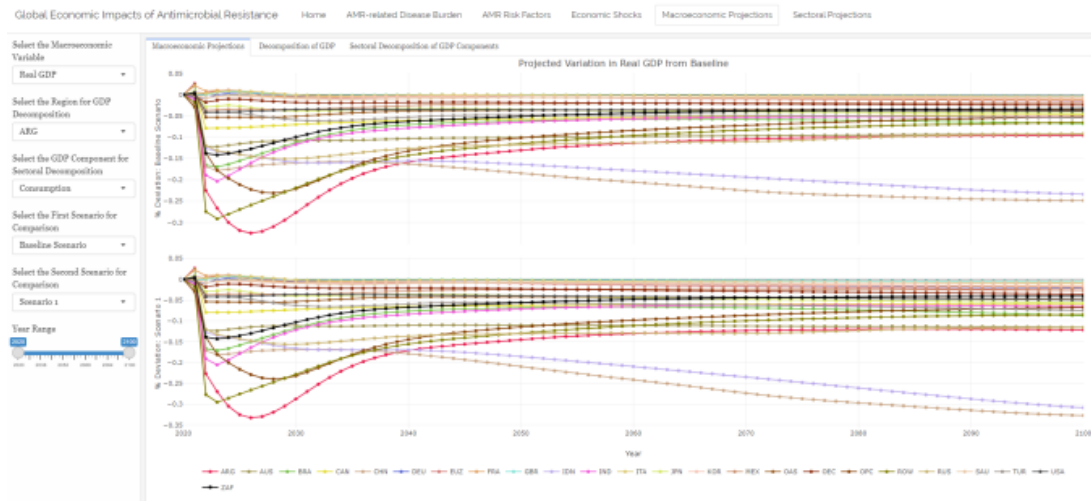
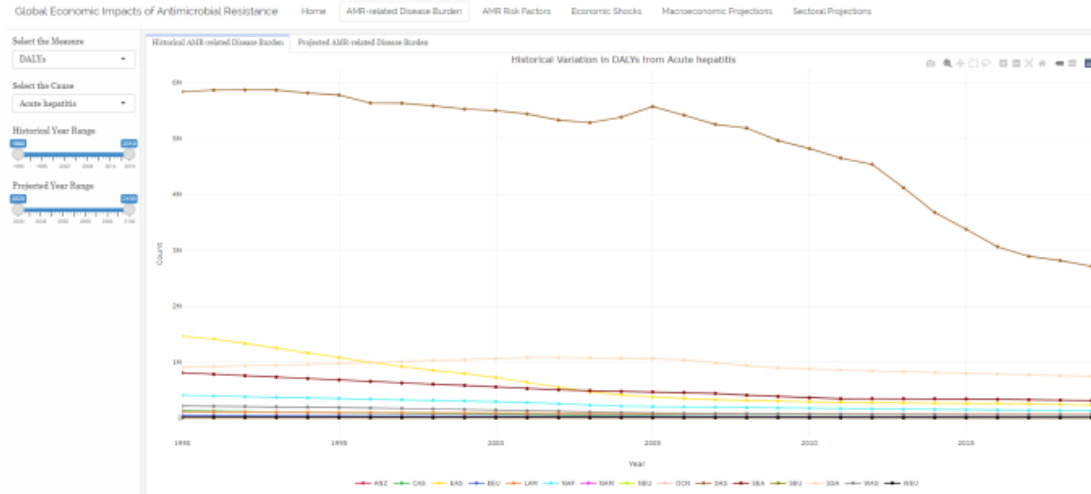


