Compendium of Practice from a Global Community of Finance Ministries and Leading Organizations

Economic analysis and modelling tools to assist Ministries of Finance in driving climate action

Summary Report

A contributing thematic report for the Coalition of Finance Ministers for Climate Action's Helsinki Principle 4 workstream: Revamping Economic Analysis and Modelling to Drive Climate Leadership for Finance Ministries

February 2025

FINAL DRAFT – NOT FOR WIDER CIRCULATION

About this report

This report is an important product of the Helsinki Principle 4 (HP4) workstream under the Coalition of Finance Ministers for Climate Action, which works towards the overall aim of mainstreaming climate action into economic and fiscal policy. It forms part of an effort focused on improving macroeconomic analysis and modelling tools for Finance Ministries to drive climate action, including the capacity to assess the economic impacts of physical climate risk, climate mitigation, and adaptation measures. This is in recognition that many Finance Ministries urgently need improved access to tools able to address the most pressing climate policy questions they face now, tailored to and appropriate for their context, and operating on timescales which meet the needs of decision makers.

The report is the product of a Compendium of Practice, a global collaborative effort which consists of contributions from over 100 leading organizations and individuals gathered for this workstream. Many thanks to the numerous Coalition members, partners, and other individuals and organizations who directly contributed to the compendium. The report presents summaries of all contributions with a navigation device organized by policy questions, analytical tools, and capacity building efforts. The summaries avoid interpretation and reflect the information provided in the original full contributions. The full contributions, which typically span between 2 and 10 pages in total, are available in a separate report (the Full Contributions Report). Plans are underway to develop a web platform to house the Compendium.

Summaries of contributions were led by Hannah Maier-Peveling and Jessica Nicol. The contributions were commissioned by Nick Godfrey and Moritz Baer and went through one or more rounds of comments and clarifications. This report was coordinated by Hannah Maier-Peveling with support from Nick Godfrey at the Grantham Research Institute on Climate Change and the Environment. The overall effort was guided by Mads Libergren (Danish Ministry of Finance) in partnership with Leon Clarke (Bezos Earth Fund). It benefitted enormously from the convening of stakeholders at the inaugural Forum on the Macroeconomics of Green and Resilient Transitions held in April 2024. All contributions were provided in-kind and voluntarily.

This report is complemented by a range of other reports which are under development, some of which draw heavily on the Compendium of Practice. These include a survey of the world's Finance Ministries, an overview of analytical tools available to MoFs, and a range of other thematic papers in areas related to pressing climate policy needs by MoFs. A summary of the overall program objectives is captured in a separate report.

Disclaimer

This work is in draft form and is not for wider circulation; content is subject to approvals and editions. It was prepared at the request of and with the guidance of the Co-Leads of the Coalition's HP4 work program and the Steering Group of members assembled for this work program, with input from its Technical Advisory Group. The Compendium does not reflect the official views of the Coalition or its members, or the host institutions of the contributing authors, nor does this report represent an endorsement of any of the views expressed herein by any individual Member.

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1 Introduction to the Compendium of Practice

This Compendium of Practice is a global repository of contributions which showcase the knowledge and experience of a growing community of MoFs and supporting partners that are making significant strides towards mainstreaming climate change in macroeconomic analysis and modelling tools and are using these to drive climate action.

The Compendium features 133 contributions from across 73 institutions - including 42 contributions from 19 MoFs - spanning all continents.[1] Notably, over 15 specific model types – from Dynamic Stochastic General Economic (DSGE) models and Computable General Equilibrium (CGE) models to physical climate risk and catastrophe models – are mentioned or described. The contributions contain descriptions of more than 30 specific models that have been developed and are in use by various organizations across these categories, though not all model types are covered.[2] The Compendium includes contributions from MoFs alongside contributions from the international financial institutions, multi-national development banks, academic institutions, think-tanks, and private sector organizations, among others. We refer to this as the Community of Practice. The compendium was assembled for a program of work focused on improving macroeconomic analysis and modelling tools for Finance Ministries as part of Helsinki Principle 4 of the Coalition of Finance Ministers for Climate Action and beyond.

The contributions are diverse and cover, among other things, MoF experiences in building analytical capacity and deploying analytical tools to help answer specific climate policy questions they face; shortcomings of existing tools for capturing physical climate risk and the economic impacts of climate policies; development and implementation of new datasets and models; and the emerging ecosystem of support available to MoFs for building analytical capacity.

The collection of contributions is not exhaustive or definitive and is likely to be expanded and added to over time. However, it represents a significant sample of the global ecosystem of actors working on analytical tools relevant to Finance Ministries and other economic decisionmakers to inform climate action.

The Compendium of Practice is designed to provide a common reference point for the growing Community of Practice assembled as part of the overall program of work. It showcases the diversity of challenges in developing and deploying relevant analytical tools and ongoing work to help address these challenges. Through this exercise in information-sharing, the Compendium is intended to serve as a starting point for further, more detailed and direct engagement among peers and between policy makers and academia. The overall aim is for the Compendium to contribute to improved analytical tools being used within Ministries of Finance to inform the decisions needed to drive climate action at the pace and scale required.

More specifically, it is designed to be a resource to:

- Help MoFs think about issues that need to be considered in addressing the pressing climate policy questions they face.
- Provide an overview of specific model types and analytical approaches that might help address pressing policy questions.
- Provide real-world examples by leading MoFs and other organizations of how modelling and other analytical approaches can be used to address climate policy questions.

[1] Table 1.1 lists all contributing organizations.

[2] This discrepancy arises because some contributions describe a model type in general without there being a contribution describing a specific model of this type.

For ease of use, the Compendium presents contributions using a navigation device.[3] The contributions are separated into three overarching, overlapping, categories:

1. Addressing climate policy questions: These contributions cover climate-related policy questions faced by MoFs, and how analytical tools have been deployed to help address them. They are further organized into the following themes:
    - The economic and fiscal impacts of climate change
    - The economic and fiscal impacts of adaptation and resilience
    - The economic and fiscal impacts of the green transition
    - Financing the green and resilient transition
    - Managing synergies and trade-offs with other policy priorities

2. Specific analytical tools and approaches: These contributions focus on *specific* tools and approaches themselves, not necessarily the results and impacts of their application. They are further organized into the following categories:
    - Specific modelling tools
    - Considerations for modelling
    - Other analytical approaches and methodologies
    - Data sources

3. Enhancing analytical capacity: These contributions outline support available to MoFs for building analytical capacity and MoF experiences in seeking to do so. Hence, they are organized into the following categories:
    - Capacity building offers: organizations showcasing capacity building support available to MoFs
    - Capacity building case studies: examples of country's capacity building efforts

Additionally, each contribution is flagged with up to five keywords which are used across all three categories.

The remainder of this document is structured as follows. Section 2 explains the navigation tool in further detail and contains a navigation table in which each contribution is placed in its respective category. Section 3 through 5 contain the contribution summaries for each of the three categories of contributions.

Importantly, the Full Contributions are available as a separate report which mirrors the structure of the navigation tool. Additionally, Appendix A (also available separately) contains a table listing all keywords used across the Compendium's contributions, an overview of contributions and their associated keywords, as well as a table listing contributions by keyword.

Table 1.1 List of contributing institutions (with some providing multiple contributions)

Institution	
Australia – Department of the Treasury	Inter-American Development Bank (IDB) / French Development Agency (AFD)
Austria – Ministry of Finance	Harvard Growth Lab
Canada – Department of Finance	IMF (Several Departments)
Denmark – Ministry of Finance	Imperial College London
Ecuador – Ministry of Economy and Finance	Independent – CETEx
European Union – European Commission (Various Departments)	Independent High-Level Expert Group on Climate Finance (IHLEG)
Finland – Prime Minister's Office	Institute and Faculty of Actuaries / M&G

[3] Section 2 explains this in further detail.

International Growth Centre – Rwanda Office (with Rwanda Ministry of Finance)	Insurance Development Forum
Ireland – Department of Finance	London School of Hygiene & Tropical Medicine
Ireland – Department of Public Expenditure, NDP Delivery and Reform (DPENDR)	Marsh McLennan
Italy – Ministry of Economy and Finance	Massachusetts Institute of Technology – Abdul Latif Jameel Poverty Action Lab (J-PAL)
Mexico – Ministry of Finance	Munich Climate Insurance Initiative (MCII)
Morocco – Ministry of Economy and Finance	NDC Partnership
Sierra Leone – Ministry of Finance	Network for Greening the Financial System (NGFS)
Spain – Ministry of Economy, Trade and Enterprises	New Climate Economy – Independent
Sweden – National Institute of Economic Research (NIER)	OECD (Organisation for Economic Co-operation and Development)
Switzerland – Federal Department of Finance	Oxford Institute of New Economic Thinking
Uganda – Ministry of Finance, Planning and Economic Development	Partnership for Economic Policy
Biden-Harris Administration – Council of Economic Advisors (CEA) / Office of Management and Budget (OMB), Executive Office of the President of the United States (EOP) under the Biden-Harris Administration	Paul Watkiss Associates
Biden-Harris Administration – U.S. Department of the Treasury under the Biden-Harris Administration	RAND Corporation
Uruguay – Ministry of Economy and Finance	Resilience Adaptation Mainstreaming Program (RAMP)
Asian Development Bank (ADB)	S-Curve Economics
Cambridge Econometrics	Sciences Po – French Economic Observatory (OFCE)
Centre for Social and Economic Progress (CSEP)	SOAS University of London
Coalition for Capacity on Climate Action (C3A)	UNEP (United Nations Environment Programme)
Coalition of Finance Ministers for Climate Action	University College London
Council on Economic Policies	University of Cost Rica
Danish Energy Agency (DEA)	University of East Anglia
Danish Research Institute for Economic Analysis and Modelling (DREAM)	University of Exeter
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)	University of Manchester
Economic and Social Research Institute (ESRI)	University of Montevideo
Environmental Change Institute – University of Oxford	University of Oxford
Environment for Development Initiative	University of Wisconsin–Madison
ETH Zürich	Willis Towers Watson
France Stratégie	World Bank (Several Departments)
Grantham Research Institute on Climate Change and the Environment	World Resources Institute (WRI)
Green Macroeconomic Modeling Initiative (GMMI)	

2 How to Navigate the Compendium of Practice: An Overview of the Contributions

As outlined in the introduction, the contributions comprising the Compendium of Practice are organized via a navigation device to make it easier to find and access contributions relevant for specific purposes. The device organizes each contribution into one of the three overarching, overlapping categories (addressing climate policy questions, specific analytical tools and approaches, and capacity building), each of which is broken down further.

The remaining parts of this section outline this breakdown and indicate which contributions are organized into which category. The contribution titles in each table are hyperlinked to the corresponding contribution summary in the main part of this report (Sections 3 through 5). This main part mirrors the structure of the navigation device, with summaries presented in the same order as contributions are listed here.

2.1 Addressing the Climate Policy Questions Facing Finance Ministries

This first category of contributions pertaining to policy questions is the most complex to navigate. Hence, it has two layers of categorization, whilst the latter two have only one. Here, the first layer consists of five themes: climate change, adaptation and resilience, green transition, finance, and interacting policy priorities. The second layer consists of a total of 15 more detailed policy questions, each of which sits within one theme. Table 2.1 draws up this structure, populated with the associated contributions. It contains 64 contributions.

Table 2.1 Contributions about addressing climate policy questions

Theme	Policy question	Contribution
The economic and fiscal impacts of climate change	What physical climate risks are there and what are their economic implications?	European Union – European Commission: A structured approach to disaster risk financing in the European Union Member States
		European Union – European Commission: Integrating physical climate risks to public debt sustainability in the European Union Member States
		Mexico – Ministry of Finance: Assessing the fiscal risks of physical climate change
		Ecuador – Ministry of Economy and Finance: Analytical tools used by Ecuador's Ministry of Finance to understand impacts of physical climate risk on economy
		Australia – Department of the Treasury: Estimating the Impact of Selected Physical Climate Risks on the Australian Economy
		Biden-Harris Administration – Council of Economic Advisors (CEA) / Office of Management and Budget (OMB), Executive Office of the President of the United States (EOP) under the Biden-Harris Administration: The United States' Efforts to Account for Climate-Related Financial Risk to the Federal Budget
		Network for Greening the Financial System (NGFS): The NGFS's approach to the macroeconomic assessment of physical risks
		World Bank: Strategic Climate Risk Modeling for Economic Resilience: A Guide for Ministries of Finance
		Institute and Faculty of Actuaries / M&G: The urgent need for Finance Ministries to factor systemic climate risk into their economic analysis and modelling approaches and principles for doing so: a view from the insurance and pensions industry
		Grantham Research Institute on Climate Change and the Environment: Climate Tipping Points
		Environment for Development Initiative: Heat waves, labor productivity and incomes in India – a rising need for adaptation policies
		World Bank – Finance, Competitiveness & Innovation Global Practice (FCI GP): Stronger Analytics for Better Financial Resilience against Climate Shocks and Disasters
		University of East Anglia: Methodological recommendations for Finance Ministries on climate change risk assessment and the enhancement of damage functions
		ETH Zürich: New Approaches to Quantifying the Fiscal Impacts of Physical Climate Change
		Marsh McLennan: How can analytical tools and methods used in the (re)insurance industry support Ministries of Finance in their understanding of physical climate risks and their efforts to support climate adaptation?
	How does the economy rely on	Finland – Prime Minister's Office: Nature and ecosystem service impacts should be better included in assessments of the economic impacts of climate

	nature and ecosystem services?	risk by Finance Ministries and Economic Decision-makers – The Experience of Finland
		Finland – Prime Minister's Office: Strengthening capabilities to undertake economic impact assessments of climate strategies and impacts – The Finnish experience
		Coalition for Capacity on Climate Action (C3A): Filling in the gaps for Ministries of Finance on nature: Assessing the tools, instruments, and macrofinancial implications of the nature transition
The economic and fiscal impacts of adaptation and resilience	What is the economic case for adaptation?	IMF – Fiscal Affairs Department: The critical role of Finance Ministries for investment in adaptation and the analytical principles and tools available
		Paul Watkiss Associates: The Analysis of Climate Impacts, Adaptation Costs and Adaptation Benefits in the UK
		Paul Watkiss Associates: Global Adaptation Finance Costs, the Adaptation Finance Gap and Adaptation Investment Planning
		Environmental Change Institute – University of Oxford: The Fiscal Case for Adaptation and Improved Sustainability Analysis
	Which measures can drive adaptation and resilience?	European Union – European Commission: Determining Investment Needs to Decarbonisation and Adaptation: The Challenge and Opportunity for Finance Ministries in the European Union
The economic and fiscal impacts the green transition	What measures can drive the green transition and climate mitigation?	Sierra Leone – Ministry of Finance: Climate Policy Priorities in Sierra Leone
		World Bank: The low-carbon challenge facing Ministries of Finance
		Massachusetts Institute of Technology – Abdul Latif Jameel Poverty Action Lab (J-PAL): How Finance Ministries and Economic Decision-Makers Can Use Ex-Post Pilot Assessments to Inform Climate Policy - Designing, testing, and scaling emissions markets in India
		Council on Economic Policies: It Takes Two to Tango – The Role of Finance Ministries in Pricing and Non-Pricing Policies for a Low-Carbon Economy
		Centre for Social and Economic Progress (CSEP): Non-Price Policies for Addressing Climate Change: Challenges in Assessing Performance of Policy Packages for Finance Ministries and Economic Decision-Makers
		France Stratégie: Key messages from the report "The economic implications of climate action"
		University College London: Analytical and policy approaches to climate policy and the economy
		Economic and Social Research Institute (ESRI) / Ireland – Department of Finance: Carbon taxes, distributional implications, and revenue recycling
	Which technologies should a country focus on?	Oxford Institute of New Economic Thinking: Time series models for forecasting technological change, particularly for energy technologies: approaches relevant to Finance Ministries
		Danish Energy Agency (DEA): Technology Catalogues – Experience from Denmark
	What measures can drive scale up of technologies?	University of Wisconsin–Madison: How government actions have accelerated clean energy innovation: Lessons for economic analysis and modelling by Finance Ministries
		S-Curve Economics / University of Exeter / University of Manchester: Policy packages for cost-effective transitions: learning from the past, simulating the future with the Future Technology Transformations model, and case studies from the Economics of Energy Innovation and System Transition project
	What are the domestic impacts of international climate policy?	Massachusetts Institute of Technology – Abdul Latif Jameel Poverty Action Lab (J-PAL): How low- and middle-income countries can prepare for carbon border adjustment mechanisms – Emerging analytical support available for Finance Ministries
	What are the macroeconomic impacts of the transition and how	Sweden – National Institute of Economic Research (NIER): NIER annual report
		Mexico – Ministry of Finance: Live transition risks – The impacts of climate action on state owned enterprises and qualitative and causal link approach in addressing challenges

	can they be managed?	Biden-Harris Administration – U.S. Department of the Treasury under the Biden-Harris Administration: Economic impact assessment of Inflation Reduction Act (IRA)
		Willis Towers Watson: The economic impacts of disorderly climate transitions - How Finance Ministries can avoid boom and bust with sound economic analysis and effective climate policy
		World Resources Institute (WRI): Informing economic modelling approaches for effective climate transitions
		Coalition for Capacity on Climate Action (C3A): Transition scenarios for Ministries of Finance: A review of relevant approaches and a roadmap for upgrading analytical capability
		S-Curve Economics / University of Manchester / University of Exeter: Low carbon innovation and industrial strategy: analytical tools and frameworks for Ministries of Finance
		World Bank: Findings from the World Bank Group's Country Climate and Development Reports on the macroeconomic impacts of resilient and low-emissions development scenarios
		World Bank: New modelling approach combining bottom-up sectoral analyses with top-down macroeconomic models to understand the economic impacts of resilient and low-emissions development
		Asian Development Bank (ADB): Helping MoFs to Understand the Macroeconomic Impacts of the Transition to Net Zero in Asia
	What are the risks to the financial system from the transition and how can they be managed?	IMF: Understanding the Financial Stability Implications of Climate Risks: Approaches to Climate Risk Analysis in FSAPs
		Network for Greening the Financial System (NGFS): The NGFS's approach to modelling the short-term macroeconomic implications of climate change and the transition
	What are the fiscal impacts of the transition and how can they be managed?	Switzerland – Federal Department of Finance: Introduction of a replacement levy on electric vehicles
		Inter-American Development Bank (IDB) / French Development Agency (AFD) / University College London: How fossil-fuel reliant ministries of finance can assess the fiscal risks of global climate action
		Inter-American Development Bank (IDB) / French Development Agency (AFD) / University of Costa Rica: Managing the Fiscal Impacts of Electric Vehicles, Public Transport, and Biking
		Ireland – Department of Finance: Modelling Carbon Tax Projected Revenues 2024-2030 in Ireland
	What are the distributional and socio-economic impacts of the transition and how can they be managed?	European Union – European Commission: Assessing the distributional consequences of the transition in the EU
		World Bank: Identifying Labor Market Frictions in the Green Transition: Implications for Finance Ministries
		London School of Hygiene & Tropical Medicine: The health co-benefits of climate change mitigation: Why climate leadership by Finance Ministries can help them to deliver on their core objectives of economic development and responsible management of the public finances
		Centre for Social and Economic Progress (CSEP): India's Net Zero Transition: The Challenges within Existing Modelling Approaches of Economic Impacts
Financing the green and resilient transition	How can MoFs help finance investment in the green transition?	Ecuador – Ministry of Economy and Finance: Ecuador's Debt-For-Nature Swap
		Coalition for Capacity on Climate Action (C3A): Financing the transition: How can MoF build sustainable financial strategies and what analytical tools do they need?
		Imperial College London: Climate Finance at Scale to Implement Nationally Determined Contributions: Decarbonizing the Power Sector
		Paul Watkiss Associates: Mainstreaming and financing climate change adaptation in Rwanda

		Independent High-Level Expert Group on Climate Finance (IHLEG): The investment imperative and the critical role of Ministries of Finance
		Environmental Change Institute – University of Oxford: Institutional Architecture and Mobilisation of Private Capital for Adaptation: The Case of Rwanda
Managing synergies and trade-offs with other policy priorities	How does climate policy interact with other policy priorities and mandates MoFs are responsible for and how can the synergies be maximized?	Asian Development Bank (ADB): Navigating the Trade-offs between Investments for Growth and Climate Action: The Role of the Social Discount Rate
		World Resources Institute (WRI): How system dynamic models can inform India's low carbon pathways

2.2 Specific Analytical Tools and Approaches relevant to Ministries of Finance

This category of contributions pertains to specific analytical tools and approaches and is further broken down into four categories: specific modelling tools, considerations for modelling, methodologies, and data sources. Table 2.2 draws up this structure, populated with the associated contributions. It contains 55 contributions.

Table 2.2 Contributions about specific analytical tools and approaches

Category	Contribution
Specific modelling tools	European Union – European Commission: Overview of the European Commission's energy and climate policy-related modelling suite
	Switzerland – Federal Department of Finance: Modeling the fiscal impacts of the net-zero target within fiscal sustainability analysis
	Italy – Ministry of Economy and Finance: The Italian Ministry of Economy and Finance climate-related modelling tools – How to build a flexible suite of models serving different purposes
	Morocco – Ministry of Economy and Finance: Assessment of the impacts of climate change on the national economy via the agricultural sector
	Morocco – Ministry of Economy and Finance: Computable general equilibrium model for the introduction of a carbon tax for the Moroccan economy
	Morocco – Ministry of Economy and Finance: DEPF models for evaluating mitigating GHG emissions and adapting to climate change policies in Morocco
	Sweden – National Institute of Economic Research (NIER): Sweden's EMEC model designed to study the long-term economic effects of energy and climate policies
	Canada – Department of Finance: Finance Canada CGE model
	Sierra Leone – Ministry of Finance: Sierra Leone's First Climate-Economy Model: Challenges Posed, Arising Opportunities
	IMF – Fiscal Affairs Department: Fiscal Risks of Climate Change: Quantitative Climate Change Risk Assessment Fiscal Tool (Q-CRAFT)
	IMF – Fiscal Affairs Department: Climate Policy Assessment Tool (CPAT)
	World Bank: World Bank Group Climate Aware Macroeconomic Models available for use by Ministries of Finance
	World Bank: MFmod – CC (country-specific macrostructural models)
	World Bank: MANAGE-WB (Recursive-Dynamic CGE model)
	World Bank: ENVISAGE (A Global CGE model covering 160 regions)
	World Bank: CPAT
	World Bank: MINDSET (An easy-to-use sectoral model covering 164 countries)
	Inter-American Development Bank (IDB) / French Development Agency (AFD) / RAND Corporation: SiSePuede: New approaches to assessing economic impacts of Net-Zero pathways
	Cambridge Econometrics: Macroeconomic modelling of climate change: The E3ME model
	Environment for Development Initiative: Facilitating socially responsible carbon pricing policies: the global Carbon Pricing Incidence Calculator (CPIC)

	Environment for Development Initiative: Pricing Carbon in the Tropics: The CP+ Model
	Danish Research Institute for Economic Analysis and Modelling (DREAM): The GreenREFORM Model
	ETH Zürich: Latest Developments in Upgrading DICE-2023: Findings and Implications for Ministries of Finance
	Sciences Po – French Economic Observatory (OFCE): ThreeME model
	UNEP (United Nations Environment Programme): IGEM's Integrated Approach to Climate-Smart Economic Decision-Making
	Munich Climate Insurance Initiative (MCII): Showcase of CLIMADA
	Austria – Ministry of Finance: Suite of Analytical Tools: Integrating Climate Projections into Austria's Long-Term Budget Forecasts
	Economic and Social Research Institute (ESRI) / Ireland – Department of Finance / Department of Public Expenditure, NDP Delivery and Reform (DPENDR): Macroeconomic analytical tools
	IMF – Research Department: GMMET
	IMF – Research Department: IMF-ENV: Integrating Climate, Energy, and Trade Policies in a General Equilibrium Framework
	IMF – Research Department: DIGNAD
	Inter-American Development Bank (IDB) / French Development Agency (AFD) / University of Costa Rica: OSeMOSYS
Considerations for modelling	Italy – Ministry of Economy and Finance: The importance of inter-model comparisons to inform robust decision-making – The example of the Italian Ministry of Economy and Finance
	Canada – Department of Finance: The challenges of uncertainty in climate-economy modelling
	OECD (Organisation for Economic Co-operation and Development): The New Macro-Structural Climate Adaptation and Mitigation Framework by the Economics Department of the OECD
	Coalition for Capacity on Climate Action (C3A): Climate macro-modelling tools to address emerging policy questions in Ministries of Finance: why new tools are now needed for the urgent task of implementation - An overview by C3A
	World Bank: A bottom-up approach to estimating climate-development investment needs
	Partnership for Economic Policy: The use of computable general equilibrium models for practical policy analysis by finance ministries: The case of climate policy in South Africa
	Spain – Ministry of Economy, Trade and Enterprises: The use of external models and the climate policy decisions they inform
	SOAS University of London: Ecological stock-flow consistent modelling: an emerging tool for Finance Ministries
	Grantham Research Institute on Climate Change and the Environment: Advancing Macroeconomic Modelling for the Energy Transition: Harnessing Production Networks Models
	Network for Greening the Financial System (NGFS): Summary of the NGFS Climate Macroeconomic Modelling Handbook
	Canada – Department of Finance: Finance Canada's approach to climate-economy modelling
	Network for Greening the Financial System (NGFS): Short-term climate scenarios
Other analytical approaches and methodologies	Independent – CETEx: Towards an integrated transition planning ecosystem: Implications for Ministries of Finance
	S-Curve Economics: Risk-Opportunity Analysis: Policy appraisal in contexts of structural change, uncertainty, and diverse interests
	Harvard Growth Lab: The Atlas of Economic Complexity: Supporting Strategic Economic Planning and Green Industrial Policy in Finance Ministries
	University of Oxford: The value of using systems mapping to help Ministries of Finance understand the impacts of transformative climate policy
	UNEP (United Nations Environment Programme): Sustainable Budgeting Approach
	Ecuador – Ministry of Economy and Finance: Use of budget tagging to better understand climate financing gaps
	Austria – Ministry of Finance: Green Budgeting in Austria – Frameworks, Implementation, and Lessons Learned
	Ireland – Department of Finance: Green budgeting
Data sources	Sweden – National Institute of Economic Research (NIER): Database on estimated elasticity values for use in quantitative analysis of climate and energy topics by agencies and economic modelers
	World Bank: Data sources for the macro modelling of climate

2.3 Enhancing Analytical Capacity in Finance Ministries

This category of contributions pertains to building analytical capacity and is further broken down into two categories: capacity building offers (organizations showcasing capacity building support available to MoFs) and capacity building case studies (examples of country's capacity building efforts). Table 2.3 draws up this structure, populated with the associated contributions. It contains 14 contributions.

Table 2.3 Contributions about building analytical capacity

Category	Contribution
Capacity building offers	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ): Modelling Climate Resilient Economic Development – GIZ's Approach to Support Sustainable Economic Growth
	Coalition for Capacity on Climate Action (C3A): The Coalition for Capacity on Climate Action (C3A) – Major Programme to Support the Emerging Analytical Needs of Ministries of Finance
	Coalition for Capacity on Climate Action (C3A): C3A's Assessment of the Emerging Analytical Needs of Finance Ministries – Opportunities and Challenges
	Environment for Development Initiative: EfD – a global research network combining research, academic training, training of civil servants and advisory to inform policy
	NDC Partnership: Unpacking options for Ministries of Finance to leverage modelling and economic analysis to accelerate climate action
	World Resources Institute / SOAS – Resilience Adaptation Mainstreaming Program (RAMP): Resilience and Adaptation Mainstreaming Program (RAMP): Building capacities at ministries of finance through local universities
	New Climate Economy: Summary of emerging and new approaches to modelling the economic case for climate action: Lessons from New Climate Economy for Ministries of Finance and future model development agenda
	Coalition of Finance Ministers for Climate Action (CFMCA): Capability Assessment Framework: Mainstreaming Climate Action in Ministries of Finance - a New Self-Assessment Tool to empower Ministries of Finance to Build Capabilities to Drive Climate Action
	Insurance Development Forum: Support for sovereign climate and disaster risk functions: the Global Risk Modelling Alliance
	Green Macroeconomic Modeling Initiative (GMMI): The Green Macroeconomic Modeling Initiative
Capacity building case studies	International Growth Centre – Rwanda Office: The use of climate-economy models in Rwanda's Finance Ministry and public institutions – The challenges in building analytical capability
	Australia – Department of the Treasury: Re-establishing the Australian Treasury's Climate Modelling Capability
	Uganda – Ministry of Finance, Planning and Economic Development: Analytical tools used for climate policy analysis at the Ministry of Finance, Planning, and Economic Development in Uganda
	Denmark – Ministry of Finance: Leadership and governance of analytical capabilities: The story of the 'non-technical' side of how the GreenReform model came to be
	Uruguay – Ministry of Economy and Finance / University of Montevideo: Uruguay's MoF efforts in mainstreaming climate economic analysis

3 Summaries of Contributions: Addressing the Climate Policy Questions Facing Finance Ministries

This section contains the summaries of the first overarching category of contributions pertaining to climate policy questions. There is a sub-section for each of the 15 policy questions. Additionally, a range of analytical questions are provided for each policy question, as indication of which more detailed questions may arise. This is not to say that the contributions provided address all the analytical questions; the latter are merely to help outline the remit of each policy question in more detail.

3.1 The economic and fiscal impacts of climate change

3.1.1 What physical climate risks are there and what are their economic implications?

Table 3.1 Contributions about physical climate risk

Analytical questions	Contributions
• What are the current and expected future impacts of physical climate change on productivity and output across sectors? • What are the benefits to mitigation? • How are risks of extreme events changing vis-á-vis climate change? • How big are current and future resilience and protection gaps? • What are the budget impacts of disaster risk finance in the context of changing frequency and magnitude of extreme events? • What are potential sovereign credit risks emanating from physical climate risks?	European Union – European Commission: A structured approach to disaster risk financing in the European Union Member States
	European Union – European Commission: Integrating physical climate risks to public debt sustainability in the European Union Member States
	Mexico – Ministry of Finance: Assessing the fiscal risks of physical climate change
	Ecuador – Ministry of Economy and Finance: Analytical tools used by Ecuador's Ministry of Finance to understand impacts of physical climate risk on economy
	Australia – Department of the Treasury: Estimating the Impact of Selected Physical Climate Risks on the Australian Economy
	Biden-Harris Administration – Council of Economic Advisors (CEA) / Office of Management and Budget (OMB), Executive Office of the President of the United States (EOP) under the Biden-Harris Administration: The United States' Efforts to Account for Climate-Related Financial Risk to the Federal Budget
	Network for Greening the Financial System (NGFS): The NGFS's approach to the macroeconomic assessment of physical risks
	World Bank: Strategic Climate Risk Modeling for Economic Resilience: A Guide for Ministries of Finance
	Institute and Faculty of Actuaries / M&G: The urgent need for Finance Ministries to factor systemic climate risk into their economic analysis and modelling approaches and principles for doing so: a view from the insurance and pensions industry
	Grantham Research Institute on Climate Change and the Environment: Climate Tipping Points
	Environment for Development Initiative: Heat waves, labor productivity and incomes in India – a rising need for adaptation policies
	World Bank – Finance, Competitiveness & Innovation Global Practice (FCI GP): Stronger Analytics for Better Financial Resilience against Climate Shocks and Disasters
	University of East Anglia: Methodological recommendations for Finance Ministries on climate change risk assessment and the enhancement of damage functions
	ETH Zürich: New Approaches to Quantifying the Fiscal Impacts of Physical Climate Change
	Marsh McLennan: How can analytical tools and methods used in the (re)insurance industry support Ministries of Finance in their understanding of physical climate risks and their efforts to support climate adaptation?

3.1.1.1 European Union – European Commission: A structured approach to disaster risk financing in the European Union Member States

In the context of increasing incidence and cost of climate-related disasters, budgetary processes need to be upgraded to reflect their macro-fiscal risks. At present, disaster risk financing (DFR) is mostly ad-hoc and fiscal impacts of climate change only considered in a limited manner in national budgets across EU member states. While financing strategies reflect national choices, these need to be evidence based; thus, structured data collection on macro-financial risks and fiscal impacts is of the essence.

Key messages

- The European Commission has developed a stepped approach to DRF to support Member States in understanding, planning, and managing the fiscal impacts of disasters (see Radu, 2024). This approach is structured around four pillars: (1) assessing the fiscal impact of disasters; (2) private sector risk ownership; (3) public sector disaster risk management; (4) institutional arrangements, and outlines stages for development under each.

- Explicitly addressing fiscal impacts of climate change in budgetary processes, including from climate-related disasters, would be beneficial. It avoids needing to find funds post-disaster without having budgeted for them and helps proactively manage risks to debt sustainability from extreme weather and climate events. By embedding climate risks into fiscal planning, governments can adopt more proactive, risk-informed budgeting practices, align fiscal strategies with climate goals, and enhance public financial management.
- The reformed EU economic governance framework introduces requirements to assess and report on the macrofiscal risks from climate change, disaster- and climate-related contingent liabilities, and the fiscal costs incurred due to disasters and climate-related shocks. The requirement for Member States to report these risks "to the extent possible" acknowledges the current lack of a single or common methodology, differences in data availability, and variations in country-specific contexts.
- A structured stock-take of each EU member states' current approach to DRF (including data collection) using the framework in Radu (2024) would help countries determine the state of their approach to DRF and how and where to improve. Granular and accurate information is especially important for evidence-based strategies, regardless of the political priorities these strategies seek to advance, and Ministries of Finance are well-placed to support this.

3.1.1.2 European Union – European Commission: Integrating physical climate risks to public debt sustainability in the European Union Member States

To ensure sound and sustainable public finances, it is essential to provide an order of magnitude of potential macro-fiscal impacts from climate change, while also accounting for their expected timing, persistence, and uncertainty. Doing so is challenging due to difficulties in conceptualizing and quantifying such issues. The European Commission developed a stepped approach to the integration of climate change into its standard Debt Sustainability Analysis (DSA), including via an empirical assessment of the potential impact of extreme weather events on public finances was undertaken via stylized stress tests.

Key messages

- Extreme weather events may pose some risks to debt sustainability, and the adverse fiscal impact increases in higher projected warming scenarios.
- Impacts of acute physical risks on debt-to-GDP projections appear to be heterogeneous across countries while remaining subject to large uncertainties. The analysis makes simplifying assumptions due to current data and methodological limitations and only provides a partial perspective of climate-related fiscal (debt) sustainability risks, given the focus on the fiscal impact of acute physical risks alone.
- Results are likely to underestimate the overall expected fiscal impact. This may be due to potential underreporting of economic losses in existing global disaster databases, the use of lower bound estimates of the expected adverse economic impact from climate events in the European Union, as well as unaccounted-for risks from non-linearities and tipping points, potential negative feedback effects across sectors, or adverse spillover effects across countries.
- Overall, the results emphasize the relevance of implementing large-scale, rapid, and immediate climate mitigation and adaptation measures to dampen the adverse economic and fiscal impacts of potentially more frequent and intense extreme weather events, thereby reducing countries' exposure, vulnerability, and debt sustainability risks.

3.1.1.3 Mexico – Ministry of Finance: Assessing the fiscal risks of physical climate change

Climate is integrated to budget considerations in Mexico via qualitative analysis of how climate-related issues can affect inflation and interest rates, which features in two reports submitted to Congress by the MoF each year. Going forward, more quantitative analysis is called for.

Key messages

- Via the Pre-economic Guidelines and the Economic Guidelines, submitted to Congress by the MoF in April and September, respectively, qualitative analysis of the potential impacts of climate-related issues, especially those relating to agricultural production, on macro-economic variables (inflation, interest rates) is brought to bear on the budget.
- As a next step, quantitative analysis of how adverse scenarios impact public finances (i.e., income, expenditures, and debt) is needed.
- Quantitative analysis provides clearer insights into fiscal risks associated with climate change, which can strengthen discussions with the policy maker and enable more informed decision-making.

3.1.1.4 Ecuador – Ministry of Economy and Finance: Analytical tools used by Ecuador's Ministry of Finance to understand impacts of physical climate risk on economy

Ecuador's Ministry of Economy and Finance has integrated environmental variables, specifically precipitation in the context of the El Niño phenomenon, into its macroeconomic forecasting. This has impacted model results through increased inflation and producer prices in the quarter(s) following the event. The ministry has also employed a CGE model to understand the impact of an energy crisis caused by an extended and extreme dry season on macroeconomic variables.

Key messages

- In 2023, the ministry integrated the El Niño phenomenon and associated changes in rainfall into its recurrent macroeconomic forecasting. It was estimated that the 4 millimeters increase in maximum rainfall estimated by the El Niño phenomenon would cause an immediate increase in annual inflation of 0.40 percentage points that would last for at least 2 more quarters and an increase in producer prices by 0.59 percentage points in the quarter following the event.
- Scenarios used in the periodic external sector programming include external shocks such as climate-related events, specifically the effects of the El Niño phenomenon on exports. Qualitative meetings were held with stakeholders to determine sensitive products in addition to the assumed damages to roads and logistics interruptions.
- The MoF has used a dynamic recursive CGE model to measure the impact of electricity rationing caused by the dry season, diminished capacity to generate electricity since October 2023, and capped imports of electricity from neighboring countries. The estimated impact on GDP growth is -0.27% below the counterfactual, with a slight permanent effect of -0.01%.
- The CGE model can perform analyses for different sectors, including construction, health, manufacturing, and electricity. It also has the capacity to perform microsimulations to determine impacts on poverty and inequality indicators. It does not consider the monetary sector, and as it is deterministic in nature, inferences have not been made about the results. However, sensitivity analysis on elasticities within the behavioral equations has been performed.

Other physical impacts of climate change include forest fires and shortages of public water in main cities. However, no impact assessments have been carried out for these events due to the uncertainty about the real impact of the energy crisis on the year's multifaceted crisis.

3.1.1.5 Australia – Department of the Treasury: Estimating the Impact of Selected Physical Climate Risks on the Australian Economy

Australia's 2023 Intergenerational Report – the 40-year economic and fiscal outlook – included an analysis of the impacts of physical climate risk on the Australian economy for the first time. A subset of physical climate risks was selected for the first stage of analysis based on likelihood of being realized in the coming decades, measurability, and applicability to economic modelling frameworks. The potential impacts of these selected risks were estimated using bottom-up damage functions applied to the Treasury Industry Model (TIM), a multisector general equilibrium model of the Australian economy with forward-looking agents.

