

Regulatory Climate Change Stress Testing Scenarios: Global Perspective

June 1, 2021



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Today's Speakers

Predictive Analytics



Luca Magni
Director



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Senior Director



Chris Lafakis
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Janet Lee
Director



Martin Wurm
Associate Director

Moody's Climate Risk Solutions

Forward-looking exposure metrics and risk analytics



Transition Risk Data

Assessment of 5,000 listed companies and on-demand scoring available to identify transition risk exposure from different fossil fuel resource types and power generation technologies.

Macroeconomic Scenarios

Climate-adjusted macroeconomic forecasts with an 80-year horizon. Fully aligned with the Network for Greening the Financial System's (NGFS) representative scenarios for physical and transition risk.

Climate Pathway Scenarios

Tools that translate climate pathways into financial risk variables to inform asset allocation and liability models. Based on Moody's award-winning scenario generation software.



Physical Risk Data

Forward-looking data capturing exposure to climate hazards for 5,000 listed companies with 2.5m corporate facilities globally and 10m commercial real estate properties in the US. On-demand scoring is also available.

Climate-Adjusted PDs

Climate-adjusted probability of default (PD) for listed and unlisted companies powered by Moody's award-winning Expected Default Frequency (EDF™) model.

Compliance Tools

Powerful yet easy-to-use reporting tools and analytics based on climate scenarios and climate-risk data. Used for stress testing and Task Force on Climate-related Financial Disclosures (TCFD) reporting.

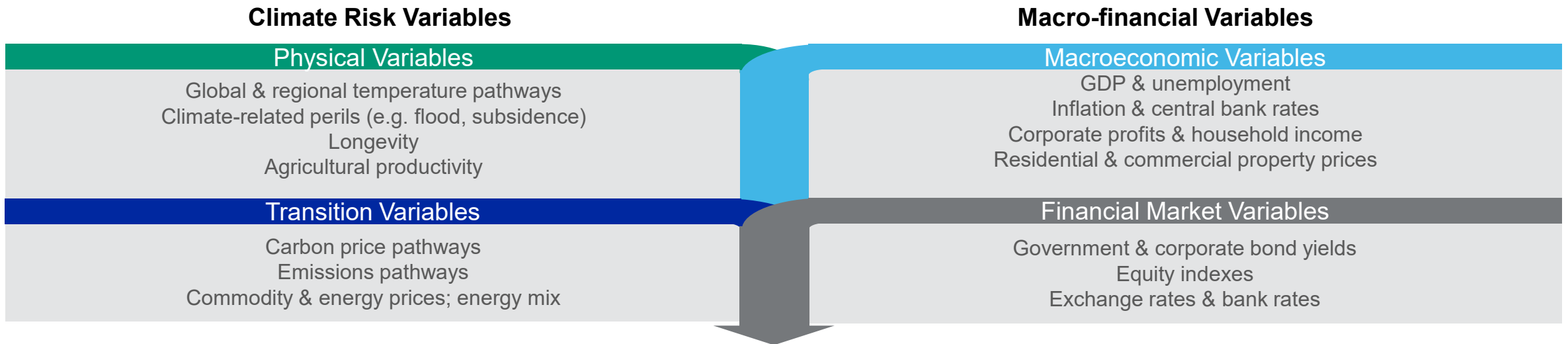
Agenda

1. Climate change regulatory stress testing: Arising industry standard
2. Physical risk impact channels
3. Generating transition risk scenarios
4. Approach to market risk modelling

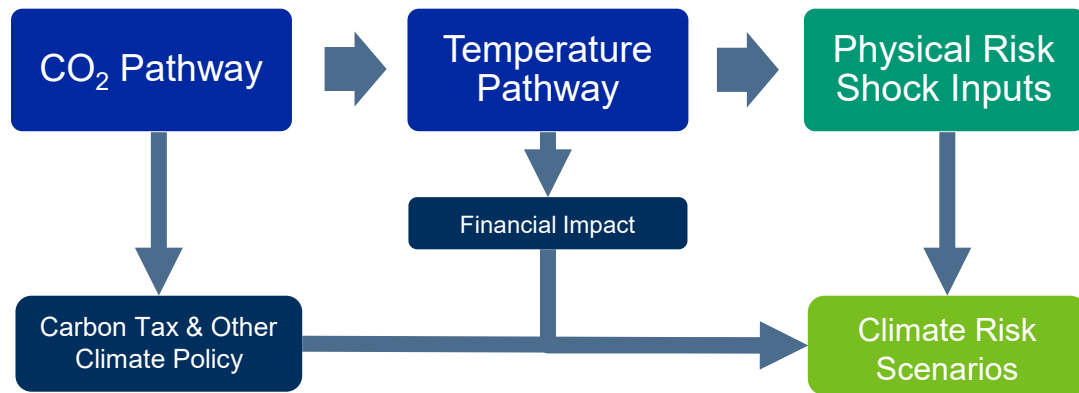
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Climate change regulatory stress
testing:
Arising industry standard

Climate Risk Scenarios

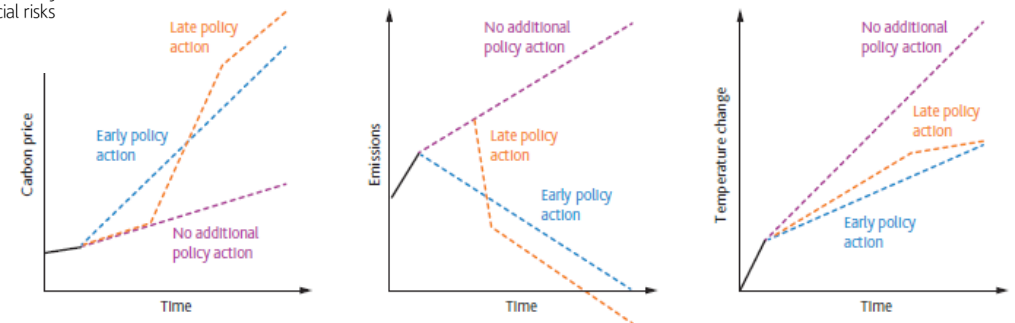


Start with parameters from regulators or clients and expand scenarios to populate additional variables using our Global Macro Model with climate risk components



BANK OF ENGLAND
 Financial Policy Committee
 Prudential Regulation Committee
 Discussion Paper
 The 2021 biennial exploratory
 scenario on the financial risks
 from climate change
 December 2019

Illustrative Variable Pathways in each Scenario



Modelling Framework



Impact Channel

1. Sea level rise
2. Agricultural productivity
3. Heat stress effect on labor productivity
4. Human health effects
5. Tourism
6. Energy demand

Mnemonics

- FC\$_GEO*
- FPROD\$_POT_GEO*
- FPROD\$_POT_GEO*
- FPROD\$_POT_GEO*
- FNETEX\$_I_GEO*
- FCPIFICEBOIU_US*

Energy Consumption

1. Coal
2. Natural gas
3. Petroleum and othe liquid

Mnemonics

- FCOALCONQ_IGEO*
- FNGASCONQ_IGEO*
- FPETCONQ_IGEO*

CO2 Taxes

1. Dividend dummy
2. Carbon tax dummy
3. Carbon tax rate
4. Carbon tax revenue
 - 4-i. Carbon tax revenue: Coal
 - 4-i. Carbon tax revenue: Natural gas

Mnemonics

- DUM_CARBDIV_IGEO*
- DUM_CARBONTAX_IGEO*
- FCARBONTAX_IGEO*
- FCARBONREV_IGEO*
- FCOALREV_IGEO*
- FNGASREV_IGEO*

CO2 Emissions

1. Coal
2. Natural gas
3. Oil and petroleum products

Mnemonics

- FCOALCO2EQ_IGEO*
- FNGASCO2EQ_IGEO*
- FPETCO2EQ_IGEO*

Energy Prices

1. Coal
2. Natural gas
3. Oil

Mnemonics

- FPCCOALDOM_IGEO*
- FPCNGASDOM_IGEO*
- FPCOILDOM_IGEO*

Government Finances

1. Total revenue
2. Total expense
3. Expenditure intermediate term
4. Expenditure residual

Mnemonics

- FGGREV_IGEO*
- FGGEXP_IGEO*
- FGGEXP_I_IGEO*
- FGGEXP_RESID_IGEO*

Regulatory Environment



- » Network for Greening the Financial System (NGFS) and Task Force on Climate-related Financial Disclosures (TCFD) are leading voices for a call to action in the financial system.
- **NGFS** is a group of over 35 central banks and regulatory agencies worldwide established at the Paris “One Planet Summit” in December 2017. Includes: BoE, ECB/EBA, the FED, HKMA, The Peoples Bank of China, EIOPA
- **TCFD** is a taskforce set up by the Financial Stability Board, comprised of over 785 influential organizations from around the world.
- Scenario-based risk analysis is an integral part to both the NGFS and TCFD’s action plans.