The G-Cubed Model: Sectors



ECONOMIC CONSEQUENCES OF AMR

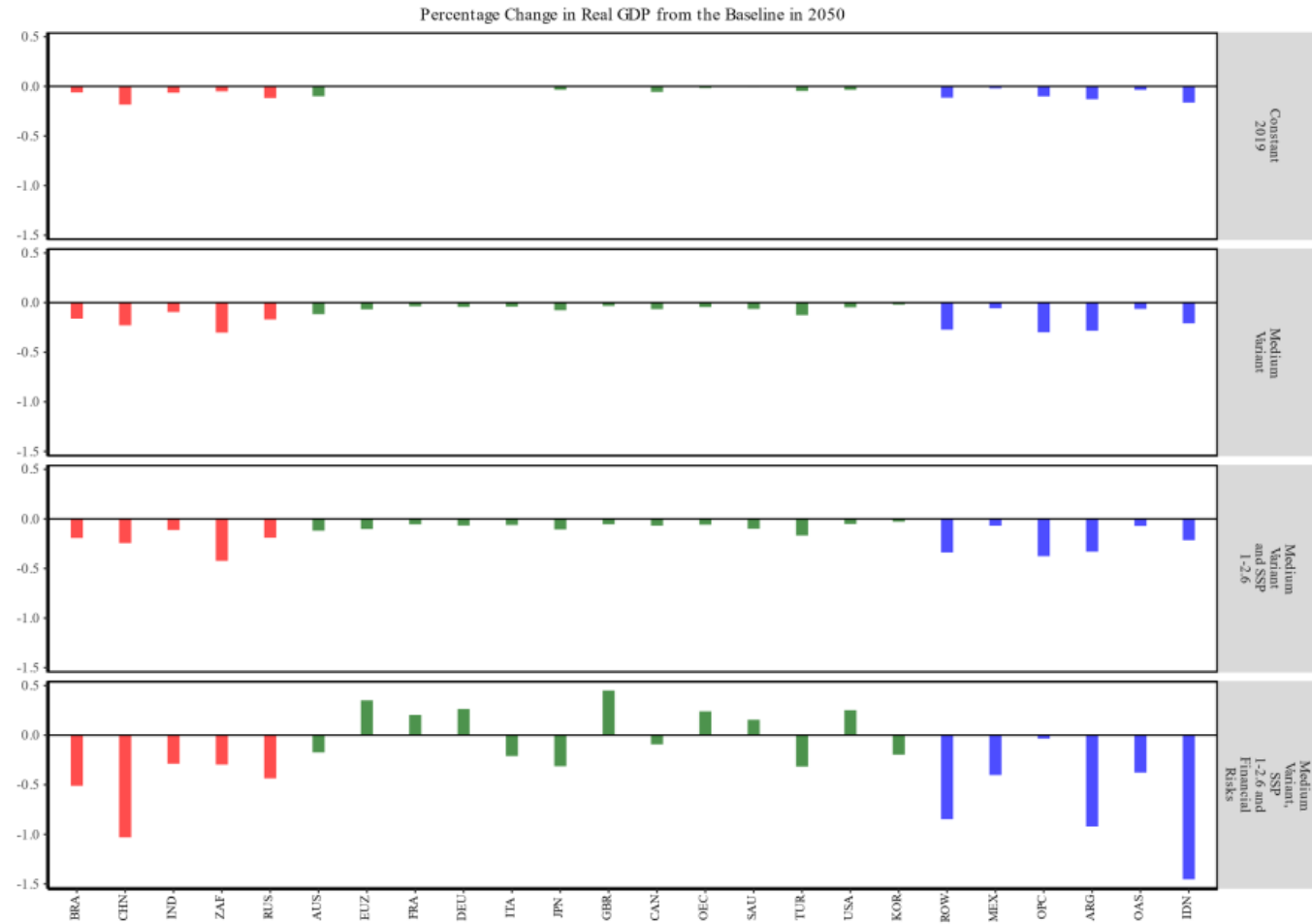
Results Dashboard



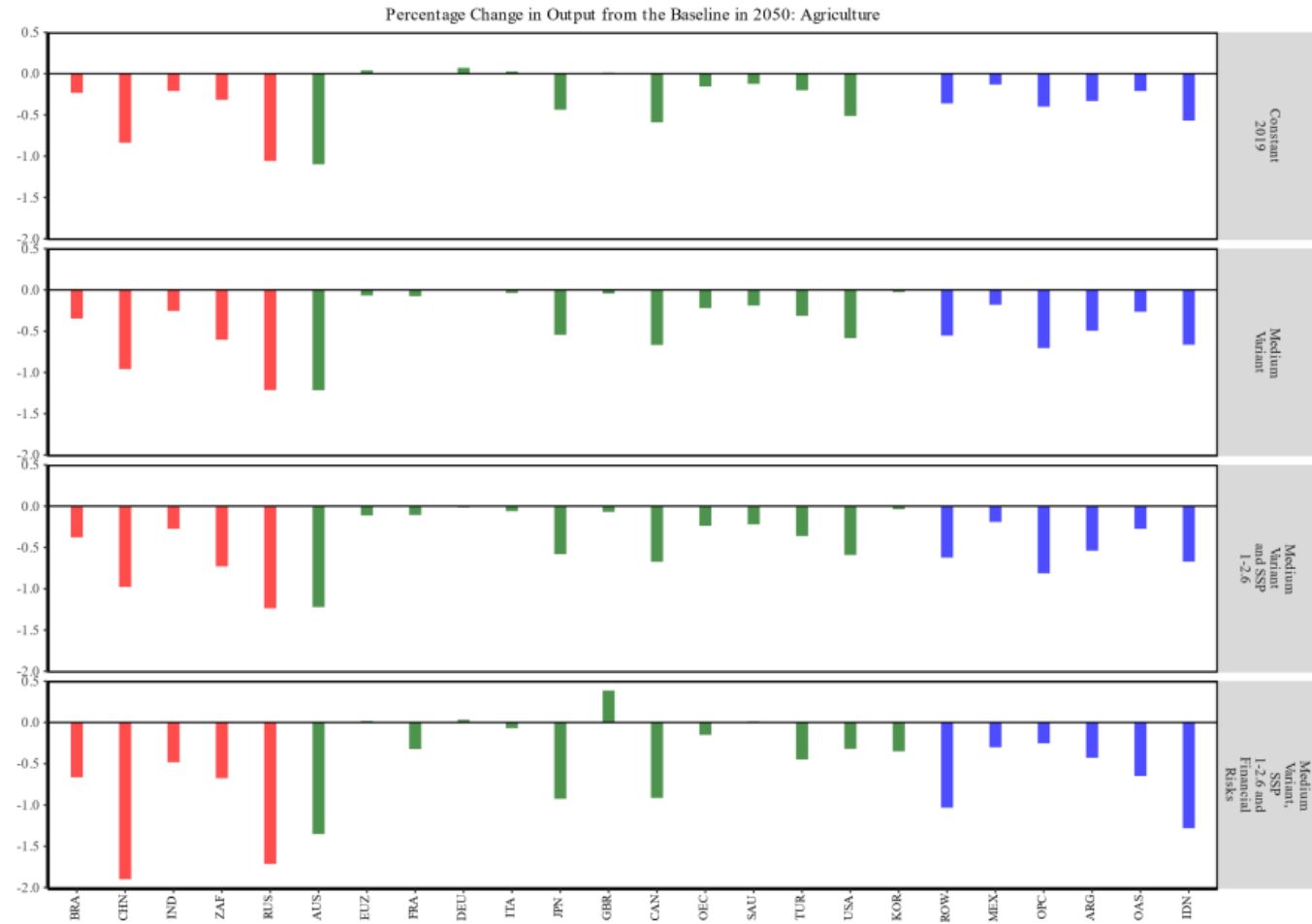
Cumulative Real GDP Losses from 2021 to 2100