Key messages

- Risks considered were the impact of heat stress on labor productivity, of heat stress and lower precipitation on agricultural productivity, and of environmental degradation and travel disruption on tourism flows and expenditure. This is necessarily a partial analysis, and tipping points and tail risks are not considered.
- Results were reported under several climate scenarios and based on climate projections from four Global Circulation Models (GCMs) to help communicate possible future global emissions pathways and their effects. The impact estimates should not be considered forecasts given the inherent uncertainty in predicting long-term climatic conditions.
- If global temperatures increase beyond 2°C by 2100, direct impact from heat stress on labor productivity could reduce economic output by between $135 billion and $423 billion in today's dollars over the next 40 years. The agricultural, construction, manufacturing, and services sectors could be particularly exposed to labor productivity impacts.
- The agricultural sector is particularly vulnerable also due to its dependence on natural resources and climatic conditions. Without adaptation, Australian crop yields could be up to 4% lower by 2063 in a scenario where temperature increases by 3°C or more this century.

The first stage of analysis was to develop a set of detailed, Australia-specific damage functions and to incorporate these within an economy-wide modelling framework. Future work could include additional damage functions, e.g., related to sea-level rise, using more disaggregated data to calibrate existing damage functions, and using alternative estimation techniques to better capture the compounding effects of multiple physical climate impacts.

3.1.1.6 Biden-Harris Administration – Council of Economic Advisors (CEA) / Office of Management and Budget (OMB), Executive Office of the President of the United States (EOP) under the Biden-Harris Administration: The United States' Efforts to Account for Climate-Related Financial Risk to the Federal Budget

President Biden's Executive Order 14030 on Climate-Related Financial Risk calls for the Government to assess, disclose, and mitigate the financial risks posed by climate change to Federal Agencies and the Nation more broadly. Section 6 directs the Office of Management and Budget (OMB), the Department of the Treasury (Treasury), the Council of Economic Advisers (CEA), and others to develop methods to quantify risks posed by climate change to the Federal fiscal outlook, improve accounting of climate-related Federal expenditures, and reduce long-term risk exposure through the formulation of the President's Budget and oversight. It also emphasizes the importance of accounting for physical risks and transition risks and opportunities.

Key messages

- In 2021, the CEA and OMB established an interagency technical working group (ITWG) to further develop the United States' analytical capabilities on climate-energy-macroeconomic issues by leveraging the Federal Government's climate and energy-systems modeling as well as macroeconomic modelling of the CEA, OMB, and Treasury.
- A 2024 white paper presents a methodological framework for integrating climate risk into a macroeconomic forecast, organized as a playbook. The supply-side identity of GDP underpins the framework as it forms the foundation of the Budget's economic assumptions and can also be used to systematically aggregate across bottom-up estimates or decompose top-down estimates over a range of macroeconomically relevant variables. The white paper also considers a range of existing modelling techniques and discusses their relative strengths and weaknesses in different contexts.
- A chapter in the FY2024 President's Budget outlined three core data requirements for any physical climate risk assessment methodology: (i) exposure modelling, (ii) downscaled climate data at appropriate spatial and temporal scales for the programs under consideration, and (iii) program- or

sector-specific damage functions (physical and economic) to express modelled physical changes as financial estimates.
- The FY2024 President's Budget describes three ways to assess financial risk due to physical climate impacts on Federal programs and assets: (i) comprehensively modelling physical damages and expenditures, (ii) modelling expenditures directly from climate variables, and (iii) modelling expenditures as a proportion of economic damages.
- Distinct methodologies for macroeconomic and programmatic risks are important also because climate-related risks do not have uniform geographic effects and for understanding which government capacities are most sensitive to particular risks.

Opportunities to improve climate-energy-macroeconomic modelling include accounting for distributional effects, extreme weather risks, regional demographic and socioeconomic changes pertinent to climate risk management, physical risks and transition risks and opportunities already reflected in data, and relationships between climate information at high spatial and temporal resolutions and macroeconomic outcomes. Opportunities to improve climate-budgetary modelling include developing a common framework for assessing exposure to climate-related financial risks, establishing a framework for quantifying mission and operations risks to Federal Agencies, and identifying further climate data and information resources.

3.1.1.7 Network for Greening the Financial System (NGFS): The NGFS's approach to the macroeconomic assessment of physical risks

The NGFS, founded in December 2017, is a group of central banks and supervisors with (as of July 2024) 141 members that shares best practice and contributes to the development of environmental and climate risk management in the financial sector, including via its workstream on *Scenario Design and Analysis*. Assessing the economic impacts of climate change is difficult in the context of insufficient data, metrics, tools, and fundamental uncertainty in the tail end of the distribution. To analyze how climate change and the transition could take shape, NGFS provides scenarios (or "narratives") based on current scientific consensus to serve as common reference point.

Key messages
- The NGFS advocates for and implements an incremental approach to developing scenarios based on evolving scientific evidence and aims to be transparent about underlying assumptions in each update.
- The long-term scenarios currently measure chronic risks (from gradual changes) and acute risks (from extreme events) separately. Chronic risk assessments rely on a top-down approach with macroeconomic damage functions while acute risk assessments aggregate granular impacts from peril-specific models.
- Recent advancements in modelling the macroeconomic impact of chronic damages point towards higher damages than previously considered.

The strength of using top-down empirical damage functions for chronic risks is their data-based approach and relative simplicity. However, they rely on past data and struggle to capture non-linear damages and the impact of crossing climate tipping points. In Phase V, set to be published by the end of 2024, NGFS scenarios will introduce a damage function based on Kotz et al. (2024), which offers two advances: (i) a broader scope of climate variables (e.g., accounting for temperature and precipitation variability as well as the mean) and (ii) modelling semi-persistent effects of climate shocks on economic growth, which offers a middle ground between purely transitory impacts and permanent effects on growth. The method points to higher damages than previously considered.

Forward-looking assessments of the macroeconomic impacts of acute risks are difficult due to the multiplicity of transmission channels and second-round effects. Past NGFS iterations have expanded the set of acute perils considered from flood risk and cyclones to also include droughts and heatwaves. Future developments include improving the interaction with chronic risks, as expansion of the variables considered in damage functions may increase the risk of overlap.

MoFs can use NGFS scenarios to assess, for instance, the cost of a lack of mitigation in the long run or the scale of the adaptation challenge. However, there is no one-size-fits-all approach to physical risk modelling. Employing the scenarios should be based on an understanding of their underlying hypotheses and limitations and requires complements to meet user's specific objectives.

3.1.1.8 World Bank: Strategic Climate Risk Modeling for Economic Resilience: A Guide for Ministries of Finance

Economic damage assessments should differentiate between risk types and ideally use biophysical models rather than relying on aggregate econometric methods. Biophysical models can be integrated into macroeconomic frameworks, facilitating bottom-up policy analysis in a general equilibrium context. Even so, macroeconomic analysis can miss relevant social impacts and some of the most critical risks are not explicitly considered as they defy easy quantification.

Key messages

- Biophysical models use the principles of physics, chemistry, and biology to forecast responses of natural systems to climatic changes, with Global Circulation Models (GCMs) as foundational inputs.
- Assessing economic damages from physical climate risks econometrically captures large-scale trends and economic vulnerabilities based on past experience. However, the approach struggles to account for entirely new climate phenomena or predict cascading effects of complex disruptions. By construction, the econometric approach tends to average out effects, removing outliers that may be critical to understanding risks.
- Assessing economic damages from physical climate risks through the enumerative approach often relies on biophysical models and is more bottom-up in that modelers identify and quantify economic losses from specific climate impacts. This offers a detailed picture of potential costs across different sectors, including adaptation and resilience action, and helps develop actionable policy recommendations.
- Differentiating between chronic and acute risks and most probable and tail shocks is crucial for crafting suitable policy responses, as these have different characteristics and potential impacts.

Using biophysical models in macroeconomic analysis is not a silver bullet to assessing the impact of physical climate risks. Biophysical models may not capture the full range of economic damages from physical climate risk, and macroeconomic analysis focused on national trends and economic indicators can miss relevant social impacts of physical climate risk such as displacement, cultural loss, and mental health burden. Beyond this, some of the risks with greatest potential for causing disruption and societal instability (e.g., cascading ecosystem collapse, resource scarcity-related conflicts) defy easy quantification in terms of monetary damage or probability of occurrence. Their omission from impact assessments justifies a nearly systematic methodological caveat when presenting results.

Developing biophysical models is resource intensive, particularly in terms of data and time. MoFs may wish to use global datasets for climate impact assessments initially and only develop biophysical models once the most impactful models for a specific country context have been determined to avoid expending resources on model with negligible impact on economic forecasts.

3.1.1.9 Institute and Faculty of Actuaries / M&G: The urgent need for Finance Ministries to factor systemic climate risk into their economic analysis and modelling approaches and principles for doing so: a view from the insurance and pensions industry

MoFs support important government decisions on the prioritization of climate change: how much to spend on countering it relative to spending on other priorities. Whilst IAMs are often used to assess the economic implications of climate change risks and opportunities, they can underestimate both climate risks and the opportunities arising from the energy transition such that basing policy decisions on them may lead to inadequate adaptation, loss of resilience, and missed economic opportunities. To address this, MoFs can draw on actuarial principles to carry out realistic risk assessment of climate change, including economic impacts, and invoke the precautionary principle to justify long-term policy actions required to avoid economic and societal collapse.

Key messages

- MOFs should adopt a set of principles to develop realistic economic assessments of climate impacts and opportunities, which includes adopting a precautionary approach and developing risk management capacity, to provide decision makers with better information.
- MOFs should lead the development of National Transition Plans (NTP): strategic pan-economy plans that direct private sector action around financing, incentivizing, coordinating, and enabling the transition. NTPs should include requirements for realistic risk assessment to support policy decisions to accelerate mitigation and build resilient infrastructure.
- Global warming has accelerated, the twelve-month average temperature is now above the 1.5°C goal, and this trend is likely to continue. Such warming is driving increasingly severe impacts (fires, floods, heat, and droughts), such that climate change is becoming a national security issue with food, water, and heat stresses impacting populations.
- Warming above 1.5°C is risky as it involves a high chance of triggering multiple climate tipping points, such as ice sheet collapses, permafrost melt, Amazon die back, and halting major ocean circulation, with potentially catastrophic consequences.
- Through a series of reports over the past few years, the IFOA, Earth System Scientists at the Climate Crisis Advisory Group, and the University of Exeter have sought to combine actuarial risk management principles (often concerned with assessing low-probability, high-impact events and referred to as the precautionary principle) with cutting edge science to shine a light on areas of risk and uncertainty, with the objective of improving the risk management of climate change.

A key challenge is the present gap between the climate science, economic impact, risk assessment, and policy making. Hence, it is critical that MoFs bridge these areas by building capacity to put in place policies backed by science as well as enhanced economic models, while being clear on limitations of models and outputs. International collaboration, e.g., to develop a central repository of resources and practical considerations covering climate science, economic models, and risk management, can be useful to aid this effort.

3.1.1.10 Grantham Research Institute on Climate Change and the Environment: Climate Tipping Points

Climate tipping points highlight that climate change could involve relatively sudden and substantial changes and that such changes might be irreversible on timescales relevant to human societies. Even if information that a tipping point is plausible or expected is robust, the probability of occurrence sought as input into economic models is unlikely to be available. In this context, economic modelers and physical scientists need to be brought together to ensure robust knowledge is used effectively without over-interpretation of the data.

Key messages

- The possibility of climate tipping points goes against widely held perceptions about threats of climate change being gradual and potentially reversible. Tipping points have the potential to cause huge economic shocks, including via cascading impacts through trade, migration, and conflict.
- New approaches to economic assessment are needed to capture understanding of risks related to climate tipping points. Existing approaches include physically based storylines, approaches in decision making under uncertainty, and new proposals to explore model uncertainty.
- Our knowledge of uncertainty is part of our knowledge about climate change and needs to be more effectively connected between science and economics. Economic modelling needs to be faced with the ambiguities in the physical science and seek out the robust messages across the combined economic / social / physical system.
- Climate tipping point research includes three domains: (i) information about the likelihood of crossing a tipping point, (ii) information about the consequences of crossing a tipping point, and (iii) early warning systems (EWS) that indicate proximity to a tipping point.

Two intertwined tasks are to be tackled: First, a big-picture analysis of the risk and physical consequences of crossing climate tipping points which allows for diverse academic perspectives on the uncertainties and conditionalities. Second, a similarly big-picture analysis of economic assessments of tipping points and the consequences for the global and national economies. Ministries of Finance should drive this work, as climate tipping points could fundamentally affect both the scale of the financial impact of climate change and the distribution of those impacts.

3.1.1.11 Environment for Development Initiative: Heat waves, labor productivity and incomes in India – a rising need for adaptation policies

Climate change has fiscal implications operating via a reduction in the tax base if output declines and via a need for increased expenditure on adaptation and social insurance. Recent research in India has shown that in the absence of climate control, worker productivity declines on hot days. Workplace adaptation, e.g., climate control alone is insufficient to mitigate the effect of heat on absenteeism.

Key messages

- The formal manufacturing sector experiences an output loss of about 2% per degree increase in temperature.
- In the informal sector, which accounts for 80% of employment, may be more adversely affected. Recent survey-based research indicates that a one-degree increase in wet bulb temperature is associated with a fall in income by 19% (16% for a one-degree increase in mean temperature).
- Temperature is expected to continue increasing such that large effects concentrated in hot months that affect urban workers need to be addressed. Public policy should enable adaptation and social insurance, with fiscal consequences the MoF needs to plan for.

Worldwide, it is estimated that around 320 million informal-sector workers, most in LMICs, are already exposed to comparable heat for at least one month per year. Hence, the results have implications across the tropical and sub-tropical developing world.

3.1.1.12 World Bank – Finance, Competitiveness & Innovation Global Practice (FCI GP): Stronger Analytics for Better Financial Resilience against Climate Shocks and Disasters

The World Bank's Crisis and Disaster Risk Finance global team have developed a framework and suite of analytical tools and models on climate and disaster risk finance to inform Ministries of Finance and other public sector entities in the design of cost-effective financial strategies against climate shocks and disasters. The approach has been used in > 50 vulnerable emerging markets and developing economies to improve financial resilience against climate shocks and disasters through fiscal and financial sector reforms and the development of innovative financial solutions.

Key messages

- Catastrophe risk models use a bottom-up approach based on scientific and engineering knowledge of hazard, exposure, and vulnerability (each captured explicitly), and the overall model is calibrated and validated based on historical events. This differs from, e.g., economic damage functions based on empirical analysis on historical damages, which do not analyze underlying hazard, exposure, and vulnerability dynamics driving the risk in detail.
- Catastrophe risk models yield a distribution of damage or financial loss estimates. This can be used as input for, e.g., estimating climate-related contingent liabilities, financial protection gap analysis, and climate risk finance instrument structuring and pricing. It can also be used in modelling chains, e.g., as input for macroeconomic models, the outputs of which can then be used in, for instance, sovereign credit rating analysis.
- There is potential to incorporate future climate projections data in hazard modules, enabling climate-conditioned catastrophe models that can be used to understand potential future climate-related disaster risks.
- Where existing models are unavailable or not suitable, a sequential approach of leveraging existing global and local datasets to provide initial risk estimates prior to investing in the development of a full catastrophe risk model may be appropriate.
- Quantitative analysis is complemented with broader considerations, including basis risk, product quality, additional benefits, and political economy and practical considerations.
- The World Bank has a Climate and Disaster Risk Finance (CDRF) value for money process to help governments with their CDRF strategy. Its 4 steps are: (i) identifying the funding gap, needs, and objectives, (ii) assessment of existing and potential instruments, (iii) consideration of climate and disaster risk financing strategies, and (iv) comparison of suitable products.

Ongoing efforts include better representing potential climate adaptation measures in catastrophe models, and to extend their analysis of indirect impacts of disasters (e.g., via critical infrastructure and supply chain disruptions). Continuous engagement with experts is also needed to refine hazard and vulnerability modules, and collecting local data for model calibration and validation can help refine vulnerability assumptions to better reflect local circumstances and reduce reliance on assumptions based on data from other countries. Linkages between models can be improved, for example with respect to how information on the geographic distribution of impacts modelled by spatially explicit catastrophe models are retained in macroeconomic and macro financial models.

3.1.1.13 University of East Anglia: Methodological recommendations for Finance Ministries on climate change risk assessment and the enhancement of damage functions

Economic damage functions represent the impacts of climate change on the economy at different levels of global warming. When used in cost benefit analysis, the choice of damage function and discount rate are key determinants of the benefits of climate policy. Since even the best damage function-based approaches available today (Yumashev et al 2019, Barrage and Nordhaus 2024) do not capture many important pathways through which the economy would be damaged by climate change, other approaches are recommended.

Key messages

- As even the best damage-function based methods to estimate economic damages from climate change underestimate costs, it is prudent to put in place more stringent policies than those emerging from such calculations.
- Key aspects of substantial additional climate risk that voters and decision makers will be concerned about that are either not represented or not fully included in damage functions include effects of extreme weather, biodiversity loss, ecosystem and Amazon rainforest collapse, and ice sheet collapse.

- Alternative methods to assess risk include quantification of physical/social risk metrics such as those made available in the IPCC Sixth Assessment Report (O'Neill et al. 2022, Ranasinghe et al 2021).
- If damage functions are used despite the above concerns, it is important to select the most up to date, complete approaches and models. The PAGE-ICE model is particularly useful as it treats uncertainty well and incorporates discontinuities. The outputs are probabilistic and the upper tails of the resulting estimates of climate related risk should be used to inform policy decisions.

If economic CBA is felt by MoFs to be a necessary component of any analysis of a proposed climate policy, complementary approaches to CBA, such as risk assessment, should be used. Within this, any effort to quantify climate risk should use consistent assumptions about population growth, economic growth and technological change (Diaz and Moore, 2017). However, an assessment of the health co-benefits of climate change mitigation alone is likely to be sufficient to justify the investment. If so, this obviates the need to go through a complex risk assessment process.

3.1.1.14 ETH Zürich: New Approaches to Quantifying the Fiscal Impacts of Physical Climate Change

Whilst modelling efforts have historically focused on the fiscal impacts of climate policies, a nascent literature is developing methods to quantify the fiscal impacts of physical climate change. This is being done by combining established regression methods with downscaled climate models or by integrating climate change into quantitative methods. Emerging estimates indicate the fiscal costs are large and climate change impacts thus larger than expected, yet even these are underestimated due to omitted impact channels.

Key messages

- One part of the literature uses established regression methods to empirically quantify the impacts of extreme weather events or risks on fiscal outcomes and combines them with downscaled climate models to evaluate changes in fiscal outcomes due to climate change.
- Another part of the literature integrates climate change into quantitative methods such as sovereign default models or macroeconomic public finance models to project associated fiscal and welfare costs.
- Estimates of climate change impacts using the latter method indicate damages from climate change are 23-33% higher than prior studies. Even so, these new figures are also underestimated as, for instance, wildfire impacts on healthcare costs are not included.

3.1.1.15 Marsh McLennan: How can analytical tools and methods used in the (re)insurance industry support Ministries of Finance in their understanding of physical climate risks and their efforts to support climate adaptation?

Analytical tools used in the (re)insurance context, such as catastrophe models, risk layering, and protection gap analysis, can support MoFs in understanding and managing physical climate risks. They can help governments identify and quantify risks, develop climate adaptation strategies, and prioritize resource allocation through a holistic approach to climate risk. If correctly designed and implemented, insurance provides a financial safety net and supports economic stability.

Key messages

- Holistic risk management includes risk assessment, risk mitigation, and risk financing. A range of models and approaches have emerged to evaluate the potential impact of disasters on populations, infrastructure, and economies, help quantify expected losses and probabilities of exceeding certain loss thresholds, and support decisions about adaptation (or 'risk mitigation') and risk finance.
- Catastrophe (CAT) models
  - These estimate potential losses from natural or human-made catastrophic events. A portfolio of risks (a selection of assets or asset classes) is modelled against hazard,

vulnerability, and exposure to establish 'financial loss' based on the simulation of plausible scenarios.
    - Results can inform policies and planning for infrastructure development and emergency response, public insurance schemes, and financial reserves required to cover potential losses, all supporting economic stability in the aftermath of shocks.
    - Climate change can be reflected in the hazard module of CAT models. Incorporating adaptation and resilience measures is challenging, yet an emerging area.
- Risk layering
    - This involves dividing risks into layers based on probability and severity of potential losses, each covered by specific financial instruments or strategies.
    - The concept is helpful for exploring the optimal combination of risk retention, transfer, and reduction strategies.
- Insurance protection gap:
    - The insurance protection gap represents the portion of economic losses from various risks not covered by insurance or other risk finance instruments.
    - An understanding of the protection gap helps identify the extent to which different agents are underinsured or uninsured, and the potential financial burden on government in the absence of insurance, including over time. A proactive approach to addressing the gap can help enhance economic resilience, promote financial stability, support sustainable economic development, and lead to more efficient use of public resources.
- Understanding current and future availability and affordability of insurance against specific climate risks involves analyzing insurance market data covering the supply and demand side, particularly in wildfire-prone regions.

A holistic view of risk involves considering or combining various risk assessment, resilience and adaptation, and financing strategies. Catastrophe models, risk layering techniques, and insurance analysis can be combined to explore how an optimal climate risk financing and adaptation strategy can look like today and in the future for different projected climate pathways at the state, local government, and community levels.

The probabilistic tools and underlying data for analysis outlined are not universally accessible. Some open-source tools exist but also require expertise to use. Collaboration between the insurance sector and the public sector, potentially with insurance regulators and supervisors as intermediaries, should focus on sharing data and expertise on risk (reduction) and build risk awareness and financial literacy among households and businesses.

3.1.2 How does the economy rely on nature and ecosystem services?

Table 3.2 Contributions about how the economy relies on nature and ecosystem services

Analytical questions	Contributions
• What are the state and trends of domestic ecosystem services? • How changes to biodiversity and ecosystems (incl. ecosystem services) vis-à-vis climate change be modelled, so that economic impacts can be assessed? • What are the economic impacts from nature- and ecosystem-related risks to the economy? • What role can nature-based solutions play in adaptation?	Finland – Prime Minister's Office: Nature and ecosystem service impacts should be better included in assessments of the economic impacts of climate risk by Finance Ministries and Economic Decision-makers – The Experience of Finland
	Finland – Prime Minister's Office: Strengthening capabilities to undertake economic impact assessments of climate strategies and impacts – The Finnish experience
	Coalition for Capacity on Climate Action (C3A): Filling in the gaps for Ministries of Finance on nature: Assessing the tools, instruments, and macrofinancial implications of the nature transition

3.1.2.1 Finland – Prime Minister's Office: Nature and ecosystem service impacts should be better included in assessments of the economic impacts of climate risk by Finance Ministries and Economic Decision-makers – The Experience of Finland

The functioning of ecosystems and the state of biodiversity are likely to change vis-á-vis even 2°C of global warming and thereby impact economies, meaning it is important to include ecosystems in economic modelling. Ecological accounting methods and models sensitive to the state of ecosystems are being developed, for instance by Finland, which augmented a macroeconomic model with sectoral detail in forestry and agriculture. Nonetheless, knowledge gaps and challenges around data availability remain.

Key messages

- Ecosystem services have substantial value and should be included in economic modelling, including to capture how they change and impact the economy in different climate scenarios.
- Finland analyzed potential ecosystem-related economic risks via a regional dynamic CGE model (RegFinDyn) augmented with forest and agricultural models. Results include that cascading risks associated with ecosystems are expected to be larger than the damage from extreme weather events.
- Given the challenges of complex quantitative modelling of nature-related economic risks, there are calls for using simpler but more comprehensive methods to analyze them, such as storylines, causal networks, and participatory systems mapping.

Key challenges of including natural and ecosystem services in economic modelling are the difficulty of quantifying ecosystem service impacts, data limitations, and the inability of current modelling frameworks to consider systemic risks as they fail to account for nature-economy feedback processes. To help scope research results and knowledge gaps, Finland conducts annual societal sustainability assessments covering five dimensions: ecological; human capital and culture; social and health; economic; and security, the rule of law, and democracy. The aim is to clarify linkages between sustainability challenges and identify opportunities, risks, impact channels, and leverage points.

Concrete next steps for Finland identified by the high-level Working Group on Financing the Green Transition include planning an assessment, monitoring, and analysis framework to evaluate the overall economic impacts of climate and biodiversity loss and the policy measures required to address them, and allocating more resources to applied economic research studying the links between climate change, biodiversity loss, and the economy. Next steps Ministries of Finance and economic policy makers more generally could consider include systemic risk reviews of climate-change related sudden and cascading economic risks related to ecosystem services, incorporating ecosystem-related impacts in macroeconomic risk assessments, and developing databases of the economic value of ecosystem services, e.g., UN standard-based ecosystem accounting.

3.1.2.2 Finland – Prime Minister's Office: Strengthening capabilities to undertake economic impact assessments of climate strategies and impacts – The Finnish experience

Multi-disciplinarity enables impact assessments of climate change and climate policies that leverage energy, economy, and land-use models, yet assessing short term impacts remains challenging. Further challenges include building and maintaining relevant modelling expertise, especially in the context of limited mandates for Ministries of Finance in the climate domain. Next steps include improving governance structures, enhancing national and international collaboration, and re-thinking economic modelling to better integrate climate and biodiversity.

Key messages

- Deploying system-level energy, economy, and LULUCF models and complementing their results with sector-specific modelling can yield insights into the impact of medium- to long-term climate policies and the impact of climate change. Estimating short-term impacts remains difficult.
- Climate-change related impacts on ecosystems are not sufficiently captured by current tools, though ideally climate change and biodiversity loss would be jointly considered.
- As previous economic models were not built to include climate-related shocks and struggle to do so, modelling approaches may need to be reconsidered.

A key modelling challenge is that a detailed sector-level structure is usually needed to introduce climate shocks, yet current sectoral models do not cover transition frictions, forward-looking expectations, short-term market disturbances, or public income and spending details sufficiently. Macroeconomic models do include forward-looking expectations, yet do not have the required level of sectoral detail.

There is a risk of losing know-how without a new generation of modelers. Hence, Finland's MoFs needs to widen and further strengthen competence and local modelling expertise. A challenge relating to governance structure affecting many Ministries of Finance is the lack of an explicit mandate and, relatedly, lack of engagement with developing national climate strategies and NDCS, resulting in a lack of expertise and ownership over climate assessment frameworks and macroeconomic modelling practices. Developing expertise and scaling up analytical approaches would require collaboration between MoF departments and with regional and international partners.

At the national level, strategies to overcome these challenges include raising awareness of best practices and develop modelling expertise including via academia, identifying policy questions and the tools needed to address them, and defining governance, cooperation, and coordination structures. At the international level, strategies include engaging in discussion at the highest political level, sharing expertise, driving joint technical efforts, and, more generally, communicating the importance of economic assessment in achieving climate objectives.

3.1.2.3 Coalition for Capacity on Climate Action (C3A): Filling in the gaps for Ministries of Finance on nature: Assessing the tools, instruments, and macrofinancial implications of the nature transition

A recent technical note by C3A examines the need of MoFs to mainstream nature within their agenda and the analytical tools and operational frameworks needed to support this. Current nature-related scenarios have limited capacity to provide meaningful insights for policymaking, as the complexity of nature-related processes makes predictions drawing on their dynamics unreliable, and current scenarios do not capture all relevant transmission channels between nature and the economy.

Key messages

- Capturing nature in a limited number of metrics is bound to be imperfect and is more difficult than capturing climate change via greenhouse gas emissions, for which clear metrics and targeted policy options exist. Thus, defining clear metrics of interest for nature is a work in progress.
- Existing models for assessing the macro-financial impacts of nature-related scenarios tend to underestimate and misrepresent the economic relevance of nature loss and the major changes needed to address it. IAMs in particular often assume nature is readily substitutable with other factors of production and that growth is exogenously determined, leading to artificially smooth adjustment to shocks and invisibility of possible large and non-linear impacts of nature loss and the nature transition.
- Further development of scenarios and models that address nature are needed, and MoFs would stand to benefit if this development is accompanied by knowledge-sharing.

More specifically, the note lays out a research program to advance scenario and model development. First, a "nature-transition dashboard" could help assess different nature scenarios, including against the Global Biodiversity Framework targets. A taxonomy of available financial instruments for nature mitigation and adaptation, highlighting their uses, benefits, and drawbacks in different contexts, may help MoFs determine the macro-financial and environmental impact of such instruments. Second, it can be explored whether (non-equilibrium) system dynamics models are more apt for assessing the macro-financial implications of nature loss and the nature transition. Third, training and knowledge-sharing during the process of mainstreaming nature in MoFs can build in-house capacity and help identify structural obstacles and leverage points to tackle nature-related issues.

3.2 The economic and fiscal impacts of adaptation and resilience

3.2.1 What is the economic case for adaptation?

Table 3.3 Contributions about the economic case for adaptation

Analytical questions	Contributions
• What are the benefits to adaptation, given the physical risks, across sectors and regions? Where would it be most cost-effective? • What is the magnitude of costs avoided via adaptation? • How do macroeconomic indicators evolve under different adaptation scenarios? • Which co-benefits to adaptation are there? What is their magnitude? • How can cost-effective resilient infrastructure projects be identified?	IMF – Fiscal Affairs Department: The critical role of Finance Ministries for investment in adaptation and the analytical principles and tools available
	Paul Watkiss Associates: The Analysis of Climate Impacts, Adaptation Costs and Adaptation Benefits in the UK
	Paul Watkiss Associates: Global Adaptation Finance Costs, the Adaptation Finance Gap and Adaptation Investment Planning
	Environmental Change Institute – University of Oxford: The Fiscal Case for Adaptation and Improved Sustainability Analysis

3.2.1.1 IMF – Fiscal Affairs Department: The critical role of Finance Ministries for investment in adaptation and the analytical principles and tools available

Adaptation can greatly reduce potentially devastating economic losses of climate change, but it requires additional public spending and a conducive environment for private adaptation investment. MoFs can play an important role because, at its core, climate change adaptation is a problem of economic development for which they already have a rich toolbox that can be used to derive policy priorities and estimate investment needs for adaptation.

Key messages

- Investment needs in climate change adaptation can be defined as the difference between optimal investment levels with and without climate change (strict additionality definition). This intentionally excludes investments in development that would be optimal even without climate change and the cost of closing the gap to achieve an optimal level of adaptation to current climate conditions.
- Welfare economics and cost-benefit analysis provide a concrete, useful starting point to calculate investment needs based on the criterion of economic efficiency. Whilst there are limitations and challenges to implementing CBA, it can play an important role in helping decision makers collect, aggregate, and compare information on adaptation projects.
- A lower bound on public adaptation spending can be investment in only public goods such as infrastructure, coastal areas, water management projects, weather forecasts, and early warning systems. An upper bound can include compensation to individuals and firms to offset the cost of adaptation or the cost of residual damages.
- MoFs have flexibility to determine the best allocation of funds within this broad spectrum but must remain vigilant about potential inefficiencies and inconsistencies in other areas of public spending.
- Spending needs for adaptation can be estimated using empirical methods. These include process-based or economic simulation models to estimate adaptation investment needs, cross-sectional

econometric methods to estimate the likelihood of certain adaptations being chosen (though this does not immediately reveal spending needs), and panel econometric methods to estimate the cost of climate change, including short-term adaptations (though this intentionally omits many long-term, more effective adaptations).

Two case study boxes are included: (1) estimating the cost of seal-level rise and adaptation, and (2) estimating macro-fiscal impacts of weather shocks using billions of weather observations.

3.2.1.2 Paul Watkiss Associates: The Analysis of Climate Impacts, Adaptation Costs and Adaptation Benefits in the UK

In the UK there is a statutory requirement for the Government to undertake an assessment of the risks to the UK of the current and predicted impact of climate change every five years. Three rounds of this policy cycle to date provide valuable lessons on integrating economic analysis into national risk assessment and adaptation planning. Government also has a duty to publish a national adaptation program after the CCRA, setting out how it will address the risks.

Key messages

- The 3rd Climate Change Risk Assessment (CCRA3) focused on 61 risks and opportunities, assessing the potential magnitude of the risks, as well as the urgency for adaptation.
- For the CCRA3, a three-step approach was used to identify where adaptation action is most urgently needed to inform adaptation planning: (1) What is the current and future level of risk / opportunity?; (2) Is the risk/opportunity being managed, based on government commitments and other adaptation actions?; and (3) Are there benefits to further action in the next five years, over and above that already planned?
- Analysis of the economic costs of climate change used a hybrid approach. Bottom-up approaches individually assessed the 61 risks and opportunities using sector models, and expert elicitation to fill gaps. The top-down approach took sectoral impacts and input these into a macroeconomic CGE model to assess the headline impacts on GDP.
- There is some uncertainty about the size of impacts, but a robust finding is that impacts in the UK will be significant. The studies show that most of the physical changes from climate change over the next 20 years are already locked-in and can only be reduced by adaptation. Benefits to global mitigation are very high but materialize later.
- To inform step (3) regarding benefits to further action, a bottom-up review of potential costs and benefits of adaptation for the 61 risks and opportunities was undertaken. Many but not all early adaptation investments were found to offer high value for money, with costs-benefit rations typically between 2:1 and 10:1.
- Globally, many countries have assessed the costs of their national adaptation programs, but almost none have assessed the economic benefits of these plans. Many top-down and macroeconomic frameworks are not able to assess adaptation (or only in a highly stylized way). Bottom-up analysis is more common, but faces challenges because adaptation responses are risk, location, context, and time specific, compounded by the uncertainty associated with future climate change.

In England, the 3rd National Adaptation Programme (NAP3) sets out proposed action over the next 5 years (2023-2028) and includes 511 individual adaptation actions. An initial estimate of the potential costs to deliver NAP3 was £5-10 billion per year (Watkiss, 2022). Work to refine the estimates of the costs and benefits of implementing NAP3 is underway. As part of this, CGE models are being used to assess the implications of adaptation to key risks for GDP and the public finances. This can help assess whether adaptation can reduce the macroeconomic disruption of climate change cost-effectively and whether it has net benefits for the public finances.

3.2.1.3 Paul Watkiss Associates: Global Adaptation Finance Costs, the Adaptation Finance Gap and Adaptation Investment Planning

Recent estimates suggest a very high adaptation finance gap, with adaptation finance needs in developing countries approximately an order of magnitude higher than adaptation finance flows. This gap reflects the difficulty of converting adaptation priorities into investment ready programs and mobilizing finance for implementation. Therefore, adaptation investment planning is a key priority.

Key messages

- The UNEP Adaptation Gap Report (AGR) and the Adaptation Finance Update estimate the adaptation finance gap for developing countries by comparing their modelled adaptation costs and finance needs with current adaptation finance flows to developing countries.
- The AGR 2023 estimated adaptation costs and financing needs at US$231 billion/year to US$416 billion/year (2022 prices) for developing countries this decade (0.6-1.0% of GDP for all developing countries). Adaptation finance flows to developing countries in 2022 were assessed at US$27.5 billion (public flows only) and US$32 billion (leveraged finance flows included) (OECD 2024). The implied gap is lower due to domestic public adaptation flows and private sector finance, but there is no robust data on these.
- The magnitude of the adaptation finance gap reflects the difficulty in converting National Adaptation Plan (NAP) or Nationally Determined Contribution (NDC) adaptation priorities into investment ready programs and mobilizing the finance to implement these.
- Given the adaptation finance gap, adaptation investment planning is a key priority as part of the overall NAP or NDC process. It aims to take a strategic approach to develop an investment pipeline of programs, rather than working at the project level, and to unlock opportunities from various sources of finance to implement priorities at scale.
- Adaptation investment planning involves greater prioritization and integration of adaptation within existing government planning and financing frameworks, considering sequencing of actions over time, and assessing the economic benefits and potential revenues from adaptation rather than just the costs.
- Supporting this is an analysis of the enabling conditions to help implement and finance adaptation, including capacity building, institutional strengthening, and addressing barriers and constraints.

There are several initiatives supporting countries convert their NDCs and NAPs into adaptation investment plans, i.e., that support the development of a pipeline of bankable projects and provide methodological frameworks and key lessons.

3.2.1.4 Environmental Change Institute – University of Oxford: The Fiscal Case for Adaptation and Improved Sustainability Analysis

The costs of climate disruption to infrastructure assets can strain fiscal budgets and reduce productivity, with knock-on effects for growth, investment, and poverty alleviation. There are estimated to be significant fiscal benefits of early investments in resilient infrastructure, both in terms of reduced costs and long-term macroeconomic trajectories. The public sector plays multiple critical roles in this respect: financier, regulator, catalyst, and policy maker, to name just a few.

Key messages

- Climate disruptions to infrastructure already cost EMDEs an estimated 390 billion USD per year, and this will almost certainly deteriorate further in the coming decades unless mitigation and adaptation are significantly increased.
- Climate change should routinely be integrated with fiscal risk and debt sustainability analyses, including analyzing the benefits of adaptation for fiscal space, fiscal resilience, and sovereign credit ratings. This can help address the false dichotomy that pitches adaptation-spending against fiscal

prudence and help avoid a self-reinforcing cycle of rising costs of climate-related disasters, lower sovereign credit ratings, and reduced investment in adaption, mitigation, and the SDGs.

- Finance ministries can actively investigate how the cost of capital for sovereign financing instruments could be reduced through investment in adaptation, including appropriate disaster risk financing strategies and opportunities for labelled bonds and sustainability-linked sovereign finance.
- Ending counterproductive expenditures, including climate-damaging subsidies, should become a priority for all stakeholders involved in planning and implementing climate-compatible public finance across the world.
- A case study for Thailand shows that avoided costs in terms of reduced borrowing costs and lower probability of default by sovereigns could significantly outweigh the necessary initial investments in climate adaptation.

3.2.2 Which measures can drive adaptation and resilience?

Table 3.4 Contribution about measures to drive adaptation and resilience

Analytical questions	Contributions
• How can MoFs incentivize adaptation? • Which barriers to adaptation are there, and how can they be overcome? • How can the financial resilience of those most impacted by physical climate events be increased?	European Union – European Commission: Determining Investment Needs to Decarbonisation and Adaptation: The Challenge and Opportunity for Finance Ministries in the European Union

3.2.2.1 European Union – European Commission: Determining Investment Needs to Decarbonisation and Adaptation: The Challenge and Opportunity for Finance Ministries in the European Union

Large-scale investments are needed for climate mitigation and adaptation, yet more work is needed on quantifying additional mitigation investment needs, costs of climate hazards, and adaptation investment needs. In particular, the additional investment needs for mitigation and adaptation in different scenarios are not well quantified, though may require public support. Work for Finance Ministries includes developing an understanding of how expenditures and revenues impact and are impacted by climate-related hazards and policies.

Key messages

- Large-scale investments are required for the transition. Current models, despite disregarding significant factors such as natural capital and climate tipping points, suggest the costs of inaction far surpass costs from the transition.
- National policy choices and funding mechanisms mobilized to support decarbonization determine to significant extent future trajectories for public expenditure, needs for financial market reform, and the saving-investment balance. While these questions are outstanding uncertainty beyond modelling remains for Ministries of Finance.
- The costs of climate hazards are not reliably measured, though modelling tools that have been deployed indicate potentially very high costs.
- Investment needs for adaptation are poorly quantified and methodological challenges remain, including precise identification of climate hazards to adapt to, definition of time horizons, estimation of vulnerabilities, definition of degrees of adaptation needs, and assessment of the types of adaptation measures to be considered.