HKMA

- Physical Risk Scenario RCP 8.5
- Transition Risk Scenarios: NGFS Orderly/Disorderly
- Time Horizon 2060
- Low Interest Environment
- Credit/Market/Operational Risk

UK- BoE/PRA

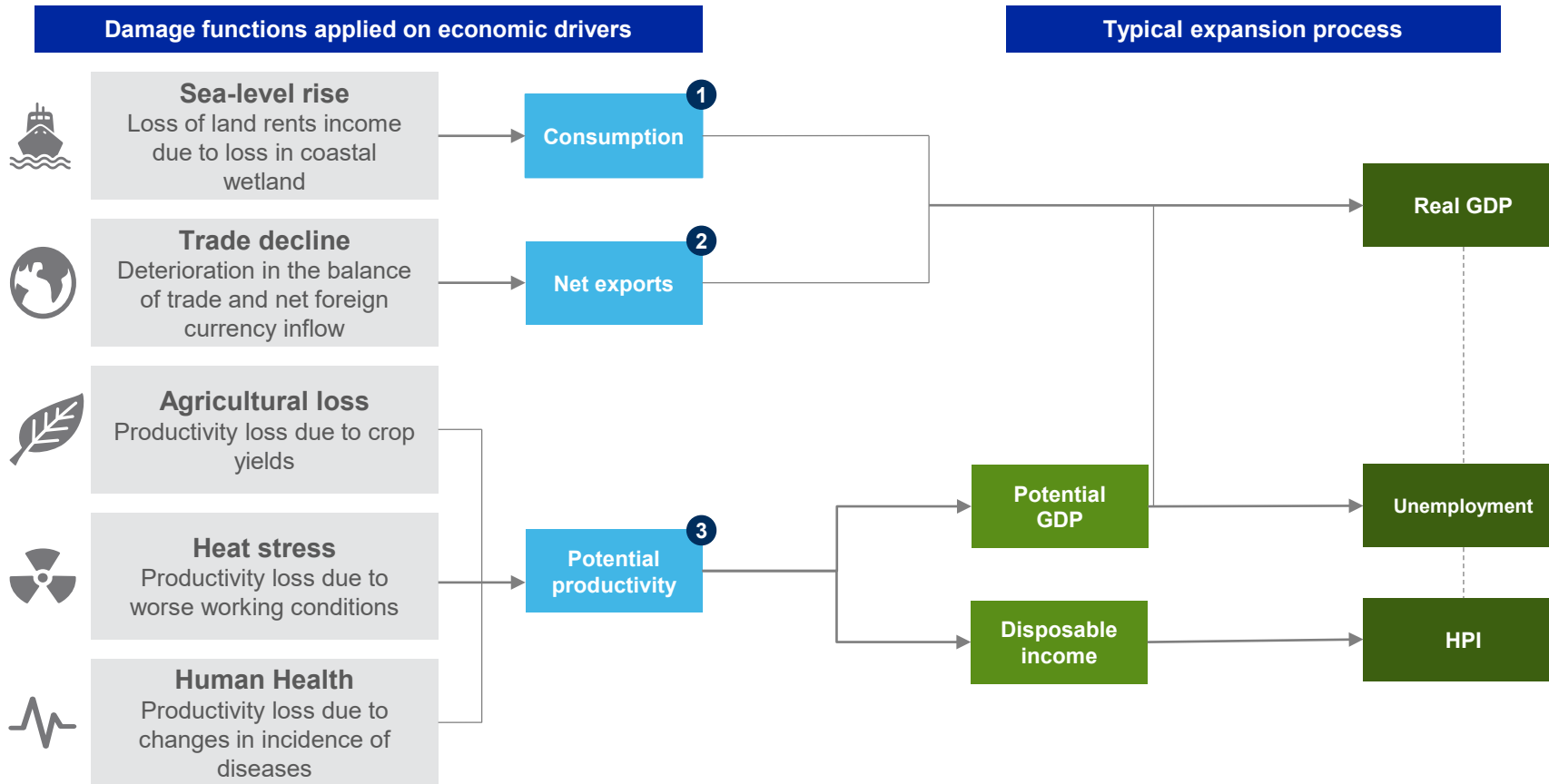
- June 8: The 2021 biennial exploratory scenario (BES) on the financial risks from climate change, BoE Discussion Paper 2019.
- Three scenarios corresponding to NGFS scenarios: Net Zero, Delay, Current Policies
- Credit/Market/Underwriting/Operational/Liquidity Risk
- No acute climate event

2

Physical risk impact channels

Physical Risk Impact Channels

Roson-Sartori Damage Function



3 economic drivers affected:

- **Consumption:** Sea-level rise causes a loss in productive lands on the coast and related rent income. This is translated into loss of income and consumption
- **Net Exports:** High increase in temperatures reduces tourism business and export services.
- **Potential productivity:** Labour productivity is affected by heat stress and diffusion of vector-borne diseases. Lower crop yield

Consumption and NX are GDP components having direct effect on the output. Productivity impacts disposable income and potential GDP.

Source: Moody's Analytics

Approach



Quarterize Temperature Pathway

Create quarterly temperature path for the climate scenario to match the Moody's Analytics global model's quarterly periodicity



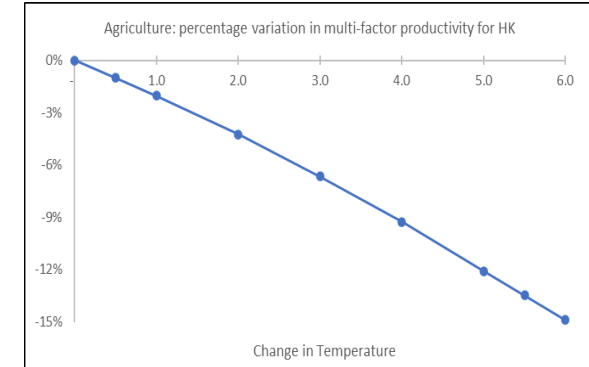
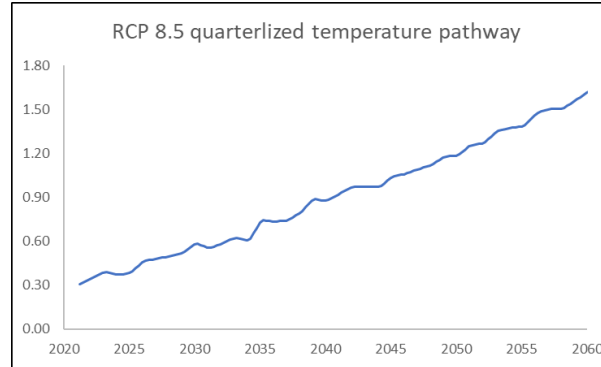
Link impact estimates from Roson & Sartori (2016) to key economic variables

Roson and Sartori (2016) summarizes climate change impacts from a series of meta-analyses that linked the impact channels to temperature fluctuations for all of the world's major countries. We connect these estimates to key economic variables



Construct time series of overlays

Construct time series of overlay from each impact channel to economic variable based on the quarterized temperature pathway



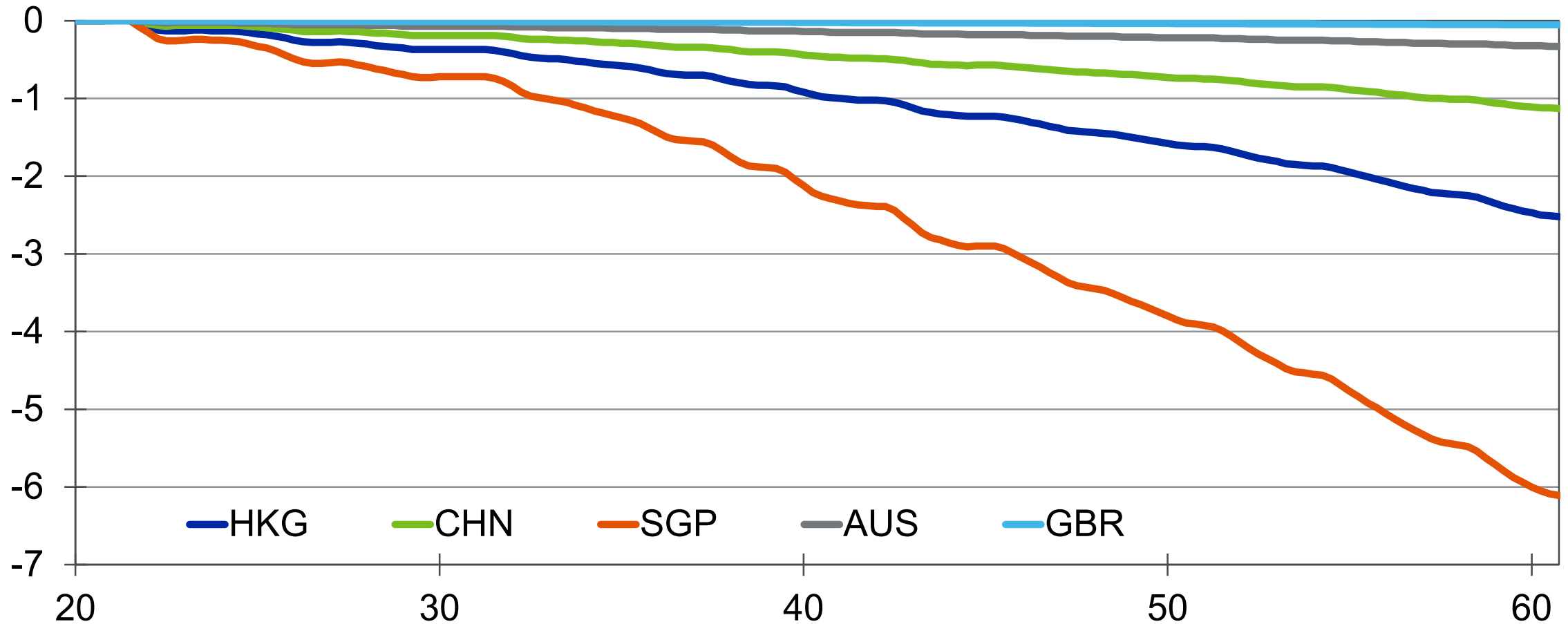
Change in Temperature	% Loss in Agr. Productivity	Agr. Share of Economy	Agr. Impact on Total Productivity
2021Q2 0.31	-0.6%	6.2%	-0.04%
2021Q3 0.32	-0.6%	6.2%	-0.04%
2021Q4 0.33	-0.7%	6.2%	-0.04%
.....
2060Q1 1.61	-3.4%	6.2%	-0.21%
2060Q2 1.63	-3.4%	6.2%	-0.21%
2060Q3 1.63	-3.4%	6.2%	-0.21%
2060Q4 1.64	-3.4%	6.2%	-0.21%