Region		Baseline Scenario	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
BRICS	BRA	-0.76	-0.90	-2.52	-2.77	-2.36	-3.07	-3.25	-10.76
	CHN	-2.56	-3.09	-3.45	-3.52	-3.41	-3.86	-4.38	-24.22
	IND	-1.09	-1.27	-1.77	-1.82	-1.73	-2.15	-2.32	-7.90
	RUS	-0.52	-0.61	-0.84	-0.87	-0.82	-0.98	-1.04	-3.34
	ZAF	-0.13	-0.15	-0.87	-0.93	-0.82	-1.25	-1.34	-0.67
Developed	AUS	-0.29	-0.34	-0.36	-0.37	-0.36	-0.38	-0.42	-0.44
	CAN	-0.29	-0.34	-0.36	-0.36	-0.36	-0.37	-0.42	-0.95
	DEU	-0.06	-0.08	-0.40	-0.44	-0.36	-0.62	-0.61	3.20
	EUZ	-0.08	-0.14	-0.79	-0.88	-0.72	-1.30	-1.36	5.98
	FRA	-0.05	-0.08	-0.30	-0.33	-0.28	-0.46	-0.46	1.94
	GBR	-0.01	-0.02	-0.35	-0.39	-0.32	-0.69	-0.72	6.01
	ITA	-0.01	-0.03	-0.29	-0.33	-0.27	-0.49	-0.51	-2.16
	JPN	-0.38	-0.45	-0.96	-1.06	-0.90	-1.68	-1.79	-4.13
	KOR	-0.03	-0.05	-0.13	-0.15	-0.12	-0.23	-0.25	-1.58
	OEC	-0.10	-0.14	-0.28	-0.30	-0.27	-0.41	-0.45	2.47
	USA	-1.49	-1.76	-2.19	-2.25	-2.15	-2.41	-2.68	18.05
	SAU	-0.02	-0.03	-0.29	-0.32	-0.27	-0.45	-0.45	2.24
	TUR	-0.14	-0.18	-0.47	-0.51	-0.44	-0.66	-0.68	-1.50
Developing	ARG	-0.25	-0.30	-0.68	-0.74	-0.64	-0.81	-0.86	-2.81
	IDN	-0.31	-0.38	-0.43	-0.44	-0.43	-0.44	-0.51	-5.24
	MEX	-0.15	-0.18	-0.49	-0.53	-0.46	-0.59	-0.63	-6.18
	OAS	-0.29	-0.36	-0.57	-0.59	-0.55	-0.63	-0.69	-6.00
	OPC	-0.97	-1.16	-2.97	-3.02	-2.93	-3.78	-4.04	5.11
	ROW	-6.57	-7.84	-16.82	-17.29	-16.45	-21.11	-22.74	-82.89
Global	-16.55	-19.86	-38.57	-40.23	-37.41	-48.82	-52.61	-115.76	