A priority for Finance Ministries is developing green budgeting tools and understanding the emissions footprint associated with public revenues and expenditures. Ministries of Finance are also well-placed to evaluate expenditures and budget plans to identify adaptation gaps and assess how to structure financial instruments to support private-sector investment in mitigation and adaptation.

3.3 The economic and fiscal impacts the green transition

3.3.1 What measures can drive the green transition and climate mitigation?

Table 3.5 Contribution about measures to drive the green transition and climate mitigation

Analytical questions	Contributions
• What are the impacts of large-scale green fiscal subsidies? How will consumer and producer behavior change in response? • What is the best way to design carbon pricing policies? • What are the short and long-term income and price elasticities of demand for energy?	Sierra Leone – Ministry of Finance: Climate Policy Priorities in Sierra Leone
	World Bank: The low-carbon challenge facing Ministries of Finance
	Massachusetts Institute of Technology – Abdul Latif Jameel Poverty Action Lab (J-PAL): How Finance Ministries and Economic Decision-Makers Can Use Ex-Post Pilot Assessments to Inform Climate Policy - Designing, testing, and scaling emissions markets in India
	Council on Economic Policies: It Takes Two to Tango – The Role of Finance Ministries in Pricing and Non-Pricing Policies for a Low-Carbon Economy
	Centre for Social and Economic Progress (CSEP): Non-Price Policies for Addressing Climate Change: Challenges in Assessing Performance of Policy Packages for Finance Ministries and Economic Decision-Makers
	France Stratégie: Key messages from the report "The economic implications of climate action"
	University College London: Analytical and policy approaches to climate policy and the economy
	Economic and Social Research Institute (ESRI) / Ireland – Department of Finance: Carbon taxes, distributional implications, and revenue recycling

3.3.1.1 Sierra Leone – Ministry of Finance: Climate Policy Priorities in Sierra Leone

Sierra Leone is advancing its climate policy on multiple fronts and in collaboration with various partners. Areas of work include fossil fuel subsidy reform, afforestation, conservation, and improving climate change data. Partners include the FAO, World Bank, and IMF, among others.

Key messages

- Petroleum subsidies have been removed, which reduced pressure on the government budget. In the first half of 2023 the government incurred a revenue loss of USD 32.8 million by subsidizing fuel prices and a loss of USD 3.3 million by direct subsidies to oil marketing companies.
- Through ministries, departments, agencies, and support from development partners, the government is implementing afforestation projects and rolling out the third phase of the Tree Planting Project to plant another 2.2 million trees. The FAO is also working with the Ministry of Environment and Climate Change to update the Forestry Inventory last developed in 1975.
- Sierra Leone's Medium-Term National Development Plan (2024-2030) focuses on doubling the area of national forest and wetlands under improved conservation management, doubling the area under sustainable carbon financing from the current baseline of 71,000 ha, plant an additional 10 million trees, and increase local revenue from ecosystem services by ≥35%.

Challenges include access to data on climate change variables, which also motivates conducting the National Forestry Inventory with support from the FAO. Via the Climate Finance Unit the MoF is seeking support from development partners including the World Bank and the IMF to develop a macroeconomic database incorporating all climate change variables. The data is to be available to all MDAs, donor partners, academic institutions, the private sector, and so on.

3.3.1.2 World Bank: The low-carbon challenge facing Ministries of Finance

Limiting climate change requires ending net greenhouse gas emissions and Ministries of Finance will necessarily be at the center of implementing the policies that will support a such a low-carbon future. For the world to reach net zero, it is important that middle- and high-income countries reduce their emissions and growth paths of low-income countries remain low-carbon. Policy packages to this end should include but not be limited to carbon pricing.

Key messages

- Comparing future emissions by country and sector between current policies and a net zero 2050 scenario shows that for many high- and middle-income countries decarbonizing the energy sector, including by eliminating coal fired power plants, is key. For many low-income countries the focus is on increasing carbon sinks or pursuing low-carbon electrification, or a mixture of both.
- No single policy can ensure an efficient and least-cost low-carbon transition. Rather, a policy package should include steps to internalize externalities, sectoral supply-side policies, and social and transition policies.
- While carbon prices are needed to align economic incentives with decarbonization, they are not a silver bullet. World Bank estimates indicate that carbon prices alone would reduce emissions by <50% for most countries evaluated.
- Complementary regulatory action and industrial policy can speed up and amplify the transition, and measures to clear non-market obstacles and ensure a just transition are also needed.
- The transition can also bring opportunities, e.g., by opening up markets and creating jobs.

Decarbonization options in transportation, heating and cooling, and light industry all include electrification, among other means. This is inefficient for heavy industry reliant on high temperatures, however. Here, low-carbon fuels such as hydrogen, reducing process-based emissions, and, where necessary, CCS can aid the transition. For effective decarbonization whilst meeting increasing energy demand from electrification and extending access to electricity to people currently without access, large-scale investments in renewable power systems are needed. This is capital intensive and financing constraints make implementation difficult.

3.3.1.3 Massachusetts Institute of Technology – Abdul Latif Jameel Poverty Action Lab (J-PAL): How Finance Ministries and Economic Decision-Makers Can Use Ex-Post Pilot Assessments to Inform Climate Policy - Designing, testing, and scaling emissions markets in India

Rigorously piloting and evaluating climate and environmental policies before scaling them up can be a good way to help ensure public sector investments are (cost-)effective. The Government of Gujarat, India adopted this design-test-scale approach in rolling out its first emissions trading scheme (ETS) to reduce industrial pollution. The Government and researchers from J-PAL conducted a randomized control trial which showed the ETS was effective in the sense that firms' particulate matter emissions decreased by 20-30% while average abatement costs fell, generating an estimated $25 in health benefits for every $1 spent on the reform.

Key messages

- If there is not yet credible causal evidence that a policy is effective, governments should consider investing in a small number of strategic impact evaluations to measure the impact of major reforms. This can help ensure they are (cost-)effective before they are scaled up widely.
- Command-and-control regulation that sets caps on individual firms' pollution can suffer from imperfect compliance, poor or corrupt monitoring, and weak enforcement, and tends not to differentiate between firms with different abatement costs.
- ETSs set a cap on total pollution across businesses such that permits can be traded between them, allowing firms with lower (higher) abatement costs to reduce pollution more (less). This can lower overall costs. While successfully implemented in high-income countries, they are rarely used in low- and middle-income countries at this point.
- The Gujarat ETS study shows that emissions markets are possible to implement and can be highly effective, including in emerging economies. This evidence helped the government make the case to

scale the emissions markets in cities across the state and inspired other states to explore plans to launch similar systems for particulate matter and other pollutants.

- Building emissions markets in this way can also help lay the groundwork for carbon trading.

Challenges of piloting and setting up an ETS include initial setup costs, continuous emission monitoring technology, regulatory harmonization, and ensuring equitable participation among industries. Addressing these challenges requires sustained institutional support and tailored capacity building efforts. MoFs can use findings from the study to explore potential benefits and costs of emissions markets in their own contexts.

3.3.1.4 Council on Economic Policies: It Takes Two to Tango – The Role of Finance Ministries in Pricing and Non-Pricing Policies for a Low-Carbon Economy

Whilst carbon pricing has long been viewed by policymakers as a primary policy tool to unlock a low-carbon economy and advance climate action, obstacles hindering low-carbon investments are increasingly being considered, which also means non-pricing measures are moving up policy agendas. It is increasingly understood that unlocking the low-carbon economy requires comprehensive changes in markets, behaviors, and expectations. Recent policy packages combine a variety of instruments to achieve this, including carbon pricing, government subsidies, public investment, and regulations.

Key messages

- Cross-country comparisons of policy packages for a low-carbon economy are useful to identify best practices. Carbon pricing is well tracked globally, yet there is a lack of information on non-pricing actions. The multiplicity of policy instruments and their complex design makes monitoring challenging, but progress is being made in international organizations.
- Models that combine macroeconomic, fiscal, energy, and climate dimensions are useful to project the impact of packages of various climate actions. They have been used to explore the impact of the Inflation Reduction Act (IRA) in the U.S. and inform long-term electricity market decisions in France. However, these models have struggled to predict turning points, such as the surge in renewable investment.
- An emerging literature is taking advantage of available micro data to evaluate the effects of non-pricing policies. Using empirical evidence from banking information, tax statements, administrative records, and novel experiments, researchers are evaluating whether government initiatives are effective for unlocking a low-carbon economy.

Next steps for the CFMCA could include establishing a workstream to support efforts to monitor policy packages and learn from the experience across jurisdictions with implementing packages of multiple provisions. The CFMCA could also establish a workstream to support the development of evaluations that use micro data, including by creating a repository of relevant research.

3.3.1.5 Centre for Social and Economic Progress (CSEP): Non-Price Policies for Addressing Climate Change: Challenges in Assessing Performance of Policy Packages for Finance Ministries and Economic Decision-Makers

In G20 countries, non-price policy levers across different sectors, serving multiple and overlapping objectives and often aligned to climate action targets, are combined with implicit carbon pricing measures such as fiscal and other financial incentives as part of the overall climate policy framework. In 2023, CSEP compiled and assessed the range of non-price policies instituted across these countries. This mapping uncovered substantial heterogeneities and complex interlinkages across sectors, tools, and policy objectives, and showcased substantial variation in sequencing patterns and stringency of non-price levers.

Key messages

- Common non-price levers include GHG reduction targets, R&D support, grants, subsidies, other financial incentives for green projects, emissions disclosure norms and standards, green infrastructure development, information, and education, including voluntary approaches. Non-pricing tools are often implicit pricing tools by pushing up costs.

- Non-price decarbonization mechanisms are crucial in establishing pre-conditions for more stringent and explicit carbon pricing at later stages.
- A comparative evaluation of non-price levers' relative efficacy and efficiency and quantification for equivalence requires a careful stocktaking and mapping of the respective emissions bases of countries. Moreover, cross-country and policy-type differences can make assessments of their sufficiency to meet net-zero goals difficult.

It is widely recognized that price and non-price emission reduction policies are complementary and there is considerable support for a mix or balance of policy levers.

3.3.1.6 France Stratégie: Key messages from the report "The economic implications of climate action"

The report "The economic implications of climate action" commissioned by France's Prime Minister Elizabeth Borne in September 2022 and co-authored by Jean Pisani-Ferry and Selma Mahfouz analyses the macroeconomic impact of climate transition in France. It was published in May 2023 and accompanied by eleven thematic reports covering wellbeing, competitiveness, loss and damage and adaptation, indicators and data, distributive issues, inflation, capital markets, labor markets, modelling, productivity, and sufficiency. Around 100 experts from government bodies, economic institutes, and the academic community contributed.

Key messages

- Achieving climate neutrality is possible, but it requires a transformation comparable to an industrial revolution. This transformation will be global, fast, and primarily driven by public policies rather than by technological innovation. Redirecting technological progress towards clean technologies, reducing energy consumption, and substituting fossil fuels underpin the transition, and there is no permanent trade-off between economic growth and climate action.
- To meet emissions reduction targets by 2030 and achieve climate neutrality by 2050, efforts must be significantly accelerated with contributions from all sectors. Binding carbon budgets at both European and national level are essential.
- Decarbonization of the French economy demands substantial additional investment, exceeding 2% of GDP per year by 2030. While stimulating demand, these investments could temporarily slow down productivity growth and necessitate labor reallocations, leading to economic and social costs in the short to medium term.
- Understanding precisely the effects and mechanisms at work during the transition towards net zero will require comprehensive analysis and improved tools.

The main models used by public administrations (ThreeMe and Imaclim in France) need to improve along three dimensions. First, by using a representative household, regressive effects are not captured. Second, the quantitative impact of specific climate measures will depend on their credibility, yet modelling tools do not currently make assumptions about expectations and credibility of public action. Third, to consider the impact of climate action in other countries or of coordinated measures between countries, a multi-regional model would be needed.

Despite climate ambitions converging globally, climate policies remain divergent. With a view to maintaining price signals, the EU and France have a better mix of subsidies, regulation, and carbon pricing than do, for instance, the United States and China. Challenges associated with the EU's climate policy landscape include needing to balance climate leadership with competitiveness and sound fiscal policy and its imperfect CBAM. Given the EU's challenges, a new governance framework is needed for effective implementation of its climate strategy.

3.3.1.7 University College London: Analytical and policy approaches to climate policy and the economy

It is now generally accepted that there are no 'single bullet' climate policies that exert the necessary influence on the full range of stakeholders, from industrial sectors and firms to households and individuals. Different policy levers can be suitable for agents that respond to different incentives. For market-based decision-making seeking optimization, price-based policy may work well; for decisions determined more by behavioral traits, regulation may be better suited; and innovation and technological change can be incentivized by carbon pricing, though also requires strategic investment.

Key messages

- Carbon pricing can be implemented either via a carbon tax or via an emissions trading system (ETS). The former always raises revenue, whilst the latter only does so if the emission allowances are auctioned. Revenue raising potential may be an important consideration also because the political acceptability of carbon taxes can be increased by spending the revenue on climate projects or on mitigating adverse impacts for vulnerable groups.
- The effect of carbon pricing depends on the elasticity of demand for fossil fuels. Elasticity is higher in the long run, as this allows for investments in alternatives. If complementary policies are put in place before carbon pricing to accelerate such investments and thereby increase the price elasticity of demand, the effectiveness of carbon pricing could be enhanced.
- In the energy sector most strategic investment will need to come from the private sector, which requires an acceptable risk-return ration. Governments can decrease the relative risk by co-investing or providing assurance of future markets and prices (e.g., via CfDs), and by clarifying the risks of high-carbon investments via a credible decarbonization roadmap. To increase returns, subsidies, removal of fossil fuel subsidies, pricing carbon, stable tax incentives for private innovation, product standards, demand-generating effects of regulation, and quality requirements can be leveraged. For renewable energy, feed-in tariffs, renewable obligation certificates, or quota models such as renewable portfolio standards are also thinkable.
- Explicit fossil fuel subsidies (FFS) have stayed at around USD 500 billion per year since 2018, with a pronounced spike in 2022. They rise to USD 7 trillion in 2023 if implicit subsidies from unpriced externalities are considered.
- In principle, there are five stages to FFS subsidy reform: (i) assessment of subsidies and pricing mechanisms, (ii) building public acceptance, (iii) social protection and compensation, (iv) revenue redistribution and reinvestment, (v) complementary measures, (vi) timing and price smoothing.
- Ministries of Finance are in a good position to make use of sustainable finance, provided they have clear criteria for the kinds of investments that will qualify as 'green' and that they are able to assess investment risks.

3.3.1.8 Economic and Social Research Institute (ESRI) / Ireland – Department of Finance: Carbon taxes, distributional implications, and revenue recycling

ESRI used its I3E (Ireland, Environment, Energy and Economy) CGE model to examine the environmental and economic impact of increasing the Irish carbon tax along a trajectory to €80 per ton by 2030 using various revenue recycling schemes. This research was funded by the Irish Department of Finance and the Department of Communications, Climate Action and Environment (DCCAE) under a Joint Research Programme on Macroeconomy, Taxation and Banking in 2019. Since this research, legislation has been implemented to increase the carbon tax in Ireland to €100 per ton by 2030, which impacts the estimates presented.

Key messages

- A carbon tax increase to €80 per ton in 2030 alone will not be sufficient to reduce emissions to the levels needed to reach the EU emissions targets for 2020 and 2030. Although the increase in carbon

tax decreases emissions by 15% in 2030 compared to no tax, emissions increase significantly over time due to economic growth.
- The carbon tax is estimated to have limited impacts on GDP, especially if carbon taxes are used to reduce other distortionary taxes. The tax will increase prices of Irish goods, reducing domestic and international demand for them.
- Though rural households emit less than urban households, they face higher price impacts from the carbon tax. The impacts for rural households are regressive, with poorer households facing the highest price increases.
- With revenue recycling, real disposable income can increase despite a decrease in consumption. Revenue recycling through transfers that benefit particularly poorer household can be progressive, while revenue recycling through wage tax reduction has regressive impacts, despite resulting in the highest average increase in real income.

Since the publication of this research, implemented fiscal policy changes mean that carbon tax revenue raised from programmed rate increased over and above the first €20 per ton CO2 is ring-fenced for specific climate action expenditures.

3.3.2 Which technologies should a country focus on?

Table 3.6 Contributions about which technologies a country should focus on

Analytical questions	Contributions
• Which technologies have the most potential for cost reductions and deployment at scale? • Given cost projections, what are the decarbonization costs in different sectors? • How much can or should carbon capture and storage be relied upon to reach emissions targets? What are the cost trajectories and how reliable are they? How reliable is the technology? • Which technologies have the potential to generate a national competitive advantage? • Which technologies need and should receive policy support? • In which technologies does the economy have a competitive disadvantage? • Which technologies are expected to become obsolete, and what would the economic impacts be of this occurring? • What are the potential gains from investing in green technologies?	Oxford Institute of New Economic Thinking: Time series models for forecasting technological change, particularly for energy technologies: approaches relevant to Finance Ministries Danish Energy Agency (DEA): Technology Catalogues – Experience from Denmark

3.3.2.1 Oxford Institute of New Economic Thinking: Time series models for forecasting technological change, particularly for energy technologies: approaches relevant to Finance Ministries

Methods to make probabilistic predictions of the cost and deployment of specific technologies based on historical data are being developed by the complexity economic economics group at the Institute of New Economic Thinking (INET) at the Oxford Martin School. Instead of relying on optimization, which does not resemble real-world policy implementation, the methods rely on historical data. Information on specific technologies' future cost and deployment can support MoFs in planning investments and identifying technologies to support.

Key messages

- IAMs and the IEA's energy models are the most widely used tools for technology forecasting. IAMs are optimizing models that aim for paths that maximize economic growth contingent on climate change. However, implementing such paths requires a benevolent global decision maker, which is

not how policies have been implemented historically. Moreover, IAMs are limited to testing policies that can be implemented as a tax (or equivalent).
- IAMs often invoke wrong assumptions, including regarding technologies' minimum costs and maximum deployment rates.
- The team at INET studies future technology cost and deployment based on past costs and deployment. Technologies with decreasing costs will very likely continue to see costs decrease, and future deployment can be forecast based on past deployment and by invoking S-curves, i.e., exponential growth followed by levelling out as maturity is reached.
- Probabilistic technology cost and deployment predictions from historical models can help identify technologies to support financially and which are likely to prevail globally.
- A limitation of this approach is that historical technology models assume typical behavior and do not consider potential changes under different policies. Additionally, the models only indicate which technologies could be good bets, but not how support is best provided.

Macrocosm Inc., an Oxford spinout, developed Excel-based tools that make the models accessible via a user-friendly interface. Alternatively, the models can be implemented inside other models; code is publicly available in Python on GitHub.

INET is also designing Agent Based Models for the energy system that represent individual companies and estimate their future profits and losses under different policy scenarios. This enables testing policy combinations (rather than just tax(-equivalent) policies) in different countries. This is expected in 2025, as more resources are required before implementation.

3.3.2.2 Danish Energy Agency (DEA): Technology Catalogues – Experience from Denmark

The DEA has produced Technology Catalogues (TCs) since the 1980s to support long-term energy planning and policymaking by providing standardized, reliable data on energy technologies. These catalogues serve as a consistent reference for national and regional infrastructure planning and evaluation of energy scenarios, climate strategies, policy impacts, and technical potential for emission reduction to be used by the public sector, private sector, academia, and beyond. Each catalogue contains qualitative information and quantitative data following a uniform structure to ensure comparability across technologies.

Key messages

- As of 2024, the TCs cover nine key energy sectors: electricity and district heating generation; distributed heating systems; renewable fuels; energy storage; energy transport infrastructure; industrial process heat; commercial road freight and passenger transport; commercial maritime freight and passenger transport; and carbon capture, transport, and storage.
- A team of seven full-time staff members at the DEA manages the TCs with input from external consultants and experts to ensure accuracy and impartiality. The step-by-step process of creating the TCs includes: advisory group consultation; consultant input (external consultants ensure objective data preparation); industry and research contributions; stakeholder review (drafts shared for feedback to improve quality and gain broader acceptance); finalization (by the DEA and consultants); and publication.
- The collaborative approach to developing the TCs ensures that they remain comprehensive, accurate, and widely trusted.

The DEA has collaborations with 25 partner countries to jointly develop country-specific TCs that are eventually published by the DEA and the partnering governmental institution, focusing on building capacity within partner countries.

3.3.3 What measures can drive scale up of technologies?

Table 3.7 Contributions about measures to scale up technologies

Analytical questions	Contributions
• Which policies should be used to support technology development and deployment? • What is needed to prepare the electricity grid for higher demand vis-á-vis electrification?	University of Wisconsin–Madison: How government actions have accelerated clean energy innovation: Lessons for economic analysis and modelling by Finance Ministries
	S-Curve Economics / University of Exeter / University of Manchester: Policy packages for cost-effective transitions: learning from the past, simulating the future with the Future Technology Transformations model, and case studies from the Economics of Energy Innovation and System Transition project

3.3.3.1 University of Wisconsin–Madison: How government actions have accelerated clean energy innovation: Lessons for economic analysis and modelling by Finance Ministries

Over the past decade, the transition to a clean global economy has become much more feasible and affordable due to dramatic cost reductions in multiple technologies. Governments, including MoFs, have played a central role in accelerating innovation for renewable energy and other clean technologies, and the arrival of low-cost clean energy should be viewed as the accumulation of purposive public investment by multiple governments over decades.

Key messages

- The cost of solar panels has declined by 85%, onshore wind power by 56%, and batteries by over 90% in the past 10 years.
- Examples of countries purposively investing in clean energy include Denmark in wind power, Germany in solar power, and China in batteries.
- Modelling of future costs and adoption of clean technologies would benefit from explicit characterization of key drivers for cost reductions via learning curves (a power function that describes the relationship between costs and experience) and S-shaped adoption curves (which outline the slow and then rapid diffusion of technology, until saturation). Learning and adoption are mutually reinforcing, creating a strong role for governments to implement policies that incentivize early adoption.
- Improvements in analytical methods would include integrating up to date information on technologies and the dynamic evolution of technology costs into economic models to bring them closer to real-world conditions. Representing the adoption of small-scale end-use technologies, linkages across sectors of the economy, and a more realistic treatment of the potential for demand-side solutions would also be helpful.

The implication for MoFs and governments more generally is that putting diverse and non-correlated policy instruments in place can help create expectations for large and growing markets that are robust against political changes, business cycles, and changing social priorities. This helps foster an environment for long term investment in the energy transition.

Policy instruments can include funding innovation directly, for instance through R&D; derisking novel technologies by co-funding technology demonstrations; creating early markets via advanced market commitments; stimulating broader adoption through subsidies; pricing pollution to improve competitiveness of clean technologies; and coordinating international cooperation. All of these are only possible with investments of public funds raised by Ministries of Finance.

3.3.3.2 S-Curve Economics / University of Exeter / University of Manchester: Policy packages for cost-effective transitions: learning from the past, simulating the future with the Future Technology

Transformations model, and case studies from the Economics of Energy Innovation and System Transition project

The Future Technology Transformations (FTT) simulation models can be used to indicate which policies, individually and in combination, are likely to help deploy new technologies cost effectively. FTT modelling studies as well as lessons from past technology transitions and recent country experiences from the low-carbon transition indicate that the most cost-effective policy combinations differ at different stages of the transition, and that policy combinations can achieve more or less than the sum of their parts.

Key messages

- Simulation models such as FTT models are complementary to cost-optimization models. While the latter can identify the least cost technology mixes for a sector, the former can identify the relevant policies to support the transition.
- Three examples where the FTT model has been used illustrate the different kinds of policies likely to be effective at each stage of the transition.
    - Emergence (early) stage: Targeted investment via, e.g., subsidies and public procurement after viable technologies emerge from R&D, is most likely to be effective (illustrated by a case study on steel).
    - Diffusion (middle) stage: Regulatory policies are especially likely to be effective to support further diffusion and cost reduction as new technologies begin to compete against incumbents; subsidies and taxes can also help (illustrated by a case study on road transport).
    - Reconfiguration (late) stage: Market reforms, infrastructure investments, and more general support for integration into social and economic systems are important as new technologies become established and price-based measures have less effect (as illustrated by a case study on the power sector).
- The general findings from studies using the FTT model are broadly consistent with findings from studies of technology transitions in the past, and the theoretical understanding described by the Multi-Level Perspective on transitions, which is based on such studies.
- FTT models can be coupled with macroeconomic models to ascertain the implications of simulated policy scenarios and associated sectoral outcomes for macroeconomic indicators such as GDP and employment. An example of this approach using the E3ME model and FTT results from technology scenarios in the power sector is included in the full contribution.

As policy combinations can achieve more or less than the sum of their parts, MoFs need to work closely with other parts of government and consider policies as packages, not just individually. Deliberate alignment of fiscal and regulatory policies is likely to lead greater cost-effectiveness.

3.3.4 What are the domestic impacts of international climate policy?

Table 3.8 Contributions about domestic impacts of international climate policy

Analytical questions	Contributions
• What are the domestic impacts of other countries' carbon border adjustment mechanisms, green subsidies, or investment in critical technologies? • How will international climate policy affect domestic competitive advantages and the trade balance?	Massachusetts Institute of Technology – Abdul Latif Jameel Poverty Action Lab (J-PAL): How low- and middle-income countries can prepare for carbon border adjustment mechanisms – Emerging analytical support available for Finance Ministries

3.3.4.1 Massachusetts Institute of Technology – Abdul Latif Jameel Poverty Action Lab (J-PAL): How low- and middle-income countries can prepare for carbon border adjustment mechanisms – Emerging analytical support available for Finance Ministries

In the context of the EUs Carbon Border Adjustment Mechanism (CBAM) imposing a levy on imported products based on the difference between the EU ETS carbon price and the carbon price paid in producing countries from 2026, governments outside the EU are attempting to understand how this impacts their exports and how to mitigate negative effects. To help in particular low- and middle-income countries (LMICs) with this process, LMIC governments, researchers, and policy experts are being brought together as an informal community of practice. Although CBAM poses challenges for exporters, some green producers may develop a competitive advantage through the policy.

Key messages

- MoFs, especially in LMICs, do not have clear models or information on how CBAM and other carbon pricing mechanisms will affect their economies.
- An informal community of practice comprised of LMIC governments, researchers, and policy experts is being built by Kimberly Clausing (UCLA) and Catherine Wolfram (MIT) in collaboration with the African Tax Institute, the Climate Action Platform for Africa, and J-PAL, to help LMICs prepare for the oncoming EU CBAM. Governments interested in joining the community of practice can contact Claire Walsh at cwalsh@povertyactionlab.org.
- CBAM has generated renewed interest in domestic carbon pricing for its potential to reduce tariff exposure and to support domestic resource mobilization and the green transition. More generally, the EU CBAM provides incentives to spur decarbonization in impacted industries, whether via carbon pricing or otherwise.
- Countries designing CBAMs should consider incorporating measures that limit their potential negative effects on low-income countries.

MoFs should take three key steps to prepare for the EU and other potential CBAMs. Firstly, analyze exposure to oncoming tariffs using models that incorporate general equilibrium effects (e.g., price changes in commodities regulated by the CBAM), the potential for market shifting, and relative competitiveness under a CBAM. Secondly, model the benefits and costs of policy responses (e.g., greening industry, domestic carbon pricing). Thirdly, build domestic carbon monitoring and reporting systems to avoid getting assigned a default carbon intensity, especially countries with greener production or a greener energy mix.

3.3.5 What are the macroeconomic impacts of the transition and how can they be managed?

Table 3.9 Contributions about the macroeconomic impacts of the transition

Analytical questions	Contributions
• Which sectors are most impacted by decarbonization? How can MoFs quantify this impact? • Which sectors face the risk of stranded assets? • What is the likelihood of a disorderly transition? • How could a disorderly transition impact the economy? • How does uncertainty concerning the transition impact the economy?	Sweden – National Institute of Economic Research (NIER): NIER annual report
	Mexico – Ministry of Finance: Live transition risks – The impacts of climate action on state owned enterprises and qualitative and causal link approach in addressing challenges
	Biden-Harris Administration – U.S. Department of the Treasury under the Biden-Harris Administration: Economic impact assessment of Inflation Reduction Act (IRA)
	Willis Towers Watson: The economic impacts of disorderly climate transitions - How Finance Ministries can avoid boom and bust with sound economic analysis and effective climate policy
	World Resources Institute (WRI): Informing economic modelling approaches for effective climate transitions

	Coalition for Capacity on Climate Action (C3A): Transition scenarios for Ministries of Finance: A review of relevant approaches and a roadmap for upgrading analytical capability
	S-Curve Economics / University of Manchester / University of Exeter: Low carbon innovation and industrial strategy: analytical tools and frameworks for Ministries of Finance
	World Bank: Findings from the World Bank Group's Country Climate and Development Reports on the macroeconomic impacts of resilient and low-emissions development scenarios
	World Bank: New modelling approach combining bottom-up sectoral analyses with top-down macroeconomic models to understand the economic impacts of resilient and low-emissions development
	Asian Development Bank (ADB): Helping MoFs to Understand the Macroeconomic Impacts of the Transition to Net Zero in Asia

3.3.5.1 Sweden – National Institute of Economic Research (NIER): NIER annual report

As part of its mandate to produce economic forecasts and analysis and support policymaking the Swedish National Institute of Economic Research (NIER) publishes an annual report series in which the environmental and economic impacts of different policies are analyzed. By independence of NIER, the series is supervised by a scientific board and topics are chosen by the institute. The latest report assesses the income-distributional effects of climate policies in Sweden.

3.3.5.2 Mexico – Ministry of Finance: Live transition risks – The impacts of climate action on state owned enterprises and qualitative and causal link approach in addressing challenges

Mexico uses qualitative and causal-link approaches to study the impact of climate policies on the environmental footprint and productivity of different industries. The aim is for the analysis to help devise strategies to ensure sustainable economic growth. Data availability and accuracy are major challenges that remain to be addressed.

Key messages

- Medium- and long-term economic planning in Mexico aims for sustainable economic growth, reducing social disparities, and mitigating the effects of climate change. Qualitative and causal-link approaches are leveraged to identify suitable policies to these ends.
- Transition-related issues are among the key challenges for state-owned enterprises, especially considering their link to fiscal revenues. The chemical sector, for instance, needs to square high technology adoption cost with innovation and climate gains against a backdrop of a highly interlinked industry. In the hydropower sector, obstacles include simultaneously managing water resources and addressing environmental concerns.
- Lack of data availability and accuracy are a current impediment to policy implementation.

The policy implementation challenge owes to lack of indicators and metrics to monitor resources such as water and minerals, and institutional barriers, such as resistance to change in established industries and capital-intensive investment in new technologies. Next steps include an effort to improve data collection, analysis, and the regulatory environment, and public-private cooperation on sustainable development goals.

3.3.5.3 Biden-Harris Administration – U.S. Department of the Treasury under the Biden-Harris Administration: Economic impact assessment of Inflation Reduction Act (IRA)

The U.S. Treasury Office of Economic Policy has a series of writings on the Inflation Reduction Act (IRA) to communicate the economics of the IRA to a broad audience. These outline that the IRA is itself contributing to economic growth, that there is a strong economic case for the IRA, and that it benefits disadvantaged communities.

Key messages

- Economic growth: Mitigating and adapting to climate change aids growth by avoiding damages and reducing pollution, which improves the health and productivity of workers. Government funding for R&D spurs innovation in clean technology, with spillover benefits. A lower reliance on fossil fuels also means a lower exposure to price volatility in those markets, which can initiate and exacerbate recessions.
- The IRAs economic case: Modelling results from academic research show that there is a strong case for the IRA. Lower bound estimates of the local air pollution health benefits range from $20 billion to $49 billion in 2030 alone (Mahajan et al. 2022; REPEAT 2022; Roy et al. 2022).
- Impact on disadvantaged communities: Renewable energy facilities are growing fastest in so-called Energy Communities, showing that the clean energy transition can benefit communities that have been historically reliant on fossil fuels for economic vitality. Since the IRA passed in December 2023, 75% of new clean facility announcements have been in counties with median incomes below the U.S. aggregate median income, and 84% in counties with college graduation rates below the U.S. aggregate college graduation rate.

To support the Biden Administration's approach to climate change, the Treasury has appointed the first-ever Climate Counselor and established the Climate Hub in the Office of the Secretary to help strategize concerning the Treasury's work on climate and to coordinate information sharing across the Department, among other things. The Climate Hub is part of an intentional effort to coordinate rather than centralize the Treasury's climate work.

3.3.5.4 Willis Towers Watson: The economic impacts of disorderly climate transitions - How Finance Ministries can avoid boom and bust with sound economic analysis and effective climate policy

MoFs need to jointly manage four sources of risk from climate change: physical risks; risks of overcapacity and stranded assets as carbon intensive industries decline; risk of potential shortages from delayed establishment of alternatives; and the impact of a disorderly transition driven by economic and political shocks, investor uncertainty, and mismanagement. MoFs can use analytical tools and policy mechanisms to help understand and manage these risks, yet more work is to be done. Of the four, the risk of a disorderly transition is particularly dangerous and poorly understood.

Key messages

- Of the four risks (physical risk, stranded assets, shortages, disorderly transition), disorderly transition risk is the least understood and, possibly, the most dangerous. Fear of disorder can drive investor and policy decisions that significantly increase costs and reduce economic growth, even if the disorder-related shocks never materialize. Similarly, uncertainty can drive investment and policy decisions that lead to disorderly transitions.
- Whilst economic analysis and modelling, including scenario analysis, sectoral models, macroeconomic models, and tax and policy mechanisms, can help the management of all four risks, the analytical tools and policy mechanisms required to manage disorderly transitions have significant gaps.
- Active management of the transition at a national and global level can create significant economic value globally by increasing confidence, lowering the cost of investment, and avoiding volatility that reduces economic growth.
- Clear and transparent plans and targets, an accelerated transition, and robust, credible and viable mechanisms are needed to manage transition relevant shocks – whether technological, economic, political, or resource driven.

To manage risks and reduce the impact of uncertainty during the transition, setting credible targets and sticking to them reduces one major source of uncertainty and volatility for all sectors. Beyond that, the first step should be to identify sectors, technologies, and regions where a mismatch between phasing out and phasing in alternative energy sources would have major economic impacts and which are highly susceptible to mismatches. Here, additional policy responses may be useful.

3.3.5.5 World Resources Institute (WRI): Informing economic modelling approaches for effective climate transitions

Quantitative economic models (QEMs) are essential tools for systematic economic analysis, identifying scenarios, and constructing narratives that can support MoFs in answering critical climate questions. MoFs need to understand the macroeconomic impacts of decarbonization on GDP and beyond. To this end, MoFs should become adept at using a range of complementary QEMs.

Key messages

- No single model is universally superior. Model selection depends on the climate policy question and objective at hand; a model's purpose, outputs, theoretical framework, data requirements, and construction time; and available national and international capacity.
- Broadly speaking, aggregate, global models such as IAMs help prepare international debates and understand economic consequences, microeconomic models help assess distributional impacts, IO (and thereby CGE) models help consider the relations of production among sectors, and GIS-based models help identify geographic differences and distributional impacts of climate change.
- Effectively deploying models can help ensure fiscal policy fosters sustainable development, builds resilience against climate shocks, and mitigates climate change.
- Models run and ideally built in collaboration with MoFs have the highest chances of being maintained and used effectively, as this ensures models are tailored, fosters a sense of ownership, and helps build in-house capacity.

The most common model types in the national context are general equilibrium models, IAMs, and policy appraisal tools. At WRI, system dynamics models are used most frequently, followed by policy appraisal and ecosystem and land-use models. This evidences that there is scope for MoFs across the board to move towards more holistic modelling frameworks than they use at present.

Recommendations from WRI to MoFs include developing an in-house model ecosystem based on the latest evidence of climate science that aims to be consistent and comprehensive. This can include integrating models with different foci, and adopting system dynamics models (scarcely used by MoFs) that can capture complex and dynamic interactions, feedback loops, and time-delays associated with the climate system and system interactions. Analysis should include metrics beyond GDP and help construct positive narratives around the wider benefits and opportunities of the transition. Finally, models should be continuously monitored, updated, and refined based on new data to ensure their sustained relevance and effectiveness.

3.3.5.6 Coalition for Capacity on Climate Action (C3A): Transition scenarios for Ministries of Finance: A review of relevant approaches and a roadmap for upgrading analytical capability

A recent technical note by C3A explores methodological approaches MoFs could draw upon to build scenarios of the climate and nature transition to support analysis of risks and opportunities and develop appropriate policies. Global climate scenarios have been developed by the IPCC, NGFS, and the IEA, for instance, with scenarios for biodiversity in the works and regional and national scenarios also being developed. These are all valuable at various stages in the policy-making process.

Key messages

- Global scenarios created by international organizations (e.g., IPCC, NGFS, IEA) helped create the general framework for assessing the long-term impacts of climate change and can be used to assess risks and opportunities of national strategies in the global context.

- Regional and national scenarios have primarily been used to inform public policies, including national contributions to global agendas such as NDCs, Long-Term Low-Emission Development Strategies, and forthcoming National Biodiversity Strategies and Action Plans (NBSAPs).
- Scenarios can be used to assess interlinkages between global trends, national vulnerabilities to climate change, and domestic policy priorities. This is especially useful for assessing the impacts of biophysical transformation on economic and fiscal aggregates, opportunities and risks of the transition, and short- and long-term impacts of climate policies, and for establishing narratives for transition pathways.
- Throughout the policy-cycle, scenario analysis can help inform decision-makers, set a policy agenda for the transition, refine priorities, and design policy options. More generally, scenarios can help open space for thinking in a context of systemic change.
- As existing scenario-based approaches are not specifically designed for decision-making processes within MoFs, the C3A technical note outlines how current or new scenarios could be developed and used by Ministries of Finance for policy appraisals in the transition process.

3.3.5.7 S-Curve Economics / University of Manchester / University of Exeter: Low carbon innovation and industrial strategy: analytical tools and frameworks for Ministries of Finance

The transition presents opportunities for economic growth and development as well as risks of losing strong competitive positions as industries undergo structural change. There is risk of stranded regions, communities, and industries as well as assets, with negative consequences for productivity, taxes, social spending, and wellbeing. Countries cannot opt-out of these risks by not decarbonizing as the transition is global and the economic context changing, but governments can decide how to respond.

