Katowice Committee of Experts on the Impacts of the implementation of response measures

16 May 2024

Tenth meeting

Bonn, Germany, 30–31 May 2024

Impacts of the implementation of domestic and international response measures – A case study on Maldives

A cover note

I. Background

1. The Conference of the Parties (COP) at its twenty-fifth session, the Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol (CMP) at its fifteenth session, and the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement (CMA) at its second session agreed on workplan of the forum on impacts of the implementation of response measure (the forum) and its Katowice Committee on the Impacts of the Implementation of Response Measures (KCI).[1]

2. Under activity 7 of the workplan of the forum and its KCI, the KCI is to implement this activity at its meetings held in conjunction with SB 59 onward, as decided by the forum or its KCI, using the modalities of input from experts, practitioners and relevant organizations, and examination of existing case studies to identify areas where it may develop new case studies, as appropriate.

3. At KCI 9, the KCI agreed to develop three case studies, on: (1) the effect of the global energy transition and related climate policy initiatives on vulnerable communities and workers, in collaboration with the Just Transition Alliance; (2) the use of standardized approaches for cost-efficient and net zero power planning for local conditions, including the consideration of severe economic and social equity issues, in collaboration with the Center for Climate Strategies; and (3) an assessment of the impact of economy-wide domestic and international mitigation policies on the economy of Maldives, in collaboration with the Maldivian Government. The KCI agreed to finalize the Maldives case study by KCI 10 and the other two case studies by KCI 11.

4. During intersessional period, the open-ended working group led by the task lead, with the support of the secretariat and the consultant, prepared the draft of case study for Maldives.

II. Scope of note

5. This cover note provides in its annex the draft of the case study for consideration by the KCI.

[1] https://unfccc.int/documents/631350

III. Expected action by the Katowice Committee of Experts on the Impacts of the implementation of response measures

6. Taking into account the information provided in the annex, the KCI is invited to provide comments on the draft of the Maldives case study with a view to finalizing it.

Annex

Impacts of the implementation of domestic and international response measures – A case study on Maldives

Draft of the case study

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I. Chapter 1: Introduction

A. Background and motivation

Global warming, caused mostly by human activities, threatens natural ecosystems as well as human and economic systems. Global warming is arguably the largest environmental externality facing economies, international organisations, citizens, and the world's ecosystems and is a global crisis that will require a reorientation of economic systems (Carney, 2020). Climate is a global public good. As such, remedying existing effects of global climate change and preventing future effects requires the implementation of coordinated response measures[2] to climate change and actions to address their (potentially negative) impacts.

There is a compelling need for the international climate regime to better understand the implications of the implementation of climate policies and actions to spur ambitious climate mitigation and adaptation actions. The global climate change regime stands to benefit by learning and sharing experiences from real and concrete sub-national and national examples and case studies about the impacts of the implementation of response measures from across the developing country and small island regions.

The aim of this case study is to support informed policy making by providing insights into the impacts of global and domestic response measures and identifying possible unintended spill over effects of the implementation of response measures. The study makes use of a toolkit based on two Computable General Equilibrium (CGE) models, which are quantitative assessment tools that are widely used in international organisations including United Nations, World Bank, and European Commission. The selection of Computable General Equilibrium (CGE) tools was guided by a report from Cambridge Econometrics (2015) and an In-forum workshop on the use of economic modelling tools for understanding the assessment of impacts of implementation of response measures (30th April to 1st May, 2018).The findings of CGE impact assessments complement insights from other quantitative and qualitative tools to inform the policy process to maximise the positive and minimise the negative impacts of the implementation of response measures.

Maldives is selected as a case study country as, like many members of the Small Island Developing States (SIDS) coalition of low-lying islands, it faces a double threat from climate change despite contributing only 0.003% to total global emissions. First, the direct threats from (i) increased extreme weather events, (ii) adverse climate trends e.g., rising sea levels and biodiversity loss, on its infrastructure and natural resources. And second, their location, reliance on fossil fuels for energy, and narrow economic base with a strong reliance on tourism, makes them vulnerable to impacts of climate policies on import prices, export demand and tourism demand upon which many island economies rely, via the impact on oil prices and transport costs.

Maldives has pledged to reduce its emissions by 26% by 2030, and to strive to achieve net zero by 2030. Emissions in 2030 are projected to be 3,284.92 Gg CO_2 equivalent under a reference scenario (Ministry of Environment, 2020), and therefore reducing emissions by 854.08 Gg CO2e. The implementation plan (Ministry of Environment, 2018) that accompanies this Nationally Determined Contribution (NDC) puts forward several options for reducing emissions including shifting the energy mix towards renewable energy which is considered in this case study alongside international response measures.

Mitigating climate change is costly. The communication of these costs is difficult as mitigation requires action now and causes costs in the short and medium term, while the costs of climate change, such as rising sea level, will be felt mainly in the long term. However, extreme events that Small Island Developing States (SIDS) experience today, such as storms, tropical cyclones, floods, droughts, and marine heat waves, show the vulnerability of small island ecosystems, human and economic systems to climate change.

Despite contributing only small proportions to global emissions these countries are especially vulnerable to climate change in two ways, first, these countries face particularly high costs of adaptation from adverse climate trends and extreme weather events. Second, their economic structure and location, such as reliance on fossil fuels

[2] Defined as policy responses to combat climate change in the form of mitigation policies, programmes and actions taken by Parties under the Convention, the Kyoto Protocol, and the Paris Agreement

for energy, transport and reliance on tourism for income, makes the countries vulnerable to impacts from climate policies.

To inform the policy process and maximize the positive and minimize the negative impacts of response measures, it is key to analyse the impacts and identify possible unintended spill over effects of the implementation of response measures. This case study analyses a set of international and national climate policies. The policies analysed include and a uniform carbon tax, maritime transport and aviation emission reduction strategies and the expansion of solar photovoltaic (PV) electricity capacity as part of meeting the Nationally Determined Contributions (NDCs) in Maldives. The aim of this study is to identify the socio-economic and Greenhouse Gas (GHG) emissions impacts of these policies in Maldives.