Changes in Real GDP by 2050 from the Baseline



Sectoral Changes by 2050 from the Baseline: Agriculture

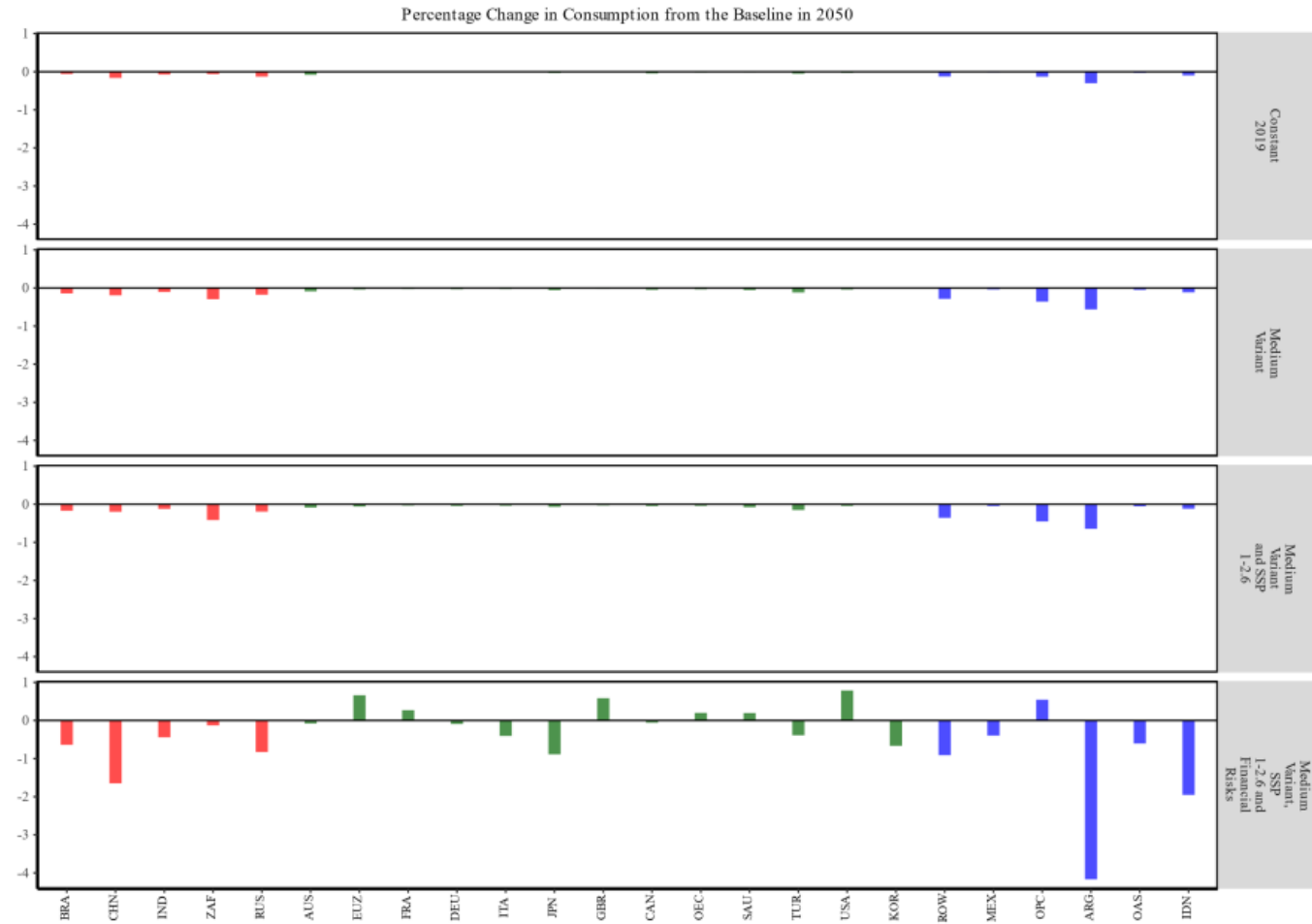


Policy Implications

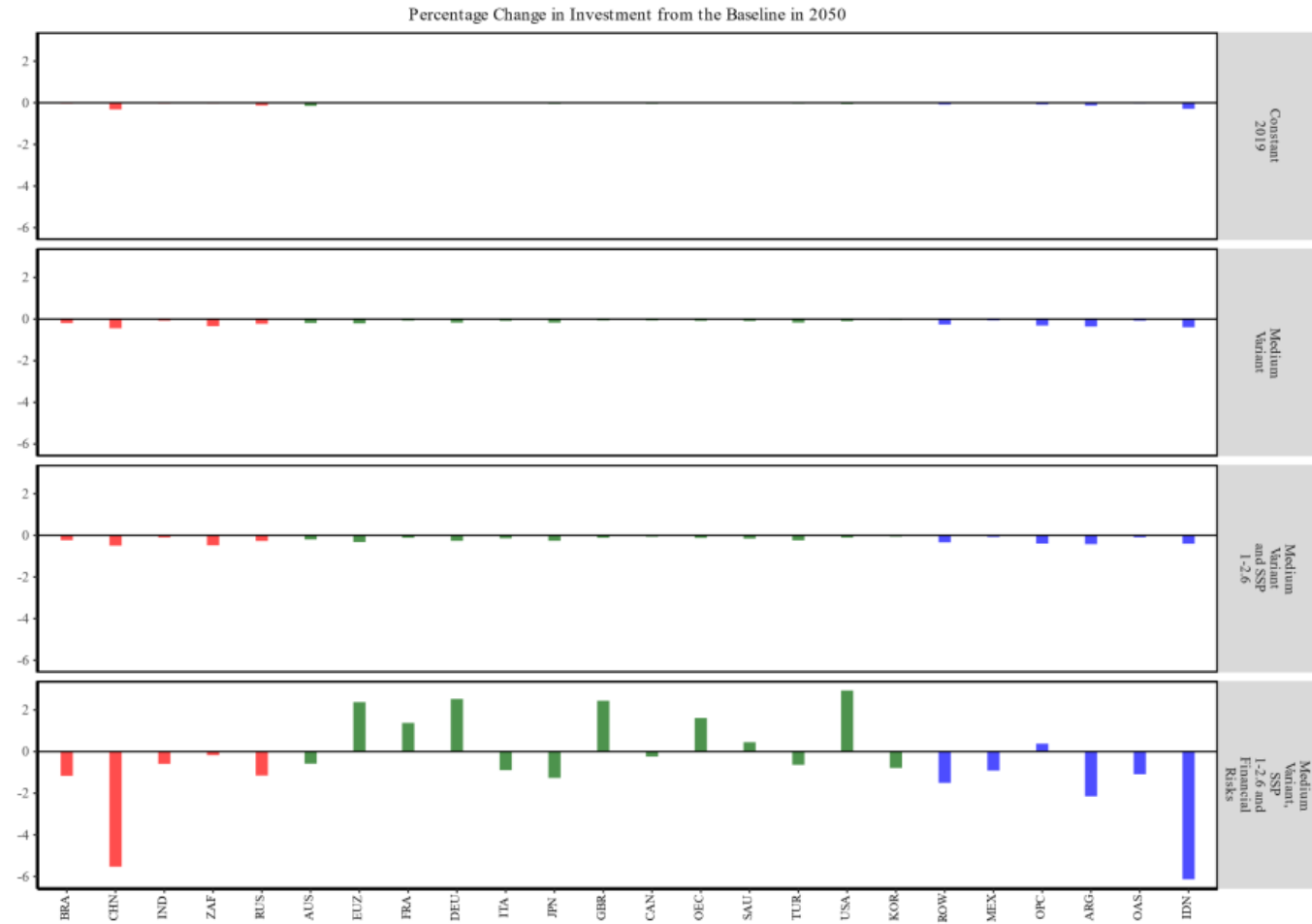
- A global economy-wide multisectoral one-health approach to AMR
 - A one-health approach factoring environmental and socioeconomic interaction
 - A global multisectoral economic approach
- Global cooperation for AMR
 - Transboundary nature of AMR
 - Disparity in economic consequences of AMR
 - Active involvement of global policy institutions
- Preserving and expanding the existing stock of antimicrobials and preventing the emergence and contagion of new diseases
- Alleviating uncertainties for policymaking
 - Sources: AMR evolution, Data & Sources, and Methods