Key messages

- If a government decides to take actions to increase national competitiveness in the context of the low carbon transition, two main policy questions arise: (1) In which technologies, sectors, or areas of economic activity these efforts be focused? and (2) Which policies are likely to be most effective in increasing national competitiveness in these areas? These are strategic questions and inherently uncertain.
- Analytical tools for identifying areas to focus on include technology learning curves, input-output analysis, revealed comparative advantage, economic complexity analysis, and gravity models. However, all these tools have limitations and should be complemented by qualitative knowledge of national industries, skills, resources, and places.
- Conceptual frameworks for understanding the role of policy include market failure, market shaping, smart specialization strategy, green industrial policy, and mission-oriented industrial strategy. These frameworks can indicate the kinds of policies likely to be successful in building competitiveness, but not the specific policies that are likely to succeed in any given situation.
- There is a foundational difference between market failure and market shaping frameworks. The former is concerned with removing obstacles to the efficient allocation of economic resources (Pareto optimality) at a fixed point in time and presumes policy intervention is only justified if it addresses a market failure. The latter is appropriate when the aim is to achieve economic change in a particular direction and presumes an intervention can be justified if it prepares for change that is likely, creates change that is desirable, or avoids change that is undesirable.
- Models that simulate processes of change in the economy can to some degree inform the selection of policies intended to build low carbon competitiveness. Technology diffusion models can indicate which policies are likely to grow domestic markets for clean technologies. Agent-based models can test the reaction to policy of industry or investors or show the effect of different countries' policies within the global market.
- Over-reliance on quantitative models can be risky as the outcomes of any innovation and industrial policy are subject to substantial uncertainties. Analysts can sense-check and complement model

outputs through comparison with other forms of information and scenario analysis can be used as a structured way of exploring uncertainty.

3.3.5.8 World Bank: Findings from the World Bank Group's Country Climate and Development Reports on the macroeconomic impacts of resilient and low-emissions development scenarios

Modelling in nearly 50 countries shows that low-emissions development pathways, in most cases, can be implemented without compromising economic growth. However, these scenarios are not necessarily consistent with a global temperature goal or a global net zero target, and the low costs of (or the benefits from) the transition depend on a range of external and internal factors, such as mitigation elsewhere, technological development, the domestic policy environment, and access to financing.

Key messages

- Country Climate and Development Reports (CCDRs) aim to help countries prioritize the most impactful actions to simultaneously boost resilience and adaptation to climate change, reduce GHG emissions, and deliver on broader development objectives. They are especially useful for MoFs by providing sectoral deep dives and macroeconomic and financial assessments. The World Bank models used for the analysis can be made available to MoFs upon request.
- The reports are housed by the World Bank yet country-specific in that they are consistent with and reflect national climate targets. They explore plausible pathways to these ends and refrain from putting forward supposedly optimal decarbonization pathways. The transition pathways also vary depending on, e.g., country-specific potential for renewable energy or the political environment.

Empirical results:

- Across 50 low- and middle-income countries economic growth can be similar or faster in low-emissions scenarios, conditional on favorable circumstances such as well-designed policies, strong participation of the private sector, reallocation of resources (including capital and labor), and complementary measures to navigate political economy challenges.
- The impact of climate-related investments on short-term economic growth depends on the return on investments and on how investments are financed (i.e., whether they crowd in or crowd out other investments). Especially in upper-middle-income countries, CCDR low-emissions scenarios tend to combine growth-enhancing reforms and investments with short-term costs and long-term benefits.
- Low-emission development scenarios almost always require higher investments and lower operational costs and thus have larger short-term impacts on household consumption than on GDP. This emphasizes the importance of interventions to facilitate a just transition.
- CCDRs show that targeted adaptation actions can reduce the impacts of climate change significantly and have high economic returns. Nonetheless, adaptation cannot fully offset climate change impacts.
- Some CCDRs adopt a triple dividend approach of avoided losses from climate change, economic benefits independent of avoided impacts, and wider environmental and social benefits. The latter two are often far greater than the first.

3.3.5.9 World Bank: New modelling approach combining bottom-up sectoral analyses with top-down macroeconomic models to understand the economic impacts of resilient and low-emissions development

The World Bank's Country Climate and Development Reports (CCDRs) use a hybrid modelling approach to explore the economic impacts of resilient and low-emissions development pathways. The approach integrates granular insights from sector-level transition pathways analyzed via sectoral technoeconomic models into macroeconomic models, which help ensure consistency, analyze general equilibrium effects, and ascertain the implications for macroeconomic variables such as GDP, employment, and debt. The implications of different financing options are also considered.

Key messages

Rationale:

- The hybrid approach can overcome some challenges of modelling the transition. It can help account for the non-marginal nature of the transition, consider the role of technologies, and reflect non-price policies via sectoral models, without sacrificing analysis of general equilibrium effects and macroeconomic feasibility, i.e., consistency across sectors.
- Through the approach, MoFs can use the work of line ministries, which use technical sectoral models to develop their detailed strategies, pathways, and policies, within a macroeconomic framework, which is needed by the MoF to finance the transition pathways, manage trade-offs across sectors, and develop consistent economy-wide strategies that account for economic and financial feasibility constraints.

Four key ideas underly the approach:

- Separating the analysis into sectoral and general equilibrium components means complexity can be captured without losing transparency and tractability.
- The approach explores feasible pathways that are consistent with each country's climate and development targets rather than being too prescriptive on what an optimal pathway looks like.
- By using sectoral models, the approach can capture the complexity and diversity of climate policies beyond (but including) carbon pricing (which, in contrast to other policies, is readily implemented in macroeconomic models).
- By using sectoral models, more market and governance failures can be captured.

A recent application of the approach to Türkiye by Hallegatte et al. (2024) considers the pathway to net zero by 2053 (the government target) using sectoral technoeconomic models for power, transport, buildings, and forest landscapes; more simplified roadmaps for industry and agriculture; and two macroeconomic models (MANAGE, a single-country CGE model, and MFMod, an aggregate macrofinancial model). Empirical results indicate the resilient and low-emissions pathway could contribute positively to Türkiye's economic growth despite substantial redirection of investment, especially if co-benefits are considered. However, this result is contingent on no crowding out of other investments.

3.3.5.10 Asian Development Bank (ADB): Helping MoFs to Understand the Macroeconomic Impacts of the Transition to Net Zero in Asia

Achieving global climate goals critically depends on Asia's development path. The 2023 ADB publication *Asia in the Global Transition to Net Zero* uses the WITCH IAM to analyze required transformations of key sectors, assess the socioeconomic implications of the transition, and explore the implications of a global transition to net zero for developing Asia. The report estimates policy costs of different climate pathways, energy investment requirements, trade and employment implications in the energy sector, and potential benefits and co-benefits of climate action.

Key messages

- The WITCH model was customized to better represent developing Asia by expanding its geographic resolution to provide disaggregated results for the three largest emitters in the region (the Peoples Republic of China, India, and Indonesia) and regional results for South Asia, Southeast Asia, and Caucasus and Central Asia.
- The report considered five policy scenarios: (i) Current policies, (ii) Nationally Determined Contributions (NDCs), (iii) NDCs followed by national net zero pledges, (iv) NDCs followed by coordinated action toward global net zero to achieve well below 2°C of warming, and (v) accelerated action toward global net zero to achieve well below 2°C of warming. Model results exhibit lower costs when there is global coordination to achieve the Paris Agreement goals, indicating that governments must not only commit to ambitious climate goals but also work together.
- One of the report's central messages is that the benefits from avoided climate change damage to the region are far greater than costs associated with the transition. Under ambitious climate action the

net present value of benefits is five times the cost for developing Asia even before considering substantial co-benefits from reduced air pollution.
- In the near term, energy efficiency and land use abatement are the most important sources of GHG mitigation in developing Asia. Improved energy efficiency will temper increase in energy demand while land use will be a major source of mitigation for some countries like Indonesia.
- As the largest source of GHG emissions, the energy sector and in particular the electricity sector will undergo rapid transformation. Average annual investment in the regional power sector will increase from $468 billion in 2021 to $707 billion under ambitious climate policy (about 2.2% of GDP).
- An additional 1.5 million energy sector jobs could be created in Asia by 2050. Nonetheless, higher residential energy and food prices due to phase-out of carbon intensive energy and diversion of land from food production could adversely affect lower income households.
- The ADB is also compiling a suite of complementary global and country level models for a modelling initiative with the Government of India, to analyze the implications of India's climate pathways.

Ministries of Finance, in their capacity to influence national budgets, economic policies, and financial regulations, have a crucial role in national climate action. The report identifies three policy pillars to attain a low-carbon development pathway. First, reforming prices via carbon pricing and fossil fuel subsidy reform could trigger a transition to low-carbon growth. Second, facilitating low-carbon innovation and investment and mobilizing finance for decarbonization are necessary to jumpstart development of low-carbon technologies and catalyze private capital. Third, policy measures to shield poorer households from high energy and food prices and support for workers to smooth labor market transitions will be required.

3.3.6 What are the risks to the financial system from the transition and how can they be managed?

Table 3.10 Contributions about risks to the financial system from the transition

Analytical questions	Contributions
• How could a disorderly transition impact the financial system? • How might financial stability be impacted by the transition? • How may physical climate risks impact financial stability? • How may climate policies affect investor expectations? • How can resilience in the financial sector be fostered in face of climate change and the transition?	IMF: Understanding the Financial Stability Implications of Climate Risks: Approaches to Climate Risk Analysis in FSAPs
	Network for Greening the Financial System (NGFS): The NGFS's approach to modelling the short-term macroeconomic implications of climate change and the transition

3.3.6.1 IMF: Understanding the Financial Stability Implications of Climate Risks: Approaches to Climate Risk Analysis in FSAPs

Climate change and mitigation actions present risks and opportunities for real economies and financial sectors. Climate risk analysis plays a crucial role in understanding the potential transmission channels of climate-related risks and assessing the broader implications for economic and financial systems. Climate-related financial risks include transition and physical risks, both of which can propagate through the financial system via multiple channels, potentially trigger financial risks in the public and private sectors, and affect long-term economic growth.

Key messages

- The analysis of climate-related financial risks has distinct characteristics that introduce new data and modeling challenges. These include longer time horizons, scarce disclosure of climate-related financial data, assessment of climate-related financial risks extending beyond the economic and

financial factors typical of conventional risk analysis, limited to no guidance from historical trends given that climate risk analysis is inherently forward looking, greater sectoral and geographical granularity, and a higher level of uncertainty and model complexity due to interactions between climate, anthropogenic activities, and economic dynamics.
- The modeling framework of the IMF's climate risk analysis for both transition and physical risk has three stages: (1) climate risk diagnostics with a global and country-specific perspective, (2) design of country- and financial system-specific climate scenarios, and (3) financial stability.
- The macro approach to assessing implications of climate-related risks for financial stability aims to quantify the impact at an aggregated economic/financial level and uses climate-augmented macrofinancial scenarios as inputs for standard stress testing methodologies to assess the financial system's resilience. The micro approach is an extension of the macro approach and examines the impact using granular income and balance sheet data of a large sample of individual firms and/or households (when reliable granular data is available). The integrated micro-macro modeling framework has been piloted in several Financial Sector Assessment Programs (FSAPs).
- Physical risks arise as the interaction of three components: hazard, exposure, and vulnerability. The macro approach incorporates analysis of the impact of aggregate shocks, due to hazard damages, on macroeconomic and financial variables by inputting country-level aggregates of granular damages estimated by catastrophe models into macro models. The micro approach requires granular transaction and loan-level data and thus has limited application due to data constraints.

The models can be improved by improving temporal resolution and refining short-term scenarios to better capture near-term shocks, enhancing sectoral and spatial granularity to better represent heterogenous climate-related risks across sectors and regions, combining transition and physical risk considerations in an integrated modeling framework, and developing more disorderly scenarios to capture tail risks and compounding impacts.

3.3.6.2 Network for Greening the Financial System (NGFS): The NGFS's approach to modelling the short-term macroeconomic implications of climate change and the transition

NGFS is developing its first vintage of short-term climate scenarios to be released in early 2025. These consider shorter term shocks, impacts, and frictions, including abrupt changes in policy, investor sentiment, or consumer behavior, and their direct and indirect effects as they propagate through the economy. Longer-term analysis may smooth over these facets.

Key messages

- Understanding the macrofinancial impacts of climate change over a shorter time frame is necessary to assess the financial risks from transition and physical risks. Relevant for MoFs, the short-term scenarios capture trends in GDP, unemployment, and inflation; sovereign spreads, bond valuations, and probability of default adjustments for public finance risk management; and can inform on the macrofinancial implications of various recycling options for carbon pricing revenue.
- Considering the financial sector and its amplifying role of (local) climate-related risks is fundamental. Sudden re-adjustments in financial market expectations can lead to, for instance, fire sales, asset stranding, and liquidity stress, which may propagate through the economy.
- Public spending is the primary shock-absorber for macro-financial impacts, though over-reliance on this can lead to perilous debt levels. Hence, carbon pricing can be attractive for its ability to fund, for instance, subsidies that counter-balance energy prices or distributional transfers that make the transition more socially acceptable.

Modelling long-term macroeconomic trends smooths changes and impacts over time, reducing the abrupt and acute nature of shocks. Specifically, IAMs used by the NGFS compute economic equilibriums over five-year timesteps, rendering them unsuitable to capture short-term frictions. Hence, dedicated short-term scenarios are important. Currently, the NGFS scenarios are targeted more specifically to a risk assessment audience and explore tail risks. This means they may not be as relevant for MoFs as scenarios designed for monetary policy, though they can be useful for financial stability exercises.

A conceptual note on short-term scenarios was published in October 2025, which develops five narratives to underpin the short-term dynamics of transition and physical risk. The narratives differ based on shock source, transmission channels, and short-term policy reactions. After releasing the initial short-term scenarios, future developments include enhancing geographic granularity and modelling climate policies explicitly.

One practical use case of these short-term scenarios is the preparation of NDCs, as their cut-off date is approaching in 2030. However, the climate policy mix employed to steer GHG emissions is ultimately at government discretion and not fully captured by the shadow price for carbon in the scenarios.

3.3.7 What are the fiscal impacts of the transition and how can they be managed?

Table 3.11 Contributions about fiscal impacts of the transition

Analytical questions	Contributions
• What are the costs of the transition (e.g., of reaching NDC targets)? • How is the tax base projected to change, especially as fossil fuels are phased out? • What are potential sovereign credit risks emanating from physical climate risks? • How can climate and environmental considerations be integrated into development of the budget? • What are potential new sources of tax revenue and what is their revenue raising potential? • How can carbon pricing revenue best be recycled?	Switzerland – Federal Department of Finance: Introduction of a replacement levy on electric vehicles
	Inter-American Development Bank (IDB) / French Development Agency (AFD) / University College London: How fossil-fuel reliant ministries of finance can assess the fiscal risks of global climate action
	Inter-American Development Bank (IDB) / French Development Agency (AFD) / University of Costa Rica: Managing the Fiscal Impacts of Electric Vehicles, Public Transport, and Biking
	Ireland – Department of Finance: Modelling Carbon Tax Projected Revenues 2024-2030 in Ireland

3.3.7.1 Switzerland – Federal Department of Finance: Introduction of a replacement levy on electric vehicles

Due to the electrification of the transport sector, Switzerland expects to lose substantial revenue from its mineral oil tax and envisions a distance-based levy on electric vehicles as alternative source of revenue by 2030. The distance-based levy would differ by vehicle type and weight, such that the tax burden on electric vehicles mimics that on fuel-based cars and the price of mobility remains unchanged.

Key messages

- Electrification of the transport sector can reduce public revenue substantially; in Switzerland, the loss is estimated at up to 2 billion Swiss francs per year (2021 prices) in a net-zero by 2050 scenario relative to business as usual.
- To address the revenue gap, alternative sources from electric mobility need to be sought, and distance-based measures are one option.

It is imperative to start the process of developing alternative revenue streams early, to allow time to enact the necessary legislation. In Switzerland, public consultations and parliamentary debates are expected in 2025 and 2026, with the levy to enter into force by 2030.

3.3.7.2 Inter-American Development Bank (IDB) / French Development Agency (AFD) / University College London: How fossil-fuel reliant ministries of finance can assess the fiscal risks of global climate action

The energy transition poses a serious challenge for oil and gas exporters, as it renders future demand and prices for oil and natural gas increasingly uncertain and threatens fiscal revenues from fossil fuels. In this context, MoFs in fossil fuel-dependent countries are re-evaluating economic dependencies and fiscal strategies, and can help build more diversified, resilient economies by leveraging strategic analyses and learning from successful examples.

Key messages

- Studies that examine how technology and climate policy can affect fossil fuel production warn of stranded assets though typically do not evaluate the associated fiscal consequences. Moreover, they typically provide numbers at the global or regional rather than the country level and rely on a single scenario for fossil fuel demand without considering uncertainty about carbon budgets and technology choices.
- Recent studies employing a combination of models (TIAM-UCL, BUEGO, and GAPTAP) integrate global energy demand forecasts and economic and geological data at the project level and represent different tax regimes that apply to each field. They focus on Latin America and the Caribbean, providing results for the region as well as 12 individual countries.
- The studies find that stringent global climate action could reduce cumulative government revenue in Latin America and the Caribbean to $1.3-2.6 trillion by 2035, compared to $2.7-6.8 trillion if oil demand followed historical trends.

To develop robust fiscal strategies, Ministries of Finance in fossil fuel-dependent countries should employ comprehensive scenario planning and modeling tools such as TIAM-UCL and BUEGO to help understand the potential impacts of different energy transition scenarios, or use alternative, simpler models. They can also draw inspiration from nations that have successfully diversified their economies, such as Dubai or Norway.

3.3.7.3 Inter-American Development Bank (IDB) / French Development Agency (AFD) / University of Costa Rica: Managing the Fiscal Impacts of Electric Vehicles, Public Transport, and Biking

For Finance Ministries concerned with fiscal stability and broader macroeconomic outcomes, it is crucial to balance the economic benefits and fiscal challenges of decarbonizing road transport. Decarbonizing road transport can yield significant economic benefits, e.g., by reducing congestion, accidents, air pollution, and energy costs, and improving health outcomes. However, it can also erode important tax bases such as fuel excise taxes or duties on the usage or import of vehicles.

Key messages

- Many existing studies on the fiscal impacts of decarbonizing road transport consider the fiscal dimension in isolation. Whilst the fiscal considerations are important, this approach disregards the broader benefits to society. Moreover, existing studies do not quantify the incidence of tax reforms on households and firms and thus do not state whether the private sector would be better or worse off.
- Recent IDB work assesses the financial, fiscal, and distributional impacts of road decarbonization in a single framework via OSeMOSYS, a bottom-up energy model, augmented by a tax and a distributional impact module.
- OSeMOSYS starts from projected mobility demand (passenger km/year) and freight demand (tons-km/year) based on assumed GDP and population scenarios and then calculates the cost to satisfy these demands using different means of transportation. The model accounts for capital costs, maintenance, and fuel expenses, and estimates the cost to deploy the needed infrastructure (e.g., bus lanes, charging stations).

- The model was applied to Costa Rica, which has a net zero by 2050 plan. Taxes on gasoline, diesel, vehicle ownership, and import duties make up 20% of its fiscal revenues.
- Empirical results include that between 2023 and 2050 decarbonizing transport brings 1.49% of GDP worth of financial benefits to households and firms, while the government faces a fiscal loss of 0.41% of GDP. The model can be used to show that there are many policy mixes that make up the lost revenue whilst leaving all groups of households and firms better off than without transport decarbonization, though there is no single best strategy.

3.3.7.4 Ireland – Department of Finance: Modelling Carbon Tax Projected Revenues 2024-2030 in Ireland

The Department of Finance in Ireland modelled and published research (2024) examining the potential impacts of the transition to a lower carbon economy on carbon tax yields in Ireland over the next six years. Increases in carbon tax revenue lead up to €935 million in revenue in 2023; approximately 1% of exchequer tax receipts. Total exchequer revenues from the carbon tax in the next six years are estimated at €8.8 billion.

Key messages

- To provide fiscal insights to inform policy, a scenario analysis of the potential impact of implementing policy measure targets of the Irish Governments Climate Action Plan 2024 (CAP24) on carbon tax revenues was conducted. The analysis maps and links forward projected estimates of energy use from the Sustainable Energy Authority of Ireland (SEAI) and expected fuel requirements to carbon tax rates and exchequer net carbon tax receipts based on 'With Additional Measure' (WAM) and 'With Existing Measure' (WEM) scenarios from the SEAI and the Environmental Protection Agency (EPA).
- In the next six years, the carbon tax is estimated to raise €8.8 billion in exchequer revenue, based on planned carbon tax rate increases and WAM fuel scenarios from the SEAI. Of this, €6.4 billion may be directly allocated to climate actions, on a no-policy-change basis.
- Under the SEAI WEM fuel scenario and planned carbon tax rate increases, net carbon tax receipts are estimated to raise an additional €9.7 billion in exchequer revenue. Of this, approximately €7.1 billion are estimated to be raised from increases above the baseline rate of €20 per ton of CO_2 emitted which is ring-fenced for 'Just Transition' climate action.

Protecting exchequer revenue streams in an environmentally appropriate fashion, alongside influencing and encouraging behavioral change to achieve decarbonization over the medium-term, aiming for carbon neutrality by 2050, will be critical. Changes to taxation alone cannot achieve the necessary greenhouse gas emissions reductions, but taxation clearly has an important role to play as part of the wider climate action response.

3.3.8 What are the distributional and socio-economic impacts of the transition and how can they be managed?

Table 3.12 Contributions about distributional and socio-economic impacts of the transition

Analytical questions	Contributions
• What are the labor market implications of structural change vis-à-vis the transition? • What policy interventions are needed to buffer labor market impacts of the transition? • What are the distributional impacts of the transition? • What policies can help manage distributional impacts and facilitate a just transition?	European Union – European Commission: Assessing the distributional consequences of the transition in the EU
	World Bank: Identifying Labor Market Frictions in the Green Transition: Implications for Finance Ministries
	London School of Hygiene & Tropical Medicine: The health co-benefits of climate change mitigation: Why climate leadership by Finance Ministries can help them to deliver on their core objectives of economic development and responsible management of the public finances
	Centre for Social and Economic Progress (CSEP): India's Net Zero Transition: The Challenges within Existing Modelling Approaches of Economic Impacts

3.3.8.1 European Union – European Commission: Assessing the distributional consequences of the transition in the EU

Implementing the Fit-for-55 package would increase the cost of energy (and related equipment) relative to the baseline, with regressive effects in the absence of re-distribution. Pairing output from the JRC-GEM-E3 model, which itself takes inputs on the transition of key sectors from PRIMES, with detailed microdata from the European Household Budget Survey (HBS) evidences the regressive effect. It also shows a progressive effect can be achieved by a lump sum transfer using (a fraction of) the additional revenue from the package's expanded carbon pricing, especially when this is targeted to households at risk of poverty.

Key messages

- The Fit-for-55 package is associated with an increase in the cost of energy relative to the baseline due to expanded carbon pricing (EU ETS expansion to include buildings and road transport) and additional investment needed to comply with more stringent standards (e.g., for buildings or vehicles).
- The JRC-GEM-E3 CGE model, designed to capture the macroeconomic implications of energy scenarios from the PRIMES energy model, does not directly account for regressive effects, as it models one representative household.
- Analyzing the CGE model output using microdata on household expenditures, from the European HBS in this case, can shed light on distributional effects and indicate the impact of redistributive policy.

Next steps for MoFs include designing redistributive policy, especially given prospects of additional carbon pricing revenues.

3.3.8.2 World Bank: Identifying Labor Market Frictions in the Green Transition: Implications for Finance Ministries

Labor market dynamics are often missing from macroeconomic models, including those used my MoFs. Whilst studies do tend to find that the green transition would lead to more job creation, these generally rely on assumptions of a flexible labor market. Accounting for frictions in macroeconomic models is important as associated analysis can help MoFs design effective labor market policies to manage the impacts of the transition.

Key messages

- Several of the World Bank's Country Climate and Development Reports (CCDRs) analyze labor market frictions empirically, including mismatches in skill, location, salary, and time via approaches based on network analysis. Efforts are underway to integrate the insights into macroeconomic models.
- A recent study in Brazil incorporated skill- and spatial-related frictions into an agent-based model, which was then linked to a CGE model to provide insights into regional and occupational unemployment outcomes associated with different development scenarios.
- MoFs can adopt strategies to identify opportunities for stimulating economic growth and boosting job creation though investments in green sectors to address regional disparities in employment.

Challenges include availability of detailed employment data and varying classification of occupations across countries, which complicates cross-country comparisons and applying a consistent methodology. Work is underway to integrate labor market frictions into the World Bank's macroeconomic models. Upon request, the World Bank can collaborate with MoFs to adjust their own models or to utilize World Bank Models.

3.3.8.3 London School of Hygiene & Tropical Medicine: The health co-benefits of climate change mitigation: Why climate leadership by Finance Ministries can help them to deliver on their core objectives of economic development and responsible management of the public finances

There are many health co-benefits of climate change mitigation policies across a range of sectors. The magnitude of the benefits depends on context, including the specific policy, baseline exposure of the population to air pollution, the sources of the pollution, prevailing patterns of physical activity, and food consumption. Capitalizing on the health co-benefits of climate change mitigation actions is a win-win strategy that can improve public health while addressing the climate crisis.

Key messages

- Health benefits from mitigation in the long term include avoiding dramatic increases in heat-related mortality projected for later this century, particularly under high emissions scenarios. In the short term, benefits include reduced air pollution, increased consumption of healthy and more sustainable diets, and increased physical health from more sustainable transportation modes.
- Fossil fuel-related ambient (outdoor) air pollution has been estimated to cause over five million premature deaths per year worldwide, over half of which are linked to coal combustion.
- The Food Systems Economics Commission has estimated the economic value of the damage caused by current food systems to human health and the planet at well over $10 trillion annually, more than they contribute to global GDP.
- A diverse diet high in plant-based foods and low in animal products could prevent about 11 million premature deaths annually by 2050 (EAT-Lancet Commission). Such a diet would greatly reduce the environmental impact of the food system, including by reducing methane emissions from ruminant animals. Affordability and cultural acceptability will be crucial in determining uptake of such diets.
- More sustainable transport systems that provide opportunities for walking and cycling in relative safety and equitable access to public transport offer prospects of reducing GHG emissions and improving health. Including economic valuation of health benefits in their appraisal can increase estimates of their cost effectiveness substantially.

3.3.8.4 Centre for Social and Economic Progress (CSEP): India's Net Zero Transition: The Challenges within Existing Modelling Approaches of Economic Impacts

A range of traditional climate-economic models have been brought to bear on the consequences of India's transition to net zero. These approaches struggle to represent structural change, are relatively insensitive to the implications of changing ownership and employment structures in the power sector, and do not consider key frictions in the inter-sectoral labor market. Nonetheless, the model analysis indicates where changes are likely to be substantial.

Key messages

- Traditional climate-economic models struggle to represent structural changes in the economy and the investment-employment impacts of changing ownership from public to private in the power sector as renewables become more dominant.
- For inter-sectoral employment shifts that do occur, key frictions such as differential geographical impacts, flexibility of different labor markets, and the mobility and ability of workers in the fossil fuel economy to adapt and reskill are not considered.
- As climate-change policies will be broad and structural, triggering productivity-driven changes in aggregate supply and through investments, consumption and wages, and changes in demand, it is not trivial that models do not capture the associated economic transitions well. This also increases uncertainties about long-run consequences of the transition.
- Nonetheless, these models can indicate which sectors and industries are most likely to be severely affected and can thereby guide further analysis.

Steps to address modelling challenges on part of economists include using outputs from climate-economic models to anticipate effects across the economy, via more data and a broader range of tools. Sharing of knowledge, best practices, and data, can also help, especially where these are key enabling factors. Qualitative analyses backed by data and potentially simulations can further help MoFs understand transition impacts.

3.4 Financing the green and resilient transition

3.4.1 How can MoFs help finance investment in the green transition?

Table 3.13 Contributions about financing investment in the green transition

Analytical questions	Contributions
• Which public financing instruments are best to support public investment in the transition? • What is the potential of private sector investment? How can private-sector finance best be leveraged, including as part of blended finance? • What is the most appropriate split between public and private investment to support decarbonization and adaptation efforts? • What financial regulation currently hinders green finance, and how could it be reformed? • What new financial instruments are needed to raise money from capital markets for green, resilient investment? • What are the net benefits of publicly backed green investment banks? • What financial tools exist to address physical risks, and will they remain available and affordable?	Ecuador – Ministry of Economy and Finance: Ecuador's Debt-For-Nature Swap Coalition for Capacity on Climate Action (C3A): Financing the transition: How can MoF build sustainable financial strategies and what analytical tools do they need? Imperial College London: Climate Finance at Scale to Implement Nationally Determined Contributions: Decarbonizing the Power Sector Paul Watkiss Associates: Mainstreaming and financing climate change adaptation in Rwanda Independent High-Level Expert Group on Climate Finance (IHLEG): The investment imperative and the critical role of Ministries of Finance Environmental Change Institute – University of Oxford: Institutional Architecture and Mobilisation of Private Capital for Adaptation: The Case of Rwanda

3.4.1.1 Ecuador – Ministry of Economy and Finance: Ecuador's Debt-For-Nature Swap

In 2023, Ecuador carried out a debt-for-nature swap that safeguards the Brotherhood Reserve of the Galapagos Islands and exchanges approximately USD 1,630 million of existing debt for a new loan of USD 656 million. The swap generates savings of USD 1,121 million in debt and enables USD 450 million previously destined to pay debt service to be directed to the newly created Galapagos Life Fund to finance conservation projects in the Galapagos Marine Reserve and the Hermandad Marine Reserve.

Key messages

- The loan is backed by insurance from the Development Finance Corporation and a guarantee from the Inter-American Development Bank, with structuring and technical advice from Credit Suisse, whilst global conservation experts helped propose and monitor the general structure of the transaction and supervise compliance with environmental and social commitments.
- The Galápagos Life Fund (GLF) is a non-profit corporation without shareholders and without stocks, and its board of directors will oversee the approval of projects to benefit the environment and society of Galápagos. The board is comprised of representatives of government, academia, and business associations, as well as international members from Oceans Finance Company (OFC), Ledunfly Philanthropy, and the NGO Pew Bertarelli Ocean Legacy.

GLF will be able to use its funds for projects focused on conservation and sustainability and the interest of the Galapagos Islands community. This can include reserve management and sustainable fishing, environmental education, sustainable tourism, and blue economy projects.

3.4.1.2 Coalition for Capacity on Climate Action (C3A): Financing the transition: How can MoF build sustainable financial strategies and what analytical tools do they need?

A recent technical note by C3A reviews the financing needs of MoFs for a climate and nature-aligned development strategy and widely used financial instruments employed to this end. The note explores micro and macro risks that can hinder effective financing and investment in the low-carbon transition and suggests approaches to design country-specific financing policy mixes that MoFs can draw on.

Key messages

- Existing estimates of financing gaps for the low-carbon transition range from 6 to 10 trillion dollars annually.
- Current climate finance is unbalanced, with the bulk of financing benefitting the Global North and going towards mitigation, rather than adaptation or nature related financing.
- Risks facing investors called upon to drive the low-carbon transition and nature-related investments, including technology or project risk at the micro level and country or policy risks, exchange rate risks, and risk of fiscal conditions impeding raising finance at the macro or institutional level, can hamper effective investment by inducing finance rationing.

Guarantee mechanisms, direct subsidies for investments, or regulatory reforms are designed to combat this rationing. Successful interventions require an understanding of transmission channels from financing strategies to macroeconomic variables, consideration of country-specific political economy, and accompanying structural policies.

3.4.1.3 Imperial College London: Climate Finance at Scale to Implement Nationally Determined Contributions: Decarbonizing the Power Sector

Avoided emissions from the phase-out of fossil fuel-fired power plants by emerging and developing market economies (EMDEs) can be monetized to generate more private finance for renewable (RE) development. More specifically, both emerging and developing market economies and developed economies can follow a 12-step ‘recipe’ to formulate, finance, and implement NDCs that are Paris-aligned.

Key messages

- Countries can use the *NDC and climate finance tool* on the website https://greatcarbonarbitrage.com and https://forwardanalytics.co to implement this approach and tailor assumptions to their preferences and circumstances.
- For large net benefits and effective, Paris-agreement-aligned implementation of Nationally Determined Contributions (NDCs), a granular system-wide country plan (rather than a project-by-project approach) that matches an optimal fossil fuel phase-out pipeline with a simultaneous RE phase-in pipeline is essential.
- One source of finance is de-risking and leveraging impact of greater flows of international public financing that should be forthcoming based on net benefits to larger developed countries from EMDE decarbonization. A second source is additional private finance generated from a new high-integrity carbon offset market that monetizes identifiable, additional, and permanent avoided emissions.
- Tying the coal phase-out to renewables crowds in additional private finance and repurposing fossil fuel subsidies can further reduce the burden on additional public financing.

Empirical analysis shows that the global and country-level benefits of a bundled fossil fuel phase-out and renewable replacement are large, and the opportunity costs of phasing out fossil fuels are relatively low. Net benefits to some of the larger developed countries provide a strong justification for greater international public financing. Simulations based on recent data show that, if the G7 and EU countries were to cover 25% of the total costs of replacement renewables, storage and grid investments plus closure-related opportunity costs from the phase-out of largely coal-fired power plants in India, Indonesia, Türkiye and Vietnam, their own net benefits would be in the order of over USD 3 trillion.

3.4.1.4 Paul Watkiss Associates: Mainstreaming and financing climate change adaptation in Rwanda

Rwanda has one of the most advanced climate policy landscapes and provides a useful case study on climate mainstreaming and finance. Following a study on the economics of climate change in 2009, Rwanda developed a Green Growth and Climate Resilient Strategy (GGCRS) (2011). This led to a set of climate mainstreaming initiatives: integrating climate change into the medium-term development plan and sector strategic plans, developing a climate mainstreaming strategy, including climate mainstreaming indicators in the annual Planning and Budget Call Circular, and implementing climate budget tagging into the national accounting system.

Key messages

- The National Strategy for Transformation (NST-1) (2017-2024) prioritized climate change and the environment across sectors, with a set of associated key performance indicators. This has been continued and further advanced in the revised GGCRS (2024) and the new NST2 (2025-2030).
- The GGCRS also led to setting up a National Fund for Climate and Environment (FONERWA) in 2012, now called the Rwanda Green Fund. The Fund issues multiple calls for proposals and funded over 50 projects.
- Recently, the Fund evolved into two facility strands. The first is the NDC Facility (Intego), which continues the public sector oriented fund, focusing on the implementation of Rwanda's updated NDC and its mitigation and adaptation priorities. The second is the Rwanda Green Investment Facility (Ireme Invest), which is a blended facility model set up to develop new financial instruments to support and de-risk private sector investment. It includes a project preparation facility (PPF) led by the Rwanda Green Fund that provides grants and recoverable grants, and a credit facility led by the Rwanda Development Bank to provide concessional loans and bank guarantees.
- In 2022, Rwanda was the first African country to be approved for the IMF Resilience and Sustainability Facility (RSF), with an arrangement of USD 319 million. This is aimed at advancing Rwanda's resilience, including through public financial and investment management reforms, and supporting the National Bank of Rwanda to strengthen its climate change policy.

The Rwandan Ministry of Finance and Economic Planning (MINECOFIN) developed a Climate and Nature Finance Strategy (CNFS) and is in the process of setting up a designated climate finance unit to support climate resilient and low carbon development and investments at scale. Additional recent initiatives include the announcement of a Green Taxonomy (2025). Sustainability-Linked Bonds, and the development of a Carbon Market Framework.

3.4.1.5 Independent High-Level Expert Group on Climate Finance (IHLEG): The investment imperative and the critical role of Ministries of Finance

Closing the gap to the investment needed to align with the Paris Agreement will avert massive future costs and unlock economic transformation, delivering substantial long-term savings and widespread co-benefits. A successful shift to a low-carbon, resilient, and inclusive economy hinges on the ability of Finance Ministries to drive strategic public investment, create incentives to attract private capital, and coordinate across sectors. To avoid far greater costs down the line, they must frontload investment, ensure national budgets reflect climate priorities, and embed just transition measures into financial planning.

Key messages

- The Independent High-Level Expert Group (IHLEG) on Climate Finance estimates that to deliver on the Paris Agreement, global investment requirements for climate action will need to reach $6.3–6.7 trillion per year by 2030, rising to $7–8.1 trillion per year by 2035. Of this, $2.3–2.5 trillion per year by 2030, rising to $3.1-3.5 trillion by 2035, is needed for EMDCs other than China. Any shortfall before 2030 will create a steeper and potentially more costly path to climate stability.

- The challenge is to foster the enabling conditions for the ramp-up of investments and mobilize affordable finance from all pools of finance. However, increasing finance does not, by itself, guarantee effective investment. For this, investment strategies must be inclusive and prioritize vulnerable groups to ensure equitable access to climate finance and economic opportunities.
- Key gaps in country-level assessments of investment needs include overlooking adaptation and resilience, loss and damage, natural capital, and just transition investment needs; not planning long-term and thereby neglecting the temporal dynamics and front-loaded nature of climate investments; and not matching investment needs to the right mix of finance. Additionally, many EMDCs do not have capacity to conduct detailed climate investment assessments.

Ministries of Finance should spearhead national efforts to build technical and institutional capacity for investment planning, leveraging multilateral support and South-South cooperation where needed. Additionally, improving data collection and methodologies and fostering coordination and collaborative frameworks within government and with external partners such as donors, regional development banks, and private-sector partners are important for strengthening country-level climate investment estimates.

3.4.1.6 Environmental Change Institute – University of Oxford: Institutional Architecture and Mobilisation of Private Capital for Adaptation: The Case of Rwanda

To achieve the SDGs, new infrastructure investment of over 1 trillion USD per year is needed until 2040, and 70% of this finance is required for investments in emerging and developing economies (EMDEs). Given the sizeable fiscal constraints many EDMEs face, there has been an increased focus on how countries can allocate scarce public funds to effectively mobilize more private investment into infrastructure. Dedicated institutional frameworks with a broad mandate to co-invest are taking shape, as outlined by the example of Rwanda.

Key messages

- Ministries of Finance (MoFs) can spearhead the creation of appropriate institutional frameworks for mobilizing and monitoring adaptation finance by setting a clear national vision and writing this into clear national targets and adaptation taxonomies.
- As exemplified by the case of Rwanda, an effective institutional landscape includes an ambitious NDC coupled with a context-appropriate green taxonomy, a national green bank, and an array of innovative finance mechanisms to mobilize private capital, possibly including green bonds or securities. These institutions should target investments intentionally towards those projects that promise the highest societal benefits from the lowest amount of concessional public capital while crowding in as much private investment as possible.
- MoFs can conduct several diagnostics to identify gaps in the policy, regulatory, and financial architecture to mobilize adaptation action and finance. These include tools such as the UNEP Sustainable Budgeting Approach (SBA), which can help MoFs identify, track, and resource strategic policy opportunities that support both national development objectives and critical environmental and social objectives.

Policies and projects to address gaps should be developed in ways that engage with local stakeholders and communities for greater impact and sustainability and to align with broader development and poverty reduction agendas.

3.5 Managing synergies and trade-offs with other policy priorities

3.5.1 How does climate policy interact with other policy priorities and mandates MoFs are responsible for and how can the synergies be maximized?