Source: Roson & Sartori (2016), Moody's Analytics

Productivity Overlay – RCP 8.5



% Deviation from CP

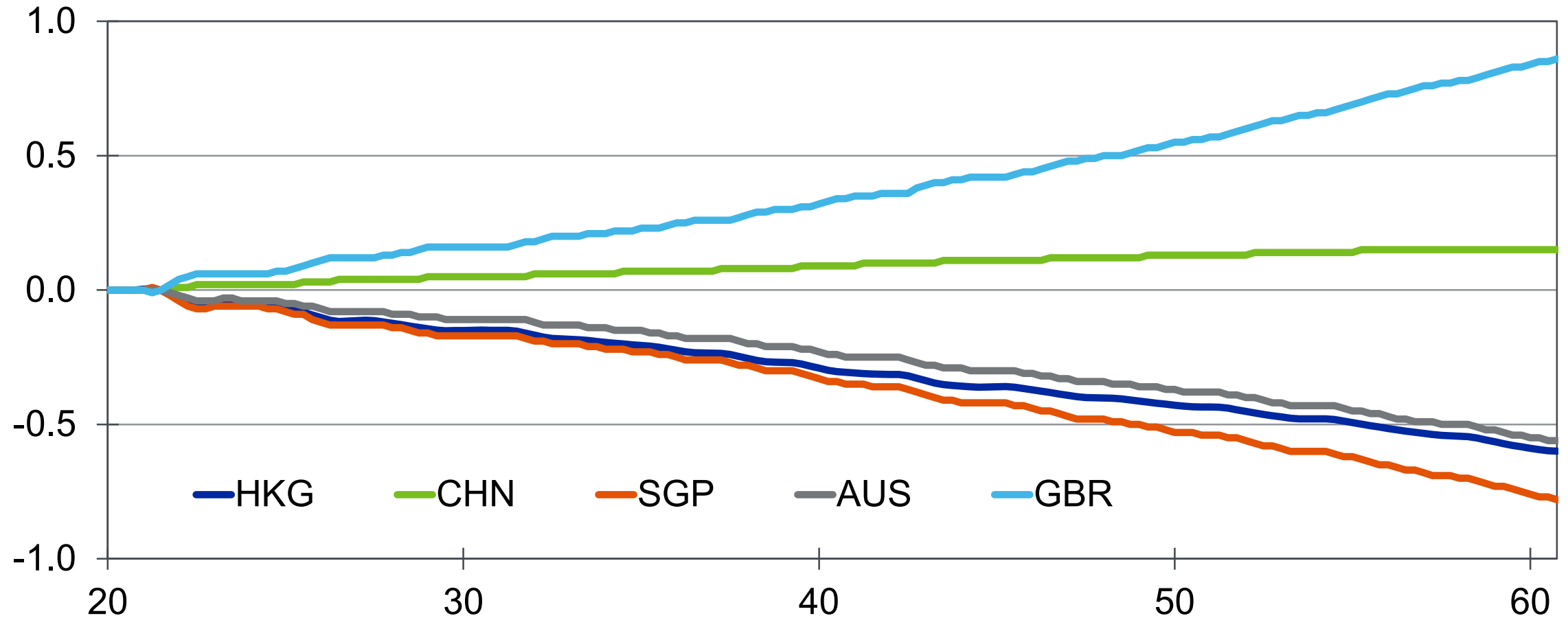


Source: Moody's Analytics

Real Exports Overlay – RCP 8.5



% Deviation from CP

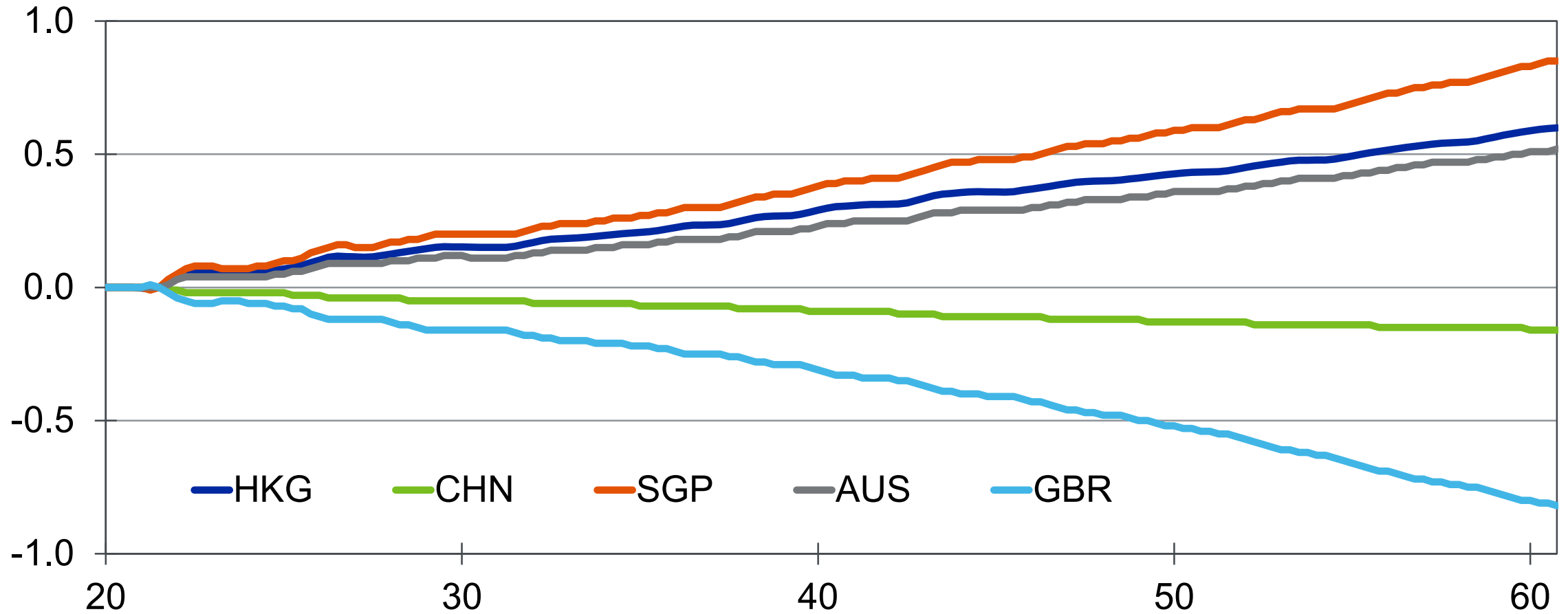


Source: Moody's Analytics

Real Imports Overlay– RCP 8.5



% Deviation from CP

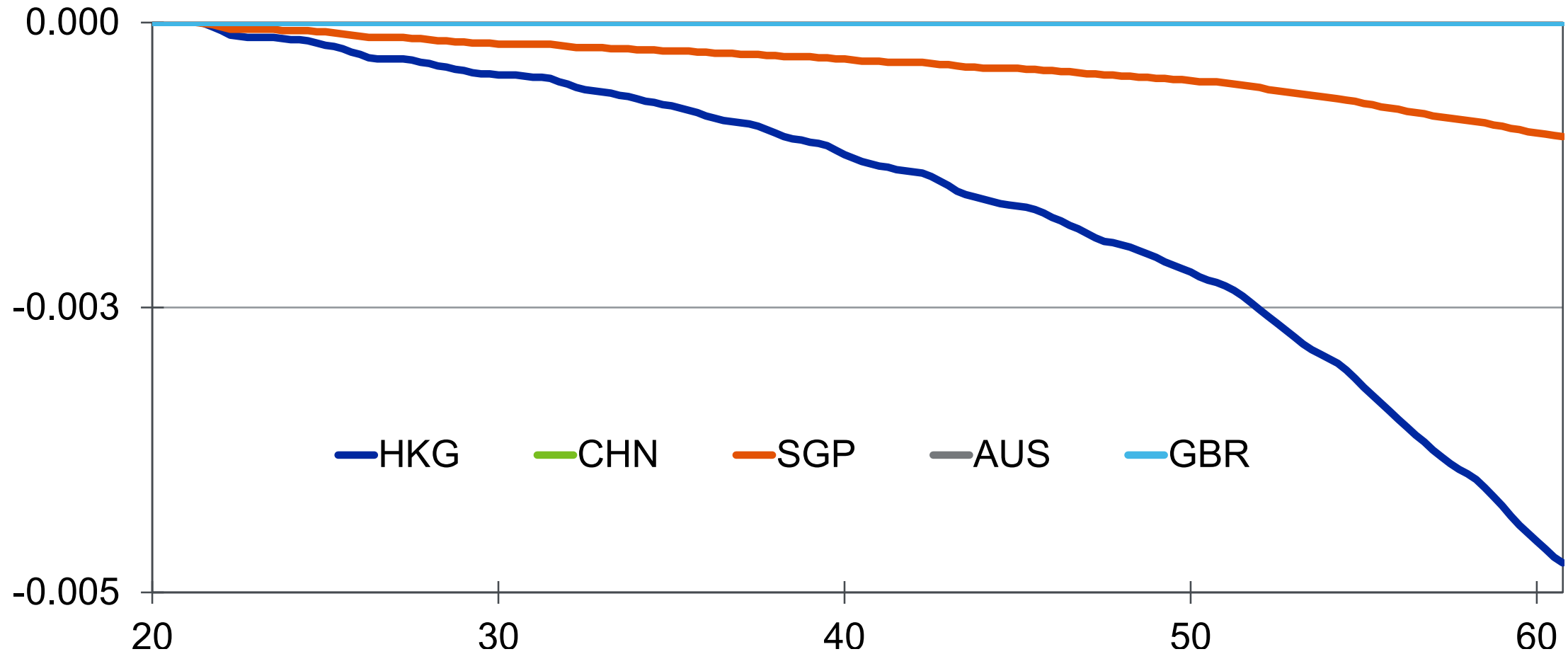


Source: Moody's Analytics

Real Consumption Overlay– RCP 8.5



% Deviation from CP

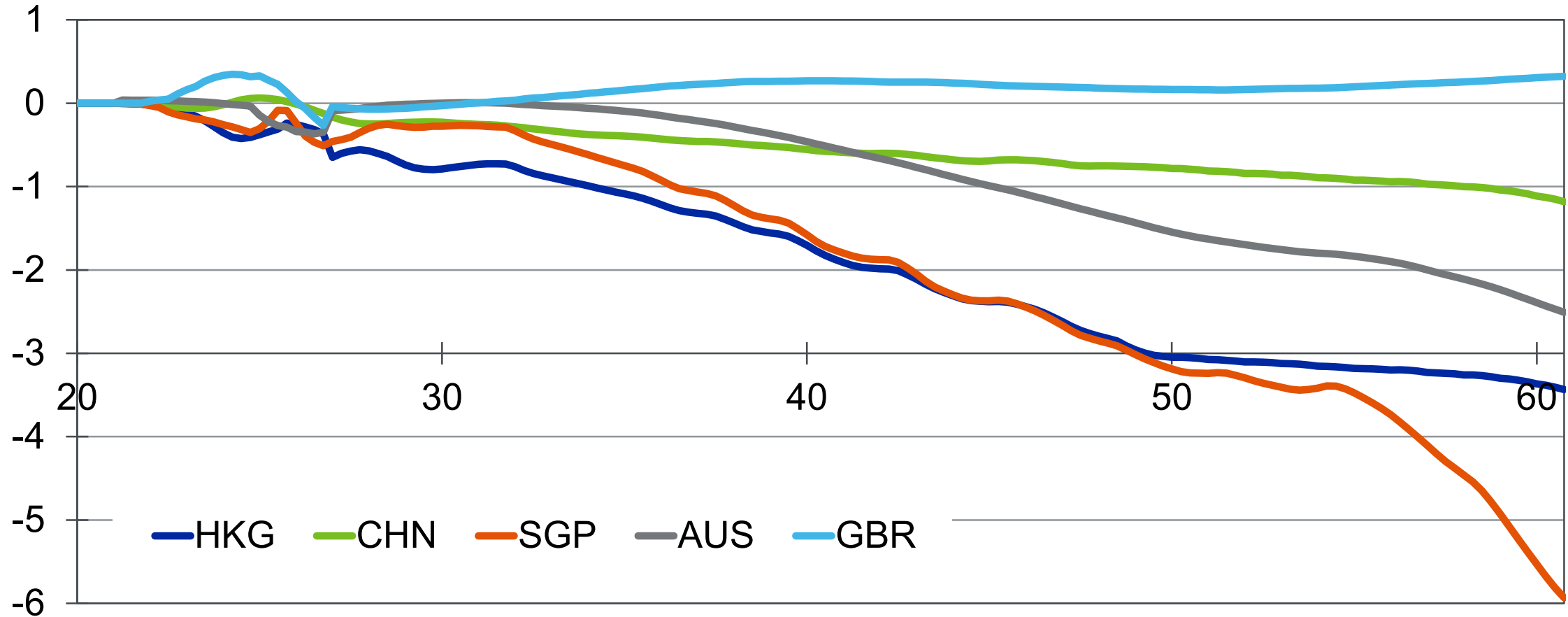


Source: Moody's Analytics

Real GDP – RCP 8.5 (PR Scenario)



% Deviation from CP



Source: Moody's Analytics

3

Generating transition risk scenarios

REMIND Region to Country Map

R5 regions were only used for Armenia and Kazakhstan.

The rest were REMIND regions.

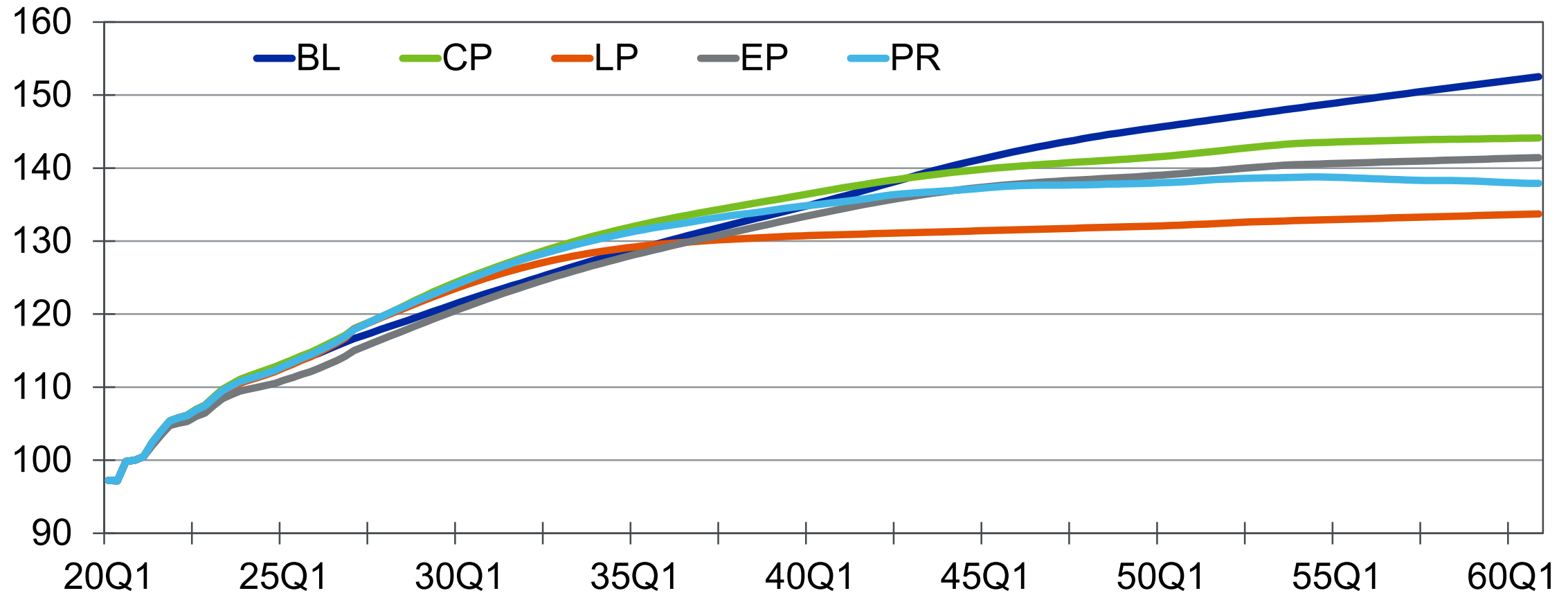
Country code	Country	Corresponding NGFS Region	Country code	Country	Corresponding NGFS Region	Country code	Country	Corresponding NGFS Region
DZA	Algeria	MEA	HUN	Hungary	EU	PHL	Philippines	Other Asia
ARG	Argentina	R5LAM	IND	India	India	POL	Poland	EU