ADDITIONAL SLIDES

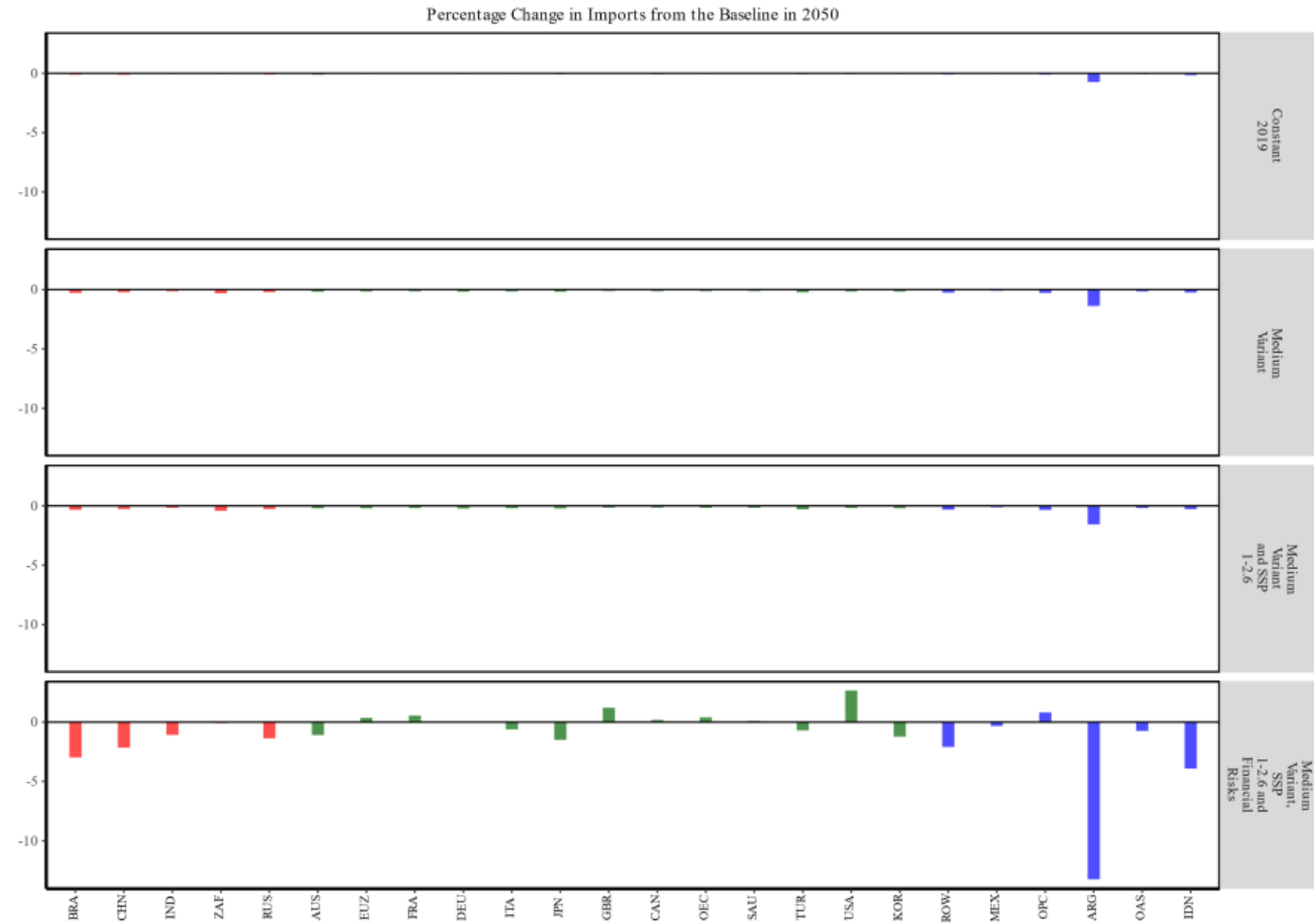
Changes in Consumption by 2050 from the Baseline