Table 3.14 Contributions about managing interactions between climate policy and other policy priorities

Analytical questions	Contributions
• How does climate policy affect other domestic policy priorities? How can it align with maintaining price stability, energy security, economic growth and other policy priorities? • Are there synergies between climate policy / addressing climate change and other policy priorities? If so, how can they best be exploited?	Asian Development Bank (ADB): Navigating the Trade-offs between Investments for Growth and Climate Action: The Role of the Social Discount Rate World Resources Institute (WRI): How system dynamic models can inform India's low carbon pathways

3.5.1.1 Asian Development Bank (ADB): Navigating the Trade-offs between Investments for Growth and Climate Action: The Role of the Social Discount Rate

While climate action and economic growth are aligned in the long term, in the short to medium term a trade-off can exist between investments for growth and climate action due to limited savings and funds. This is especially critical for developing countries, which seek to lift millions out of poverty and address climate change at the same time. Investment decisions, whether public or private, are primarily driven by the present value of expected returns over the life of the investments, such that the applied social discount rate plays a crucial role.

Key messages

- Greenhouse gas (GHG) emissions have enduring effects, necessitating their impact to be assessed across generations. The social time preference discounting approach has become conventional for this purpose.
- Social time preference is usually derived via the Ramsey formula, which expresses the social discount rate as a function of the pure rate of time preference (r), the elasticity of marginal utility of consumption (η), and the growth rate of per capita real consumption (g): $r = \rho + \eta g$. r is often set close to zero, η usually falls between 1 and 1.5, and g is proxied by growth of per capita GDP. Based on historical global GDP growth of about 1.9% per year in the past six decades, a social discount rate of ≤3% is often used and considered reasonable.
- The social cost of carbon (SCC) measures the monetary value of the future stream of net damages associated with adding one ton of GHG to the atmosphere in a given year and therefore reflects the societal net benefit of reducing emissions by one ton at present. A social discount rate is used to calculate the SCC by discounting future damages to their present value at the time emissions occur.
- The social discount rate is also used in integrated assessment models (IAMs). These tend to assume that representative agents choose climate policies to maximize their social welfare, which is represented by NPV of intertemporal utilities and for which the social discount rate is a key parameter.
- Low and middle-income economies exhibit above-average annual growth in real GDP per capita, leading to a relatively higher social discount rate. This reduces the NPV of future net returns and makes investments with more immediate returns more attractive than those with more benefits in the longer term. Thus, the attractiveness of long-term climate mitigation investments is reduced relative to immediate growth-focused projects in developing countries by virtue of the social discount rate applied.

To make the global optimum (addressing climate change) locally optimal in fast-growing developing countries with relatively higher implied social discount rates, local climate action needs to be incentivized. Two strategies can be employed to this end. First, lowering financing costs for climate investments can make climate projects with payoffs in the long term more attractive. Second, future returns to climate investments can be enhanced, e.g., if developed countries or MDBs agree to provide future payments for investments that reduce GHG emissions or restore nature's capacity to sequester carbon.

3.5.1.2 World Resources Institute (WRI): How system dynamic models can inform India's low carbon pathways

India is facing a complex challenge in simultaneously striving for sustainable economic development and Net Zero by 2070, whilst also needing to adapt to realized climate change. Competing demands on and a changing make-up of public finances mean that capturing complexity and trade-offs in policy analysis is essential for informed decision-making. WRI employed two complementary, India-specific system dynamics (SD) models to do so; the models estimate the transition can yield economic gains, albeit with heterogenous impacts on public finances, trade, and employment across sectors.

Key messages

- Required finance for mitigation is estimated in the order of tens of trillions of USD and the adaptation finance gap is estimated at ~870 billion USD until 2030.
- The India Energy Policy Simulator (EPS) simulates changes in the economy relative to an exogenous baseline and therefore assumes a static structure of the economy. However, this enables sectoral granularity—the model calculates direct, indirect, and induced impacts of mitigation policies via a fully integrated input-output table spanning 36 sectors.
- The Green Economy Model for India (GEM) models production endogenously, meaning the effect of changes in technology, energy prices, and human capital on output and employment are considered. The model also captures details on natural resources and helps understand the impact of decarbonization policies on water use and critical minerals. However, disaggregation is limited to three sectors (agriculture, industry, and services) and labor market frictions and wage-employment relations are modelled in a limited manner.

Empirical findings, caveats, and implications:

- **Fiscal**: Both models estimate overall economic gains from the transition to net zero by 2070. Tax revenue from petroleum products is reduced, though this could be offset by a linearly increasing carbon tax which widens the tax base. The fiscal deficit is estimated to be higher initially, due to clean energy investments, high cost of CCS, and land-based interventions. In the long term, public debt is expected to recover due to economic growth and tax revenue from non-energy sources.
- **Trade**: Import dependence is likely to shift from OPEC to mineral-rich countries such as China, Australia, and Argentina due to decreasing oil imports and increasing imports of minerals, e.g., for solar panels and batteries. This new dependency could be mitigated by recycling and re-use.
- **Employment**: The transition scenario is estimated to have 3.5 million additional jobs, on aggregate. However, this masks heterogenous impacts across sectors and assumes higher labor demand is indeed translated to job gains, which requires (re)skilling of the workforce. Moreover, the models do not capture informal sector impacts well, which are likely to be even larger and require welfare and social-protection schemes to ensure a just transition.

4 Summaries of Contributions: Specific Analytical Tools and Approaches Relevant to Ministries of Finance

This section contains the summaries of the second overarching category of contributions pertaining to specific analytical tools and approaches. Each sub-section contains the summaries for one of the four further categories. Table 4.1 below defines the acronyms relied upon in the summaries to classify models.

Table 4.1 Acronyms for describing model types

Acronym	Definition
CGE	Computable General Equilibrium
DSGE	Dynamic Stochastic General Equilibrium
IAM	Integrated Assessment Model
ESM	Energy System Model
IO	Input-Output
E-SFC	Ecological Stock-Flow Consistent
SD	System Dynamic

4.1 Specific modelling tools

Table 4.2 Contributions about specific modelling tools

Contributions
European Union – European Commission: Overview of the European Commission's energy and climate policy-related modelling suite
Switzerland – Federal Department of Finance: Modeling the fiscal impacts of the net-zero target within fiscal sustainability analysis
Italy – Ministry of Economy and Finance: The Italian Ministry of Economy and Finance climate-related modelling tools – How to build a flexible suite of models serving different purposes
Morocco – Ministry of Economy and Finance: Assessment of the impacts of climate change on the national economy via the agricultural sector
Morocco – Ministry of Economy and Finance: Computable general equilibrium model for the introduction of a carbon tax for the Moroccan economy
Morocco – Ministry of Economy and Finance: DEPF models for evaluating mitigating GHG emissions and adapting to climate change policies in Morocco
Sweden – National Institute of Economic Research (NIER): Sweden's EMEC model designed to study the long-term economic effects of energy and climate policies
Canada – Department of Finance: Finance Canada CGE model
Sierra Leone – Ministry of Finance: Sierra Leone's First Climate-Economy Model: Challenges Posed, Arising Opportunities
IMF – Fiscal Affairs Department: Fiscal Risks of Climate Change: Quantitative Climate Change Risk Assessment Fiscal Tool (Q-CRAFT)
IMF – Fiscal Affairs Department: Climate Policy Assessment Tool (CPAT)
World Bank: World Bank Group Climate Aware Macroeconomic Models available for use by Ministries of Finance
World Bank: MFmod – CC (country-specific macrostructural models)
World Bank: MANAGE-WB (Recursive-Dynamic CGE model)
World Bank: ENVISAGE (A Global CGE model covering 160 regions)
World Bank: CPAT
World Bank: MINDSET (An easy-to-use sectoral model covering 164 countries)
Inter-American Development Bank (IDB) / French Development Agency (AFD) / RAND Corporation: SiSePuede: New approaches to assessing economic impacts of Net-Zero pathways
Cambridge Econometrics: Macroeconomic modelling of climate change: The E3ME model
Environment for Development Initiative: Facilitating socially responsible carbon pricing policies: the global Carbon Pricing Incidence Calculator (CPIC)
Environment for Development Initiative: Pricing Carbon in the Tropics: The CP+ Model
Danish Research Institute for Economic Analysis and Modelling (DREAM): The GreenREFORM Model
ETH Zürich: Latest Developments in Upgrading DICE-2023: Findings and Implications for Ministries of Finance
Sciences Po – French Economic Observatory (OFCE): ThreeME model
UNEP (United Nations Environment Programme): IGEM's Integrated Approach to Climate-Smart Economic Decision-Making
Munich Climate Insurance Initiative (MCII): Showcase of CLIMADA
Austria – Ministry of Finance: Suite of Analytical Tools: Integrating Climate Projections into Austria's Long-Term Budget Forecasts
Economic and Social Research Institute (ESRI) / Ireland – Department of Finance / Department of Public Expenditure, NDP Delivery and Reform (DPENDR): Macroeconomic analytical tools
IMF – Research Department: GMMET
IMF – Research Department: IMF-ENV: Integrating Climate, Energy, and Trade Policies in a General Equilibrium Framework

IMF – Research Department: DIGNAD	
Inter-American Development Bank (IDB) / French Development Agency (AFD) / University of Costa Rica: OSeMOSYS	

4.1.1.1 European Union – European Commission: Overview of the European Commission's energy and climate policy-related modelling suite

Name: PRIMES (Price-Induced Market Equilibrium System)
Type: ESM
Institution: European Commission / E3M
Documentation: PRIMES Manual; also the EU Reference Scenario Report
Description: Energy system modelling suite that can integrate multiple policy targets via shadow prices associated with policy constraints.
Questions to be answered / variables considered: PRIMES provides projections of energy demand, supply, prices, and investment for the entire EU energy system up to 2050. Beyond energy variables, GHG emissions and system costs (CAPEX and OPEX), annualized investments, fuel costs, power prices for final consumers, and other indicators can be calculated from the model. It is coupled with the GEM-E3 model, which provides data on economic activity and population dynamics as input for PRIMES. Links to GAINS, GLOBIOM/G4M, and CAPRI provide non-CO_2 emission projections, LULUCF emissions and removals, and agricultural activity, respectively.
Strengths:

- It covers the entire energy system, including emissions from energy combustion and industrial processes up to 2050.
- Technology dynamics are incorporated, meaning technological progress and behavioral choices are addressed. This is an advantage over CGE models, which are considered too static and not well suited for handling technological change.

Limitations: Uncertainty about how technology costs will develop – though that is not really a weakness of the model per se.
Use:

- PRIMES contributed to all major energy and climate policy initiatives for the EU. Recently, this included the Fit-for-55 legislative package, the REPowerEU plan, and the 2040 Climate Target.
- Coupling the energy system and GHG modelling with macroeconomic models yields model results for changes in activity and employment by sector, energy expenditures for households, and revenues from carbon pricing—all useful for energy and climate policy analysis.

Name: METIS (Markets and Energy Technologies Integrated Software)
Type: ESM software
Institution: European Commission
Documentation: METIS webpage
Description: Simulates the short-term operation of energy systems and markets (electricity, gas, heat, and hydrogen sectors) across the EU and neighboring countries, and is used to assess dynamics (e.g., price shocks) and policy measures.
Questions to be answered / variables considered: It helps analyze multi-energy system integration, power and hydrogen network investments, energy infrastructure requirements, the climate-energy nexus, market price behavior, and design principles.
Strengths:

- Allows for hour-by-hour simulations for up to one year, accounting for uncertainties such as weather variations.
- Interconnected modules that can be adjusted or added to, depending on application.

Use:

- Support legislative proposals and documents by the EC on the reform of electricity market design, power and gas infrastructure, and the Projects of Common Interest (PCI) process.

- Price-setting and flexibility assessments in electricity markets.
- Assessing the uptake of an EU hydrogen network.

Name: JRC-GEM-E3
Institution: European Commission Joint Research Centre
Type: CGE
Documentation: GEM-E3 Manual, see also https://joint-research-centre.ec.europa.eu/scientific-tools-and-databases/jrc-gem-e3-model_en
Description: A CGE model with granular sectoral representation used to discern the macroeconomic effects. Often coupled with energy model scenarios (e.g., from PRIMES, see above).
Questions to be answered / variables considered: Provides economy-wide context to the energy model scenarios.
Strengths:
- Its highly granular sectoral representation of the economy makes it well-suited to track cross-sectoral impacts of energy and climate policies, including interactions between sectors and regions.
- It can be linked to energy models (e.g., PRIMES) to incorporate information describing fast changes in key sectors (e.g., transition to renewables in the power sector, rollout of EVs in transport, electrification of buildings).
- Post-processing of JRC-GEM-E3 results can show distributional impacts, incl. revenue recycling and labor market impacts by skill/occupation.

Limitations:
- Limited heterogeneity; household heterogeneity through coupling with micro-data.

Use: Estimate the impacts of climate and energy policies on the macroeconomy (e.g., GDP and its components) and sectors (e.g., sectoral output, trade, employment).

Name: E-QUEST
Type: DSGE
Institution: European Commission Directorate-General for Economic and Financial Affairs
Documentation: Varga et al. (2022)
Description: E-QUEST is a sectorally disaggregated E-DSGE model tailored to assess climate policy scenarios.
Questions to be answered / variables considered: To ensure consistent comparisons across macro-modelling outputs, E-QUEST also relies on emission trajectories generated by the PRIMES model under reference scenarios.
Strengths: Explicit micro-foundations and dynamic (forward-looking) optimization, which allows analysis of how households and firms respond to policy changes and expectations over time.
Limitations: For computational reasons, the sectoral disaggregation of E-DSGE models is significantly more limited compared to large-scale CGE and input-output models.
Use: Climate policy impact assessment, including the 2030 and 2040 Climate Target Plan assessments.
Development / lessons / challenges: Incorporating endogenous technological change and R&D investment is a critical area for further development, as these are crucial in determining the effectiveness of climate policies. The forward-looking nature of E-DSGE models makes them suited to accomplish this.

4.1.1.2 Switzerland – Federal Department of Finance: Modeling the fiscal impacts of the net-zero target within fiscal sustainability analysis

Name: Budget impact model
Type: Linked models
Institution: Federal Department of Finance (Switzerland) / Ecoplan
Documentation: References in the 2024 fiscal sustainability report.
Description: A budget impact model to analyze the long-term impact of achieving the net-zero target on public finances, based on energy system models (ESM) and a computable general equilibrium (CGE) model.

Questions to be answered / variables considered: The impact of reaching Switzerland's target of net-zero by 2050 on the economy (GDP, consumption, wages) and particularly the composition of public finances as measured by, for instance, the debt ratio, income taxes, profit taxes, VAT, mineral oil tax, and green subsidies relative to business-as-usual.
Strengths: The approach combines strengths of both ESM and the CGE model: ESM allow in-depth analysis within sectors (e.g., electricity, transport, industry) that require accurate and detailed data on the energy system, and the CGE model assess the macroeconomic impact of the energy transition.
Limitations: Due to a high degree of uncertainty, the following factors were omitted: costs of climate change itself and adaptation measures, and opportunities from a comparative advantage in green products (including technological breakthroughs) or conversely the loss of market share and increased reliance on imports, as assumed that net zero is reached globally by 2050. These omissions also mean avoided costs and benefits from mitigation are not captured.
Assumptions: The policy scenario assumes carbon neutrality is achieved by 2050 through an increase in carbon pricing, stricter emissions standards on buildings and vehicles, and an increase in subsidies. For more details see the 2024 fiscal sustainability report and references therein.
Use: The approach was developed for a pilot study published in the 2024 fiscal sustainability report for Switzerland.
Development / lessons / challenges:

- Identifying the channels and potential impacts of climate change and mitigation is important before a quantitative assessment of their economic and fiscal implications.
- The choice of policy scenario should be deliberate to inform the policy discussion, keeping in mind that whilst model-based analysis helps objectify the policy debate, politics will ultimately decide climate policies.
- Modelling should focus more on insights than on numbers and the high degree of uncertainty in medium- and long-term analyses in this field ought to be kept in mind.

Empirical findings

- Direct effects on public finances include higher CO2 tax revenues in the short- and medium-term, yet lower revenues when CO2 emissions decrease over time.
- Loss of fuel tax revenue due to electrification of the transport sector. Alternative revenue sources, such as replacement levies on electric vehicles, can mitigate the negative fiscal impact of the transition.
- Indirect effects, including decreased revenue from income tax, profit tax, and VAT due to lower growth in GDP, consumption and wages, dominate the fiscal effects.

4.1.1.3 Italy – Ministry of Economy and Finance: The Italian Ministry of Economy and Finance climate-related modelling tools – How to build a flexible suite of models serving different purposes

Name: IRENCGE-DF (Italian Regional and Environmental Computable General Equilibrium of Department of Finance)
Type: CGE
Institution: Italian Ministry of Economy and Finance, World Bank
Documentation: IRENCGE-DF Documentation
Description: Macroeconomic tool for analyzing the impact of climate-related tax policies on GDP, production, employment, GHG emissions reductions, and distributional effects.
Questions to be answered / variables considered:

- Estimate a given policy's indirect and economy-wide effects to assess multiple policy scenarios against effectiveness, efficiency, and equity principles.
- Key outputs are on main macroeconomic variables (e.g., GDP, production, employment), distributional effects across income deciles, effectiveness in reducing GHG emissions, revenue-raising potential, and impact of revenue recycling scenarios.

Strengths:

- Detailed database—the Social Accounting Matrix (SAM)—for sectoral analysis and distributional impacts. This database distinguishes between 74 activities, 68 commodities, 10 household groups and 10 tax categories.
- An environment module that includes energy as a production input alongside labor and capital, paired with inter-fuel substitution of eight energy types and multi-input and multi-output production structure
- Climate change damage module that considers impacts on total factor productivity, labor productivity, tourism export demand, sea level rise (reduction in land productivity), energy demand, and flood damages. This also includes adaptation to endogenously reduce damages.
- Calibrated to tax policy analysis through the inclusion of other microsimulation modes that analyze specific categories of taxes (e.g., Corporate Income Tax, Personal Income Tax, and Value-Added Tax)
- Ability to assess distributional impacts

Limitations:
- Simplified economy functions
- Fixed key parameters (e.g., elasticity of substitution)
- Absence of endogenous technological change
- Disregard of the role of money supply and demand in the financial sector

Assumptions:
- Standard neoclassical assumptions (e.g., perfectly competitive markets and capital accumulation deriving from savings)
- Economic agents make myopic decisions about production, consumption, and investment (i.e., their expectations are made only based on information available in the period of the decision, not on what will happen in the future).

Use: It is most suitable in the policy design phase for comparative analysis of policy scenarios, particularly for understanding distributional impacts, revenue impacts, revenue recycling scenarios, contribution to the reduction of GHG emissions.

Challenges and learnings:
- Developing this CGE model demanded substantial financial investment, diverse technical expertise, and time commitment (particularly for the development of the SAM). This can be effectively managed by leveraging existing expertise from international organizations and collaborating with other countries.
- To expand climate modeling capabilities, approaches include developing in-house simplified static models (though this may overlook economic interactions), applying user-friendly toolkits from organizations like the IMF (which may not account for country-specific details), or building an in-house general equilibrium model with technical support from international organizations or countries with existing models.

Future development:
- Collaborating with the Italian Energy Agency to develop a link with their TIMES model aims to incorporate greater energy system detail into the model and support the OECD's Inclusive Forum on Carbon Mitigation Approaches (IFCMA). Challenges to this include aligning different model’s scope, resolution, assumptions, and sector definitions. This integration could enhance both models by incorporating technological change and behavioral realism, offering insights into Italy’s path to net zero by 2050.
- The European Commission's new Technical Support Instrument (TSI), GreenReform-EU, could support the development of a supplementary model and enhance existing models through utilization of the GreenREFORM model developed by the Danish Research Institute for Economic Analysis and Modelling (DREAM). This multi-country project will facilitate collaboration, knowledge transfer, and capacity building among experts from diverse backgrounds.

Name: GEEM (General Equilibrium Environmental Model)
Type: DSGE
Institution: Italian Ministry of Economy and Finance, University of Rome
Documentation: Paper with documentation
Description: Macroeconomic tool for assessing the effectiveness of climate-energy policies, their economic impact, and (in some cases) households' distributional impacts.
Questions to be answered / variables considered:

- Allows for analysis of the macroeconomic impact of climate and energy policies designed to reduce emissions or induce utilization of clean energy sources and disentangles the effects of different shocks and performance of policy interventions independent of climate and energy instruments
- Policy interventions include technological changes, reduction in markups/increase in market competition, fiscal reforms
- Macroeconomic factors include GDP, employment, investment, and sector-specific emissions

Strengths:

- Comprehensive integration of environmental and macroeconomic policies and ability to simulate the interplay between environmental regulation and economic outcomes.
- The presence of real and nominal rigidities allows for the capture of the slow adjustments of structural change dynamics consistently with short-term economic frictions
- Consistency with the main DGE models used by the European Commission ensures that the results align with and are comparable to those produced by the Commission's leading models.
- Incorporation of cap-and-trade subject sectors according to the EU – Emissions Trading System (e.g., electricity sector and part of the manufacturing sector embodied through intermediate goods) as well as the transport sector.

Limitations:

- High computing needs (relative to number of incorporated sectors, frictions, and agents)
- Highly reliant on accurate parameterization
- Overlooks heterogeneity among economic agents
- Can fail to capture non-linear dynamics and the impact of large shocks
- Limited accounting for distributional effects

Assumptions:

- Economic actors have perfect foresight
- Representative agent (assumption that all agents are identical or can be aggregated into a single representative entity)

Use: Research purposes, assist policymakers in developing balanced and long-term economic strategies
Challenges and learnings:

- Properly calibrating the model's microfoundations required the complex integration of multiple economic and environmental datasets and implementation of intertemporal dynamics programming.
- Key learnings include the importance of flexible model designs, data updates, and continuous benchmarking to ensure the robustness and adaptability of policy analysis. Additionally, inter-university collaboration facilitates knowledge transfer and leveraging of diverse expertise in economic modelling and environmental policy.

Future developments:

- Future advancements will focus on estimating key parameters to improve reliability and accuracy. This may involve incorporating Bayesian estimation techniques for continuous data updating and collaborating with international institutions to improve the model's ability to simulate the long-term economic impacts of climate policies by incorporating more detailed data on the behavior of economic agents.

- Introduction of heterogeneity factors, inspired by recent advances in heterogeneous Agent New Keynesian models, can better capture distribution consequences and the diverse behaviors and interactions of economic agents.

4.1.1.4 Morocco – Ministry of Economy and Finance: Assessment of the impacts of climate change on the national economy via the agricultural sector

Morocco is integrating economic and environmental models to assess the impacts of climate change and policy measures on agriculture and water sectors, to aid the achievement of its NDC.
The Directorate of Studies and Financial Forecasts under the Ministry of Economy and Finance of Morocco and the French Development Agency, in collaboration with various national and international organizations (i.e. the General Directorate of Meteorology, the Water Research and Planning Directorate of the Ministry of Equipment and Water, the AAA Initiative Foundation, and the Mediterranean Institute of Biodiversity and Marine Ecology), are adapting and combining the LPJML and GEMMES models to simulate climate impacts on agriculture and water sectors under different irrigation investment scenarios. These models are being used to understand how climate change impacts water resources, agriculture, and the broader economy by simulating interactions between climate conditions, soil, crop distribution, agricultural practices, and atmospheric CO2 levels, and to evaluate strategies for mitigating the negative economic effects of agricultural shocks and water scarcity at both territorial and national levels.

Name: LPJML (Lund-Potsdam-Jena managed Land)
Type: Dynamic Global Vegetation Model
Documentation: Description
Description: The model simulates the impact of climate change on water resources and agriculture.
Questions to be answered / variables considered: This model aims to answer how climate change affects water resources and the agricultural sector through coupled simulation of the interactions of climate conditions (i.e., temperature, precipitation, cloudiness), soil type, crop distribution, agricultural practices (including irrigation), and atmospheric CO_2 levels that affect photosynthesis and plant respiration.
Use: The model was used to project quantitative changes in surface water resources, crop production potential, and water needs in Morocco up to 2050.
Future Developments: Refinement of agricultural yield calibration, land use, and regional surface hydrology.

Name: GEMMES (General Monetary and Multisectoral Macrodynamics for the Ecological Shift) – Morocco
Type: Linked models
Documentation: Project description
Description: This model was adapted to Morocco to simulate the interactions between climate, the economy, and finance, focusing on climate-related financial risks and the energy transition.
Questions to be answered / variables considered: The model simulates how the water impacts of climate change affect the economy at territorial and national levels. It explores how agricultural shocks affect the economy and compares strategies to mitigate the negative economic impacts of climate change.
Future Developments: The Directorate of Studies and Financial Forecasts and the French Development Agency are refining the GEMMES model, coupling it with the Stockholm Environment Institute's LEAP mode, to analyze energy supply, demand, efficiency, and renewable capacity to support Morocco's long-term low-emission strategy.

4.1.1.5 Morocco – Ministry of Economy and Finance: Computable general equilibrium model for the introduction of a carbon tax for the Moroccan economy

Name: DEPF CGE model
Type: CGE
Institution: Morocco, technical assistance from the World Bank
Description: Macroeconomic tool for simulating effects of different carbon tax scenarios

Questions to be answered / variables considered: Determine the macroeconomic effects of various carbon tax scenarios to support Morocco's Nationally Determine Contribution and maximize economic and societal benefits. Specifically, understanding the impacts of revenue recycling options on other economic sectors (i.e., public investment, corporate tax rate, main export industries, households).
Limitations:

- Lacks detailed granularity of electricity sector inputs
- Lacks disaggregation of household accounts in the Social Accounting Matrix, limiting the model's ability to assess social and distributional consequences (e.g., poverty and inequality).

Assumptions:

- Static neoclassical model with Walrasian general equilibrium
- Perfect competition: markets are balanced by flexible prices
- Considers the optimizing microeconomic behavior of economic agents (made up of a representative household, companies, the government, and the rest of the world)
- Factors of production are labor (perfectly mobile between sectors) and capital (specific to each sector)

Future Developments:

- Disaggregate the household account to more effectively capture social effects related to poverty and inequality.
- Disaggregate electricity sector inputs to enable a detailed assessment of energy transition impacts.
- Transition from a static to dynamic model through the introduction sequential dynamics
- Consider certain rigidities, notably in the labor market
- Integrate the financial sphere, particularly at market level

4.1.1.6 Morocco – Ministry of Economy and Finance: DEPF models for evaluating mitigating GHG emissions and adapting to climate change policies in Morocco

Morocco's Department of Studies and Financial Forecasts (DEPF) is mobilizing and coordinating national and international resources to advance economic modelling tools and expertise to assess the impact mechanisms between climate change and the national economy.
The DEPF is adapting various models (including the MIMPAS model, the GEMMES and LPJML, and LEAP models) to Morocco's agricultural and economic conditions, to enhance its capacity to forecast economic outcomes under various climate scenarios, support the green budgetary transition, and evaluate the macroeconomic effects of long-term low-carbon strategies including carbon taxes and subsidies.

Name: MIMPAS (Integrated macroeconomic model for projection and simulation analysis)
Type: IAM
Geographical scope: Morocco
Description: This model is paired with a regionalized agricultural model to simulate the agricultural production account, with quantity/price distinction, to understand the impact of droughts on the macroeconomic framework.
Questions to be answered / variables considered:

- Simulate good, bad, and average agricultural seasons (conducted with annual frequency) to understand the macroeconomic impacts of climatic hazards, particularly for cereals, livestock, and other crops.
- Enables analysis of changes in agricultural value added on GDP balance, employment, prices, trade balance, and public finances.

Limitations: Not based on physical modelling of climate scenarios.

Name: GEMMES-Morocco Project
Type: Linked models
Documentation: [Project description]

Institution: Directorate of Studies and Financial Forecasts and the French Development Agency, in collaboration with the General Directorate of Meteorology, the Water Research and Planning Directorate of the Ministry of Equipment and Water, the AAA Initiative Foundation, and the Mediterranean Institute of Biodiversity and Marine Ecology
Description: Combines the GEMMES and LPJML models to analyze the impacts of different climate scenarios on the Moroccan economy by 2050 via the agricultural sector.
Variables considered: Estimate future changes in water resources and crop production, assess economic impacts of water stress and climate change, and explore adaptation and resilience strategies.
Uses:

- Studies: The GEMMES-Morocco project: Climate, Hydrology, Agriculture and Macroeconomics
- Policy Briefs: Morocco facing Climate Change: situation, impacts and response policies in the water and agriculture sectors; The Moroccan economy facing the challenges of Climate Change: impact scenarios by 2050 and adaptation policies
- Presentation: COP26 in Glasgow in 2021

Name: GEMMES and LEAP
Institutions: Morocco's Department of Sustainable Development, French Development Agency
Description: Adapt the GEMMES model with the Stockholm Environment Institute's LEAP technical-economic sector model to assess the macro-financial and social impacts of low-carbon development pathways by 2050.
Variables considered: Consumption, production, and extraction of energy resources across all sectors of the economy, sources and sinks of greenhouse gas emissions from energy and non-energy sectors

4.1.1.7 Sweden – National Institute of Economic Research (NIER): Sweden's EMEC model designed to study the long-term economic effects of energy and climate policies

Name: EMEC (Environmental Medium-Term Economic) model
Type: CGE
Institution: Sweden (MoF); National Institute of Economic Research (NIER)
Documentation: Documentation
Description: The EMEC model is a CGE model of the Swedish economy in the medium- to long-term, capturing the primary interactions between the economy, energy use, and GHG emissions.
Questions to be answered / variables considered: In general, the long-term impacts of energy and environmental policies on the economy and emission trajectories of several pollutants. More specifically, whether a policy achieves its stated target (at lowest cost), potential conflicts between targets and policies, and expected effects on macroeconomic variables.
Strengths:

- Holistic specification of the Swedish economy, and calibration to the comprehensive system of national and environmental accounts.
- Well-suited to study the economy in different states, due to full adjustment to different equilibria.
- Can be used to determine way to achieve a climate target.

Limitations:

- Less suitable for examining frictions during transitions between equilibria.
- Does not determine an optimal climate target (a task for IAMs).
- Does not assess the likelihood or feasibility of plausible pathways (a task for ESMs).

Assumptions: Full adjustment of the economy when transitioning from one equilibrium to another.
Use: It has been used to assess the EU ETS, national energy and CO_2 taxes, renewable fuel standards for road-transport fuels, and the national energy and GHG projections.
Development / lessons / challenges:

- Developing more frictions during transition between equilibria, e.g., via more detailed capital use and vintages per sector to consider, e.g., sunk costs.

- Integrating details from ESMs, e.g., more detailed production technologies and abatement options for the steel and cement industries.
- Integrating insights from ESMs is important, as assumed abatement costs significantly influence the cost of climate policy implied by the model.
- Model transparency should not be sacrificed for additional detail, as insights on which economic channels produce the results may be more valuable than the numerical results themselves.

4.1.1.8 Canada – Department of Finance: Finance Canada CGE model

Name: Finance Canada Climate CGE model
Type: CGE
Institution: Finance Canada
Geographic coverage: Global
Description: The model has a nested production structure which allows substitution between energy types, energy efficiency improvements through substitution with capital inputs, and abatement possibilities to reduce process-based emissions.
Questions to be answered / variables considered: Model outputs include macroeconomic metrics such as regional GDP components, industry production and prices, government revenues and transfers, and detailed emissions accounting by source (incl. from intermediate and final use of fossil fuels and process emissions from production). The model has a full set of policy parameters to price emissions and has been used to discuss the relative efficiency of different potential climate mitigation proposals.
Use-cases include evaluating alternative designs of mitigation policies, sensitivity analysis of climate mitigation policies under alternative demand or technology assumptions, exploring the interaction of multiple mitigation policies, and quantifying potential emissions impacts of non-climate policies. More generally, the model is used to explore the economic channels through which climate mitigation may impact the economy. Finance Canada does not rely on the model to project or predict future economic or climate impacts of the Governments mitigation policies.
Strengths:

- Useful to quickly examine the economic channels through which climate mitigation policies may impact the economy.
- The model can be customized in a short amount of time, as it was intentionally developed and has limited complexity.
- The model can be calibrated to a GTAP aggregation or a baseline provided by Environment and Climate Change Canada (ECCC).

Limitations:

- Simplified dynamics, meaning the model needs to be supplemented by other models for short-run analysis or analysis of variables not directly included, such as inflation, interest rates, and government revenues.
- Parameterizing the model to capture real world technological possibilities is a large challenge, also because Finance Canada does not specialize in climate science or engineering. Hence, the model relies on external estimates for baseline emissions and most of the identifying assumptions which determine the ease of reducing emissions.
- Model results depend on parameter assumptions which can be challenging to verify and are subject to change.

Use: The Climate CGE model has been used to position internal Finance Canada assessments regarding climate mitigation policy in the past 20 years. The model is most useful for modelling the impacts of pricing policies, as these are directly reflected in the model. However, non-pricing measures can be incorporated via distortionary shadow prices and non-distortionary revenue return, given enough information about their direct impacts. Recently, the model has been used for sensitivity analysis on how alternative assumptions about future demand or technology may change how policies under development by ECC will impact the economy.

Development / lessons / challenges: Improvements in and access to global datasets have arguably been the largest driver of model progress. Each release of GTAP provides an incremental improvement, with the release of GTAP-ENV and GTAP-POWER being particularly important for the climate variant. GTAP is useful more generally as setting up a global SAM is non-trivial. Thus, ensuring that the model can be calibrated to any GTAP aggregation has proven very beneficial. Going forward, peer reviewed data on available mitigation technologies by GTAP sector and region would be particularly beneficial.

4.1.1.9 Sierra Leone – Ministry of Finance: Sierra Leone's First Climate-Economy Model: Challenges Posed, Arising Opportunities

Name: Macrostructural Standalone Model for Sierra Leone
Type: DSGE
Institution: World Bank
Geographic coverage: Sierra Leone
Description: The macrostructural model estimates short and long run impacts of climate change, as well as sectoral impacts climate shocks, welfare impacts, and impacts on other macroeconomic indicators such as consumption.
Questions to be answered / variables considered: Variables considered include climate variables and macroeconomic variables across the real, fiscal, monetary, and external sectors. Its coverage corresponds to that of the already-developed Sierra Leone Integrated Macroeconomic Model (SLIMM) from the IMF, which covers all economic sectors and their links. Transition risks from regulations, technology, and climate-related taxation that could impact macroeconomic indicators such as GDP, investment, government budget, inflation, and imports and exports over time are also considered.
Strengths:

- Can estimate the short- and long-term impacts of climate change on the economy.
- It is sector-specific and captures links in the economy.

Development / lessons / challenges:

- The model is the first macrostructural model for Sierra Leone to include climate change variables, and only 5 days of training were allocated by the World Bank – not sufficient for understanding such a complex model in detail.
- The MoF in Sierra Leone was not involved in model development, and thus the model formulas and underlying assumptions are not well understood. This means the MoF cannot make necessary adjustments in the future.
- Given the lack of local understanding of the model developed by the World Bank, an additional locally built model is desired by the MoF. The model should also ensure that the model's assumptions reflect the specific circumstances of Sierra Leone. The idea is for development partners to provide Sierra Leone with international consultants who would work with local consultants and staff to develop such a model.

4.1.1.10 IMF – Fiscal Affairs Department: Fiscal Risks of Climate Change: Quantitative Climate Change Risk Assessment Fiscal Tool (Q-CRAFT)

Name: Q-CRAFT (Quantitative Climate Change Risk Assessment Fiscal Tool)
Type: Spreadsheet model
Institution: IMF
Documentation: Q-CRAFT Tool and User Guide are available on the IMF Fiscal Risk Toolkit.
Geographic coverage: Single country (global)
Description: Q-CRAFT is an Excel-based tool to help governments assess the long-term macroeconomic, fiscal risks from climate change. Using country specific empirical data on the macroeconomic impacts of climate change, a production function, and the IMF's public debt dynamic equation, it analyses how macroeconomic and fiscal variables may evolve under different IPCC emission scenarios and speeds of economic adaptation to temperature changes until the end of the century. The impact of temperature on GDP is country specific

and quantified via the method outlined in Kahn et al. (2021), which links temperature to labor productivity and thereby to GDP growth. The tool is available for 170 countries and country-specific risks can be included.
Questions to be answered / variables considered: Q-CRAFT offers long-term baseline estimates (up to 2100) for key macroeconomic variables such as GDP, fiscal deficit, and the debt-to-GDP ratio. This can help MoFs understand potential long-term economic impacts and identify slow-building climate change fiscal risks not immediately visible in the budget cycle or medium-term fiscal framework. This can assist in budget preparation, debt management, and long-term fiscal (sustainability) analysis.
Strengths:

- Transparent and Excel based.
- Adaptable to national circumstances and capacities. It comes pre-loaded with public data but can be updated with national data. Assumptions for productivity growth, inflation, interest rates, and demographic growth can be customized.
- As the dataset leveraged by Q-CRAFT includes data from various emission scenarios and incorporates information from 30 different climate models, Q-CRAFT's analysis accounts for both uncertainty in future emissions (scenario uncertainty) and uncertainty in the climate system's response to emissions (model uncertainty).

Limitations:

- Results do not explicitly account for tipping points, sea-level rise, non-market damages (e.g., mortality, conflicts, and food insecurity), and other environmental risks, unless they are manually added by the user.
- Q-CRAFT results are limited to aggregate country analysis and do not provide information on specific sectors.

Use: The Q-CRAFT Tool and its User Guide are publicly available via the IMF Fiscal Risk Toolkit. As it has no scripts or macros, it can be used with any version of Excel. The IMF Fiscal Affairs Department provides Capacity Development for the implementation of Q-CRAFT, though support can extend to strengthening a country's overall macro-fiscal forecasting in the context of climate change, which also fosters cross-government collaboration and the establishment of working groups.
Countries that have used the tool include Armenia, Azerbaijan, Georgia, Jamaica, Kenya, Morocco, Rwanda, Seychelles, the Netherlands, and Uganda.
Development / lessons / challenges: Using Q-CRAFT and thereby conducting quantitative long-term fiscal analysis under various climate change scenarios is a new type of analysis for many MoFs across the globe. Future work includes incorporating other empirical datasets in Q-CRAFT as they become available, including sea-level rise risks under different climate change scenarios or the impacts of long-term trends such as climate change-induced weather volatility.

4.1.1.11 IMF – Fiscal Affairs Department: Climate Policy Assessment Tool (CPAT)

This tool is also covered by the following contribution: World Bank: CPAT.