ARM	Armenia	R5REF	IDN	Indonesia	Other Asia	PRT	Portugal	EU
AUS	Australia	ROW	IRL	Ireland	EU	QAT	Qatar	MEA
BHS	Bahamas	LAM	ISR	Israel	MEA	RUS	Russia	RUS
BHR	Bahrain	MEA	ITA	Italy	EU	SAU	Saudi Arabia	MEA
BGD	Bangladesh	Other Asia	JPN	Japan	Japan	SGP	Singapore	Other Asia
BEL	Belgium	EU	JOR	Jordan	MEA	SVK	Slovakia	EU
BMU	Bermuda	LAM	KAZ	Kazakhstan	R5REF	ZAF	South Africa	ROW
BRA	Brazil	LAM	KWT	Kuwait	MEA	KOR	South Korea	Other Asia
BRN	Brunei	Other Asia	LBN	Lebanon	MEA	ESP	Spain	EU
CAN	Canada	ROW	LUX	Luxembourg	EU	LKA	Sri Lanka	Other Asia
CHL	Chile	LAM	MAC	Macau	China	SWE	Sweden	EU
CHN	China	China	MYS	Malaysia	Other Asia	CHE	Switzerland	EU
COL	Colombia	LAM	MLT	Malta	EU	TWN	Taiwan	Other Asia
CRI	Costa Rica	LAM	MUS	Mauritius	AFR	THA	Thailand	Other Asia
CZE	Czech Republic	EU	MEX	Mexico	LAM	TUR	Turkey	ROW
DNK	Denmark	EU	NLD	Netherlands	EU	ARE	U.A.E	MEA
EGY	Egypt	MEA	NZL	New Zealand	ROW	GBR	UK	EU
FRA	France	EU	NOR	Norway	EU	URY	Uruguay	LAM
DEU	Germany	EU	OMN	Oman	MEA	USA	US	US
GRC	Greece	EU	PAK	Pakistan	Other Asia	VEN	Venezuela	LAM
HND	Honduras	LAM	PAN	Panama	LAM	VNM	Vietnam	Other Asia
HKG	Hong Kong	China	PER	Peru	LAM			