The case study describes the toolkit applied and developed for this type of analysis in chapter 1. Chapter 2 shows and discusses the model results. Policy implications are derived in chapter 3. Chapter 4 shares challenges and lessons learnt during the process of conducting the case study.

This case study is completed with a full report and a user-friendly modelling interface (MIRO_UNFCCC). The full report details model assumptions, scenario assumptions and data employed in the analysis (UNFCCC, 2024a). The MIRO_UNFCCC interface is designed based CGE model used in the study with a purpose to provide a user-friendly access of model to facilitate communication between modellers and the policy makers (UNFCCC, 2024b). Model documentations detailing equations for both models are available.

The whole package for the case study is referred here as toolkit and provides a set of analytical tools that can be customised to the specific needs of countries without incurring the large-fixed costs associated with the development of CGE-based analytical tools. As such, the case study serves as a template for other Parties wishing to conduct similar analysis.

B. Introduction to the toolkit

The toolkit developed as part of the case study has 5 components:

(a) **A global CGE model** to quantify the impacts of three global response measures on the global economy. This part of the tool kit accompanies model technical specifications document and user guide

(b) **A single country CGE model** to quantify the implications of three global response measures and two domestic response measures on the Maldivian economy. This part of the tool kit accompanies model technical specification document and user guide

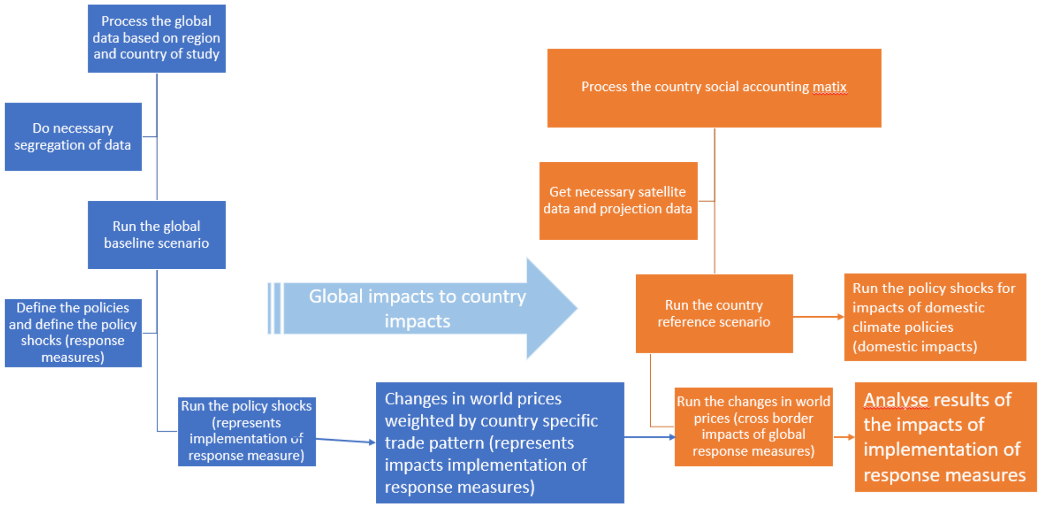
(c) **A Social Accounting Matrix (SAM) for Maldives,** consistent with the System of National Accounts of Maldives, to serve as the database for the national CGE model.

(d) **A user-friendly modelling interface**: to enable wider stakeholders to interact with the global and national CGE models to further explore the impacts of the implementation of response measures and conduct their own analysis of impacts of implementation of response measures.

(e) **Training**: to enhance the capacity of Maldivian experts, including those at Maldives Climate Change Directorate, to use the model in future.

The Figure 1 shows schematic representation of the process of using the tool kit to undertake the assessment of impacts of implementation of response measures.

Figure 1 Schematic representation of modelling process to assess impacts of implementation of response measures using the tool kit



1. Why CGE models?

The choice of a Computable General Equilibrium (CGE) model for assessing the impacts of a climate policy stems from the comprehensive nature of its economic framework. Climate policies, being multidimensional and impactful across various sectors, necessitate an analytical tool capable of capturing intricate interdependencies within and beyond national boundaries. The CGE is an economic model.

An economic model is a simplified framework for describing the workings of an economy or economies. Often a change in an economic system will have repercussions far beyond the sector in which the change occurs. Models are typically used for simulating changes in policies and/or economic trends to evaluate how the country/world would change after the introduction of a policy, relative to how it would develop in the absence of the policy e.g. what the world might look like in 2030 assuming certain future developments with and without climate response measures. The strength of a CGE model is that it is based on linkages between sectors and captures both direct and indirect inter-sectoral, inter-regional, and inter-temporal effects induced by policy changes. CGE models are based on national accounts data and, thus, incorporate unique features of an economic system. It requires the modeller to formally articulate assumptions and tease out relationships behind those assumptions. It is important to highlight that economic models provide projections rather than forecasts. They are not designed to, and cannot, forecast, i.e., predict the future.

A CGE model is a set of mathematical equations that describe a theory of economic behaviour. It is an economy wide model covering one or more countries that is solved numerically, The model moves from one equilibrium to the next, where equilibrium is defined as the situation where the optimising agents have found their best solutions subject to their budget constraints, quantities demanded equal quantities supplied in factor and commodity markets and the decisions of all agents jointly satisfy the system constraints. As such, the models are best suited for medium-long-term analysis in which markets have time to adjust, although alternative assumptions can be employed to simulate short-term events.

CGE models are sometimes viewed with suspicion by some in the economics and policy analysis communities as a "black box", whose results cannot be meaningfully traced to any particular features of their database or input parameters, algebraic structure, or method of solution (e.g., Sue Wing, 2004). Such criticism typically rests on the presumptions that CGE models contain a large number of variables and parameters and are structurally complex, both of which allow questionable assumptions to be hidden within them that end up driving their results.