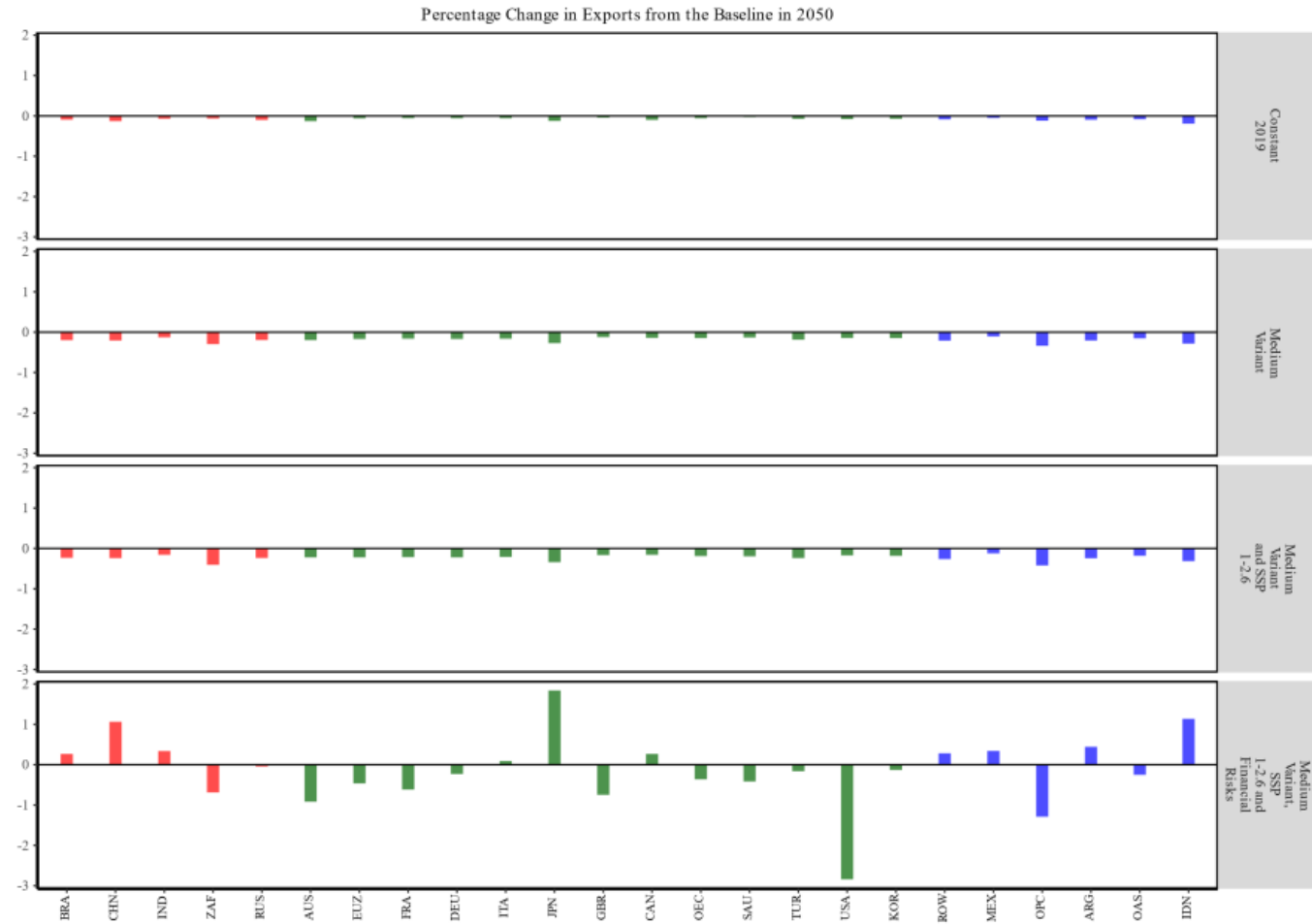
Changes in Investment by 2050 from the Baseline