Sources: NGFS, Moody's Analytics

Real GDP Index – Hong Kong



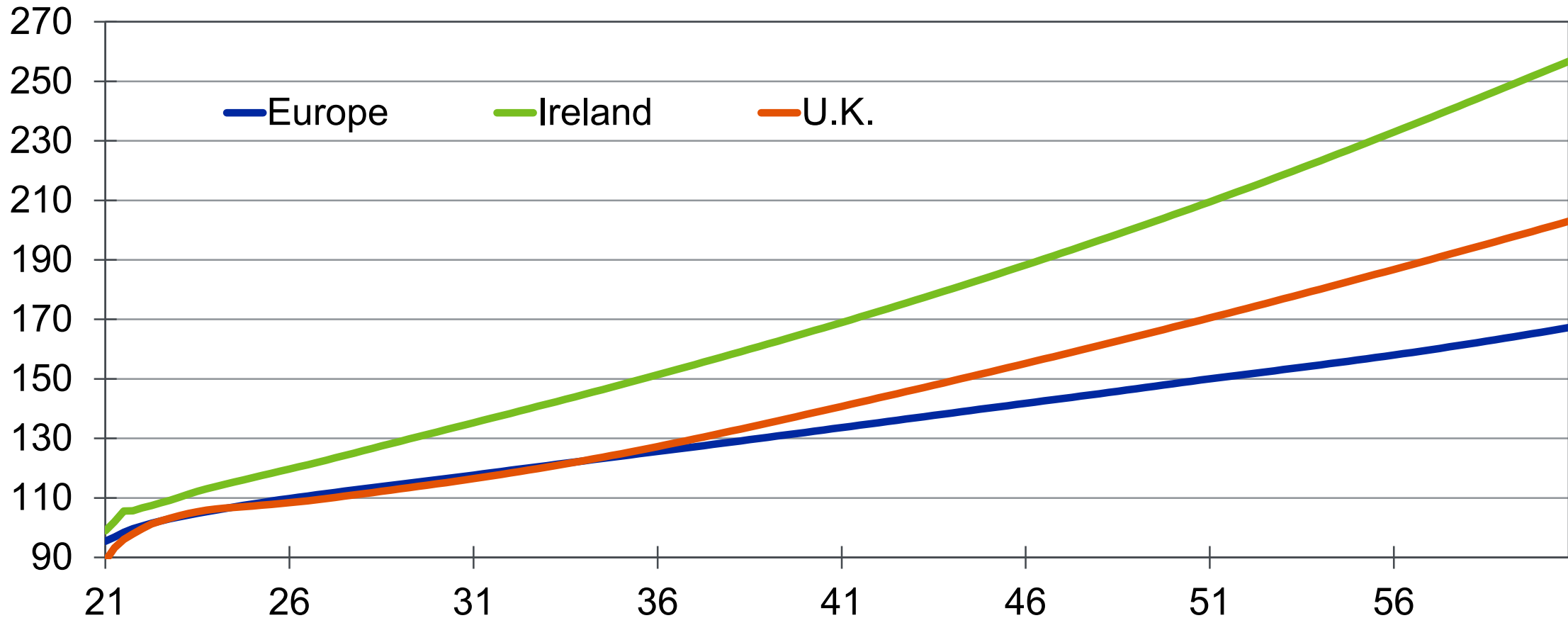
2020Q4=100



Sources: HKSARG, Moody's Analytics

Country GDP Targets Comparison

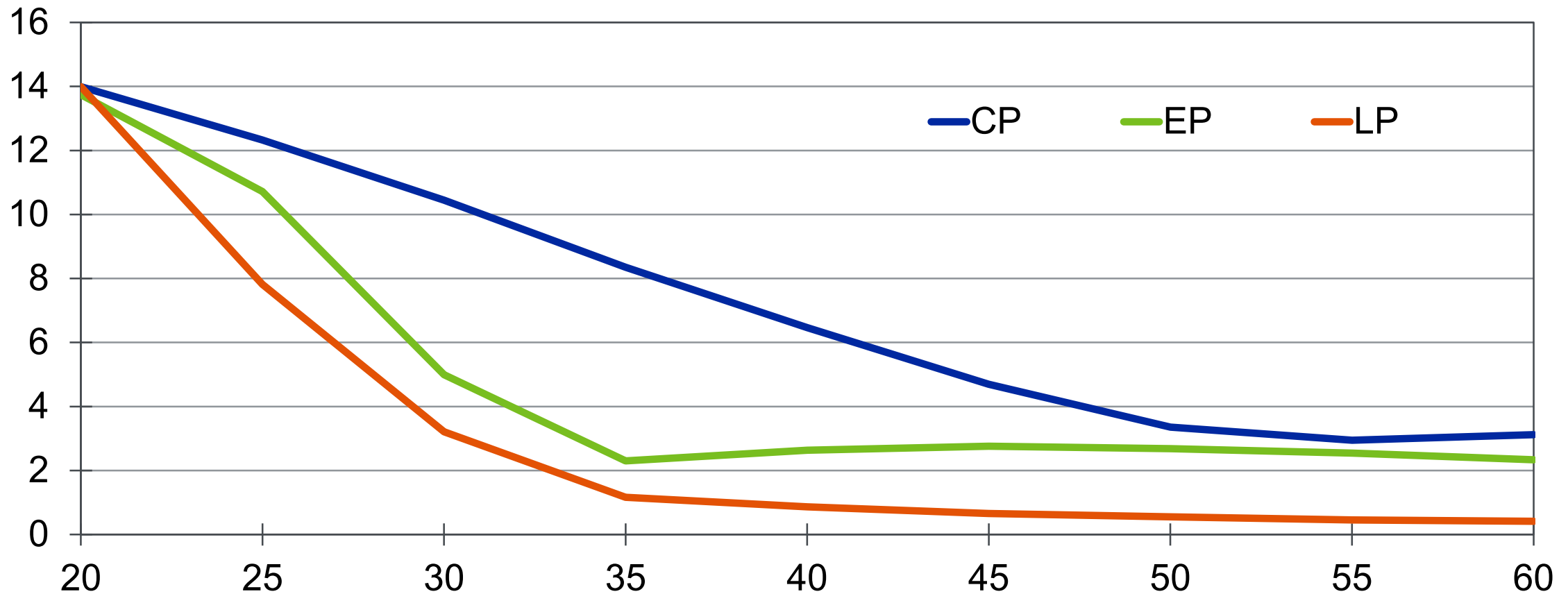
2019Q4=100, NGFS Early Policy scenario



Sources: NGFS, Moody's Analytics

Primary Energy Coal Consumption – U.S.