The critique reflects the misunderstanding of the simplicity of the algebraic foundation at the core of all CGE models, regardless of their size or apparent complexity, the key features of the data that these models use, the numerical calibration methods by which models employ these data to imbue their algebraic framework with empirical substance (Sue Wing, 2004). The critique on CGE models can be based on incomplete communication, where much of this information is often not communicated in a manner that is accessible to the broader economics or policy communities.

The results produced by the CGE models are determined by four elements:

1. the linkages in the economy and between economies as captured in the Social Accounting Matrices;
2. the 'behaviour' of the model as specified in the model's equations; determined by the functional forms and conditioned by parameter values including elasticities;
3. the closure settings for the model, which depicts the assumed functioning of the economy; and
4. the location and magnitude of the response measure.

Together these assumptions determine how resources are reallocated due to the response measure and the consequences for growth, income distribution and sustainable development indicators.

Thus, the selection of a CGE model for assessing climate policy impacts is justified by its ability to analyze the multifaceted repercussions of such policies on the economy and beyond.

2. Description of the Global CGE model, database and assumptions

The global CGE model used for the study is based on the GTAP-Power v10 database (Chepeliev, 2020) in Social Accounting Matrix (SAM) format detailing 22 regions and 46 sectors with detail in energy sectors. The GTAP database provides data on greenhouse gas (GHG) emissions for carbon dioxide (CO_2) based on extended energy balances compiled by the International Energy Agency (IEA). The emission data is distinguished by fuel and by user for each of the regions in the GTAP 10 database. The model is implemented in its recursive dynamic mode. The model consists of a series of single country CGE models that are linked through trade relationships. The model is linear homogeneous of degree zero in prices, and each region has its numéraire and an exchange rate that is defined relative to an exchange rate index of reference regions.

Production maximises profits and is depicted by nested mix of Constant Elasticity of Substitution (CES), assuming imperfect substitutability, and Leontief production functions, assuming consumption in fixed shares. CES technology is employed between aggregate primary inputs and aggregate intermediate inputs, with CES production functions over primary inputs and Leontief technology across intermediate inputs. Aggregate primary inputs are formed by labour, a composite of skilled and unskilled, land, and a capital-energy composite. This capital-energy composite is formed from capital and an energy composite, which is depicted by nested CES functions.

Households receive income from factor (like labour and land) ownership and spend their income on consumption after paying income taxes and saving. Households maximise utility subject to preferences represented by a nested linear expenditure system, where subsistence consumption of households is selected from aggregate commodity groups – food, manufacturing, energy, construction, and services – within aggregate commodity groups commodities are substitutable (CES) depending on relative price changes.

Domestic and foreign products, and from different origins, are assumed imperfect substitutes. Domestic final demand chooses between aggregate imports and domestic supply based on relative prices employing CES technology. CES technology is further employed to form aggregate imports from different regions in two steps, allowing to differentiate imports sourced from low-, middle- and high-income regions and oil exporters. Exports and domestic supply are assumed to be homogeneous goods. The distribution of exports between regions is determined by the relative export prices.

The Government receives income from taxes that are mostly expressed as *ad valorem* and specific tax rates, while income taxes are average rates based on household incomes. Government expenditure consists of commodity demand, which is assumed to be in fixed proportions, and government saving is defined as a residual. Total savings come from the households, the internal balance on the government account, and the external balance on the trade account. The external balance is defined as the difference between the value of total exports and total imports, converted into domestic currency units using the exchange rate. Expenditures by the capital account consist solely of commodity demand for investment.

The model includes regional tax instruments on emissions of greenhouse gases. The carbon tax is levied on the CO_2 emissions associated with inputs in the production process (scope 1) and CO_2 emissions associated with household consumption of fossil fuels. In addition, the model includes a carbon tax, levied as specific tax on exports and based on scope 1 emissions. This carbon tax on exports serves to model taxation of international traded goods and services, such as international water and air transport.

The climate policy instruments allow carbon tax revenues to be used partially or fully for investment purposes inside a region and/or fund transfers to other regions in the form of development aid. Two specifications are available for these aid flows, they can be bound for investment purposes or unbound.

Dynamic modelling requires the development of a reference scenario that projects development of a future. A reference scenario is a simulation of one possible future. Effects of scenarios, such as policy changes, are analysed relative to a future as reported from the reference scenario. The reference scenario depicts the time span between 2019 and 2045 and follows the narrative of a middle of the road scenario with intermediate mitigation and adaptation challenges, Shared Socio-Economic Pathway 2 (SSP2), incorporating projections from the EconMap 3.1 database (Fontagné *et al*., 2021; Fouré *et al*., 2013), with the addition of carbon prices. The SSP2 projections provide forecasts of macroeconomic aggregates including GDP, capital, labour force, population and the share of the working age population with secondary and tertiary education. The projections are aggregated to the regions in this study using GDP or population weights as appropriate.

The model is solved for annual steps under the maintained assumption that agents make decisions about resource allocations at the start of the current period. These decisions are then revised based on the outcomes, primarily prices, in the current period to determine the decisions about resource allocations at the start of the next period. Between each solution, the elasticity, shift and share parameters for all non-linear functions, and any parameters calibrated from current period data, are updated. This ensures that as economic systems evolve as the behaviour of the agents, primarily producers and consumers, evolve.

Capital assets are assumed to be tied to activities once they are installed, i.e., buildings and activity specific plants, such as gas-fired electricity generators. New capital stocks are allocated taking into account historic allocation of capital stock and a part of new capital is allocated taking into account changing rates of return across sectors. Noting the various factors influencing the trade balances, the model allows for partial adjustment of the trade balance and a reduction of global fossil demand will reduce the trade balance of net oil exporters.

3. Description of the single country CGE model, Social Accounting Matrix and assumptions

A single country CGE model has the advantage that it can incorporate more detailed data that might not be available on a global scale, particularly relating to household groups which can be used to assess distributional impacts. Therefore, a single country CGE model was utilized to assess both the impact of global response measures and domestic climate policies aimed at fulfilling a country’s Nationally Determined Contributions (NDCs).