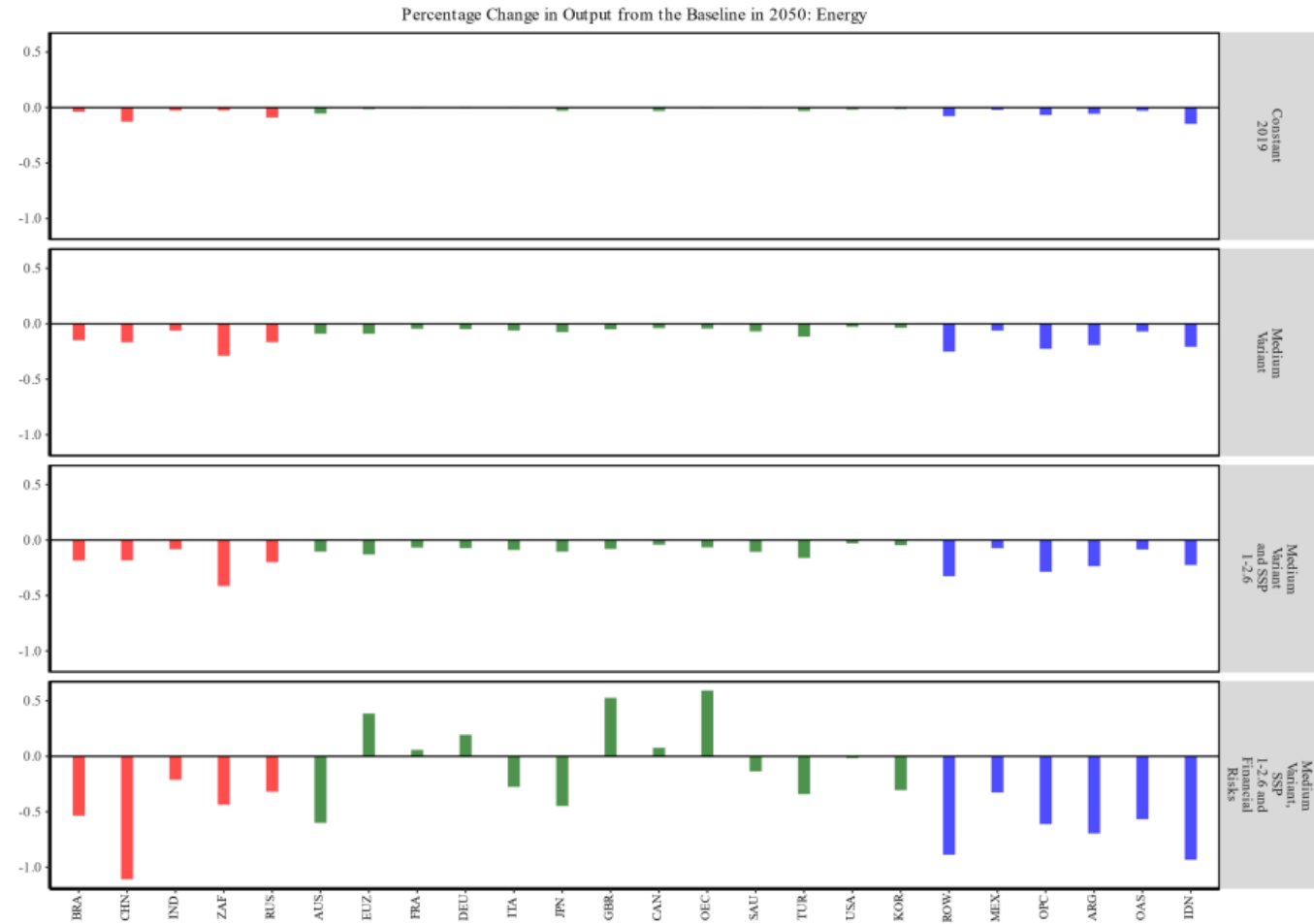
Changes in Imports by 2050 from the Baseline



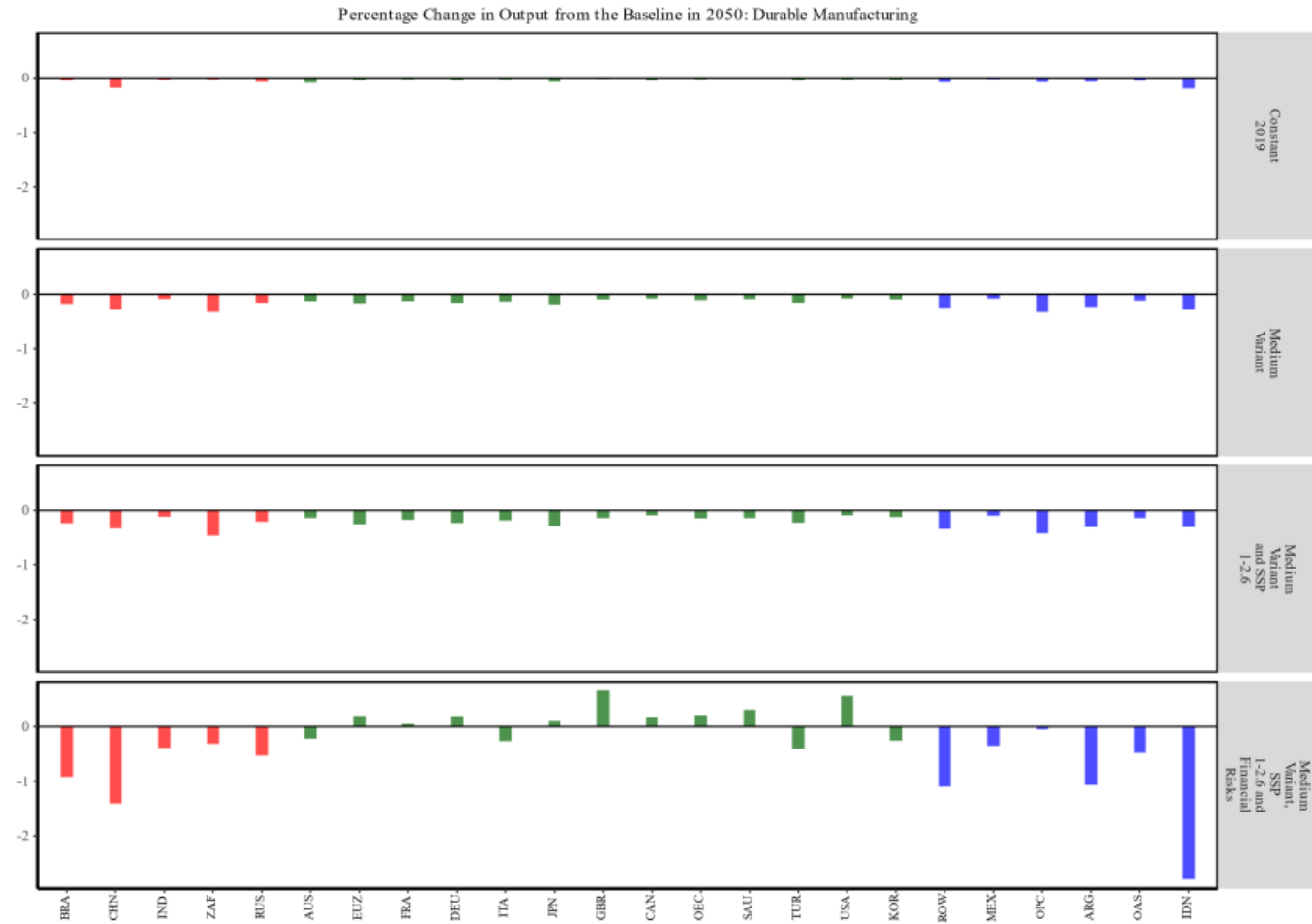
Changes in Exports by 2050 from the Baseline