Name: CPAT (Climate Policy Assessment Tool)
Type: Spreadsheet-based 'model of models'
Institution: IMF and World Bank
Documentation: Documentation; Working paper on methodology; Website
Geographic coverage: single country (global, over 200 countries covered)
Description: The model draws on multiple economic models for rapid estimation of effects of mitigation policies. Its four modules include: (i) a mitigation module (reduced-form macro-energy model), (ii) a distribution module (cost-push microsimulation model), (iii) an air pollution module (reduced-form air pollution and health model), and (iv) a transport module (reduced-form model to relating motor fuel price changes to changes in congestion and road accidents / fatalities and their external costs). Together, these can be used to evaluate carbon taxes, ETSs, fossil fuel subsidy reform, energy price liberalization, electricity and

fuel taxes, removals of preferential VAT rates for fuels, energy efficiency and emission rate regulations, feebates, clean technology subsidies, and combinations of these policies (‘policy mixes’).

Questions to be answered / variables considered: Model output includes impacts on energy production, consumption, trade, and prices; emissions of local and global pollutants including reductions needed to achieve NDCs; GDP (disaggregated by revenue usage) and economic welfare; revenues (by fuel, sector, and tax instrument); industry incidence; household incidence (by decile, urban vs rural, and horizontal equity); and development co-benefits (local air pollution and health impacts). This allows for assessment of trade-offs (e.g., among efficiency, equity, or administrative burden) and hence tailoring of policy design to each country’s context.

Strengths:

- The model is among the most comprehensive multi-country climate mitigation models, in terms of countries, climate mitigation policies, and their short- and medium-term effects (up to 2040).
- It covers many different trade-offs of climate policies for rapid policy assessment and design.

Limitations:

- It cannot answer all questions, and more tailored models can provide further economic insights, estimate international impacts, assess technological effects, and examine climate-economy interactions beyond CPAT’s 2040 horizon.

Use: CPAT covers over 200 countries with complete input data, though users have the option to customize data and parameter assumptions. The model is spreadsheet-based, and users interact with a dashboard. IMF staff have used it extensively for country-level, regional, and global climate mitigation policy analyses. It has also informed thematic analyses for the IMF’s Staff Climate Note (SCN) series, such as quantified comparison of mitigation instruments (e.g., carbon taxes and ETSs), fossil fuel subsidy reform, methane taxes, and the carbon price equivalence of mitigation policies.

Development / lessons / challenges:

- Models with dynamic capital stock for transport and buildings that have been developed separately for buildings and transport will be integrated. This will allow for better modelling of sectoral policies and can allow for quantification of the spillover effects of technology policies on costs due to learning curve effects and the impact of capital vintages on optimal mitigation strategies.
- More refined industry- and activity-specific sectoral models, e.g., for the steel, chemicals, cement, agriculture, and forestry sectors are being developed.
- Economic impacts, policy coverage, and international linkages will be enhanced.
- It is envisioned that CPAT will increasingly allow for linkages with external models.

4.1.1.12 World Bank: World Bank Group Climate Aware Macroeconomic Models available for use by Ministries of Finance

The World Bank’s Climate Country Climate and Development Reports (CCDRs), of which around 60 have been released as of September 2024, include an evaluation of the macroeconomic impacts of climate change and of climate policies, supported by a suite of models. Beyond standard analytical work of MoFs, these models can be used to analyze economy-wide impacts of decarbonization policies, estimate macroeconomic damages of climate change, and better understand the trade-offs between climate policy and other economic priorities.

Key messages

- The models can be used stand-alone, yet in virtually all CCDRs they have been used in conjunction with more specialized models to maximize the granularity and country-specificity of the analysis.
- Bio-physical models, energy and transportation models, and microsimulation models are regularly used to capture sectoral and distributional impacts of climate change and climate policy. Specific details about planned policies, e.g., investment needs for adaptation plans, or the details of power-sector development plans, are usually supplied to the macroeconomic model from external sources rather than derived by the model itself.

- In this context, the macroeconomic models are mainly focused on whole-of-economy effects and how firm and household reactions shape the final products.
- Apart from MFMod-CC, MANAGE, ENVISAGE, CPAT, and MINDSET[4], other models used to analyze climate-related issues for CCDRs include SHOCK WAVES, UNBREAKABLE, and OMEGA.

The World Bank has active programs for building country-specific versions of the models for client countries as well as training on how to use, maintain, and revise the models. Local country economists or MacroModelling@worldbank.org can be contacted for more information.

4.1.1.13 World Bank: MFmod – CC (country-specific macrostructural models)

Name: Macroeconomic and Fiscal Model (MFMod) – CC (Country Climate Change)
Type: Macroeconometric
Institution: World Bank
Documentation: Documentation
Geographic coverage: single country (global)
Description: MFMod CC is a family of country-level macro-structural models akin to models traditionally used by central banks and MoFs. It has empirically determined short-run dynamics that allow for frictions and theory-informed long-run dynamics. Long-run supply is anchored in labor supply, capital stock, and total factor productivity, all endogenized to various extents. Parameters are country-specific and estimated econometrically using historical data. MFMod CC includes GHG emissions from five sources, five types of economic damages, transition effects of moving towards a renewable energy economy, co-benefits from mitigation, and an adaptation module.
Questions to be answered / variables considered: Variables include GDP, household consumption, inflation, interest rates, unemployment rates, CO2 emissions, energy mix, sovereign debt, fiscal balances, value-added by sector, and trade (current, financial, and capital accounts). Questions it can help answer concern the economic, fiscal, and monetary policy implications of the energy transition / climate policy; how climate policies stack up against other policy priorities; the implications of climate change and policies for people, jobs, wages, and consumer prices, how this affects households, and whether household subsidies can mitigate the impact on the poorest without excessively impacting growth; and the interaction of physical and fiscal constraints with climate policy.
Strengths:

- Relatively easy to use and as climate is integrated into a modelling framework that is standard for MoFs and central banks the learning curve is not as steep.
- Country-specific parameter estimates and behavior.
- Transition dynamics to long-run equilibrium consistent with economic behavior, structural transformation, and local circumstances. Supply side constraints are considered via a production function, limiting the benefits of policy responses relative to demand-only models.
- Explicit household and firm optimizing behavior and thus endogenous adaptation, and endogenous reaction of supply and demand to changes in technology, prices, and resources.
- Supports Monte-Carlo experiments.

Limitations:

- Less sectoral detail than CGE or IO based models, as this is not often available in time-series data. However, IO tables can be used to generate a finer disaggregation (via fixed coefficients or by taking a CES-style production approach).
- Disaggregation of results to the sub-national level is not possible if sub-national time-series data are lacking, which is the case for most countries. This can be overcome by coupling model results with household surveys or biophysical models.

[4] Each of these models is featured in more detail in a separate contribution.

Assumptions: Neoclassical in that households and firms maximize utility and profits subject to budget and resource constraints.
Use: MFMod is built on and includes standard macroeconomic accounts. Its Excel interface allows non-specialist analysts to construct baseline forecasts and scenarios, yet the code is transparent and can be modified by staff wishing to delve deeper (in Eviews and Python). The model can be used for standard macroeconomic policy analysis, for climate analysis, and to evaluate the climate impacts of policies without an explicit climate focus. It supports macroeconomic projections and simulations.
Development / lessons / challenges: Current work includes endogenizing more features of total factor productivity via endogenous changes to land demand and supply, adding Schumpeterian assumptions for growth, and enriching the financial sector.

4.1.1.14 World Bank: MANAGE-WB (Recursive-Dynamic CGE model)

Name: Mitigation, Adaptation, and New Technologies Applied General Equilibrium at the World Bank (MANAGE-WB) model
Type: CGE
Institution: World Bank
Documentation: Documentation
Geographic coverage: single country (global)
Description: MANAGE-WB is a single-country recursive dynamic CGE model that can capture country- and sector-specific physical and transition risks associated with climate change. The model is calibrated to social accounting matrices, and integration with GTAP provides coverage for ca. 140 countries across 80 sectors and with specifics on power generation, GHG emissions, and land use. It stochastically assesses climate change damages for 15 damage vectors and is mindful of resource constraints.
Questions to be answered / variables considered: Variables considered include fiscal outcomes, standard national accounts indicators, distributional effects via welfare metrics for different household groups, sectoral outputs and prices, employment, and wages, as well as GHG inventories (including non-CO2 process emissions), air pollution and land cover change. Questions it can help answer concern the identification of policies that support development and long-term climate outcomes and short-term actions that avoid costly 'traps' and long-term policy reversals; the level of taxation and / or public and private investment needed to meet development and climate objectives; sustainable and realistic financing options; revenue recycling schemes post subsidy reform; and quantification of cost-effective interventions and the economy's vulnerability to climate risks and resource limitations.
Strengths:

- Rich depiction of mitigation strategies, which allows for feedback loops with detailed sector models, e.g., energy system, transport, agricultural, and climate change damage models. Rich sectoral detail and robust micro-foundations also enable modelling structural change.
- It contains a sensitivity and stochastic module to assess climate damages, including from extreme climate events.
- It supports Monte-Carlo experiments.

Limitations:

- The model clears markets in each time period (one year), limiting its suitability for analyzing shocks that take more than one year to resolve. This is not a serious shortcoming for slow-moving effects such as gradual temperature rise of changes in rainfall patterns.
- As other macroeconomic models, MANAGE-WB uses smooth functional forms to characterize technology. Rapid development of new sectors requires external-to-the-model information.
- Monetary policy, rational expectations, and nominal rigidities are not generally modelled.
- By default, the model depends on estimates of elasticities of substitution estimated by GTAP, which may not be suitable for the country in question. The most important elasticities are usually re-estimated at the country-level, yet many retain their default value.

Assumptions: Neoclassical assumptions, including market clearing and flexible prices.

Use: The model can be used for standard macroeconomic policy analysis, for climate analysis, and to evaluate the climate impacts of policies without an explicit climate focus. It supports macroeconomic projections and simulations. More practically, the MANAGE-WB has been employed in 14 country-specific climate-focused macroeconomic analyses, and 8 other climate-focused country studies are currently underway.
Development / lessons / challenges: MANAGE-WB is currently being linked with INVEST natural capital models to quantify the impact of policy and changes of ecosystem services globally. Further areas of work include improving the depiction of the labor market, including from a gender lens, endogenous technological change, and monetary policy.

4.1.1.15 World Bank: ENVISAGE (A Global CGE model covering 160 regions)

Name: Environmental Impact and Sustainability Applied General Equilibrium (ENVISAGE) model
Type: CGE
Institution: World Bank
Documentation: Documentation
Geographic coverage: global
Description: ENVISAGE is a global recursive dynamic CGE model designed to assess the interactions between economies and the global environment. It revolves around non-linear behavioral equations representing consumption and production choices of key economic agents. The model relies on the GTAP database, which covers 160 regions (including 141 individual countries) and 76 sectors. Given numerical and algorithmic constraints, disaggregation is usually limited to 25-30 sectors and 20-25 regions.
Questions to be answered / variables considered: Variables considered include changes in welfare, GDP, output, producer and consumer prices, exports and imports, value-added by sector, energy balances, investment across sectors, tax revenue by type, GHG emissions, and carbon prices. The model contains a climate module determining the level of radiative forcing and temperature change, which in turn impacts economic variables such as agricultural yields and damages from sea level rise. It also supports global and regional collaborations scenarios, e.g., via regionally uniform CO2 prices or linked ETSs. Questions the model can help answer consider baseline emissions under BAU vs mitigations scenarios; impacts of climate change on the economy (via damage functions); adaptation options; and economy-wide implications of GHG mitigation policies (e.g., taxes, cap-and-trade, border adjustment taxes) and industrial policies (e.g., subsidies to renewable generation, fossil fuel subsidies reform) and associated revenue recycling options.
Strengths: Consistent representation of inter-dependencies between sectors, agents, and markets within and between economies.
Limitations:

- The model lacks the technological and/or spatial granularity available in sectoral models.
- Some IO tables in the GTAP database are dated and inconsistencies with national trade or fiscal statistics can occur.
- Emissions data are not always based on country-specific data and may rely on technologies deployed in other countries.

Use: The model is suited to 'what-if' type assessment of the macroeconomic and sectoral implications of alternative climate policies. The model has been provided input for World Bank publications on the Trade and Climate Change Nexus, CCDRs, country publications in the context of CCDRs, and IMF publications.
Development / lessons / challenges: Current work includes incorporating marginal abatement cost curves for non-CO2 GHGs, incorporating critical minerals value chains in the underlying database, incorporating additional technological details (e.g., hydrogen, CCS), and adding detailed representation of abatement opportunities in the livestock sector and food loss and waste management practices.

4.1.1.16 World Bank: CPAT

This tool is also covered by the following contribution: IMF – Fiscal Affairs Department: Climate Policy Assessment Tool (CPAT)**.**

Name: Climate Policy Assessment Tool (CPAT)
Type: Tool
Institution: World Bank and IMF
Documentation: Documentation
Geographic coverage: single country (global)
Description: CPAT comprises four modules: at its core is a mitigation module (a reduced-form macro-energy module), followed by a distribution, an air pollution, and a road transport module.
Questions to be answered / variables considered: The mitigation module estimates, among other things, price changes, energy consumption, revenue generation, GDP impacts, and emissions changes (GHGs and local pollutants). The distribution module estimates household consumption effects by income decile, the air pollution module estimates the impact from burning fossil fuels on ambient pollution, and the road transport module evaluates benefits, including reduced mortality from traffic accidents, decreased congestions, and lower road maintenance costs. The model can model the impact of carbon taxes, the elimination of fossil fuel subsidies, and various revenue utilization strategies. It cannot be used to model net-zero scenarios as it does not include every sector (most notably it excludes LULUCF) and does not account for non-carbon pricing policies.
Strengths:

- Rapid deployment, easily accessible via an excel platform, and immediate results.
- It provides metrics absent from other models, e.g., air pollution- and transport-related co-benefits and distributional impacts. Via soft links to other models, e.g., to MFMod or TIMES, CPAT can augment their results by these metrics.
- It is transparent and flexible in the sense that users can track and modify calculations and assumptions and input local data.

Limitations:

- Sectoral coverage is limited to the energy sector, and as partial equilibrium model, it cannot capture second or third order effects.
- Analysis is restricted to the short- and medium-term, as its timeframe only extends to 2035.
- The policy space is limited to fuel pricing.
- As it is elasticity-based, CPAT is meant for simulating relatively small carbon price variations.
- The pre-loaded fuel price and subsidy data for many countries originates from global sources, which may not accurately reflect local prices.

Assumptions: No supply constraints except in the power sector model via the techno-economic option.
Use: CPAT can be requested from the Coalition Secretariat or the CPAT team (cpat@worldbank.org), which can also assist with deployment and provide training materials. It comes with pre-loaded data for most countries, though verification that fuel prices and subsidies are accurately represented is crucial. CPAT has informed various World Bank publications and lending operations, including CCDRs.
Development / lessons / challenges: Current work includes exploring integration with Future Technology Transformations (FTT) models. Tailoring this as well as the MFMod and TIMES connections to specific national needs will require additional resources. Areas for potential future work include integrating CPAT with models that encompass broader climate policies (e.g., carbon border adjustment mechanisms, electromobility, and forest management, among others).

4.1.1.17 World Bank: MINDSET (An easy-to-use sectoral model covering 164 countries)

Name: Model of Innovation in Dynamic Low-Carbon Structural Economic and Employment Transformations (MINDSET)
Type: Macroeconometric
Institution: World Bank
Documentation: Documentation
Geographic coverage: Global

Description: MINDSET is a macroeconometric input-output model that assesses impacts of climate change, adaptation measures, and mitigation strategies with high sectoral and regional granularity. Its core element is a detailed network of linkages between sectors and countries along global value chains, based on a global, multiregional input-output database and IEA energy balances.
Questions to be answered / variables considered: Key outputs include standard macroeconomic indicators, plus sectoral emission levels, production, and employment. Links with national labor force and household survey data yield impacts on workers and consumers across income strata, skill levels, occupation types, and subnational provinces. It does not include budgetary accounts or debt. MINDSET can be used to assess sector- and country-specific, single- or multi-country scenarios according to the above variables and can be linked to Future Technology Transformation (FTT) models to capture within-sector transitions and their impact on, for instance, tax revenue.
Strengths:

- MINDSET combines the strengths of IO analysis (being empirically grounded) with those of demand-led macroeconomic models.
- It captures direct, indirect, and induced supply-chain impacts that feed into fiscal multipliers, and incorporates sectoral and cross-country spillovers from climate change, domestic climate policies, and policies of other countries.
- In contrast to other CGE and aggregate models, it can inform on short-term distributional and sectoral frictions.

Limitations:

- Scenarios where capacity constrains matter require off-model analysis, though introducing supply-side constraints, e.g., from labor immobility and climate damages, is underway.
- Within-sector transformations require input from other models.

Assumptions:

- Bounded rationality and knowledge limitations.
- Derived demand will be met by additional supply.
- Excess labor supply at existing wages (i.e., involuntary unemployment or underemployment), in contrast to equilibrium assumptions.
- No crowding out of investment (i.e., spare economic capacity).

Use: Access to MINDSET is currently available only via World Bank engagement, though plans for a web-based user interface and an open-source version exist for the medium- to long-term. Scenario and model parameter templates are available. MINDSET has been used to inform estimates of macro, sectoral, distributional, and employment outcomes in three CCDRs and further country-specific analyses.
Development / lessons / challenges: MINDSET is a relatively new model with many ongoing developments. Key components, including price formation, investment, and trade effects are being revised to improve empirical relationships, and financial stocks and flows are to be better integrated. A supply-side treatment based on economic complexity will inform labor supply bottlenecks and potential suppliers of new technologies and minerals.

4.1.1.18 Inter-American Development Bank (IDB) / French Development Agency (AFD) / RAND Corporation: SiSePuede: New approaches to assessing economic impacts of Net-Zero pathways

Name: SiSePuede (SImulation of SEctoral Pathways and Uncertainty Exploration for DEcarbonization)
Type: Emissions modelling framework
Institution: open source
Documentation: Documentation: https://github.com/jcsyme/sisepuede; model: https://hub.docker.com/r/jsyme816/sisepuede
Geographic coverage: single country (global)
Description: SiSePuede is a bottom-up partial equilibrium model with sector detail. Rather than using an abatement cost curve, the model links emissions back to technical choices. Benefits associated with emissions reductions are systematically quantified. Using the model involves, first, translating emission

reduction goals into concrete sector pathways, for which the development benefits also need to be quantified. Then, the costs and benefits of the transition are analyzed by translating the development benefits into economic terms, such as GDP, labor, or trade balances via rules of thumb and simple coefficients. The model can help manage uncertainty by running different development pathways under a wide range of future conditions.

Questions to be answered / variables considered: The model seeks to analyze the economic impact of different development pathways and thereby help governments design emission reduction targets that enjoy broad support. By showing the changes needed in each sector and their development benefits, the model also helps ministries make public investments and policy reforms to encourage private investment in net zero solutions as well. Variables include the impact on GDP, labor, and trade balances.

Use: Ministries of finance can run it in house or collaborate with local universities to run the model on their behalf. An application to Latin America and the Caribbean, for instance, found that reaching net-zero emissions by 2050 could bring the region up to USD 2.7 trillion in net benefits compared to a "traditional development" trajectory following historical development patterns (Kalra et al, 2023).

4.1.1.19 Cambridge Econometrics: Macroeconomic modelling of climate change: The E3ME model

Name: E3ME
Type: Macroeconometric
Institution: Cambridge Econometrics
Documentation: Webpage
Geographic coverage: Global
Description: E3ME's structure is based on systems of national accounts with linkages to energy demand and environmental emissions. There are 33 sets of behavioral equations, parameterized using historical data, for household consumption, investment, international trade, prices, and energy demand. The model includes 71 global regions, including G20 and EU Member States explicitly, 43 sectors, 28 categories of household expenditure (more detail for Europe), 25 users, and 12 fuel types. Time series model output runs through to 2050 on an annual basis. The model can be linked to Future Technology Transformation (FTT) sub-models, which currently exist for power generation, steel production, residential heating, and passenger car transport sectors. These simulate the uptake of new technologies within sectors based on consumer demand, technology-specific costs, and market conditions such as regulation, financial support, and deployment rates.

Questions to be answered / variables considered: E3ME considers three areas of uncertainty related to 'policy indecisiveness': the rate of technology diffusion, macroeconomic impacts of low-carbon policies, and the scale and channels of energy-environment-economy interactions. Uncertainty around anticipation of policy outcomes is not modelled explicitly but can be explored via scenario and sensitivity analysis. The model can help with incentive design, based on within-country, -sector, and -group behavioral patterns. Policy questions concern whether climate action is (in)expensive for the economy, the extent to which a carbon price can reduce emissions, possible policy combinations including revenue recycling, price and income effects from switching from high-emissions to low-carbon technologies and their distribution across household, firms and the government, identifying which sectors are likely to be exposed to restructuring and job reallocation and might therefore need government support, whether net zero can be reached without a specific technology, and how change in the technology mix affects the cost of and demand for energy including distributional consequences.

Strengths:

- Innovation is explicitly represented in the model's behavioral responses.
- Highly disaggregated and comprehensive.

Assumptions:

- Integrating uncertainty allows for, e.g., involuntary employment.
- Investment is not constrained by savings, such that under some conditions energy and climate policies can be implemented without crowding out, which would dampen growth.

Use: The E3ME model has a web-based graphical user interface, and model code and database are maintained by Cambridge Econometrics. The model is licensed to research institutions, government departments, and universities for public policy analysis. Active users include the South African Treasury, the World Bank, and the UN Economic Commission for Latin America and the Caribbean (ECLAC).
Development / lessons / challenges: Ongoing efforts are focused on improving understanding of E3ME's approach and increasing accessibility for technically minded audiences. Further development includes expanding FTT sub-models to more sectors, introducing new socio-economic dimensions, incl. inequality and skills indicators, explicitly capturing non-financial obstacles such as skills shortages and finite material resources, and increasing the resolution of fiscal balances and the financial sector.

4.1.1.20 Environment for Development Initiative: Facilitating socially responsible carbon pricing policies: the global Carbon Pricing Incidence Calculator (CPIC)

Name: CPIC (Carbon Pricing Incidence Calculator)
Type: Policy assessment tool
Institution: Mercator Research Institute on Global Commons and Climate Change (MCC) (with funding by GIZ)
Documentation: Website, Methodology
Geographic coverage: single country (global)
Description: The Carbon Pricing Incidence Calculator (CPIC) is an interactive web tool which allows to explore the vertical and horizontal distributional consequences of carbon pricing and various compensation measures for currently 88 countries. To this end, it combines country-level household budget surveys and multi-regional input-output data (GTAP). The tool calculates the additional costs to households after a carbon price is introduced, i.e. the carbon pricing incidence.
Questions to be answered / variables considered: CPIC is designed to provide insights for a broader policy dialogue on design and implementation of carbon pricing schemes. It can be used to explore different carbon pricing scenarios and stylized redistribution mechanisms and compare the distribution of additional costs in or between different groups of the population in the selected country.
Development / lessons / challenges: The tool was developed in an iterative process between MoFs and other relevant stakeholders, supported by the GIZ. Government staff was trained to use CPIC to enable them to produce results and evaluate stylized scenarios independently, and to help inter- and intra-ministry dialogue.

4.1.1.21 Environment for Development Initiative: Pricing Carbon in the Tropics: The CP+ Model

Name: CP+ (Carbon Pricing Plus) Model
Type: Spreadsheet model
Institution: Environment for Development (EfD) at Universidad de Los Andes, with Centro de Estudios Manuel Ramirez (CEMR), Environmental Defense Fund (EDF)
Geographic coverage: Colombia
Description: The model is an excel-based model that brings the analysis of regulated (via carbon pricing) and unregulated emissions under one umbrella. Using estimated Marginal Abatement Cost (MAC) curves for the regulated sector (energy and industry) and the unregulated sectors (forestry) in Colombia, the model considers scenarios where reduced deforestation may be funded by three different sources: the national budget, a national ETS coupled with a high-intensity (jurisdictional) carbon forest offset mechanism, and international sources of funding. The analysis is carried out over 7 years, 2024-2030.
Questions to be answered / variables considered: The model allows for the analysis of emissions and abatement costs in the forestry sector under alternative carbon pricing policies and alternative financing streams for avoiding deforestation.
Strengths: From a policy perspective, greenhouse gas (GHG) emissions from land use (which clearly dominate those from fossil fuels in the tropics) are difficult to analyze particularly because they are diffuse and unregulated in most countries. This model attempts to begin filling that gap.
Use: An empirical result of the application to Colombia is that if reduced deforestation is linked to a national carbon pricing scheme and international results-based payments, the public funding needed to achieve the

Nationally Determined Contribution deforestation target in 2030 is about ten times lower when compared with the scenario where only government funding is used.

Development / lessons / challenges:

- Next steps include generalizing the model so it can be applied to tropical countries other than Colombia.
- The model was shared with modelers from the Ministry of the Environment and the National Planning Department in 2023.

4.1.1.22 Danish Research Institute for Economic Analysis and Modelling (DREAM): The GreenREFORM Model

Name: GreenREFORM Model
Type: CGE
Institution: Danish Research Institute for Economic Analysis and Modelling (DREAM)
Documentation: Relevant publications
Geographic coverage: Denmark
Description: The core of GreenREFORM is a dynamic CGE model with forward looking behavior, overlapping generations, and frictions to achieve credible short-run dynamics. Production is divided into 52 sectors with 81 products and services, including 26 types of energy. Energy demand is categorized into 6 tax purposes, for accurate representation of marginal tax rates. Sub-models provide sectoral detail, and the abatement sub-model contributes a bottom-up representation of technological abatement options across sectors. All sub-models are solved simultaneously yet can be turned on and off at will.
Questions to be answered / variables considered: The model is aimed at evaluating combined effects of economic and environmental policy within a unified framework. It provides information on emission accounts, land-use and livestock accounts, changes to return to capital and the value of firms in each sector, changes to the market price of agricultural land, macroeconomic impacts (incl. changes in production, employment, wage rates, private consumption, exports, imports, and investments), and detailed fiscal impacts (incl. derivate changes to, e.g., unemployment benefits and VAT revenues).
Strengths:

- The technical framework of GreenREFORM and full model integration is more efficient than iterating between a CGE and a system optimization model. Given a baseline, results for standard shocks can be generated in minutes and hence be used in political negotiations.
- GreenREFORM creates some functional overlap and hence redundancy with sector-specific models. However, this can be beneficial for building mutual understanding of complexities and bringing knowledge from sector experts into the macroeconomic decision environment.

Limitations:

- Supporting all sub-models with data and establishing the baseline requires a lot of information and strong support from sector experts and institutions.

Assumptions: Technology cost trajectories are exogenous, as Denmark is a small open economy.
Use: The MoF used GreenREFORM as the centerpiece for analyzing combinations of taxes on agricultural emissions and government support schemes for afforestation, food additives, biochar, and more in support of the Expert Group on Green Tax Reform. The work of the expert group laid a solid foundation for informed political debate and paved the way for parliamentary agreement on a reform addressing agriculture and LULUCF emissions in late 2024. The Danish Environmental Protection Agency uses the model to forecast waste generation and recycling as part of the Danish emission inventory. Outside of government, GreenREFORM has been used to assess the importance of credible announcement of climate policy and the National Bank of Denmark has developed a method for assessing economic and financial risks associated with the transition based on simulations from GreenREFORM.
Development / lessons / challenges:

- The primary challenge was reformulating existing power market and energy system models into a continues problem space, for seamless integration with the macroeconomic model.

- A key to success has been close collaboration between a dedicated model team, university researchers, sector experts, and end users. Getting various ministries engaged during development was challenging, showcasing the importance of top-down commitment and enforcement, planning, and stakeholder management when developing and introducing a new complicated tool across institutions.
- The model's success relies on high data quality in Denmark and the sophistication of other models already in use at DREAM, the MoF, and the Energy Agency. Where this is not given, a lower level of ambition may be advisable whilst making sure the core framework supports the level of ambition ultimately desired.
- The current focus is supporting model implementation in the MoF and other government agencies, with courses run to build capacity and agencies developing plans for making the best use of relevant sub-models.
- DREAM is engaged in an EU Commission sponsored TSI-program to develop a 'work horse' version of GreenREFORM for institutions in four EU countries. The project also serves as a blueprint for other countries to build customized models.

4.1.1.23 ETH Zürich: Latest Developments in Upgrading DICE-2023: Findings and Implications for Ministries of Finance

Name: Dynamic Integrated model of Climate and the Economy (DICE) model
Type: IAM
Institution: William Nordhaus
Documentation: Documentation and model
Geographic coverage: Global
Description: DICE offers internally consistent framework based on a standard Ramsey growth model for analyzing the interplays between the macroeconomy, greenhouse gas emissions, climate policies, and climate change. Key elements include portable modules and quantifications for climate change damage functions, dynamic estimates of aggregate emissions reduction costs, a simplified carbon cycle-climate system representation, dynamic social cost of carbon estimates, and a flexible discounting module.
Key innovations in DICE-2023 (updated from DICE-2016) include (i) a new carbon cycle-climate system representation, (ii) an updated damage function based on a synthesis of 56 estimates across 33 published studies that includes post-2016 research, (iii) a new representation of non-carbon dioxide GHG emissions and abatement, and (iv) a new approach to discounting that incorporates uncertainty. These updates lead to substantially higher SCC, lower cost of maintaining the 2°C limit, and a lower cost-benefit optimal emission and warming profile than in previous versions.
Questions to be answered / variables considered: The model can be used to (i) quantify the social cost of carbon (SCC), quantify cost-benefit optimal climate policy paths under different parameter choices, (iii) quantify cost-effective policy paths given policy targets, and (iv) characterize the costs and benefits of arbitrary policy paths under different parameter scenarios. Endogenous outputs include GDP, climate change damages, mitigation expenditures, consumption/investment, carbon prices, the SCC, industrial carbon emissions, land-use carbon emissions, abatable non-carbon dioxide emissions, global mean surface temperature change, and carbon concentrations.
MoFs can use DICE (or RICE, the multi-region version of DICE) to help inform long-run macroeconomic and fiscal projections of global or regional GDP impacts of different climate policy scenarios, and output on the SCC can inform carbon pricing policies, public cost-benefit analysis, and setting subsidy rates. Moreover, DICE-2023 model elements can be integrated into, e.g., models of short-run economic fluctuations such as DSGE models or New Keynesian frameworks, to help address questions DICE is not designed to answer.
Strengths:

- Simplicity, flexibility, and portability of modelling elements.
- Given DICE's simplicity, uncertainty and sensitivity analyses are relatively easy to conduct.

Limitations:

- DICE's simplicity means it abstracts from many complexities of modern macroeconomies.
- As the time step is 5 years, DICE is not suited to study short-run macroeconomic frictions and fluctuations.
- The model focuses on a representative consumer and final goods production sector.
- The multi-regional version of DICE, RICE, allows country- and region-level analysis, but the model is not designed to answer some of the granular questions relevant for MoFs (e.g., on targeting clean technology subsidies or distributional impacts of carbon pricing).

Assumptions: Evolution of technology and emissions reduction costs are taken to be exogenous, i.e., not affected by climate policy. The cost of mitigating carbon emissions is taken to be a proportional and contemporaneous fraction of GDP, which increases non-linearly in climate policy stringency. Population growth is taken to be fixed, though mortality impacts of climate change are valued in the damage function. Climate change damages are assumed to be quadratic in global mean surface temperature change. This is in line with estimates for modest temperature change, but evidence on damages is very limited for higher levels of warming and a damage function does not reflect threshold damages.
Use: Code, user manual, and data sources are publicly available and can be readily modified by users. DICE runs on GAMS, and thus a GAMS license and programming expertise are needed to use the model. An Excel version is available but comes with additional caveats noted in the documentation. For older versions of DICE, MATLAB code is publicly available from other scholars.

4.1.1.24 Sciences Po – French Economic Observatory (OFCE): ThreeME model

Name: ThreeME (Multi-sector Macroeconomic Model for the Evaluation of Environmental and Energy policy)
Type: CGE
Institution: OFCE (French Economic Observatory)
Documentation: Documentation
Geographic coverage: single country (global; given data it can be adapted for any country)
Description: A single country, open-source model designed to evaluate short-, medium-, and long-term impacts of environmental and energy policies at the macroeconomic and sectoral levels. It combines features of neo-Keynesian models with elements of bottom-up energy models and can assess the impacts of decarbonization scenarios and climate policies. The model is built in a block-like structure, with core elements (consumers, producers, prices) and optional elements (transportation choices, housing energy efficiency).
Questions to be answered / variables considered: Outputs include standard macroeconomic indicators such as GDP, employment, inflation, public deficit, and debt-to-GDP ratio, and sectoral variables such as production, employment, and investment by sector. Environmental indicators include GHG emissions and energy consumption by source and sector. It also provides consumer, production, and energy prices and trade outcomes, including imports, exports, and the trade balance.
The model can evaluate the effects of carbon taxes and green subsidies and can project government revenues and expenditures under different policy scenarios, making it useful for budget planning. It can also help analyze the impact of green transitions on public debt trajectories, assess fiscal risks associated with climate change mitigation and energy transition, and design and evaluate climate-aligned fiscal policies. The disaggregation helps inform decisions on targeted support and compensation mechanisms. The model can also be used to stress-test fiscal projections against various climate policy scenarios. In some calibrations, the model provides distributional impacts of policy at the sector and household level. The model's focus on energy means the model can be used to answer more precise questions, e.g., in France the model has been used to evaluate comprehensive green transition scenarios with diverse measures including incentives, subsidies, change in the energy mix, and change in agents' behaviors (e.g., increasing remote work).
Strengths:

- High sectoral and energy disaggregation, enabling detailed analysis of activity transfers and modelling of a broad range of climate and energy policies across economic agents.

- Short-run dynamics akin to neo-Keynesian models, allowing analysis of adjustment processes in the short- and medium-term, as well as long-term macroeconomic impacts.
- Hybrid structure that integrates bottom-up modelling of household energy consumption (where data is available) offers a comprehensive view of policy impacts.
- Open-source model that runs on open-source software, enabling transparency and adaptability.

Limitations:
- The detailed structure yields many results for each run, which can be difficult to interpret.
- Extensive data requirements: detailed sectoral and energy data is needed for calibration.
- Results can be sensitive to the calibration of behavioral parameters.
- Financial sector representation is limited.
- No explicit spatial dimension meaning regional impacts are not modelled.

Assumptions:
- Frictions on the adjustment of prices and quantities.
- A choice of wage curve or Phillips curve relationship for wage determination.

These assumptions are crucial in driving the model results, especially in terms of employment and inflation dynamics.

Use: The infrastructure of the simulations and user interface are built in R. The model is open source and a version with French data is available via GitHub. Calibrated versions for the 27 EU member states plus the UK are available by relying on the free Exiobase database and Eurostat data. The research team is working with government organizations in, e.g., France, Mexico, and Luxemburg, and provides initial technical training for economists to access and use the model. In France, the model has become the Treasury's primary tool for environmental policy analysis. To support this, some modifications were made to replicate the short-term dynamics of the existing macroeconomic model, especially of equations in the foreign trade and investment blocks. As a collaborative effort, it is regularly used to assess the economic impact of the French low carbon strategy (SNBC). Similar exhaustive low carbon scenarios have been implemented for Tunisia, Mexico, and Indonesia with support from UNEP and the AFD (the French Development Agency).

Development / lessons / challenges:

Partnerships with local users, especially with an institutional partner (e.g., economic or energy ministry, energy or environment agency), are crucial for credibly evaluating projected national policies and adapting the model to the country-specific context. In the experience of the ThreeME team, also involving an academic partner is crucial for long-term use and maintenance of the model.

There are three categories of future development. First, improving the user experience by enhancing technical performance and developing interactive tools for analysis of data and results. Second, improving the interconnections between top-down and bottom-up modules, which remain challenging. Third, developing new modules, including for financial markets, the electricity network and market, and climate damage. Additionally, creating a multi-regional version of ThreeME with explicit trade-linking is important.

4.1.1.25 UNEP (United Nations Environment Programme): IGEM's Integrated Approach to Climate-Smart Economic Decision-Making

Name: IGEM (Integrated Green Economy Modelling) framework

Type: Modelling framework

Institution: PAGE (Partnership for Action on Green Economy), with UNEP, UNDP, ILO, UNIDO, and UNITAR.

Documentation: Documentation

Geographic coverage: single country (global)

Description: IGEM provides a methodology to integrate System Dynamics (SD), Computable General Equilibrium (CGE) models, and Input-Output Accounting Matrices (IO-SAMs). It integrates economic forecasts from the CGE model and sector-specific insights from the IO-SAM with social and environmental projections derived from system dynamics, to capture economic, social, and environmental dimensions. The framework is designed to be adaptable, allowing different models to be emphasized depending on the focus of the analysis. IGEM also allows for target-driven and investment-driven scenario simulations.

Questions to be answered / variables considered: The CGE model provides insights on economic effects, e.g., how green tax reforms impact economic growth, sectoral outputs, consumption, income distribution, employment, and trade. The SD model adds depth to the assessment of long-term environmental and social impacts. The IO-SAM reveals sector-specific responses to economic change. Hence, IGEM can be used to estimate the impact of green policies on GDP, employment, investment, and government revenue and help understand the trade-offs between economic growth and sustainability.

More specific questions include how green subsidy reforms are likely to impact productivity in green economy sectors, how tax reforms and removing fossil fuel subsidies mobilizes domestic revenues for green investment, which labor market interventions deliver high quality green jobs, and how interventions can improve access for the un- and under-employed. It can also be used to compare scenarios incorporating green economy principles with BAU, which helps identify investment and expenditure strategies that enhance economic resilience to external shocks.

Strengths:

- The integrated approach can inform fiscal strategies, guide budget allocations, and support long-term economic planning.
- Detailed sectoral analysis helps target interventions and optimize resource allocation.
- SD models contribute non-linear, dynamic interactions and feedback loops which are often absent in traditional CGE models, allowing for more realistic policy simulations.

Limitations:

- Traditional model assumptions such as perfect information, rational decision-making, product homogeneity within sectors, and instantaneous market clearing may not fully capture real-world dynamics, leading to potential prediction inaccuracies. Integrating SD with CGE models mitigates this somewhat.
- Full integration between the CGE and SD components is difficult. Currently, they are not fully harmonized and only have a soft link (i.e., the output of one model is sequentially fed into the next).
- The approach is data intensive and may require substantial adaptation and recalibration when applying it to different countries.

Use:

- The IGEM framework can be tailored to country-specific contexts by MoFs. Reports and resources are available via PAGE, and MoFs can contact the PAGE secretariat for additional information or support. MoFs can also access online and in-person training.
- It has been used to model a carbon tax on fossil fuels in Mexico, specifically the impact of different rates on emissions and the consequences for GDP, investment, and consumer welfare. Two revenue recycling options, support of renewables and rebates to customers, were analyzed. The SD model highlighted social benefits, especially health improvements from lower pollution, which increased productivity.

Development: The aim is for deeper integration beyond the soft-linking approach and integrating additional tools such as biophysical models or Geographic Information System (GIS)-based systems.