The model employed in the study belongs to the category of single country CGE models, which are successors of the CGE modeling approach described by Dervis et al. (1982). Specifically, the implementation of this model, utilizing the GAMS (General Algebraic Modeling System) software, is a direct evolution of models developed in the late 1980s and early 1990s, particularly those reported by Robinson et al. (1990), Kilkenny (1991), and Devarajan et al. (1994). The model operates in its recursive dynamic mode and is linear homogeneous of degree zero in prices, with the Consumer Price Index (CPI) serving as the benchmark against which price changes are measured.

The single country model is a SAM based CGE model, wherein the SAM serves to identify the agents in the economy and provides the transactions database with which the model is calibrated. The Maldives version of the single country model is based on a 2019 Social Accounting Matrix (SAM) (Mainar-Causapé et al., 2023) with an explicit depiction of renewable energy sources. The representation of the economy includes 48 commodities (of which 37 are produced within Maldives), 38 production activities, 12 factors of production (labour and capital), and 10 household groups. Of the 12 factors included, there are 6 labour types grouped by location (Malé/Atoll[3]) and skill level, and 6 capital types grouped by location (non-resort/resort) and type of capital (other/energy capital by fuel input). Households are disaggregated into 10 representative groups by location and income quintile. The remaining accounts consist of enterprise (corporation) accounts, a margin account, the government account and six tax accounts, the capital account (savings and investments) and the rest of the world (RoW) account. Key features of the Maldivian economy including the importance of the fishing and tourism sectors, differences in Malé and Atoll labour markets and households, and capital holdings differentiated by fuel type are captured both through the detail in the Social Accounting Matrix (SAM) and the behavioural relationships in the model.

The SAM reflects the narrow economic base of Maldives that relies on tourism as the mainstay of production and exports. Exports of services dominate the exports of goods in Maldives by a factor of 9. Construction is the second largest production activity, and passenger transport and fish processing follow tourism as key exports. The economy is highly import dependent and ran a trade balance deficit in 2019. Maldives is wholly reliant on imports for diesel fuel, minerals (a key input into the construction industry), and machinery. Aside from fish, Maldives is highly dependent on imports for food including dairy products. Maldives is linked to global energy markets through a high dependency on diesel imports. Almost all electricity was produced using imported fossil fuels in 2019, with limited use of renewables.

Producers' decisions regarding what to produce and which inputs to use, as well as consumers' decisions about which products to consume, follow the same processes as those in the global model. Products for the domestic and export market, and imports from different origins, are assumed to be imperfect substitutes. The exchange rate is fixed to reflect the managed nature of the Rufiyaa exchange rate, with a varying external balance. It's assumed that the Maldives operates as a price taker in global markets, resulting in fixed world prices.

Households receive income from capital rents and wages plus payments from corporations and transfers from the government. Households located in Malé have a higher average income per capita than those located on the Atolls and own a larger share of capital and skilled labour, which contributes to their higher income status. The government receives income from taxation as in the global model plus capital rents and transfers from outside Maldives. The economy is assumed to be investment driven with savings of households and corporations adjusting to provide investable funds. Government borrowing is fixed as a share of GDP to prevent additional expenditure beyond the designated proportion being financed by government debt. Instead, additional government income comes from returns to government owned capital and corporation income tax.

All factors are assumed to be fully employed, recognizing the role of labour in providing non-market services including home and caring duties which are not captured in the standard definition of the labour force. Some sectoral rigidities are introduced into the model, specifically, electricity generation capital by fuel type (generators, PV cells etc.) is fixed into non-resorts and resorts use to prevent the movement of capital when investments are made in non-resorts and not resorts, or vice versa. This factor market specification results in economy-wide returns to labour and capital and sector-specific returns for electricity generation capital by fuel type. Technology is fixed at all production levels.

The model is configured to include a production system that captures changes in the emissions of Greenhouse Gases, here measured as CO_2 equivalent. These Greenhouse Gases are determined endogenously using CO_2 emissions coefficients (emissions per unit) as patterns of production and consumption change due to climate policies. Emissions by industry change as their consumption of intermediate inputs changes. Emissions by households change in line with changes in consumption of final goods. Total emissions in the economy are the sum of industry and household generated emissions. The

[3] Islands other than the capital island of Malé

model contains an explicit modelling of renewables and emissions for investigating the impact of domestic response measures. Maldives does not have, nor intended to have at present, a carbon tax in place.

The reference scenario for the national model is specified for the same period as the global model, 2019-2045 following the SSP2 narrative for Maldives (Fontagné *et al*., 2021; Fouré *et al*., 2013). The SSP2 database projects 0.5% annual average GDP growth over the period, driven by growth in investment of 0.2% per year, population and employment growth of 0.1% and 0.02% respectively, and technological change (derived as the residual growth when other growth factors are accounted for). The process of moving from one year to the next is the same as in the global model with the exception of the treatment of capital. Investment in each type of capital is converted into installed capital at the end of each period. Non-energy capital, which is not tied to specific sectors, can be reallocated to other sectors in response to changes in relative returns.

The model includes a set of selected Sustainable Development Goal indicators covering SDG 1 'No poverty', SDG7 'Affordable and clean energy', SDG8 'Decent work and economic growth', SDG9 'Industry, innovation and infrastructure' and SDG10 'Reduced inequalities'.

4. Linking the Global and Single Country models

To understand the effects of global response measures on the Maldives economy, the global and national model are connected using a 'soft-linked' to transmit changes in world market prices to Maldives economy. Through this connection, the production and consumption decisions are aligned between the South Asia region of the global model, of which Maldives is a part, and the Maldives' national CGE model. The product aggregation of the global model is chosen to resemble the product aggregation in the Maldives SAM and the assumptions of the functioning of the economy are the same (where appropriate).

Domestic impacts of global policies are evaluated by passing changes in world market prices arising from the implementation of global climate policies from the global to the national model. Price changes are weighted by the pattern of trade in Maldives to reflect differences in trade patterns between Maldives and the wider South Asia region. Response measures are introduced over the period 2020-2045 using recursive dynamic variants of both models.