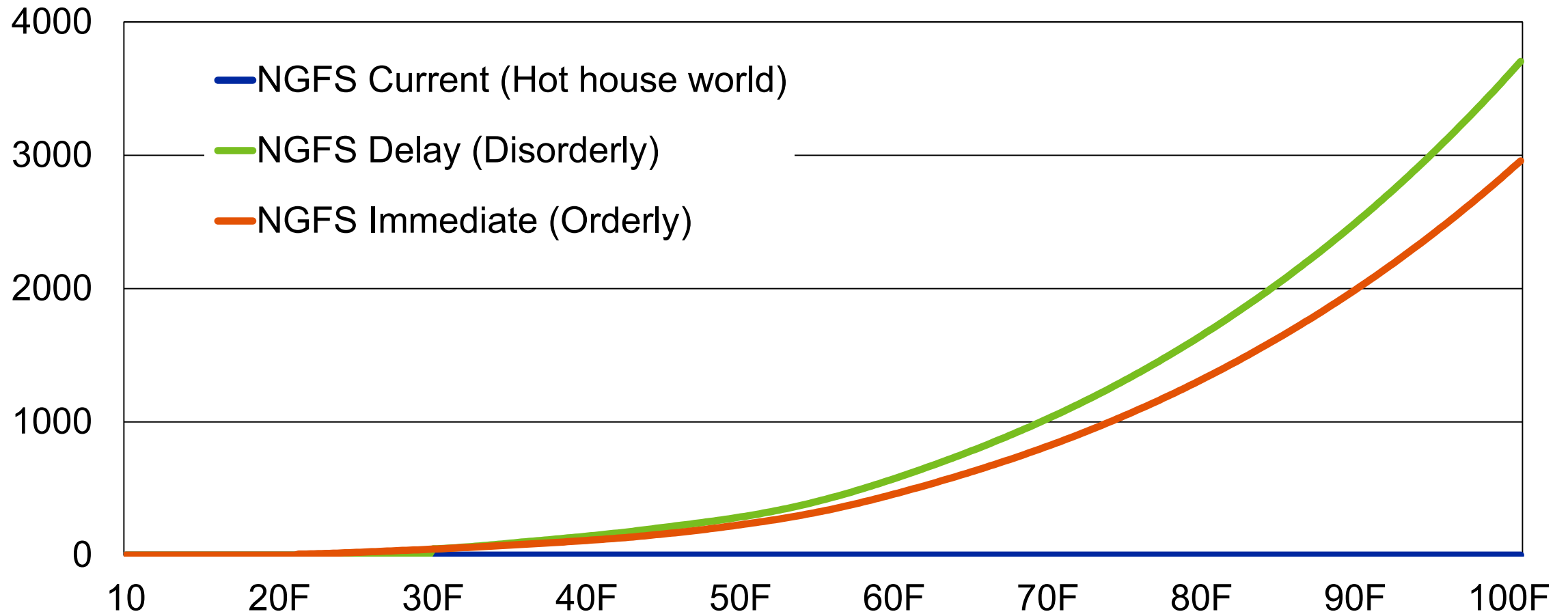
EJ/yr



Sources: NGFS, Moody's Analytics

U.K. Carbon Dioxide Tax Rate

GBP per metric ton, NSA

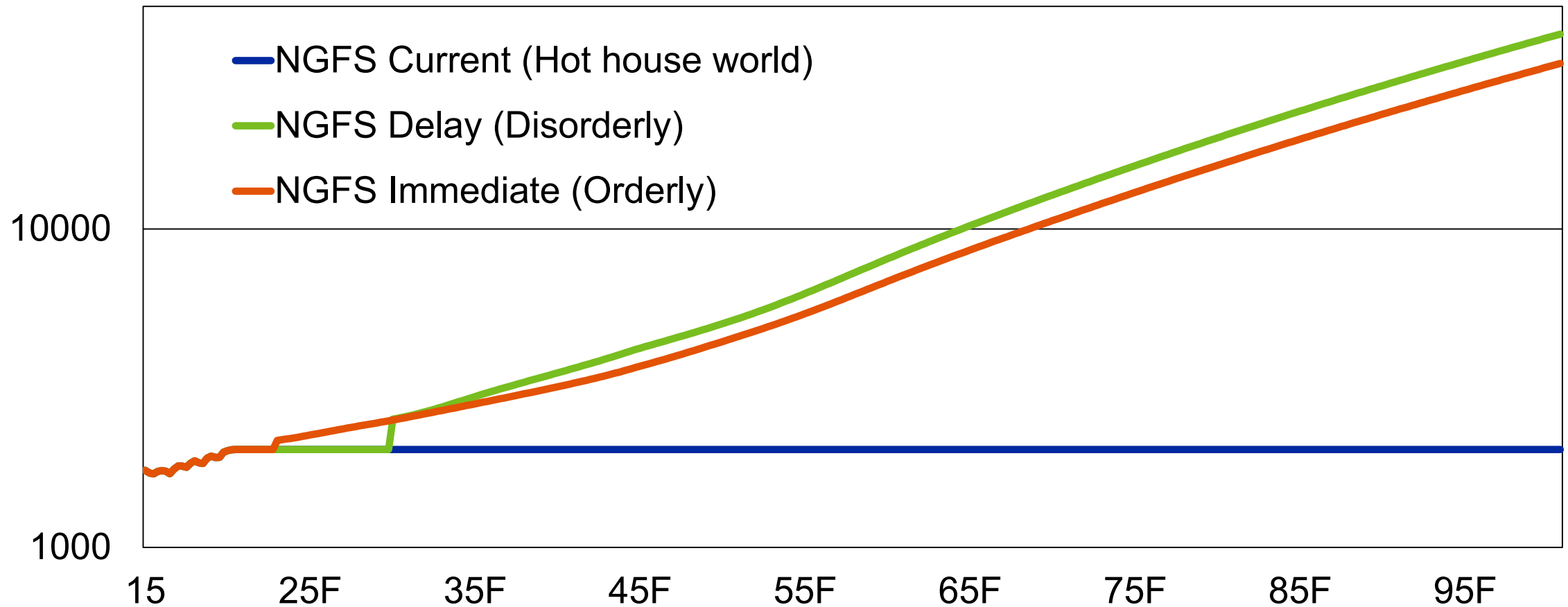


Sources: Network for Greening the Financial System; Moody's Analytics

U.K. Effective Domestic Price: Coal



1/100 GBP per #, NSA (Log scale)



Sources: U.K. Department for Business, Energy & Industrial Strategy; Moody's Analytics

4

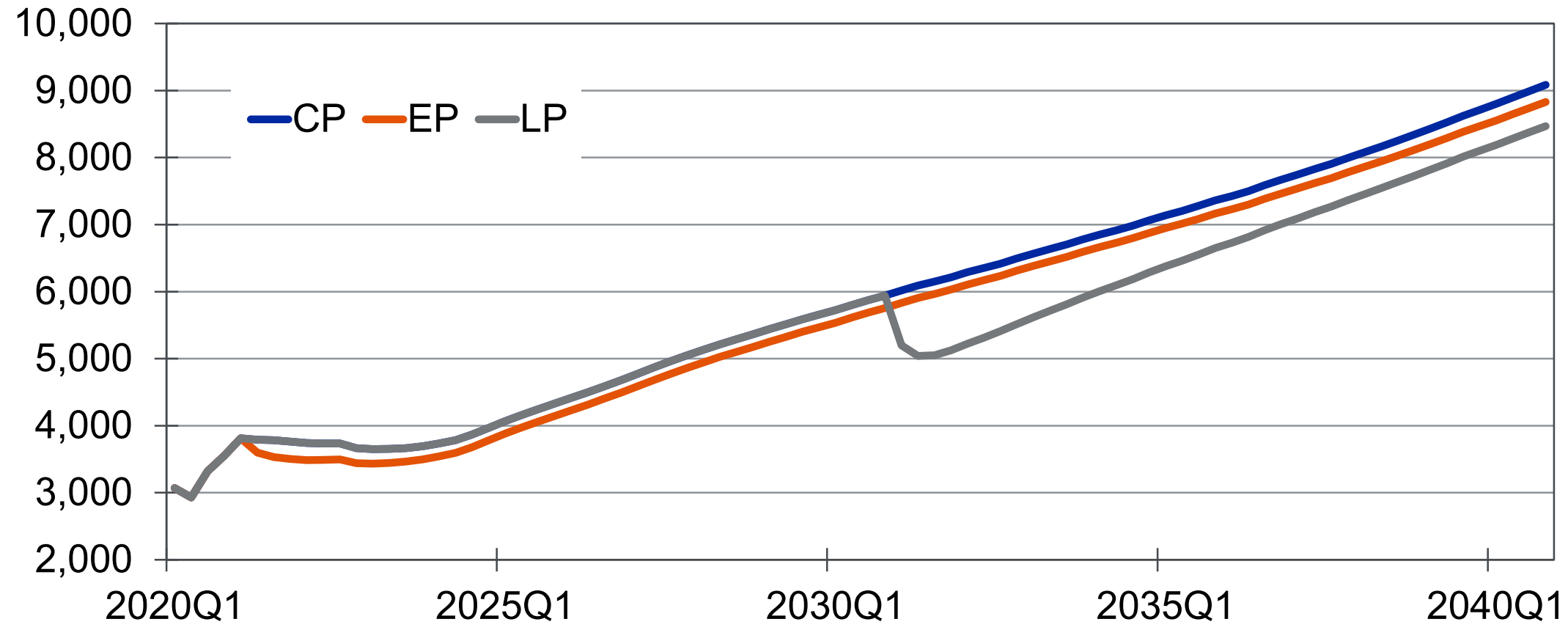
Approach to market risk modelling

Key Steps

- » We model the impact of physical and transition risks on equity and credit markets, frontloading shocks as markets process them.
- » We assume markets overreact under a disorderly transition.
- » We distinguish equity and credit market responses between more affected carbon-intensive and less affected other industries.
- » We model equities directly based on physical and transition risks in the macro-economy.
- » We model credit spreads based on aggregate credit spread widening and each industries credit transition, consistent with equity market responses.

U.S. Equity Prices

S&P 500, Index 1941-43=10 NSA



Sources: Standard & Poor's, Moody's Analytics

Aggregate Equity Shock by Geography

% Long-run decline in market value relative to current policy

Geography	Early Policy	Late Policy
United States	5.6%	8.3%
Hong Kong	4.1%	6.7%
China	17%	23%
Germany	6.8%	10.4%
India	9%	12%

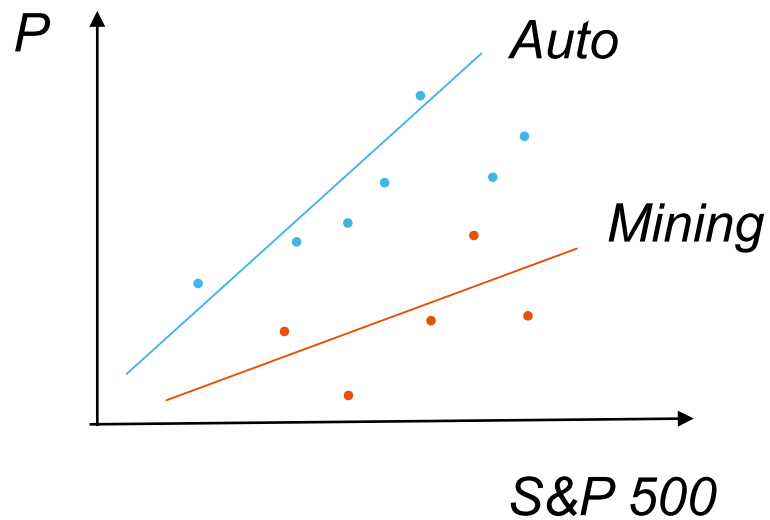
- Determined by pre-specified equity shocks by industry and country industry mix. All numbers are illustrative.
- Industrial breakdowns and member weightings obtained from Bloomberg, S&P Global, BSE India, and SIBLIS Research