4.1.1.26 Munich Climate Insurance Initiative (MCII): Showcase of CLIMADA

CLIMADA (CLIMate ADAptation) is an open-source analytical tool designed to assess physical risks and formulate effective adaptation strategies in response to climate change. It sits at the core of the stakeholder-inclusive Economics of Climate Adaptation (ECA) framework to provide science-based support for decision-making and investment in adaptation. It evaluates the cost-effectiveness of various adaptation measures to identify strategies that effectively mitigate future impacts on infrastructure, agriculture, and other vital sectors, which facilitates informed resource allocation and can enhance climate resilience.

Key messages

- The Munich Climate Insurance Initiative (MCII e.V.) uses the ECA framework and CLIMADA in practice, to determine climate risks faced by populations and countries most exposed to increasing impacts of climate change, and to identify, quantify, and suggest measures to close the protection gap.
- In applying the model, significant stakeholder engagement and knowledge transfer is helpful, including for independent future application of the model.

For MoFs, CLIMADA can aid proactive financial planning and risk management by quantifying the economic impacts under various climate and socio-economic scenarios.

Institution: ETH Zürich
Documentation: GitHub

4.1.1.27 Austria – Ministry of Finance: Suite of Analytical Tools: Integrating Climate Projections into Austria's Long-Term Budget Forecasts

[TO BE ADDED]

4.1.1.28 Economic and Social Research Institute (ESRI) / Ireland – Department of Finance / Department of Public Expenditure, NDP Delivery and Reform (DPENDR): Macroeconomic analytical tools: The Ireland Environment, Energy and Economy (I3E) model

Name: Ireland Environment, Energy and Economy (I3E) model
Type: CGE
Institution: Economic and Social Research Institute (ESRI)
Documentation: Documentation
Geographic coverage: Ireland
Description: The model is an intertemporal CGE model that represents productive sectors, households, and the government, among others, with a horizon to 2050. Producers and consumers maximize profits and utility, respectively. As sectoral inter-linkages are modelled explicitly, wider economic impacts of a (policy) shock via different transmission channels can be examined. This is particularly useful for examining policies which are expected to have a substantial indirect effect in addition to their direct effect, as is the case for energy-related policies.
Questions to be answered / variables considered: The model includes energy flows and emissions in addition to monetary flows. Inputs to production are labor, capital, material inputs, and energy inputs. Carbon commodities represented include peat, coal, natural gas, crude oil, fuel oil, LPG, gasoline, diesel, kerosene, and other petroleum products. Commodities are produced as cheaply as possible, conditional on relative prices and substitution possibilities, such that external shocks (e.g., an increase in carbon tax) can result in substitution away from energy inputs or reduced demand for carbon-intensive energy inputs. Economic growth is driven by population growth, investment, and growth in total factor productivity, with population and productivity assumed to grow at a constant rate.
Use: The model was developed to help inform the design of energy policies to ensure a smooth and least-cost transition to a low-carbon economy, by helping better understand the economic and environmental impacts of policies.

4.1.1.29 IMF – Research Department: GMMET

Name: GMMET (Global Macroeconomic Model for the Energy Transition)
Type: Dynamic General Equilibrium Model
Institution: IMF
Documentation: Documentation
Geographic coverage: Global

Description: The model is a multi-sector, multi-region dynamic macroeconomic model aimed at mapping mitigation policies to emissions reduction and macroeconomic and sectoral variables covering the real, external, fiscal, and monetary sectors of the economy.
Questions to be answered / variables considered: The model can inform the tradeoff between growth friendly mitigation policies (focused on subsidies) and debt sustainability (focused on GHG tax), investigate the impact on the external sector from decarbonization depending on country-specific international specialization, or assess inflation dynamics and monetary policy response in different regimes. It may also put in perspective mitigation policies with other structural policies (labor policies, tax reform).
Strengths: The model balances sectoral granularity needed to discuss sector-specific policies with a macroeconomic framework needed to discuss structural, fiscal, and monetary policies.
Limitations: Redistributive implications (inequalities) and details labor market analysis are not covered specifically, and climate damage and resilience policies are not within scope.
Assumptions: The main model results (impact of mitigation policies on growth, inflation, fiscal balance) depend on key elasticities for which the range of estimates is large, like the substitutability (i) between energy and capital and (ii) between technologies or energies at the sectoral level.
Use:

- The documentation of the model is publicly available and sharing procedures with central banks and MoFs is envisioned.
- A two-country (individual country plus rest of world) version of the model exists and is particularly suitable to assess the macroeconomic impact of different domestic decarbonization strategies for forecasting or public finance management.
- The model has been used to assess the impact of the United States Inflation Reduction Act on domestic and global greenhouse gas (GHG) emissions, inflation, growth, public revenues, and expenditures. An application for the Dominican Republic focuses on a reform of the energy sector and its implications for the economy.

Development / lessons / challenges: The model is under continuous development. The modeling team is exploring the international specialization of transition commodities such as metals and goods like electric vehicles and solar panels and working on two aspects of the modeling infrastructure: (i) streamlining and simplifying the model's calibration to enhance usability, and (ii) improving the reporting of model results.

4.1.1.30 IMF – Research Department: IMF-ENV: Integrating Climate, Energy, and Trade Policies in a General Equilibrium Framework

Name: IMF-ENV
Type: CGE
Institution: IMF
Documentation: Chateau et al. (2025, forthcoming)
Geographic coverage: Global
Description: The model is a global dynamic CGE model based on input-output tables for 160 countries and 76 commodities. It models the real economy with sectoral and country granularity and comprehensive representation of trade flows.
Questions to be answered / variables considered: The model is well suited to study medium- and long-term effects of policies which cause structural change. It shows how policies impact the allocation of factors of production across sectors, trade flows, and international competitiveness, as well as standard real economic variables and emissions. Policies that can be simulated include different carbon pricing schemes, energy policies including subsidies and (in)direct regulation, sectoral regulation, and new green technologies. The model can account for climate change damages (long-term shifts and variation in extreme weather events) at both sectoral and aggregate levels. It can also be linked to sector-specific models, e.g., for energy, agriculture, or land-use, and use household survey data or links to microsimulation models to analyze poverty and inequality effects.

Strengths: The model is well-suited for analyzing sectoral effects from structural shifts and the impact of energy and climate policies. It considers interlinkages among various sectors, agents, markets, and international transactions, thereby showing the broader domestic and global economic impacts of policies and uncovering indirect (general equilibrium) effects.
Limitations: CGE models like IMF-ENV are limited in analyzing short-term macroeconomic fluctuations and, as they are real economy models, unable to examine monetary policy effects.
Use:

- Global CGE models like IMF-ENV typically use subscription-based datasets like the GTAP database along with a wide range of parameters from the literature.
- The model has been used in a variety of contexts, including multi-country studies on international climate policy cooperation and supporting climate policy analysis within individual countries.
- Economic strategy and policy: IMF-ENV can be used to simulate alternative fiscal policy packages to reach NDCs and assess their fiscal and economic implications.
- Fiscal policy and budget: sectoral granularity and the incorporation of general equilibrium effects allow better estimates of revenue and spending implications of different climate policies.
- Financial policy and oversight: The NGFS scenarios have been modeled within IMF-ENV to produce outcomes such as sectoral value-added, capital and labor demand, and overall GDP impacts for all G20 economies. These results have been integrated into the Financial Sector Assessment Programs (FSAPs) to examine transition risks and enhance the understanding of their potential effects on financial stability.

Development / lessons / challenges:

- IMF-ENV is in continuous development. Current development efforts are aimed at creating an R&D and technology diffusion module and updating the characterization of international capital flows in the model.

Developing CGE models from scratch is a resource intensive-task and requires specialized expertise. A pragmatic strategy for ministries may include enhancing their current analytical tools to establish a link between economic and environmental outcomes.

4.1.1.31 IMF – Research Department: DIGNAD

[TO BE ADDED]

4.1.1.32 Inter-American Development Bank (IDB) / French Development Agency (AFD) / University of Costa Rica: OSeMOSYS

Name: OSeMOSYS
Type: ESM
Institution: open source
Documentation: Documentation / website; GitHub.
Geographic coverage: single country (global)
Description: A bottom-up energy system model initially developed to assess the costs and benefits of net-zero strategies for the energy sector.
Questions to be answered / variables considered: Whilst the model was initially developed for CBA of net zero strategies for the energy sector, it has also been used to assess financial, fiscal, and distributional impacts of road decarbonization in a single framework.
The model projects demand for mobility and freight, typically by 2050, from assumed gross domestic product and population scenarios. Other variables considered include capital costs, maintenance, and fuel expenses, and estimates the cost to deploy the needed infrastructure (e.g., bus lanes, charging stations). It also calculates the costs and benefits of choosing a decarbonization scenario instead of a business-as-usual scenario, and the incidence of these costs and benefits on households grouped by income quintile or region of residence as well as the costs for different types of firms.
Strengths: The model is free and open source and can be applied to different countries.
Assumptions: GDP and population scenarios are exogenous.

Use: The model has been augmented with a tax and distributional impact model by the IDB, to analyze the fiscal and distributional impacts of decarbonizing road transport and of policies designed to create alternative revenue streams. The model has also been applied to Peru by the World Bank to investigate similar issues.

4.2 Considerations for modelling

Table 4.3 Contributions about considerations for modelling

Contributions
Italy – Ministry of Economy and Finance: The importance of inter-model comparisons to inform robust decision-making – The example of the Italian Ministry of Economy and Finance
Canada – Department of Finance: The challenges of uncertainty in climate-economy modelling
OECD (Organisation for Economic Co-operation and Development): The New Macro-Structural Climate Adaptation and Mitigation Framework by the Economics Department of the OECD
Coalition for Capacity on Climate Action (C3A): Climate macro-modelling tools to address emerging policy questions in Ministries of Finance: why new tools are now needed for the urgent task of implementation - An overview by C3A
World Bank: A bottom-up approach to estimating climate-development investment needs
Partnership for Economic Policy: The use of computable general equilibrium models for practical policy analysis by finance ministries: The case of climate policy in South Africa
Spain – Ministry of Economy, Trade and Enterprises: The use of external models and the climate policy decisions they inform
SOAS University of London: Ecological stock-flow consistent modelling: an emerging tool for Finance Ministries
Grantham Research Institute on Climate Change and the Environment: Advancing Macroeconomic Modelling for the Energy Transition: Harnessing Production Networks Models
Network for Greening the Financial System (NGFS): Summary of the NGFS Climate Macroeconomic Modelling Handbook
Canada – Department of Finance: Finance Canada's approach to climate-economy modelling
Network for Greening the Financial System (NGFS): Short-term climate scenarios

4.2.1.1 Italy – Ministry of Economy and Finance: The importance of inter-model comparisons to inform robust decision-making – The example of the Italian Ministry of Economy and Finance

Enhancing understanding of climate policy impacts and decision-making through inter-modal comparisons. *IRENCGE-DF and GEEM were employed to assess the economic impact of a gradual carbon tax increase to reduce emissions by 35% by 2030. Despite differences in model design, both models provided similar qualitative and quantitative results, such as predicting decreases in GDP, consumption, and labor (though with slight quantitative disparities). However, each model offers unique insights: IRENCGE-DF predicts increased distributional inequalities, a shift from high- to low-emission industries, and a greater share of renewables in the energy mix, while GEEM emphasizes more severe short-term economic effects due to forward-looking behavior and New Keynesian elements (e.g., imperfect competition and price-setting frictions). This emphasizes how the two models can complement each other, providing a more comprehensive analysis of policy development.*

- IRENCGE-DF and GEEM complement each other, providing a detailed analysis of distributional effects and sectoral impacts for the former, and macroeconomic fluctuations, and short and long-term policy impacts on overall economic stability and growth for the latter.
- Integrating the strengths of both models provides a robust framework to understand the trade-offs and synergies of different climate mitigation strategies, supporting more effective policy design and implementation
- MoFs should consider integrating both CGE and DSGE models to capture a fuller range of economic and distributional impacts from climate policies.

4.2.1.2 Canada – Department of Finance: The challenges of uncertainty in climate-economy modelling

Uncertainty about how climate change will impact economies is a major challenge for economic modelling that has not yet been resolved. It is challenging due to the difficulty of quantifying uncertainty of, e.g., different climate futures, technological progress, and policy. However, given uncertainty in the real-world, models which do not incorporate it may yield biased results.

Key messages

- Quantifying the impacts of uncertainty might change the timing of optimal climate policies. This is especially important because simple economic models with discounting often find that optimal policy is to delay action.
- Models that assume agents have perfect foresight about the climate scenario they are in will tend to underestimate impacts of the transition; agents making optimal decisions under uncertainty will tend to delay decisions or choose investments with shorter time-horizons.
- Policies that reduce uncertainty and achieve policy objectives in all future conditions will be relatively more beneficial than policies that need to be fine-tuned to future conditions.
- Strong early climate actions that decrease the likelihood of extreme climate futures will reduce uncertainty and benefit the macroeconomy.

A useful next step would be to create and maintain a database of potential climate scenarios which include estimates of their likelihood under different assumptions about global climate mitigation actions. This would enable attaching probabilities to sensitivity analysis and support better recommendations to policymakers.

4.2.1.3 OECD (Organisation for Economic Co-operation and Development): The New Macro-Structural Climate Adaptation and Mitigation Framework by the Economics Department of the OECD

The OECD is engaged in an effort to use conceptual and quantitative models to guide policymaking in the climate space, as current approaches lack a framework of how to use climate-related tools to achieve policy goals within short- to medium-term horizons (up to 5-10 years). The OECD's research and its development of a macroeconomic model explicitly considers key market failures such as labor market mismatches, missing demand externalities, and learning-by-doing externalities which are often overlooked in existing approaches.

Key messages

- Climate science has made progress in estimating the economic impacts of climate change via CGE models and IAMs, though these tend to focus on long time horizons. This does not necessarily align with the shorter time frames relevant for MoFs.
- Many macroeconomic models that do integrate climate only do so in a limited manner. Climate damages are often treated as ad hoc and feedback loops between economic policies and climate outcomes are inadequately captured. Non-linear effects (including tipping points), uncertainties, and structural changes are also often overlooked.
- Some studies account for complexities such as labor market frictions, green innovation, and green technology adoption, though these are still rare and fragmented.
- The framework and general equilibrium macroeconomic model being developed by the OECD will consider macroeconomic and structural impacts of climate policies, provide baseline projections of investment, growth, and fiscal trajectories under various climate policies, integrate market failures, and, crucially, consider climate mitigation and adaptation strategies simultaneously. This model thus allows policymakers to evaluate the economic impacts and interactions of policy alongside potential damages from climate change.
- By endogenizing choices for green innovation and investment in a dynamic framework, the model can capture policy mixes that bring green investment to surpassing a critical threshold beyond which the economic trajectory is one of high green investment and growth with low climate impact.

The framework being developed will add to existing tools at the OECD, including its country-level model for producing long-run economic scenarios and its existing dynamic CGE model ENV-Linkages. The aim is to help OECD member countries better understand and factor in the costs of climate change and the impacts of various policy options in decision-making.

4.2.1.4 Coalition for Capacity on Climate Action (C3A): Climate macro-modelling tools to address emerging policy questions in Ministries of Finance: why new tools are now needed for the urgent task of implementation - An overview by C3A

Via the development of NDCs, the IPCC evidence review process, and particularly the implementation of national climate strategies, climate change considerations are being mainstreamed across government departments including Ministries of Finance, giving rise to new questions that require new types of analytical tools and frameworks. Conventional climate-economy modelling approaches do not necessarily serve this purpose well, such that new approaches that take into account more complexity, including the physical realm and dynamic feedback effects, are called for.

Key messages

- Policy issues with which MoFs are confronted are moving away from sustained growth narratives and towards structural transformation.
- The implementation of climate action plans requires detailed policy frameworks that can consider multiple objectives, including decarbonization and sustainable economic development, and multiple constraints, including the global economic and financial climate.
- Conventional climate-economics does not provide the requisite answers at this point and thus new approaches are needed.
- Emerging approaches include system mapping and dynamic system modelling extended to bio-physical systems, measuring cascading impacts via network analysis, and integrating financial and macroeconomic dynamics allowing for different kinds of disequilibria.

4.2.1.5 World Bank: A bottom-up approach to estimating climate-development investment needs

The World Bank Group's Climate and Development Reports (CCDRs) cover nearly 50 low- and middle-income countries and serve to estimate the (additional) investment needed to shift towards more resilient and lower-emission pathways. The reports take a hybrid approach to modelling, with technoeconomic sectoral models used to generate investment, cost, and benefit estimates sector-level pathways, which are input to macroeconomic models to assess their feasibility. For low- and lower-middle income countries development needs cannot be separated from climate-related needs and *total* investments are large, whilst in upper- and middle-income countries *additional* investments are calculated to be manageable.

Key messages

- For upper- and middle-income countries, additional investment needs are calculated as the difference between a resilient low-emission scenario and a BAU scenario, with results showing the additional investment needs are manageable in that these would not substantially affect their financing challenges. The estimates include negative costs from, e.g., avoided investment in fossil fuel infrastructure, and account only for the incremental cost of resilient infrastructure rather than the total cost of the asset.
- A key challenge when studying low- and lower-middle income countries is singling out *additional* investment needs, as their development needs are not separable from their climate-related needs. Hence, *total* investment is reported in the CCDRs for these countries. The financing needs are substantial and may contribute to financial challenges if development is to be achieved sustainably.
- Resilient and low-carbon pathways call for high upfront investments, with offsetting benefits occurring at a later point. In principle, the private sector is essential in closing the financing gap; the potential for and thus reliance on it is also assessed in CCDRs and found to vary substantially across countries, however.

MoFs can replicate methods applied by the World Bank for CCDRs and indeed most leveraged models can be made available to MoFs. Questions that could be answered with the approach include how much investment is needed for a low-emission development path, which development milestones and ambitions are realistic, which sequencing of interventions across sectors may be realistic, or what the best source of finance and its macroeconomic implications may be.

4.2.1.6 Partnership for Economic Policy: The use of computable general equilibrium models for practical policy analysis by finance ministries: The case of climate policy in South Africa

Modern CGE models capture real, financial and environmental inter-linkages in the economy and trace through the impact of various external shocks or policy interventions across a broad range of variables and over time, relative to an unperturbed business-as-usual baseline. CGE models are useful for MoFs because measuring the general equilibrium effects of a policy, i.e., accounting for both direct and indirect impacts across all markets and actors in the economy, allows for detailed fiscal analysis at both national and subnational level.

Key messages

- CGE models are underpinned by large economy-wide datasets grounded in national accounting frameworks (e.g., supply-use tables or social accounting matrices). These work in combination with a rigorous theoretical specification that determines how variables move and respond to the policy shock or intervention under investigation.
- CGE models are detailed in that they can simultaneously accommodate many industries, household income groups, labor skill or occupation groups, fiscal details such as tax types, and regions within a country.
- Simulations to be run on a CGE model need to be described in terms of the set of exogenous shocks and economic environment or assumptions under which it is to be implemented. Assumptions about the economic environment are needed to solve CGE models, as the models contain many more variables than equations.
- Many CGE models allow for different model closure specifications, which effectively describe different policy implementation conditions and assumptions to be tested.
- To ensure CGE model results are informative, modelers and policymakers must work together to ensure policy shocks are introduced as intended, assumptions imposed through the choice of model closure are fair and reflect the anticipated policy environment, and to build confidence that the results are relevant and credible.

In South Africa, CGE modelling played an important role in designing the carbon tax by providing an understanding of the policy's expected real economic impacts, which reduced uncertainty and allowed for greater buy-in from stakeholders. Currently, it is being used to support the just energy transition, as it helps unpack structural shifts, short-term adjustment costs, and net macroeconomic impacts over time, which also helps analyze the regional and household-level impacts of the transition. Additionally, CGE models are being used to analyze revenue impacts of a large-scale transition to EVs in the context of heavy petroleum taxation. The key institutional stakeholder for these research efforts is the National Treasury, in partnership with the Presidential Climate Committee (PCC) and the Development bank of Southern Africa (DBSA).

4.2.1.7 Spain – Ministry of Economy, Trade and Enterprises: The use of external models and the climate policy decisions they inform

Policy simulation is an important part of medium-term economic planning and policy coordination between countries. The coordination cycle of the EU and its National Recovery and Resilience Plans all benefit from policy modelling for informing and assessing policy decisions. In Spain, modelling exercises, e.g., for assessing energy mix objectives, are primarily based on DSGE models calibrated to the Spanish economy, namely EREMS, REMS, and QUEST R&D.

Key messages

- DSGE models aim to capture relations between economic agents (households, companies, public fiscal and monetary authorities, and the rest of the world) by defining their behavior and interactions in key markets (goods, labor, capital). They consider endogenous responses from all agents, as well as market clearing conditions in long-run equilibrium, providing an advantage over models based on constant multipliers or input-output analysis.

- In DSGE models, policies are represented via shocks to exogenous variables and parameters. The model then estimates the reaction of endogenous variables such as prices, employment and GDP to such shocks.
- Energy mix objectives, i.e., reducing dependency on fossil fuels, contained in the Spanish National Integrated Climate and Energy Plan have been analyzed from a macroeconomic perspective and a case-by-case policy perspective.
- The macroeconomic perspective involved modelling the associated policies as parameter shocks. First, a positive TFP shock as result of decreased dependency on imported fossil fuels, which reduces firm costs, increases external competitiveness, and thus increases productivity. Second, a temporary increase in the depreciation rate of capital, due to fossil-fuel dependent capital becoming obsolete. In conjunction, these shocks generate a demand-driven positive impact in the short run due to increased investment in green capital, and a positive structural, long-term impact due to higher TFP.
- The case-by-case policy perspective uses administrative data and surveys to study exposure of companies and families to price and income changes due to green policies. DSGE simulations are sometimes used for this but should become more precise in the future.

Work is underway to better understand the macroeconomic impacts of exposure to climate change. This includes studying the macroeconomic impact of increased uncertainty from climate volatility and the implications for investment in obtaining information and insurance. Another concern is identifying markets where market failures prevent adequate responses to climate change, and where policy intervention may thus be needed.

4.2.1.8 SOAS University of London: Ecological stock-flow consistent modelling: an emerging tool for Finance Ministries

Ecological stock-flow consistent (E-SFC) models provide more realistic representation of the role of banks, the dynamic behavior of economic systems, the interplay between demand and supply, and the role of green investment than standard general equilibrium models used by MoFs. E-SFC models are well-suited to analyze the macrofinancial and environmental implications of different policy scenarios, allowing MoFs to evaluate the trade-offs of environmental policies and identify environmental policy mixes that maximize benefits and reduce risks. This includes the evaluation of carbon taxation, green subsidies, and green public investment.

Key messages

- E-SFC models consider that banks create money endogenously and are crucial drivers of macroeconomic activity and investment. This representation can make green investment less costly than in DSGE and CGE models, where there is crowding out of investment.
- In E-SFC models spending is not just a cost for the government and private sector, but also a source of income that can increase economic activity and generate additional jobs with positive spillover effects, especially where unemployment is high.
- E-SFC models rely on a systems dynamic approach where path dependency is an inherent feature, such that long-run outcomes depend on short-run outcomes.
- E-SFC models take underutilization of labor and capital into account, such that demand is an important driver of economic activity in the short and long run. In general equilibrium models, by contrast, demand tends to play a role only in the short run or not at all.
- MoFs should draw on NGFS scenarios to develop country-specific scenarios, including by distinguishing between national and global green policies and considering the country-specific context of the green transition.

- SFC models are useful for scenarios of 5-10 years; longer time horizons require additional assumptions. They are not suited to short-run forecasting.

Whilst there have been efforts to integrate E-SFC model characteristics into general equilibrium models—GEM-E3 integrates a more realistic financial system in the standard CGE structure, for instance—it remains difficult to integrate all features into a CGE model, and it is generally more complicated than in an E-SFC framework. Skills needed for developing E-SFC models include standard macro modelling skills and familiarity with macroeconomic theories, familiarity with national accounting and environmental data, and a very good understanding of balance sheets. Partnerships with research institutions can be helpful, so long as building MoF capacity is the end goal.

4.2.1.9 Grantham Research Institute on Climate Change and the Environment: Advancing Macroeconomic Modelling for the Energy Transition: Harnessing Production Networks Models

The primary mechanism through which decarbonization will impact the macroeconomy is through sectoral shifts, accompanied by significant reallocations of economic activity and employment throughout. Whilst traditional models that simply partition the economy into "green" and "brown" sectors fail to capture the intricate network of inter-sectoral linkages that structure modern economies, recent advances in modelling economies as production networks offers a promising avenue for enhancing our understanding of the macroeconomic impacts of the energy transition.

Key messages

- One advantage of production network models is that they provide closed-form approximations for decomposing welfare impacts of policy and price shocks, addressing the "black box" criticism often leveled at traditional large-scale multi-sectoral models such as CGEs.
- Production network models also allow for simultaneous analysis of several critical aspects of the energy transition, including sectoral reallocations of employment and activity, inflationary impacts of carbon pricing with sticky prices, investment needs through explicit capital dynamics, and distributional effects.
- These models do not currently include core components of the low-carbon transition, such as greenhouse gas emissions or energy consumption and their calibration need not align with the requirements of a climate policy assessment tool. Hence, more work is needed before they can be used for MoF climate policy assessments.

Future work includes integration of the following features: hybrid calibration that reconciles monetary national accounts with physical energy and emissions data; explicit modelling of links between physical entities and monetary macroeconomic aggregates; precise sectoral calibration compatible with energy transition scenarios; use of recent national accounts for calibration; and a flexible calibration that allows for regular updates. Integrating these features would allow for development of a new generation of macroeconomic models that offer insights into the complex dynamics of the energy transition, providing the policymaker with more detailed and thus more useful information.

4.2.1.10 Network for Greening the Financial System (NGFS): Summary of the NGFS Climate Macroeconomic Modelling Handbook

The NGFS Climate Macroeconomic Modelling Handbook is an in-depth survey of structural macroeconomic modelling work of academics and policymakers in the context of the physical and transition impacts on the macroeconomy. The first section of the handbook covers advances made in modelling and quantifying the physical impacts of climate change. The second section covers advances in the work on transition modelling.

Key messages

- To model chronic physical impacts of climate change, the handbook recommends the use of models based on a Computable General Equilibrium (CGE) structure. This assumes perfect foresight, and the

simplification of dropping uncertainty in this manner allows other factors, including greater sectoral granularity, to be included.
- To understand the effects of acute climate impacts, models based on a Dynamic Stochastic General Equilibrium (DSGE) are suggested. These are better at dealing with stochastic events and can help evaluate policy scenarios, though they have a higher level of aggregation.
- Damage functions are often used to analyze the physical impacts of climate change. Mean temperature rise is usually the main climate stressor, yet the handbook emphasizes that other climate dimensions should be considered as well.
- Modelling the macroeconomic implications of decarbonization involves considering the (limited) substitution of production inputs and how to model technological change, which can play a role in the speed of the transition.
- There is no silver bullet to modelling climate change. Central banks should develop a research agenda that gradually incorporates and adapts different models into a broader analytical toolkit.

Regarding physical impact, the key uncertainty is about physical climate change (e.g., tipping points) and how it will interact with economies. Regarding transition impacts, there is uncertainty about technological change and how it may impact the rate of change toward net zero in different industries. Importantly, firms and households also face policy uncertainty, i.e., the possibility that climate policies could be implemented or reversed due to the political cycle, with consequences for resource allocation.

4.2.1.11 Canada – Department of Finance: Finance Canada's approach to climate-economy modelling

Finance Canada uses a suite of four models for macroeconomic analysis and has developed an additional in-house climate variant of its CGE model. The experience has been that building and maintaining such a multi-country, multi-region CGE model that tracks emissions is possible within the capacity of a small team of experienced economic modelers.

Key messages

- Whilst Environment and Climate Change Canada (ECCC) maintains its own suite of models, building a climate variant of the Department of Finance's CGE model was deemed necessary because of the magnitude of potential economic and fiscal impacts, the likelihood that a climate specific model would be used repeatedly, and the absence of key variables, in particular emissions, in existing models.
- Having a model that was developed and is maintained internally is a benefit, as the expertise exists to quickly adapt the model to analyze a diverse set of topics.
- Ensuring that the expertise is maintained requires resources for senior modelers to train new modelers.

For many projects, discussions between modelers and subject matter experts lead to decisions about how best to approximate the scenario within the existing structure of the models rather than building a new purpose-built model.

4.2.1.12 Network for Greening the Financial System (NGFS): Short-term climate scenarios

Name: Short-term climate scenarios
Type: Scenario suite drawing on an IAM, a stock-flow consistent macrofinancial model, and risk modules.
Institution: NGFS
Documentation: Forthcoming yet see the preliminary note.
Geographic coverage: Global
Description: There are five scenarios. Three narratives focus on the effect of transition risks at different levels of disorderliness of the transition. A fourth narrative considers transition and physical risks by assuming strong discrepancies between region's climate ambitions and localized acute weather events in EMDEs and

LICs. The fifth narrative considers catastrophic regional weather events and associated substantial macroeconomic impacts.

To calibrate these scenarios, a range of models are deployed. An IAM offers a bottom-up representation of the energy sector and detailed disaggregation of the rest of the economy, at yearly time resolution. A stock-flow consistent macrofinancial model and corporate and sovereign risk modules provide monetary policy reactions and scenario-contingent valuation of bonds and equity, which feed back to the IAM through the cost of capital.

Questions to be answered / variables considered: There are three categories of output variables: (i) climate-related (e.g., country-level GHG emissions and carbon price, energy production, and power generation), (ii) macroeconomic (e.g., country-level GDP, unemployment, sectoral production, investment, population, import/export data), and (iii) financial (e.g., corporate and sovereign bond spreads, probability of default adjustments, price level, and policy rates). Combined, these variables can be used to, for instance, explore the macrofinancial impact of carbon price revenue recycling.

Strengths:

- The framework can help explore the propagation of transition and physical shocks through the real economy, considering their possible amplification and spillover effects induced by the financial system.
- Increased time resolution relative to medium- and long-term scenarios enable better capturing of the short-term development of key climate and economic variables.

Assumptions: A key assumption concerns how revenue is recycled.

Use: Currently, they are targeted to a risk assessment audience and thus focus on exploring tail risks. The resulting dataset will be suited to climate stress testing exercises and macroeconomic assessments on a near-term time horizon. The credit risk modules also provide a consistent set of risk metrics for risk assessment of portfolios and balance sheets. Ministries of Finance can also use them to explore the macrofinancial implications of revenue recycling, and for financial stability assessments.

Development / lessons / challenges: The immediate next step is to release the scenarios in early 2025. Thereafter, developments could include enhancing geographic granularity and modelling climate policies explicitly.

4.3 Other analytical approaches and methodologies

Table 4.4 Contributions about other analytical approaches and methodologies

Contributions
Independent – CETEx: Towards an integrated transition planning ecosystem: Implications for Ministries of Finance
S-Curve Economics: Risk-Opportunity Analysis: Policy appraisal in contexts of structural change, uncertainty, and diverse interests
Harvard Growth Lab: The Atlas of Economic Complexity: Supporting Strategic Economic Planning and Green Industrial Policy in Finance Ministries
University of Oxford: The value of using systems mapping to help Ministries of Finance understand the impacts of transformative climate policy
UNEP (United Nations Environment Programme): Sustainable Budgeting Approach
Ecuador – Ministry of Economy and Finance: Use of budget tagging to better understand climate financing gaps
Austria – Ministry of Finance: Green Budgeting in Austria – Frameworks, Implementation, and Lessons Learned
Ireland – Department of Finance: Green budgeting

4.3.1.1 Independent – CETEx: Towards an integrated transition planning ecosystem: Implications for Ministries of Finance

Manning et al. (forthcoming) call for a whole-of-system response to climate change in recognition of the interaction between physical, societal and financial risks and, more generally, the systemic nature of the problem. This would be operationalized via an effective national transition plan (NTP) with government at the center to help set the direction and provide incentives, finance, and support to actors across the economy. The framework is presented under five “pillars”: foundations, implementation strategy, engagement strategy, metrics & targets, and governance (the same five as frameworks for private sector transition plans of, e.g., TPT and GFANZ).

Key messages

- An NTP would involve a clear national strategic ambition to be integrated into a whole-of-government strategy, a costed action and investment plan with targeted allocation of public funds to crowd in private capital at scale, and communication and coordination with private actors, whilst remaining accountable to citizens and other stakeholders.
- Aligning the framework proposed for the NTP with private-sector transition plans is meant to support the emergence of an integrated transition planning ecosystem with information flows and policy feedback between national and private sector plans.
- Both a clear strategic ambition to anchor all actions of the plan and to outline the government's vision for the transition, and sectoral pathways aligned with this are important. The latter can be used to inform policymaking and further provide a reference point for private-sector transition plans and financing activities. A recent example of an NTP is Brazil's Ecological Transformation Plan, whilst France and Japan are two countries developing detailed sectoral pathways.
- An important tool for implementation is a national investment plan, and MoFs play a crucial role for this. It should set out the financing needs to achieve the national strategic ambition, the gap between needs and expected public and private sources of capital, and the policy instruments to fill the gap. Engagement with the private sector can be helpful here. Emerging examples of such investment plans include South Africa's Just Energy Transition Investment Plan and Kenya's Energy Transition Investment Plan.

For MoFs seeking to develop investment plans, the Green Climate Fund (GCF) and the NDC Partnership developed a framework to emphasize three phases of investment planning to support finance mobilization: (i) investment planning and mobilization capacity, (ii) identifying and prioritizing investment needs, and (iii) setting a financing strategy.

4.3.1.2 S-Curve Economics: Risk-Opportunity Analysis: Policy appraisal in contexts of structural change, uncertainty, and diverse interests

Risk-opportunity analysis (ROA) is a generalization of cost benefit analysis (CBA) appropriate for use in contexts where change is structural, important outcomes are uncertain, and diverse interests are affected. This is important because CBA is a marginal analysis technique generally only appropriate when economic structures can be assumed to be unchanged by the intervention. Whilst ROA does not provide simple and definite answers about which course of action is the best, it is useful precisely when complexity and uncertainty mean that no simple answers exist.

Key stages of ROA:

- First, a dynamic assessment of a policy's effect on processes of change as well as expected outcomes at specified moments in time (CBA only does the latter). Systems mapping can be used to first understand the dynamics of the economic system of interest and then assess whether a policy is likely to be self-amplifying or self-limiting in this context. To quantify the dynamics, system dynamics or agent-based models can be used.
- Second, a multi-dimensional assessment which avoids collapsing all outcomes into one metric. This preserves the integrity of information relating to diverse actors, interests, and policy outcomes, and avoids making arbitrary choices and implicit assumptions concerning the relative value of outcomes in different dimensions. It should also be considered whether policy objectives are primarily concerned with the expected, worst-case, or best-case outcome.
- Third, an uncertainty assessment that considers how policy outcomes may be affected by factors outside the control of the decision maker. Scenario analysis can help to this end.

Once these three components have been completed, policy options can be compared in terms of their expected, worst-case, or best-case outcomes in different dimensions, dynamic effects (i.e., whether the policy is likely to be self-reinforcing or self-limiting), and performance (robustness, resilience, or contingency) under uncertainty. The greatest challenge in applying ROA lies in bringing together high quality, subject-matter knowledge, on which the analysis crucially depends. Whilst detailed quantitative modelling results can be an input to ROA, such models are not essential on every occasion.

4.3.1.3 Harvard Growth Lab: The Atlas of Economic Complexity: Supporting Strategic Economic Planning and Green Industrial Policy in Finance Ministries

The Atlas of Economic Complexity is a data visualization tool and analytical framework that measures countries' productive capabilities developed by Harvard University's Growth Lab. It provides Ministries of Finance (MoFs) with a country's export and import portfolio (and its evolution over time) and complements this with insights into economic diversification, growth potential, and development pathways, for use in economic policymaking.

Key messages

- Economic complexity measures an economy's embedded knowledge, production capabilities, and patterns of specialization by comparing which economic activities tend to co-occur in different locations. Whilst initially applied to export data, it is now being applied to the energy transition, technology, research, skills and workforce training, and scientific publications, among other things.
- Economic complexity correlates strongly with countries' economic growth, indicating the process of economic growth involves diversification into more, and more complex industries. Climate action can thus offer on opportunity for green growth by supporting countries' efforts to diversify into green industries via strategic industrial policy.
- Economic complexity analysis can help formulate green industrial policy around countries' strengths and inform policymaking around economic growth and strategic economic planning more generally. Practical applications include identifying industries a country is competitive in, nearby parts of green value chains, emerging sectors with growth potential, and whether a country has been successfully diversifying in the past (or why not).
- Economic complexity analysis preserves the granularity associated with non-fungible, activity-specific, and hard-to-move capital assets and relevant know-how, which methods such as CGE modelling struggle to reflect. It also improves on older methods of addressing similar topics, such as input-output analysis, export analysis, and analysis of revealed comparative advantage.

Challenges include that economic complexity analysis often groups industries via industrial classification codes (e.g., NAICS, NH codes) which are more aggregated than product markets. Analyses based on VAT data are being developed to overcome this concern. Moreover, the method is backward looking in that it relies on historical data. Where technology and market structure are changing this may be a limitation. Bottom-up or 'genotypic' approaches to measuring industry-relatedness are being developed to overcome this challenge. Time series data to discern how capabilities have been developing can also be helpful.

MoFs can access the Atlas through the online platform at atlas.cid.harvard.edu. It can be augmented by other datasets on firms, trade, and employment for more nuance. For in-house complexity analysis, datasets such as production networks derived from VAT data and information matching workers to industries and occupations may be useful.

4.3.1.4 University of Oxford: The value of using systems mapping to help Ministries of Finance understand the impacts of transformative climate policy

Whilst quantitative analysis is typically the dominant approach in economic analysis for climate action, this narrows perception and analysis to topics and issues which are easily quantifiable and for which reliable

data is available. This leaves out many vitally important influences and effects of climate action, such as political pushback and trust, and informal economic sectors which are complex and dynamic and therefore difficult to model or think about intuitively. In this context, non-quantitative methods can help assess how systems work, including feedback effects, relationships, trade-offs, and synergies, though it is crucial that outputs are directly usable for them to be useful.

Key messages

- Systems mapping refers to a suite of related methods that all attempt to describe or model a system. A common organizing principle in many (but not all) methods of system mapping, is the use of networks of boxes and arrows, representing factors and their causal influence.
- Two specific types of systems mapping—causal loop diagrams (CLDs) and participatory systems mapping (PSM)—have been used extensively in policy analysis. PSM could be used to show the coverage of a selection of quantitative models (i.e. which variables, factors, and parts of a system they cover, or not), or CLDs could be used to show which key feedbacks are covered in quantitative models. PSMs can also be used to inform a policy's Theory of Change (as discussed below) or strategic business case.
- ROA is an expanded form of CBA, useful for the context of transformational change where narrow or point estimates can be meaningless. The aim is still to produce quantitative estimates of risks and opportunities yet focused more on distributions of outcomes based on best- and worst-case scenarios, rather than single figures.
- Within ROA, a CLD exercise can be used to scope out the dominating feedbacks in a policy area first, before choices on quantitative modelling are made. This can help ensure the identified dynamics are better represented, or where they are missing, the omission is clearer. A PSM could be used to build a larger picture of a policy area to help understand what topics are not being modelled quantitatively and in which areas there is weaker or no evidence.
- Theory of Change diagrams (ToCs) attempt to describe the 'theory of change' of an intervention, i.e. the assumptions, intentions, and causal thinking behind it. They do this by showing the inputs, activities, outputs, outcomes and long-term impacts of a policy, using a network of boxes and arrows. This can help discipline policy design discussions but has mostly been used ex-post to inform the design of evaluation studies.