5. MIRO_UNFCCC interface as tool for interaction and communication

MIRO_UNFCCC offers a user-friendly platform that empowers individuals without modeling expertise to conduct their own assessments. Through this interface, users can run policy scenarios and visualize results using the same models utilized for detailed impact assessments within the core model. There is increasing demand to conduct impact assessment of actions for future. Recognizing the significance of future consequences, climate change is progressively being incorporated into environmental impact assessments. Impact assessments are regularly conducted by international organisations and national governments. However, the models used to assess these impacts are often complex and using them requires substantial training.

MIRO_UNFCCC developed under this study, powered by GAMS MIRO (GAMS, 2023), enables stakeholders to interact with comparative static versions of the models to explore the impacts of the implementation of climate response measures in three ways:

- Evaluate the impact of global response measures at the global level with and without transfers
- Evaluate the impact of global response measures at the national level
- Evaluate the impact of national response measures (including policies aimed at achieving Nationally Determined Contributions (NDCs) at the national level

MIRO_UNFCCC is aimed to serve a complementary role in providing insights from the core model to policy advisors and stakeholders. It should be noted that, while MIRO_CC utilizes complex impact assessment models, the interface itself does not replace the in-depth policy analysis conducted by policy analysts using the core models. In depth analysis is needed ahead of any policy change being implemented.

MIRO_CC serves as a supplementary tool rather than replacing the direct use of the core model which offers a wider range of options for policy analysis.

C. Description of scenarios

1. Global response measures and associated scenarios

The case study assesses three global climate change response measures:

(a) Global scenario I: Uniform carbon tax rates to achieve atmospheric carbon concentrations consistent with limiting global warming to 1.5 and 2.0 above preindustrial levels. (Temperature goal scenario)

The sixth assessment report of the IPCC (IPCC, 2022) provides the most up-to-date evidence on global emission pathways related to specific global warming outcomes. Each emission pathway has different likelihoods with respect to temperature and peak temperatures, and this data is employed in the simulations for this study. The selected emission pathways are based on those identified in the sixth assessment report of IPCC aiming to limit warming to the respective temperature goal with a probability greater than 50%. Following the classification of emissions scenarios into warming levels (IPCC, 2022), three scenarios are run:

- limiting warming to 1.5°C,
- returning to 1.5°C after a temperature high, and
- limiting warming to 2.0°C.

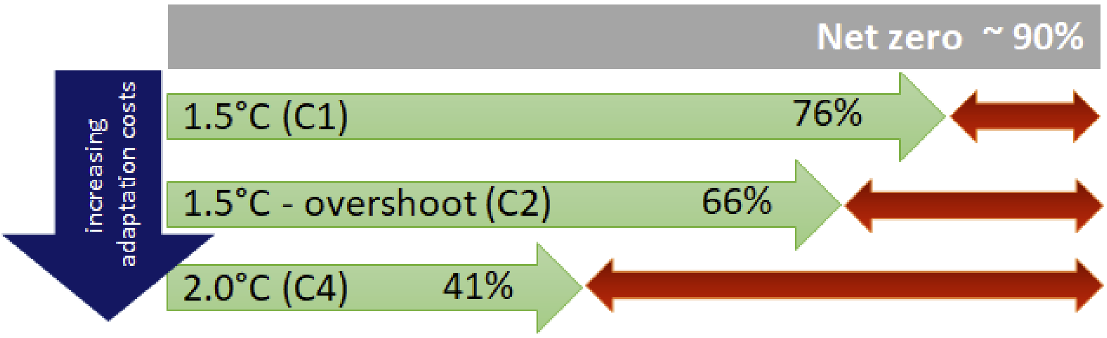
Each of the three temperature scenarios aiming to reach a specific global warming threshold was implemented in three variations to understand the effects of transferring the received revenue back to countries in different ways: (A) Low-income regions are included in the reduction of emissions in combination with transfers from high-income to low-income regions, used for green investment. *This variant serves as a standard simulation presented below. (B)*All regions are subject to the carbon tax, no transfers. (C) The low-income regions are exempted from reducing emissions.

In the scenarios, emission reductions are induced by a uniform tax on carbon emissions across all sectors and regions, aiming to achieve global greenhouse emission pathways consistent with different thresholds of global warming (hereafter referred as temperature goal). Thus, taxes are levied on the base of actual emissions in each modelled year.

Limitations: The modelling exercise in this study covers the time until 2045, this means that it covers only a part of the journey to net zero emissions. Because of remaining gap, we may not get the full picture of results. Even though all scenarios report effects up to same year, they vary in how close they get to the net zero target (Figure 2). The more ambitious emission reduction pathways will impose stronger pressure on economy in the near future and will cost more during this time. **Emission reduction pathways that are less ambitious will transfer these costs to a future period** that is not captured in this modelling exercise.

Therefore, less ambitious emission reduction pathways leave unanswered questions about inter-generational equity. These less ambitious pathways will also result in higher costs for adapting to impacts of global warming, including environmental impacts that are hard to reverse, e.g., projected sea level rises and human health. Additionally, ambitious emission reduction pathways - require more and earlier action for mitigation, which can also bring economic challenges, such as, scrapping power plants earlier, reducing people’s living standards to fund accelerated investment programmes, etc.

Figure 2 Global temperature goal scenario I coverage to net zero emissions.



Note: Green arrows depict emission reductions captured by simulations until 2045 (in % to 2019) Red arrows represent the remaining gap to net zero. Net zero is assumed to equal a 90% reduction of fossil CO_2 emissions.

Source: authors' compilation

(b) Global scenario II: Impact of initial IMO Strategy on reduction of GHG Emissions from Ships (global maritime transport scenario).

Emissions from international shipping are not subject to limitation and reduction commitment under UNFCCC because they're not accounted for in national totals of national GHG inventories and are not covered by latest submitted NDCs. The International Maritime Organization (IMO) controls these emissions. The initial IMO strategy (IMO, 2018) aims to peak global carbon emissions from international shipping as soon as possible and then reduce these carbon emissions by 50% by 2050 compared to the levels in 2008. Considering for developments in the sector until 2019, this translates to a yearly reduction of emissions by about 3% (IEA, 2022). Mid-term measures, targeting the period 2023-2030, might include market-based approaches to incentivise emission reductions. In this scenario (hereafter referred as Global Maritime Transport), a carbon tax is applied to emissions from water transport to ensures a 50% reduction of the sector's emissions of each region by 2050. Revenue from this tax is reinvested in the water transport sector to support technological advancements, and 5% of carbon tax revenue is transferred to low-income regions and SIDS to assist in their climate response efforts.