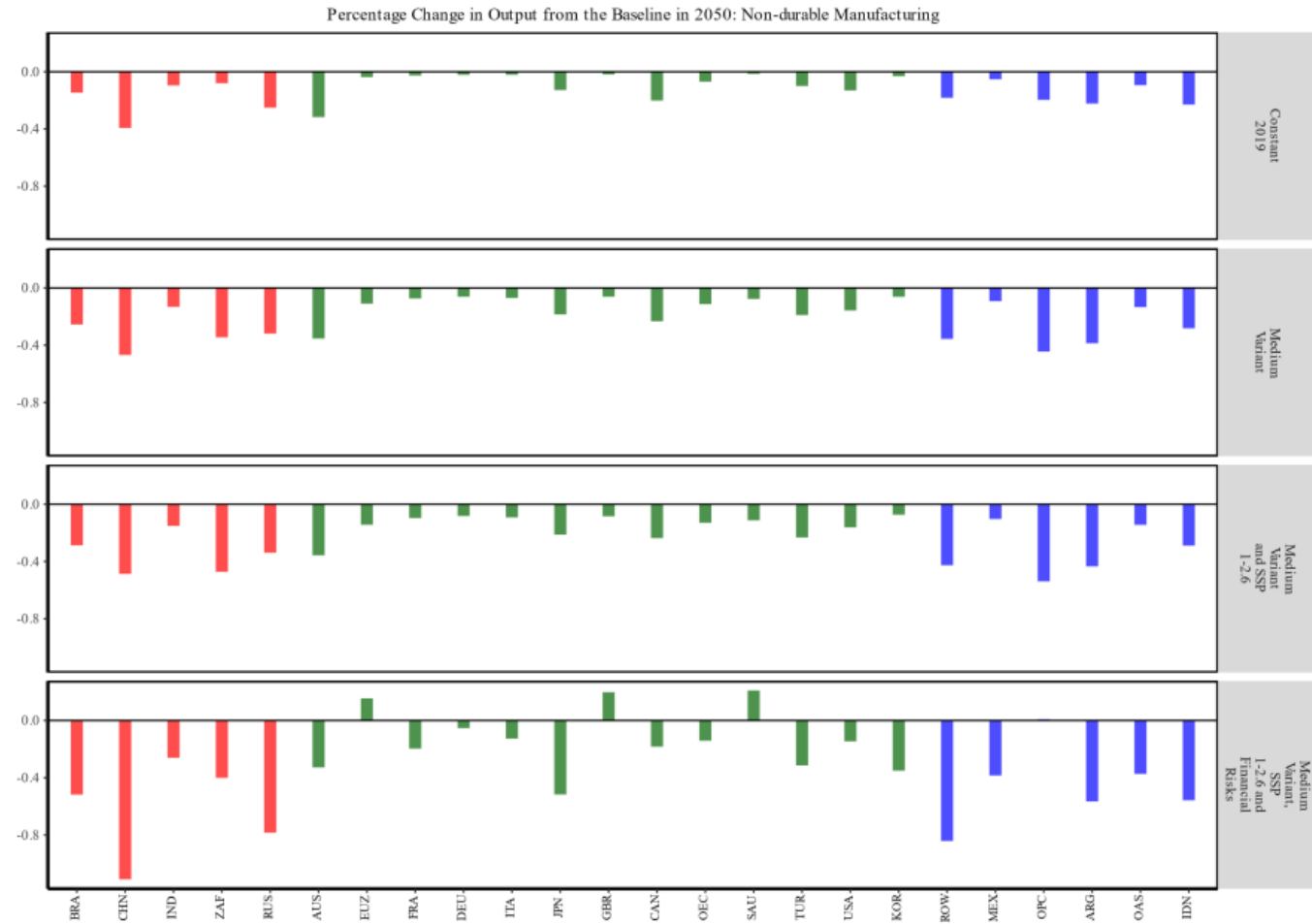
Sectoral Changes by 2050 from the Baseline: Energy



Sectoral Changes by 2050 from the Baseline: Durable Manufacturing



Sectoral Changes by 2050 from the Baseline: Non-durable Manufacturing



Sectoral Changes by 2050 from the Baseline: Services