4.3.1.5 UNEP (United Nations Environment Programme): Sustainable Budgeting Approach

The UNEP-University of Oxford Sustainable Budgeting Approach (SBA) is a decision-support tool designed to help policymakers identify and resource strategic policy opportunities that promote national economic development while addressing critical environmental and social objectives. It is intended for use by many stakeholders, including finance and line ministries, and can be a starting point for governments wishing to adopt budgeting processes where decisions are informed by a wide range of "green", as well as social and economic criteria.

Key messages

- SBA provides a taxonomy for categorizing policies based on shared environmental and economic characteristics; a method to assess potential policy impact on economic, social, and environmental grounds for every policy category and individual county; and a tool to compare policy options against each other and aggregate net impacts across an entire budget (or a subset thereof).
- At a high-level, SBA can help align fiscal policies with national and global objectives, maximize the impact of public spending, support sustainable financing mechanisms, and facilitate evidence-based decision-making.
- Key policy and analytical questions SBA can help address concern how fiscal policies can be optimized for promoting long-term growth, emissions reduction, and social equity simultaneously; the trade-offs between different policy options across relevant indicators and how to structure fiscal

policies to balance competing national objectives; which policies can produce win-win outcomes and are aligned with international commitments; and which policies performed best relative to desired national outcomes in countries across the globe.

- Steps to adopt SBA include adopting standardized SBA taxonomy for categorizing policies, identifying which economic, environmental, and social criteria are important, and fine-tuning the potential impacts of each policy category on the selected criteria. From there, an entire budget or trade-offs in decision-making can be analyzed.
- Strengths of SBA include that it is easy to use, evidence-based, and contextualized for each country. By tracking the overall environmental, development, or social characteristics of an entire budget it can help MoFs ascertain the degree to which line ministry spending proposals support national objectives and thereby provides guidance for line ministries as well. It also systematically identifies new policy ideas by collating and reporting policy measures from many nations in unified and granular categories.
- Limitations include that the approach is static, with limited ability to account for interactions between policies, and relies heavily on the accuracy of policy descriptions provided by governments. It omits impacts such as health, education, and security, amongst others.
- In practice, SBA relies on strong political commitment to be successful.

A case study application is an effort of the Government of the Gabonese Republic in 2021-2022 to understand the overall “greenness” of the national budget and to introduce a semi-automated tool to allow the same process to be repeated every year. Currently, SBA implementation is being started in Lao PDR, Cambodia, Viet Nam, El Salvador and 12 other countries across Asia-Pacific, Africa, and Latin America and the Caribbean. Linking SBA to DFI operations is being discussed with the ADB and CAF.

Future refinements may include more granular taxonomies, expanded impact assessments (e.g., health and security), integration with dynamic economic modeling, and automated policy analysis via machine learning.

4.3.1.6 Ecuador – Ministry of Economy and Finance: Use of budget tagging to better understand climate financing gaps

Ecuador is implementing its Expenditure Classifier for Policy Guidance on Environment and Climate Change (COGPACC), which is expected to unlock access to a broader portfolio of domestic and external financing that includes an environmental component. The Ecuadorian public sector is legally required to use this classifier, and the Climate Change Activities Catalogue (CACC) contained within, to register public resources destined for environmental and climate change policies, to improve the transparency of resources linked to climate change.

Key messages

- The CACC outlines 41 categories and 240 subcategories to classify activities within every institutional budget in Ecuador. The dimensions of climate change in the budget tagger are mitigation, adaptation, and means of implementation (for climate finance).
- The purpose of CACC is to identify the amounts invested in climate change, achieve an adequate mobilization of economic resources, and facilitate the quantification of existing financing gaps to meet climate goals.
- To apply the expenditure classifier (COGPACC), three steps are required. First, identification of the environment and climate change policies to which the entity contributes. Second, analysis of the projects and therefore budgetary activities related to national, sectoral, or institutional policies identified in step 1. Third, registration of the environment and climate change code at the budget activity level in the financial administration system. Expenditure guide classifiers are used in current expenditure and investment programs.

4.3.1.7 Austria – Ministry of Finance: Green Budgeting in Austria – Frameworks, Implementation, and Lessons Learned

[TO BE ADDED]

4.3.1.8 Ireland – Department of Finance: Green budgeting in Ireland

As traditional measures of economic performance do not fully capture the specific impacts of climate and environmental policies on public finances, green budgeting is part of the annual budgetary process in Ireland. Green budgeting refers to the process of documenting the impact of budgetary measures and wider fiscal policy on the transition to a more sustainable and climate friendly economy. The objective is to make Government action on climate change more transparent, which can help promote policy changes with improved environmental outcomes.

Key messages

- In Ireland, the Department of Finance sets out a Green Budgeting methodology by which government can measure and design fiscal policy to influence individual and business behavior towards supporting and away from harming climate and environmental goals.
- The method considers the climate impact of tax measures from a monetary perspective and encompasses both tax revenue and expenditure measures (including subsidies related to potential revenue foregone). Measures are considered to have a climate-positive (-negative) impact if they make a substantive (negative) contribution to climate change mitigation or adaptation objectives.
- This tax analysis undertaken by the Department of Finance complements the green budgeting expenditure analysis undertaken by the Department of Public Expenditure, NDP Delivery and Reform (DPENDR).

At a European level, Ireland is an active participant in the European Commission's Green budgeting Expert Group, and the OECD Paris Collaborative on Green Budgeting, as well as the Coalition of Finance Ministers for Climate Action. These engagements include training, exchange, and sharing expertise to learn from best practices for green budgeting.

4.4 Data sources

Table 4.5 Contributions about data sources

Contribution title
Sweden – National Institute of Economic Research (NIER): Database on estimated elasticity values for use in quantitative analysis of climate and energy topics by agencies and economic modelers
World Bank: Data sources for the macro modelling of climate

4.4.1.1 Sweden – National Institute of Economic Research (NIER): Database on estimated elasticity values for use in quantitative analysis of climate and energy topics by agencies and economic modelers

The Swedish National Institute of Economic Research (NIER) had compiled a database of income and price elasticities for selected energy products (gasoline, diesel, and electricity), for use in quantitative analyses of climate and energy prices. The elasticities measure the sensitivity of demand for these energy products to changes in income, own-price and cross-price in the short and long term. The data and guidance for its use is publicly available.

Key messages

- When using the elasticities in research, it needs to be considered that the estimates apply to Sweden and comparable countries and are contingent on time, context (e.g., region and income group), and econometric method used.

- Given the contingency of the estimates, a guidance document to aid users in understanding and applying the elasticities is provided. It has for instance been used to guide the Swedish Energy Agency in updating its price elasticities for fuel consumption in the transport sector.

4.4.1.2 World Bank: Data sources for the macro modelling of climate

[Subject to approvals and editions – not for wider circulation.]

This contribution outlines data sources that can be useful for macroeconomic modelling of climate change impacts and policies, including energy and emission datasets, and datasets that can help in understanding the impacts and risks of climate change. The World Bank maintains its climate data service—the Climate Change Knowledge Portal—for development-related data, and houses further databases containing data on energy, emissions, and climate change adaptation and mitigation projects. Data sources from other providers are also outlined.

Key messages

- Both data sources to be inputted into bespoke modelling as well as already estimated risk profiles for certain types of events are available.
- Data provided via the Climate Change Knowledge Portal (CCKP) is spatially explicit and can be downloaded in gridded format. Its granularity means MoFs can use it to tailor financial policies and allocate resources more effectively, such that interventions target areas most vulnerable to climate change. An example use-case is using the data to evaluate how risk factors in medium and high-emission futures may impact agricultural productivity, and by extension farmer livelihoods, food security, and associated ripple effects.
- Nationally gathered statistics can help ensure country-specific factors are appropriately studied when considering policy questions. However, international datasets, where an effort has been made to impose some degree of cross-country consistency in the data, may be useful for cross-country comparisons.

Gaps of various kinds are still prevalent in the available sources of climate data. This includes limited availability of data that is granular and local, real-time and high-resolution, or long-term and historical, particularly in developing country contexts. Data sources that capture sector-specific emissions, climate-related financial flows and investment, or non-GHG pollutants such as particulate matter and ozone-depleting substances, or integrate economy and climate are also scarce. Moreover, data accessibility and useability could be improved, including to widen stakeholder access.

5 Summaries of Contributions: Enhancing Analytical Capacity in Finance Ministries

This section contains the summaries of the third overarching category of contributions pertaining to capacity building. Each sub-section contains the summaries for one of the two further categories.

5.1 Capacity building offers

Table 5.1 Contributions about capacity building offers

Contributions
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ): Modelling Climate Resilient Economic Development – GIZ's Approach to Support Sustainable Economic Growth
Coalition for Capacity on Climate Action (C3A): The Coalition for Capacity on Climate Action (C3A) – Major Programme to Support the Emerging Analytical Needs of Ministries of Finance
Coalition for Capacity on Climate Action (C3A): C3A's Assessment of the Emerging Analytical Needs of Finance Ministries – Opportunities and Challenges

Environment for Development Initiative: EfD – a global research network combining research, academic training, training of civil servants and advisory to inform policy
NDC Partnership: Unpacking options for Ministries of Finance to leverage modelling and economic analysis to accelerate climate action
World Resources Institute / SOAS – Resilience Adaptation Mainstreaming Program (RAMP): Resilience and Adaptation Mainstreaming Program (RAMP): Building capacities at ministries of finance through local universities
New Climate Economy: Summary of emerging and new approaches to modelling the economic case for climate action: Lessons from New Climate Economy for Ministries of Finance and future model development agenda
Coalition of Finance Ministers for Climate Action (CFMCA): Capability Assessment Framework: Mainstreaming Climate Action in Ministries of Finance - a New Self-Assessment Tool to empower Ministries of Finance to Build Capabilities to Drive Climate Action
Insurance Development Forum: Support for sovereign climate and disaster risk functions: the Global Risk Modelling Alliance
Green Macroeconomic Modeling Initiative (GMMI): The Green Macroeconomic Modeling Initiative

5.1.1.1 Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ): Modelling Climate Resilient Economic Development – GIZ's Approach to Support Sustainable Economic Growth

Planning and investing in systematic adaptation actions, and in the innovations that come with it, can unlock new opportunities and provide a triple dividend: they avoid economic losses, support economic growth, and deliver additional environmental and social benefits. Through the Climate Resilient Economic Development (CRED) and DIAPOL-CE[5] projects, GIZ supports its partner countries in the development of human and technical capacities in the economic and planning ministries, subordinate sectoral authorities, and institutes in charge of economic modelling to develop and disseminate methods and tools for Climate Economic Modelling. This enables partners to independently model the economic impacts of climate change and translate results into policy advice.

Key messages

- Including macroeconomic effects into assessment and planning of adaptation actions enables policy makers to make investments necessary to direct the economy towards climate resilience. Evidence-based adaptation actions can be incorporated into long-term economic and adaptation planning and thereby unlock climate-resilient economic and job-rich development in the partner countries.
- Climate data and results from sector models need to be fed into macroeconomic models to map the impacts of climate change on key socio-economic indicators such as prices, income, or employment and to further identify appropriate adaptation actions.
- The cornerstones of GIZ's activities are jointly developed country-specific macroeconomic models, which enable economic ministries to model the economic impacts of climate risks. The results are then used to create country specific policy advice and recommendations on implementation options for adaptation policies. GIZ also supports the identification of appropriate financing options.

Such work has been undertaken in Kazakhstan, Georgia, Mongolia, and Nigeria. This provides valuable insights on capacity development, model building, and policy support for climate change adaptation planning and helps identify strategies to enhance coordination, streamline processes, and ensure the long-term success and sustainability of climate resilience initiatives for future applications.

To build capacity, it is important to consider the distinct needs of model builders and users, and, to help with the effort, regular, shorter training sessions, assigning responsibilities, showcasing data needs and partners, maintaining a detailed model handbook, and transferring full ownership to local model builders can be useful. High-quality data is crucial, and national statistical offices and international partners are needed to ensure its availability. Model complexity should be kept low whilst ensuring policy questions are addressed. High-level support for the economic evaluation of adaptation options is critical before beginning a modelling exercise, and regular updates to high-level officials and stakeholders can foster common understanding and

[5] Policy Dialogue and Knowledge Management on Climate Protection Strategies

cooperation. Early feedback from national partners and a memorandum of understanding between relevant stakeholders are essential to avoid delays and align on the method. At the political level, central domestic strategies are needed as entry points to ensure implementation and institutionalization is key for long-term success.

Applying these learnings can strengthen cooperation and help ensure that economic modelling efforts are effectively integrated into the country's fiscal policy framework and contribute to informed decision-making. This involves emphasizing the practical application of modelling results in budgeting and financial planning, such that results are used to inform resource allocation decisions, prioritize investments in climate adaptation, and assess the long-erm economic impacts of policy choices.

5.1.1.2 Coalition for Capacity on Climate Action (C3A): The Coalition for Capacity on Climate Action (C3A) – Major Programme to Support the Emerging Analytical Needs of Ministries of Finance

The Coalition for Capacity on Climate Action (C3A) is a knowledge-exchange and capacity-building program for MoFs hosted and funded by the World Bank that aims to bridge the science-policy gap and support MoFs in taking on a leadership role in tackling climate change. It was created in June 2023 on the sidelines of the Paris Summit for a New Global Financing Pact to addresses the lack of attention paid by MoF's to developing a systemic vision for dealing with the challenges of climate change (impacts).

Themes: C3A takes a demand-driven approach, meaning thematic activities are chosen to address cross-cutting issues and stimulate knowledge creation where MoFs have specific needs, e.g., in green innovation and structural change, fiscal policy, debt sustainability and financing strategies for the transition, as well as nature transition aspects.

Activities: C3A supports MoFs by providing access to a knowledge network (research-to-policy, policy-to-research, and peer-to-peer), technical trainings, and in-depth capacity building on analytical tools. More generally, core C3A activities include regional conferences, national, regional, and global trainings, collaborations with 'champion' countries, and an annual global symposium. C3A also publishes an editorial series of technical notes relevant for MoFs, policy briefs on country experience, working papers on frontier topics, and global flagship reports.

Delivery: Activities are delivered through C3A network partners and regional and thematic hubs. Regional hubs apply thematic knowledge and contextualize it to specific issues, and their responsibilities include assessing capacity-creation needs, assessing priorities for policy design and peer-to-peer exchange, engaging with local partners to develop local knowledge and analytical tools, and facilitating capacity creation and peer-to-peer exchange between MoFs within and across regions.

5.1.1.3 Coalition for Capacity on Climate Action (C3A): C3A's Assessment of the Emerging Analytical Needs of Finance Ministries – Opportunities and Challenges

C3A's demand-led approach is an ongoing consultative process that identifies possible contributions of MoFs to climate action and what is needed to realize these. This includes encouraging strategic, holistic thinking within MoFs, building connections to support MoFs in accessing and developing analytical tools that are fit-for-purpose, and building capacity to ensure tools can be put to effective use.

Key messages

- Concerns common to MoFs of different countries include the risks of the transition to macroeconomic and financial stability, and how to harness opportunities for economic growth, jobs, fiscal revenues, and exports.
- Prevailing analytical approaches are ill-equipped to deal with the non-linearity, rapid change, complexity, interconnectedness, and high scientific, technological, and policy uncertainties of the

transition. Models that account for such complexities and evaluate the associated financial and fiscal risks are needed to help MoFs mainstream climate in their analysis and agenda.

- Relevant policy experience and analytical solutions are emerging, yet urgently need to be piloted, refined, and scaled, all of which requires significant resources. Building capacity should be a priority to prevent bottlenecks.
- Some though not all MoFs consider forecasting and accelerating the deployment of low-carbon technologies as part of their mandate. This requires decision-making frameworks that evaluate risks and opportunities in the context of uncertainty, technology cost forecasts, economic models that capture (the dynamics of) structural changes, and tools to identify areas of potential competitive advantage in the context of the global transition.

It is a challenge that teams with the responsibility to embed climate and nature within MoFs are often missing due to, e.g., capacity constraints, limited expertise, lack of political signals, and competing priorities. This can but should not prevent strategic, holistic thinking and decision-making or the development of better analytical approaches to meet MoFs needs.

5.1.1.4 Environment for Development Initiative: EfD – a global research network combining research, academic training, training of civil servants and advisory to inform policy

The Environment for Development initiative (EfD) is a global research network rooted in Low- and Middle-income countries that tackles urgent climate, environment and development challenges. It has twelve environmental economics research centers, hosted at universities in Chile, Colombia, Costa Rica, Ethiopia, Ghana, India, Kenya, Nigeria, South Africa, Tanzania, Uganda, and Vietnam. These engage with South-South-North collaborations with partners in China, France, Germany, Ireland, the Netherlands, Sweden, and the US.

Key messages

- One of EfD's research programs, Emission Pricing for Development, addresses the problems related to the implementation of carbon pricing in the Global South aiming to produce appropriate analyses and designing effective polices that are politically viable.
- Recent work in the Emission Pricing for Development program includes developing the Carbon Pricing Plus Model to consider both regulated and unregulated emission sources in Colombia; analyzing optimal carbon tax pricing policy for Nigeria; providing technical support to the government of Ethiopia by generating data-driven evidence on climate change issues via economy-wide models such as CGE models; and developing a dynamic CGE model to analyze the economy-wide impact and relative effectiveness of India's tradable performance standard (TPS) for energy intensive industries vis-à-vis renewable portfolio standards and deployment policies contained in its NDC.
- EfD works closely with Ministries of Finance in East Africa in the Inclusive Green Economy in Practice capacity building program. The five-year program fosters knowledge exchange between academia and senior civil servants for a just green transition.

Sida (the Swedish International Development Cooperation Agency) provides core funding for EfD.

5.1.1.5 NDC Partnership: Unpacking options for Ministries of Finance to leverage modelling and economic analysis to accelerate climate action

The NDC Partnership is a global coalition of >130 developed and developing countries and >100 institutional members to create and deliver ambitious NDCs. Governments identify their NDC implementation priorities, and the support needed to translate them into actionable policies and programs, based on which the Partnership offers a tailored package of expertise, technical assistance, and funding. This collaborative response has fostered synergies, generated economies of scale, and increased the impact of capacity building programs, providing developing countries efficient access to a wide range of resources to help achieve climate and development objectives.

Key messages

- As of 2024, the Partnership provided >100 member countries with targeted support, such as (i) specialized technical assistance, (ii) embedded advisors in finance and economy, and (iii) peer exchanges and skills sharing programs.
- Lessons from the Partnership include that advancing national capacities requires comprehensive support and a whole-of-government approach, and that increasing expertise within national institutions accelerates climate action and ensures sustainability of interventions. Collaboration and coordination of support mechanisms ensure continuity, reduce transaction costs, and promote cohesive assistance to countries in this journey.
- Peer exchanges and skill sharing programs to raise awareness and exchange best practices can catalyze the uptake and continuous improvement of tools and capacities.
- While many global and regional analyses and models exist, a localized approach is critical to ensure adherence to the local reality. It can also increase adoption rates and improve the effectiveness and sustainability of interventions.

Non-member countries can apply for membership anytime and support can be requested via a country's NDC Partnership Government Focal Points. For more information contact Joaquim Leite (Head of Climate Finance) and Adrian Flores (Climate Finance Associate).

5.1.1.6 World Resources Institute / SOAS – Resilience Adaptation Mainstreaming Program (RAMP): Resilience and Adaptation Mainstreaming Program (RAMP): Building capacities at ministries of finance through local universities

RAMP leverages leading universities, research institutes and international technical partners to build the capacity of ministries of finance in vulnerable countries to better manage climate change risks. As RAMP focuses on building local capacities and local expertise, it partners with local universities. Through its University Network, which currently has 20 members in Africa, Asia and the Caribbean and keeps expanding, RAMP promotes multi-disciplinary academic teaching and research in areas important for strengthening macrofinancial resilience to climate change.

Key messages

- The RAMP University Network develops curricula and course materials to enable universities in climate-vulnerable countries to offer high-quality graduate-level teaching and professional training, including for MoFs and other relevant ministries. Member universities are committed to building capacities to carry out relevant high-quality teaching and research to support this.
- Through such capacity-building and by educating future and current leaders, the RAMP University Network contributes to systemic change in public financial management, public policy for climate finance, central banking and financial markets in climate-vulnerable countries.
- Recognizing that MoFs need support and capacity in macro modelling and that the current suite of models is largely unfit to properly assess climate risks and impacts, the RAMP University Network has begun teacher trainings on macro modelling, with some macro simulations also integrated into practitioner courses for government officials.
- RAMP also supports member universities through research grants, contributing to the development of country-specific knowledge that will support better policymaking. As such, the RAMP member universities act as strategic and knowledge partners of ministries of finance and other government departments.

RAMP is a strategic partner of the Coalition of Finance Ministers for Climate Action and works in close partnership with the Bretton Woods institutions, UNDP, regional development banks, and other stakeholders. RAMP's secretariat is hosted by the World Resources Institute. The RAMP University Network is managed by a Secretariat hosted by the Centre for Sustainable Finance at SOAS, University of London.

5.1.1.7 New Climate Economy: Summary of emerging and new approaches to modelling the economic case for climate action: Lessons from New Climate Economy for Ministries of Finance and future model development agenda

The NCE model is based on international engagement, research, and targeted country support that combines the use of tools for economic policy analysis with methods of engagement and capacity building. Methodologically, NCE fosters the use of a System Thinking framework for policy analysis. This framework seeks to make sense of the complexity of the world by looking at it in terms of wholes and relationships and aims towards a reconciliation of tools for coherent and comprehensive analysis.

Key messages

- Uncertainties and the complexity of climate impacts render tools and methods used by MoF increasingly unsuitable for policy analysis. Reasons include the model's inability to capture non-linear and threshold; a failure to consider impacts of depletion and degradation of natural capital on the provision of environmental goods and services; an inadequate understanding of climate related risks; a general disregard of the role and magnitude of externalities; inadequate representation of climate damages and of the benefits of adopting low carbon, climate resilient technologies; and uncertainties regarding transition costs.
- The Systems Thinking framework is generally applied with System Dynamics tools which can be integrated with other methods and tools typically used by MoFs, including CGE models. Several country representations referred to as *Green Economy Models* were produced under such framework using System Dynamics tools as part of NCE country support.
- The System Thinking framework enables policy makers to integrate climate impacts under alternative global warming and national climate action scenarios. It also allows for a comprehensive assessment of climate policy packages, transitional effects, costs of interventions, and medium- and long-term benefits, including on monetary and non-monetary metrics of wellbeing.
- Models developed under NCE are fully owned by the client institution to which NCE provided implementing support, with no copyrights involved. These models generally incorporate publicly available and peer-reviewed data and are advanced under a consultative research process.

Two takeaways of the NCE approach, apart from the benefits of a participatory process, include firstly the superior benefits from a low-carbon paradigm, despite transitional challenges and secondly the realization that especially for developing countries there are large financing needs that exceed countries' fiscal space, highlighting the need for financing support from IFIs and country measures for green finance mobilization and boosting revenues.

Learnings and recommendations in terms of modelling domain include the need to incorporate tools traditionally used by MoFs with ones that incorporate climate impacts, highlight interactions with natural capital, and incorporate a diverse set of mitigation and resilience policies; the desirability of participatory processes for modelling, bringing in experts from different disciplines, facilitating information exchange, and reconciling policy questions, assumptions, data, methods, and scenarios; and prioritizing capacity building and peer exchanges to overcome knowledge constraints and increase transparency.

5.1.1.8 Coalition of Finance Ministers for Climate Action (CFMCA): Capability Assessment Framework: Mainstreaming Climate Action in Ministries of Finance - a New Self-Assessment Tool to empower Ministries of Finance to Build Capabilities to Drive Climate Action

The Capability Assessment Framework (CAF) provides Ministries of Finance (MoFs) with a tool to rapidly assess their climate capabilities. Building the capabilities needed to successfully integrate climate into their core functions is a relatively new and ongoing challenge for MoFs. In this context, the CAF aims to provide a high-level assessment that can serve as a 'conversation starter' on how to further strengthen the MoF's role in whole-of-government climate action.

Key messages

- The CAF is designed to help MoFs gain clarity over the extent to which climate action is integrated into their core responsibilities and capabilities; take stock of and connect climate-related activities, policies, and initiatives, including to identify gaps and barriers to action; and define priorities and determine the need for follow-up assessments, capacity building, or technical assistance.
- The CAF consists of 30 questions divided into five parts: internal governance and leadership, functions for driving climate action, overall operating environment & cross-governmental coordination, human capabilities, and wrap-up and next steps. The questions can be completed relatively fast, by a single responder or small team.

Interested parties can request access to a pilot version by getting in touch with the Coalition Secretariat at coalitionsecretariat@financeministersforclimate.org. The final version will be launched in 2025.

5.1.1.9 Insurance Development Forum: Support for sovereign climate and disaster risk functions: the Global Risk Modelling Alliance

The Global Risk Modelling Alliance (GRMA) was founded at COP26 in 2021 by the V-20 Group of Ministries of Finance and the Insurance Development Forum to help Finance Ministries draw on the re/insurance sector's experience of quantifying risk at the portfolio level to price in risk arising from catastrophes and a changed climate. A probabilistic understanding of risk can equip sovereigns to quantify risk beyond the bounds of historical experience, under changed climate, economic, and demographic conditions. This quantitative approach is fundamental for guiding finance, adaptation planning, and fiscal policy.

Key messages

- Ministries of Finance can lead in bringing together the components needed to calculate catastrophe risk across public institutions. They should manage this process not as technical experts, but as risk managers defining the right questions for adaptation planning and commissioning the analysis that know where to go for support. Nonetheless, they should be able to interpret results, understand remaining uncertainties, and develop a policy or make a decision on this basis.
- Critically for MoFs, re/insurance style risk models contain a financial module that can indicate thresholds for risk retention or risk transfer for mode extreme events.
- Policy questions raised in GRMA workshops have covered the relationship between national disaster risk reporting and sovereign credit ratings and what impacts governments may care about most. Technical questions have included how to prioritize and plan the range of responses to risk, where to source data, how to make decisions under uncertainty, and

The GRMA operates at the request of countries, and each program is co-defined with a locally led technical working group. Typically under the mandate of the MoF, the GRMA initiates its work by bringing together ministries, departments, agencies, and research institutions to develop a synthesis of prioritized risk questions and the modeling required to address them.

The GRMA's work so far shows the importance of prioritizing owning the problem, embracing the idea that MoFs can have a leadership role in bringing together the best of global and local, public and private, and recognizing the need for a continuously developing view of risk as a core function for MoFs.

5.1.1.10 Green Macroeconomic Modeling Initiative (GMMI): The Green Macroeconomic Modeling Initiative

The Green Macroeconomic Modeling Initiative (GMMI) is a community platform aiming to accelerate progress in assessing green economic transitions and ensure up-to-date, fit-for-purpose analytical methods and data are used when providing numbers and advice to governments. The GMMI brings together leading economic analysis teams from around the world to evaluate specific economic policies and issues, test new approaches, compare results, and rapidly mainstream approaches most viable for real-world policy contexts. The GMMI is a forum for leading practitioners to learn from one another and build collaborations needed to support policy-making around green economic transitions.

Key messages

- The GMMI is following the well-established practice of model intercomparison. Every GMMI study is led by a steering committee of leading economic analysts and experts and linked with key policy constituents to ensure relevance and constant communication between the applied economic analysis community and the policymakers they inform.
- The inaugural GMMI study (GMMI-1) is focused on better estimating the core macroeconomic metrics used to evaluate and justify green economic policies—jobs, inflation, exports and imports, investments, and interest rates. Participating modelling teams meet regularly to compare methods and results, to then improve models and assumptions. GMMI-1 is set to run for two years to late 2026 or early 2027.
- GMMI-1 is loosely linked to Helsinki Principle 4 of the Coalition of Finance Ministers for Climate Action, on mainstreaming climate into finance ministries. It is coordinated by the Bezos Earth Fund.

5.2 Capacity building case studies

Table 5.2 Contributions about capacity building case studies

Contribution title
International Growth Centre – Rwanda Office: The use of climate-economy models in Rwanda's Finance Ministry and public institutions – The challenges in building analytical capability
Australia – Department of the Treasury: Re-establishing the Australian Treasury's Climate Modelling Capability
Uganda – Ministry of Finance, Planning and Economic Development: Analytical tools used for climate policy analysis at the Ministry of Finance, Planning, and Economic Development in Uganda
Denmark – Ministry of Finance: Leadership and governance of analytical capabilities: The story of the 'non-technical' side of how the GreenReform model came to be
Uruguay – Ministry of Economy and Finance / University of Montevideo: Uruguay's MoF efforts in mainstreaming climate economic analysis

5.2.1.1 International Growth Centre – Rwanda Office: The use of climate-economy models in Rwanda's Finance Ministry and public institutions – The challenges in building analytical capability

Rwanda's MoF and central bank are beginning to integrate climate change into their economic modelling, risk assessments, and forecasting, currently relying on external tools and assistance, e.g., from the IMF and World Bank, yet building capacity is challenging. The dominant challenge for deepening the integration of climate change into analytical frameworks is lack of staff and skills, which also limits the current potential for in-house capacity building, there is room for deeper coordination and collaboration within and between government agencies to help mainstream climate in analytical frameworks.

Key messages

- The key limiting factor to use and further explore climate-related components in analytical work is the lack of a sufficient number of staff and, relatedly, a lack of necessary skills. Hence, analytical work that has and will support revisions of Rwanda's NDC will rely heavily on external consultants.
- Collaboration with external partners, including internationally, is crucial, as Rwanda's current labor market does not provide the necessary skills in sufficient quantities to build capacity independently. As such, the BNR's taskforce for integrating climate change into analytical tools collaborates with other central banks. Building such embedded institutions can technically and financially be supported by, e.g., the Coalition and the NDC Partnership.
- Whilst building internal capacity, e.g., by placing external experts in relevant teams, is be desirable per se, limited staff capacity would currently prevent this from being effective.

- There is room for more coordination between teams and disciplines, e.g., between research and policy teams, and data scientists and economists, both within and across government ministries.

Concrete next steps for the BNR include updating short or near-term forecasting with quantitative meteorological data from satellites in collaboration with the meteorology agency, after already having started integrating climate change into its economic forecasts via qualitative data on food price expectations and the impact of rainfall on crops obtained via local surveys. A more general challenge is that climate economy models tend to be tailored to advanced economies. The World Bank's centrally developed and locally calibrated MANAGE model helps overcome this barrier, yet more work is needed on adapting IAMs to developing-country contexts.

It is unclear whether retrofitting existing models with climate modules or adopting new models with already built-in climate modules is preferred. The latter approach is currently prevalent in Rwanda, though a concern is that this is less efficient as changing models entails adaptation to a new modelling approach.

5.2.1.2 Australia – Department of the Treasury: Re-establishing the Australian Treasury's Climate Modelling Capability

With a step up in the Australian Government's climate change agenda, the Treasury was positioned to take a leading role in modelling climate risks and opportunities, with substantial long-term funding to rebuild its modelling capability and expertise. For the first time since 2011, a dedicated Climate and Industry Modelling team of around 30 professionals was established at the Treasury. In addition to spearheading major planned modelling exercises, it is establishing new relationships and acting as central nexus between various government agencies engaged in climate analysis, to ensure cohesive and integrated efforts across the public sector.

Key messages

- The analytical frameworks have been designed to help understand transition risks and opportunities, as well as the physical impacts of climate change on the economy.
- The new capability includes sectoral, domestic, and global partial and general equilibrium modelling frameworks to form a comprehensive integrated assessment of climate impacts.
- A key part of the endeavor is understanding the potential sector transition pathways.
- The Treasury developed one general equilibrium model. The Treasury Industry Model (TIM) is a forward-looking, multi-sector model of the Australian economy that is being expanded to capture details needed to analyze the net zero transition and physical climate impacts.
- The Treasury developed two partial equilibrium models. The Model of Industrial and Resources Abatement (MIRA) is a techno-economic model of least-cost abatement for large industrial emitters. The Australian Lifecycle Energy eXpenditure (ALEX) model is a household cameo model to assess household energy costs across certain types of consumption.
- The Treasury uses several externally developed models, including EMM (with Australia's Department of Climate Change, Energy, Environment, and Water), GTEM, and G-Cubed.
- Models are used individually and together, and are complemented by data analysis, consultation and qualitative assessments.

The 2023 Intergenerational Report chapter on Climate and Energy Transition explored potential long-term fiscal and economic impacts of climate change for Australia and was a pivotal first step in testing the Treasury's frameworks and modelling. Since then, the focus has been on providing advice on whole-of-economy impacts of the Government's Net Zero Plan. The work also includes integrating six sectoral decarbonization plans – transport, industry, resources, agriculture, energy, and electricity, and the built environment – across government agencies. Current work also includes better capturing developments in industries likely to see significant changes to production processes vis-à-vis the global net zero transition, to improve the representation of technology options and interlinkages with other sectors of the economy.

The primary challenge has been balancing model and capability development with meeting immediate analytical demands of the Government's climate agenda. Integrating bottom-up sectoral insights and ensuring the models remain adaptable to evolving policy landscapes required more time and resources but resulted in more sophisticated and robust outcomes. Inter-agency and industry collaboration and harmonization of data sources and analytical approaches is also challenging but necessary for coherent and actionable insights. Critically, long-term sustainability of the modelling capability depends on staff retention and development.

5.2.1.3 Uganda – Ministry of Finance, Planning and Economic Development: Analytical tools used for climate policy analysis at the Ministry of Finance, Planning, and Economic Development in Uganda

Uganda is in the process of integrating environment and climate considerations into its analytical tools. This includes creating Natural Capital Accounts (NCAs), integrating environmental and climatic variables in Uganda's Social Accounting Matrix (SAM), and integrating these into the suite of models used by the government and in particular the MoF. These efforts are being undertaken with development partners, such as the FAO and the World Bank.

Key messages

- Uganda is developing Natural Capital Accounts (NCA) to provide a comprehensive overview of a country's wealth that includes the value of natural assets. As part of the process, an ecosystem monetary services account, which tracks loss and gains of ecosystem services over time was established.
- There is increasing recognition that climate and environmental considerations should be considered in SAMs. Uganda has taken steps to do this, in collaboration with government agencies, research institutions, and international partners, as well as a consultant provided by the World Bank, though continued research and capacity development is needed to obtain up-to-date data.
- Research questions currently being addressed concern the impact of current (fiscal) policies on natural capital and climate change, the impact of climate adaptation on mitigation measures on the economy, policy options that minimize transition risk, the impact of the EU's CBAM and deforestation regulation, the impact of climate shocks, and the economic benefits of the green energy transition.
- The Uganda Integrated Macroeconomic Model (IMEM) is a CGE model with environmental and climatic variables to be integrated into its SAM and the model equations. Advantages include that backward and forward links are considered, and both prices and quantities can change in this model. However, results are not instantaneous, as designing scenarios to reflect policy proposals can be difficult.
- The Rapid Environmental Economic Assessment (REEA) is a static multiplier model based on the IO model developed with support from the World Bank. The tool can generate quick results, though more detailed analysis using the CGE model often follows.
- UGAMOND was developed with support from the World Bank and is mainly focused on energy and long-run simulations. It is based on time-series data and thus useful for long-term climate modelling. However, it has limited coverage of the broader economy and does not capture inter-sectoral dynamics due to limited sectoral detail.

The main challenges in using these models and tools include the need for capacity-building to enhance expertise in model usage, data availability, and effective uptake of the results in policy design and implementation. There are plans to expand the NCAs to sectors such as minerals, agriculture, and tourism.

Whilst the accounts have been used to inform the National Development Plans (III and IV), annual budgets, and the Tenfold Growth Action Plan (2025-2040), the data could still be better integrated into budgeting processes to ensure their systematic consideration.

5.2.1.4 Denmark – Ministry of Finance: Leadership and governance of analytical capabilities: The story of the 'non-technical' side of how the GreenReform model came to be

[TO BE ADDED]

5.2.1.5 Uruguay – Ministry of Economy and Finance / University of Montevideo: Uruguay's MoF efforts in mainstreaming climate economic analysis

In 2020, Uruguay put into law that the Executive Branch should incorporate national climate change adaptation and mitigation objectives into the analysis and design of economic policy and planning of public finances. This called on the Ministry of Economy and Finance (MEF) to play a role in the design, evaluation, and implementation of public policies on climate change. As part of this process, the MEF worked with the Ministry of Environment and other sectoral ministries to study the macroeconomic impact and cost-effectiveness of measures included in the first Nationally Determined Contribution (NDC) and new measures proposed in the second NDC.

Key messages

- As part of the development of Uruguay's second NDC, the MEF developed a DSGE model that would, for the first time, provide information on the economic impacts of climate policies aimed at mitigating GHG emissions for consideration in the process. Model development, parameterization, and calibration were led by Serafín Frache from the University of Montevideo.
- To prepare the data required for the modelling exercise, the MEF worked closely with technical experts from other government ministries and experts in Chile that were involved in a similar exercise for Chile's Long-Term Climate Strategy.
- Initially, the model was used to evaluate 12 mitigation measures presented in the second NDC by modelling a baseline, low-investment, and high-investment scenario. One measure corresponded to the LULUCF sector and eleven to the energy sector, the two most relevant sectors in terms of national emissions.
- While estimated GDP initially decreases relative to the baseline in both investment scenarios, it increases above the baseline in both at a later stage. By 2030, the projected GDP is projected to be 0.57% and 0.52% higher than the baseline under the low and high investment scenarios, respectively, highlighting the positive economic impact of mitigation measures.
- Coordinated work between the MEF and other ministries also resulted in the development of GHG abatement cost curves. Challenges such as limited cost quantification and vague definitions of policy measures highlighted the need for continuous analysis and updated studies to refine data. One use-case of the resulting data was an MEF-led proposal to move the urban bus subsidy scheme from diesel to electric buses that was implemented in 2024.

Key takeaways include that (1) it is important to apply different economic exercises and tools to compare results, (2) applying macroeconomic models is knowledge, time, and resource intensive and requires collaboration between MoFs and research and multilateral institutions, and (3) given the tight timeframes in policymaking, tools other than macroeconomic models such as Marginal Abatement Cost Curves (MACCs) and Cost-Benefit Analysis (CBA) have a role to play.