In July 2023, the IMO adopted the "2023 IMO Strategy on Reduction of GHG Emissions from Ships" (2023 IMO GHG Strategy). The 2023 IMO GHG Strategy outlines a goal to decrease the carbon intensity of international shipping (which means reducing CO2 emissions per transport work) by at least 40% by 2030, on average across international shipping. Additionally, the strategy aims for a significant increase in the adoption of zero or near-zero GHG emission technologies, fuels, and energy sources which are to represent at least 5%, striving for 10% of the energy used by international shipping by 2030.

(c) Global scenario III: Impact of Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) proposals (Global air transport scenario)

Emissions from international flights in the aviation sector are not accounted for in national totals of national GHG inventories and are not covered by latest submitted NDCs. The International Civil Aviation Organization (ICAO) controls these emissions. The ICAO agreement aims to improve global fuel efficiency of planes by 2% per annum and reach a point where the emissions from the air sector remains to as 2020 levels. Secondly, the agreement aims to reduce carbon emissions by 50% by 2050 compared to 2005 levels. This can be translated into a yearly reduction of emissions of 3%. Aviation is pursuing its climate action goals through a four-pillar strategy. A key element in this strategy is the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). The other three pillars include new less carbon-intensive technology, more efficient operations, and better infrastructure. CORSIA is a global offsetting scheme, which require airlines and other aircraft operators to offset any growth in CO2 emissions above 2020 levels. Thus, the CORSIA scheme implements a price for carbon that exceeds 2020 levels in international air transport. The scenario, referred to as "Air transport" simulates the carbon offsetting price path needed to achieve a 50% reduction in carbon emissions by 2050. The generated income is used for investments in environmental initiatives.

2. Domestic response measures and associated scenarios

The impact of the global response measures is examined for the world as a whole and for the Maldives specifically using the linked models.

Increasing the share of renewable energy in the energy mix to 15% is a key part of achieving the NDC emissions reduction goal by 2030 (Ministry of Environment, 2020). In 2019, diesel consumption accounts for around 80% of total emissions in Maldives (Ministry of Environment, 2018). The non-tourism and tourism sectors account for 18% and 8% of the demand for diesel respectively. Two domestic response measure scenarios to contribute to meeting the NDC are considered using the national CGE model of Maldives.

(a) NDC Scenario I: Increasing the share of renewable energy in the non-tourism[4] sectors via solar PV

The components of this scenario are (i) an expansion in photovoltaic (PV) energy production capacity to 112GWh by 2045 to meet 15% of demand for electricity by the non-tourism sector, (ii) a phase out of the subsidy on fossil-based electricity production (9% in 2019), (iii) introduction of a 9% subsidy on PV-based electricity. All three changes are implemented simultaneously in the scenario.

Assumptions: The scenario includes two assumptions: no substantial investments were made in non-resort PV before 2020 and the investment in PV is government financed, funded by increases in the general GST rate.

(b) NDC Scenario II: Increasing the share of renewable energy in the tourism sector via solar PV

In 2019, almost all resorts had their own diesel generators, thus moving part of resort energy demand to PV will reduce emissions. The impact of an expansion in PV energy production capacity to 36GWh by 2045 to meet 15% of demand for electricity by the tourism sector is examined in this scenario.

Assumptions: The scenario includes three assumptions: no substantial investments were made in resort PV before 2020, the investment in resort PV is funded by private corporations, and the government continues not to subsidise resort electricity use.

II. Chapter 2: Results and discussion

A. Costs of action and costs of Climate Change[5]

Mitigation of climate change is costly. The communication of these costs is difficult, as mitigation requires immediate action and is causing costs in the short and medium term, while the costs of climate change will be felt in the long term. However, extreme events experiences by SIDS today, such as storms, tropical cyclones, floods, droughts, and marine heat waves, clearly demonstrate the vulnerability of small island systems. The scientific evidence, published by IPCC (IPCC, 2021), about sea level rise is clear: during the period 1901–1990 the global mean sea level rose by 1.5 mm yr–1, and accelerated to 3.6 mm yr–1 in 2005–2015. Without mitigation efforts the global mean sea level is likely to rise 0.61 - 1.10m by 2100 and could even rise by two or more metres.

Without ambitious adaptation, accelerating sea level rise will combine with storm surges, tides and waves to generate extreme sea level events causing shoreline changes, flooding, resulting in salination of soils and water resources. Ocean warming and acidification will combine and negatively affect marine ecosystems, decreasing species' abundance and species' distribution, and impact the ecosystem services benefiting human societies. Effects extend to risks to coral reefs and associated living resources, affecting recreational activities and tourism.

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[4] Non-tourism sectors are all parts of the economy not related to resorts

[5] Costs of climate change, i.e., to SIDS are discussed in Oppenheimer et al. (2019) and Magnan et al., (2019), these reports also serve as sources on costs of climate change for this section

Coastal infrastructure and facilities, such as harbours and resorts, are at risk of storm waves and extreme weather events, negatively impact coastal tourism

Coastal communities can in principle protect against sea level rise with ‘hard protection’, like dikes and seawalls, and, thus, can effectively reduce risk. However, magnitude and frequency of extreme weather events make hard protection difficult, and it is inevitable that these protection measures will have limits. Retreat becomes inevitable for those unable to afford protection, unable to accommodate or advance measures, or when protection measures are no longer viable or effective. This will impact distinctive cultures and could be devastating to the culture’s ways of life.

Ambitious climate policy can lower these risks and restrict sea level rise to 1–2 m in 2300 under a future scenario where temperature rise is likely kept below 2°C. However, with 80% of its islands lying below the average elevation of 1m above sea level, sea-level rise remains a threat to Maldives even under ambitious climate goals.