Sources: BoE, Bloomberg, S&P, BSE India, SIBLIS, Moody's Analytics

Equities Disaggregation

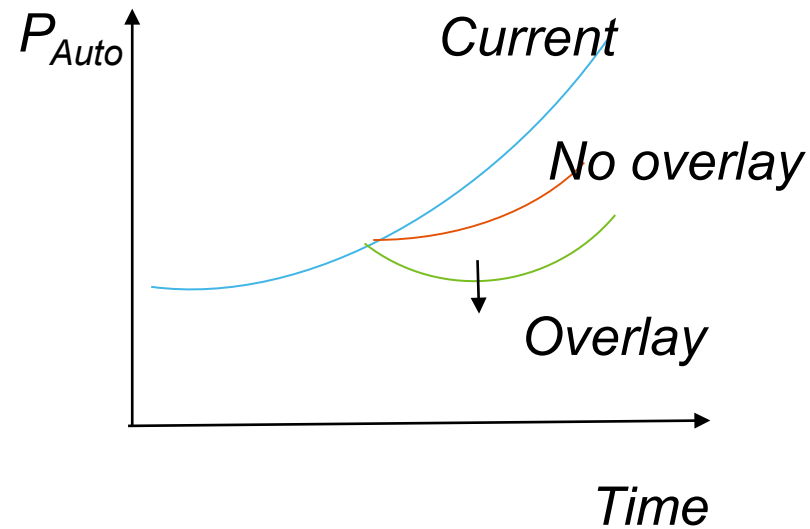
Step 1

Produce equations for each industry linking industry index to country index and other drivers