B. Regional impacts of global response measures

Overall response measures have significant distribution effects. The analyses demonstrate that the potential policy implications of mitigation policies are multi-faceted. Even a market-based mitigation policy, such as uniform carbon taxes, will have substantively different implications for different countries and different households within those countries. This discrepancy party comes from past emissions/energy tax policies and partly from the extent of structural adjustments required in countries with high emission intensities (emissions relative to GDP). In particular, the results indicate how the costs of achieving a global temperature goal affect income distribution both between and within countries.

(a) How do different regions respond to a uniform carbon tax: impacts of the global temperature goals scenario on regional emissions?

The results from the implementation of a uniform carbon tax in Scenario I, aimed at curbing temperature rise to three distinct pathways, illustrate that emission reductions vary by region (Table 1). The pattern remains similar across pathways, the emission reductions and associated economic costs are highest for the most ambitious pathways, as they incorporate more of the adjustment costs in the period under review, the less ambitious scenarios transfer these adjustment costs to the future and in addition will cause higher adaptation costs. All regions participate in the tax scheme and low income-SIDS regions[6] receive transfers destined for investment in renewable energy. This happens because different regions have varying emission intensities in production[7]. When the carbon tax is levied per ton of CO_2, it generates different impact to each region according to their respective production emission intensities and therefore changes the composition of the regional contributions to emissions. So, regions that currently contribute relatively large shares to global emissions, achieve large absolute reductions.

Reductions are considerably below average and partly increase in the warmer pathway for the low income-SIDS regions Pacific Islands, Western and Eastern Africa, which receive transfers and thus experience a boost in economic growth. Reductions are low and positive in the 2.0° pathway for India, which is predicted to grow strongly and has a high emission intensity in production making emission reductions relatively costly relative to the other regions. These increases are relatively low in absolute terms, except for India. In contrast, Australia and New Zealand, USA and Canada, Eastern Europe and Central Asia, Russia, Gulf States and SACU are showing the strongest reduction of emissions in relative terms. The policy, thus, changes the composition of the regional contribution to emissions. Most regions that currently contribute relatively large shares to global emissions, such as China, USA and Canada, EU, Gulf States, Russia, Japan and Korea, have large absolute reductions. India, Rest of South Asia and Southeast Asia, are increasing their share in global emissions.

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[6] Low income-SIDS regions in this study are Pacific Islands, Western and Eastern Africa, Caribbean, Rest of South Asia, and Rest of Asia

[7] Production is a measure of total output produced in an economy. It reflects the process of using intermediate inputs, labour capital and natural resources to produce output in form of goods and services.

Table 1 Global temperature goal scenario I – Reduction in emissions in 2045 relative to 2019, by region

	relative			*absolute (Gt CO2)*		
	1.5° (C1-c)	*1.5° (C2-c)*	*2.0° (C4-c)*	*1.5° (C1-c)*	*1.5° (C2-c)*	*2.0° (C4-c)*
Global reduction	**-76**	**-66**	**-41**	**-26.2**	**-22.8**	**-14.0**
Australia and New Zeala	-86	-81	-64	-0.4	-0.4	-0.3
Pacific Islands	-47	-24	33	0.0	0.0	0.0
China and Hong Kong	-75	-66	-41	-7.4	-6.5	-4.1
Japan and Korea	-74	-66	-44	-1.2	-1.1	-0.7
Rest of the World	-64	-50	-13	-0.7	-0.6	-0.2
South East Asia	-66	-53	-20	-1.0	-0.8	-0.3
Rest of South Asia	-63	-49	-14	-0.2	-0.1	0.0
India	-42	-16	48	-1.1	-0.4	1.2
USA and Canada	-87	-82	-67	-5.4	-5.1	-4.2
Central America	-78	-69	-44	-0.4	-0.4	-0.3
South America	-78	-70	-46	-0.6	-0.5	-0.3
Brazil	-82	-76	-55	-0.4	-0.4	-0.3
Carribean Islands	-67	-57	-33	-0.1	-0.1	0.0
European Union	-76	-68	-47	-2.3	-2.1	-1.4
Rest of Europe	-73	-63	-39	-0.5	-0.4	-0.3
Eastern Eur. and C. Asia	-89	-81	-57	-0.7	-0.7	-0.5
Russia	-90	-83	-63	-1.3	-1.2	-0.9
Gulf States	-98	-92	-69	-1.5	-1.4	-1.1
North Africa	-78	-67	-38	-0.4	-0.3	-0.2
West Africa	-30	-3	63	0.0	0.0	0.1
East Africa	-27	1	65	0.0	0.0	0.1
SACU	-94	-92	-83	-0.4	-0.4	-0.4
CO2 emitted in 2045				*8.2*	*11.5*	*20.4*

Source: model result;

(b) How do regional production affect by uniform carbon tax in global temperature scenario I?

The carbon tax was observed to have a negative effect on the production of goods and services across all regions, particularly impacting emission-intensive regions. While the emission intensive regions typically show a significant decrease in production, the impact on production is not directly proportional to emission intensities (Table 2). The trading structure plays a crucial role in that regard. Production in regions that have high emission intensities, and which heavily rely on fossil fuels export experience the strongest negative effects, i.e., the Gulf States, Russia, 'Eastern Europe and Central Asia' and North Africa. Regions with high emission intensities but where fossil fuel exports do not play a big role also face significant impacts, e.g., India, China and Hong Kong, and South African Customs Union (SACU). In these regions, carbon taxes affect domestic production. Regions with low emission intensities but high dependency on fossil exports also see significant impact in production, such as West Africa, 'Australia and New Zealand' and South America.

In summary, regions with high emission intensity experience significant production effects, especially if they rely on heavily on fossil fuel exports. Similarly, regions with low emission intensity but a dependence on fossil fuel exports also receive the impacts when a uniform carbon tax is implemented to limit global temperature rise.