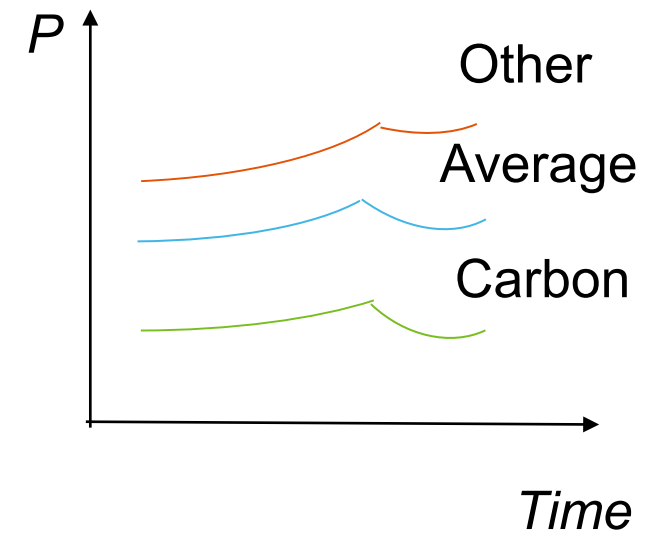
Step 2

Combine forecasts using country-specific drivers and bottom-up overlays



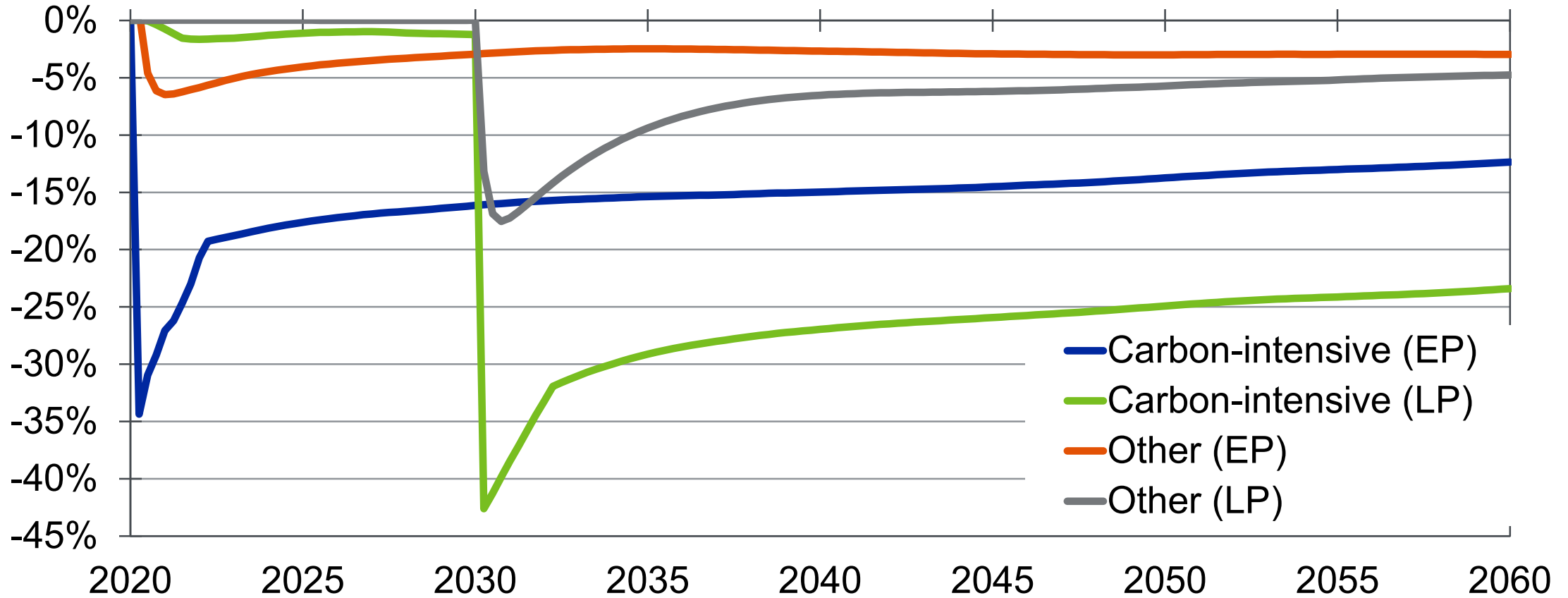
Step 3

Extract non-carbon intensive industries as residuals



U.S. Sub-index Equity Shocks

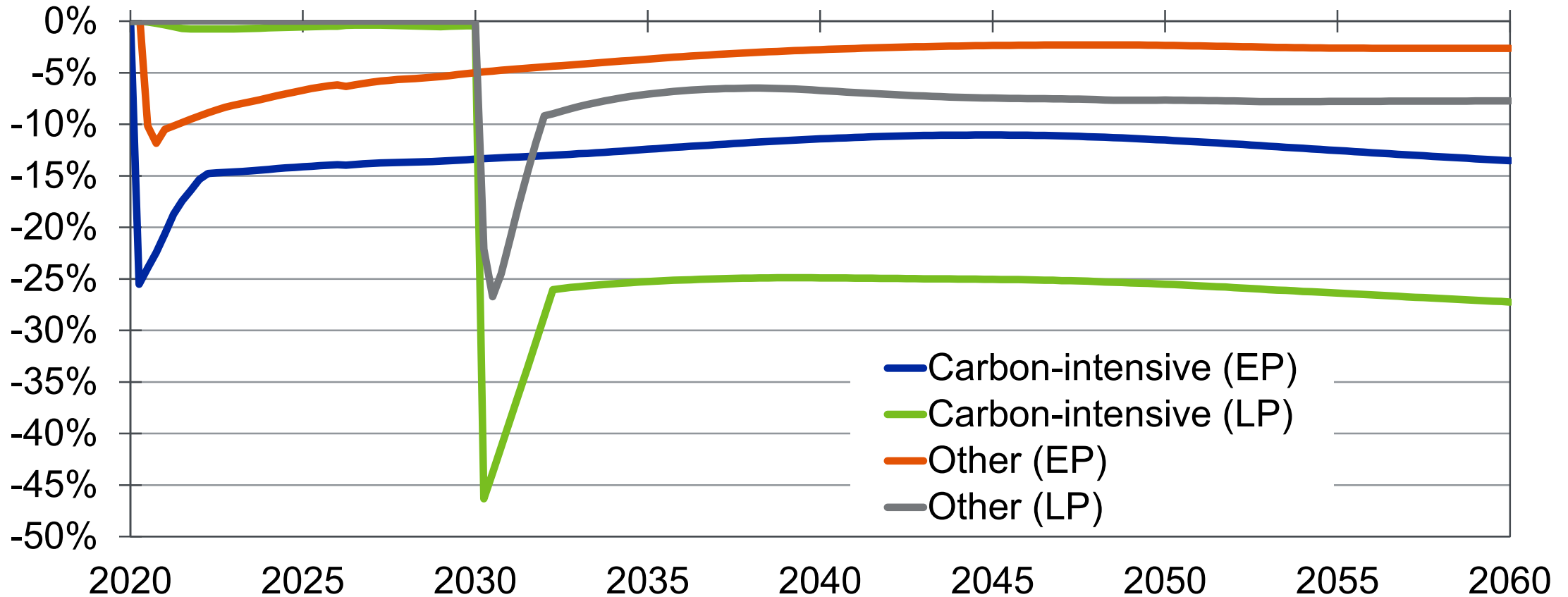
S&P 500, Shock relative to CP, %



Sources: Standard & Poor's, Moody's Analytics

HKG Sub-index Equity Shocks

Hang Seng, Shock relative to CP, %



Sources: SIX Financial, Moody's Analytics

Corporate Credit Spreads With Ratings Transition

Step 1

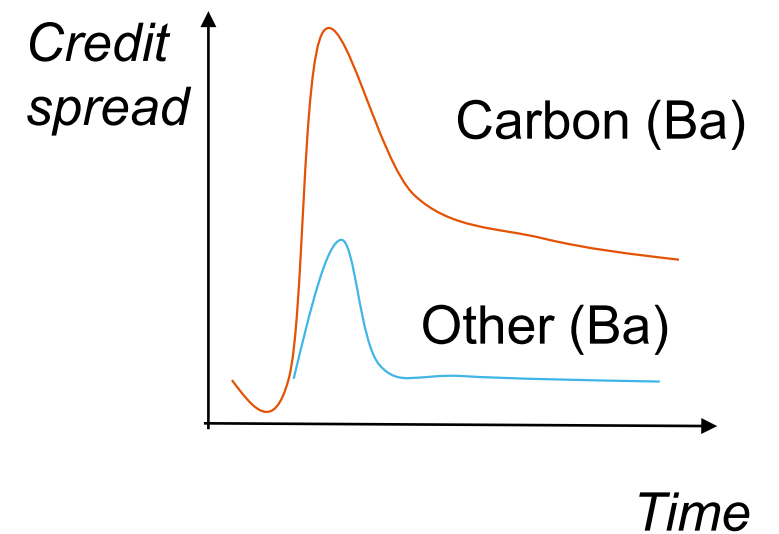
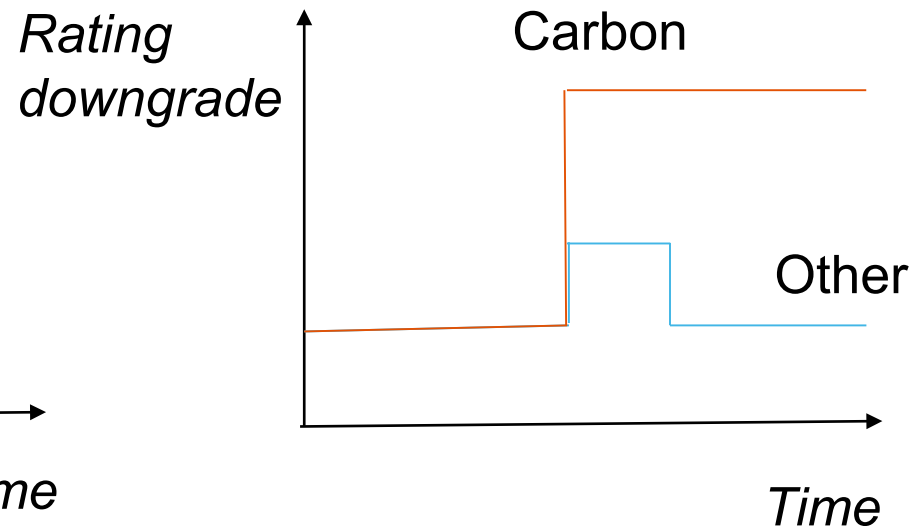
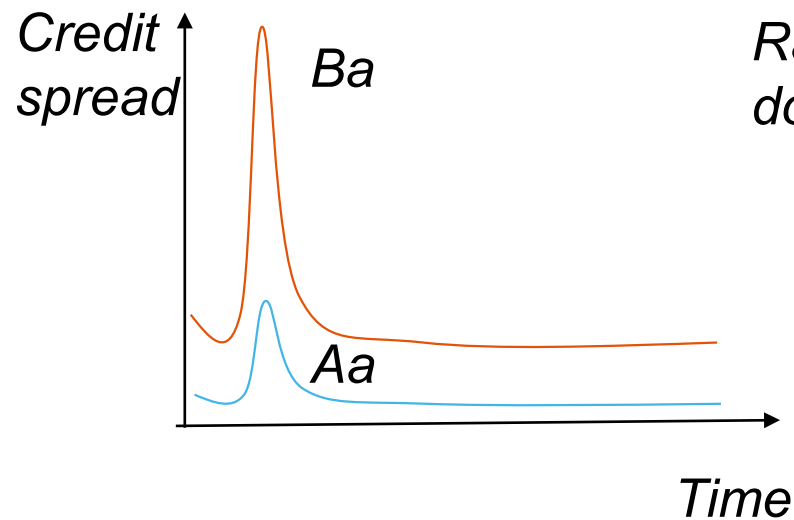
Forecast equations for aggregate ratings categories linking to market volatility

Step 2

Combine sector specific ratings with sector equity shocks to predict ratings transition

Step 3

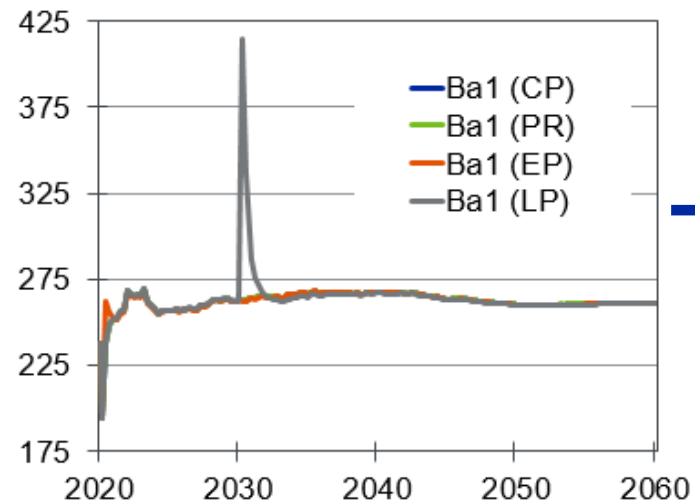
Combine aggregate credit spread with ratings transition



Ba1: HKG – Credit Shocks

Aggregate Credit Spreads

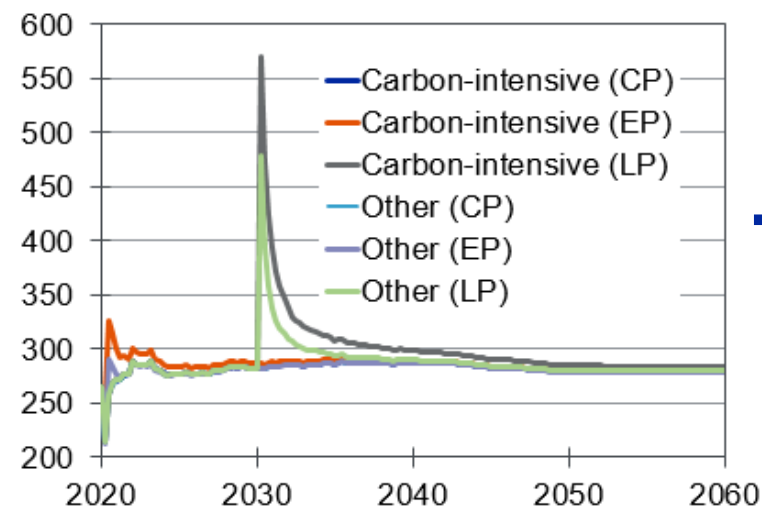
USD-yield spread over treasury, BPS



Sources: Moody's Investor Services, Moody's Analytics

HKG – Adjusted Credit Shocks

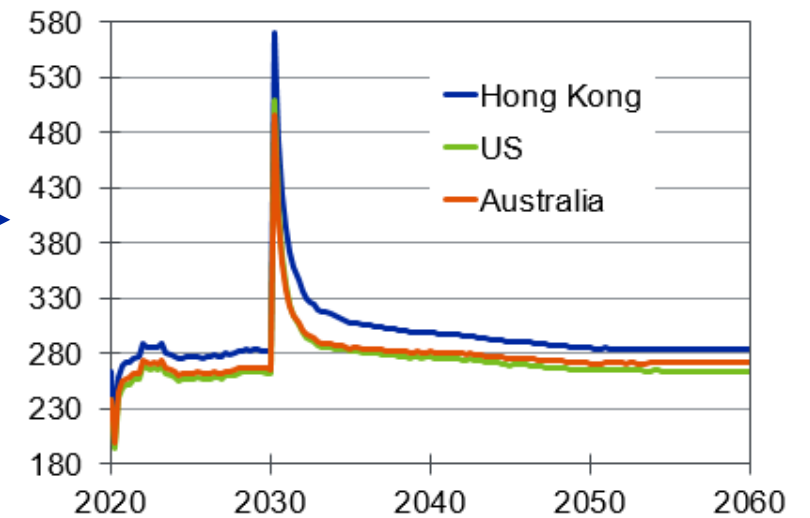
CDS-adjusted yield differential to treasury, BPS



Sources: Moody's Investor Services, Moody's Analytics

Country Comparison

CDS-adjusted yield differential to treasury, BPS



Sources: Moody's Investor Services, Moody's Analytics

Key Takeaways

- » Physical risk affects countries in APAC more than in the U.S. and the U.K.
- » Transition risk impact is generated via carbon tax.
- » HKMA separated physical risk from the transition risk.
- » A reference scenario is required.
- » Additional assumptions on pricing of assets are required to quantify the impact of climate change.
- » The impact of climate change varies across industries although the aggregate impact may be smaller.

Q&A



Additional questions? Email us at help@economy.com

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ANALYTICS

 SUSTAINABILITY
IN FOCUS

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