Table 2 Global temperature goal scenario I - Effect on production and emission intensity by region

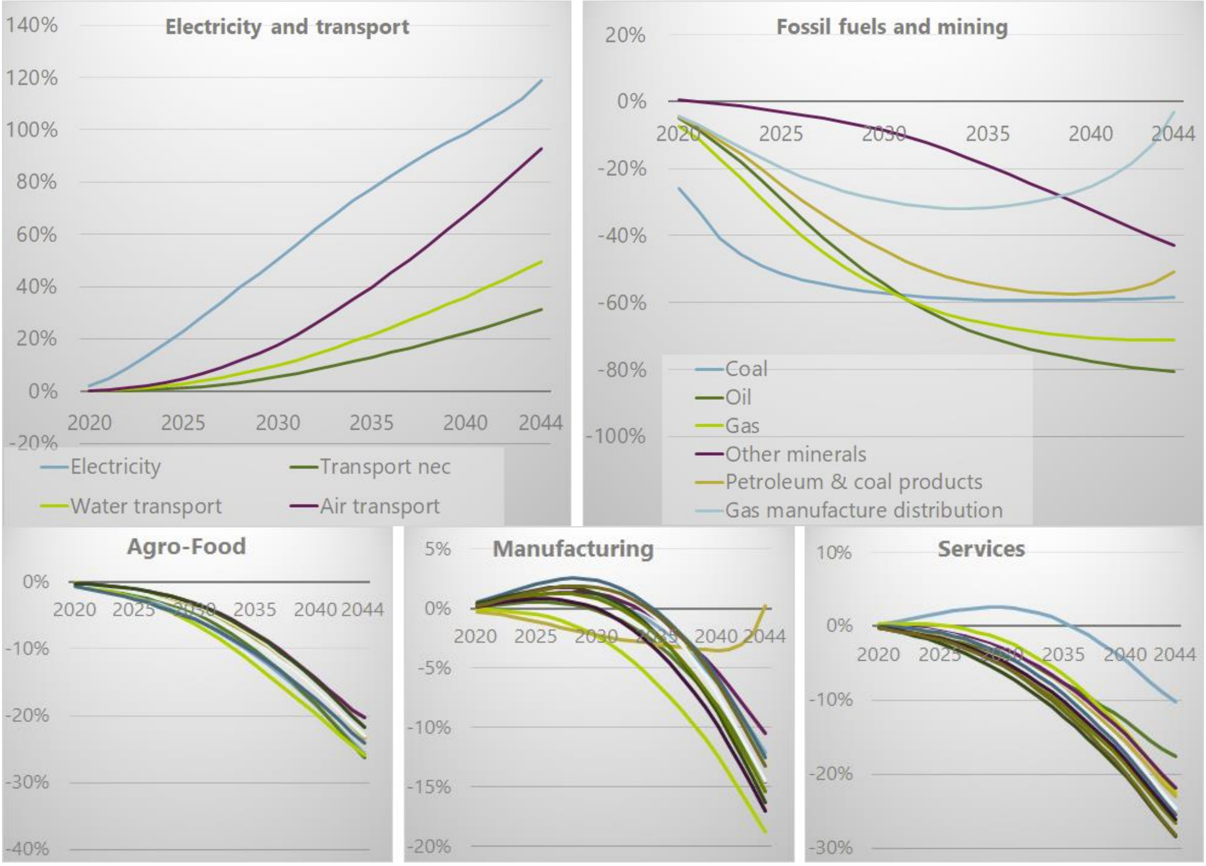
	Production: % change from reference scenario in 2045			Emission intensity	
	1.5° (C1-c)	1.5° (C2-c) overshoot	2.0° (C4-c)	Fossil C02 Emissions (t)/ GDP (million)	Fossil exports relative to total exports
Australia and New Zealand	-12	-10	-7	0.2	0.2
Pacific Islands	-13	-10	-6	0.3	0.1
China and Hong Kong	-16	-12	-7	0.8	0.0
Japan and Korea	-9	-6	-2	0.3	0.0
Rest of the World	-12	-8	-1	0.4	0.2
South East Asia	-15	-11	-5	0.5	0.1
Rest of South Asia	-4	-2	0	0.4	0.0
India	-13	-9	-4	0.9	0.1
USA and Canada	-11	-9	-5	0.3	0.1
Central America	-13	-10	-5	0.3	0.1
South America	-15	-12	-7	0.3	0.3
Brazil	-13	-10	-6	0.2	0.1
Carribean Islands	-4	-1	2	0.3	0.2
European Union	-7	-5	-2	0.2	0.0
Rest of Europe	-5	-4	-1	0.1	0.1
Eastern Eur. and C. Asia	-40	-31	-17	1.1	0.4
Russia	-44	-35	-19	0.7	0.5
Gulf States	-66	-48	-25	0.7	0.7
North Africa	-21	-16	-8	0.6	0.4
West Africa	-12	-11	-7	0.2	0.7
East Africa	-6	-4	-2	0.2	0.2
SACU	-28	-22	-14	1.1	0.1

Source: model result; emission intensity: model database

(c) Impact of uniform carbon tax in global temperature goal scenario I on sectoral prices and global trade

The uniform carbon tax affects sectors differently. A uniform carbon tax affects world market prices (Figure 3). World market prices are mainly influenced by the emission intensity of the respective commodity and demand effects. In 1.5º pathway, world market prices for electricity double, and transport service prices increase considerably. Coal prices, which contribute the highest share of emissions, experience a sharp drop but stabilise at around -60% after production adjusts to the carbon tax. Export prices of crude oil and gas decrease steadily over the period under review, while prices for processed oil and gas show a U-shaped curve, benefiting from increased substitution away from the raw products. Export prices for other commodities like agri-food, manufacturing and services are lower compared to the reference scenario, reflecting decreasing demand. This trend starts later for manufacturing where prices increase due to higher input costs and start decreasing after 2035 when decreasing demand dominate the price effects. An outlier is the chemicals and rubber sector – subject to relative high taxes – and prices increase with increasing taxes in later period. These price changes lead to decreased global trade in all scenarios compared to the reference scenario.

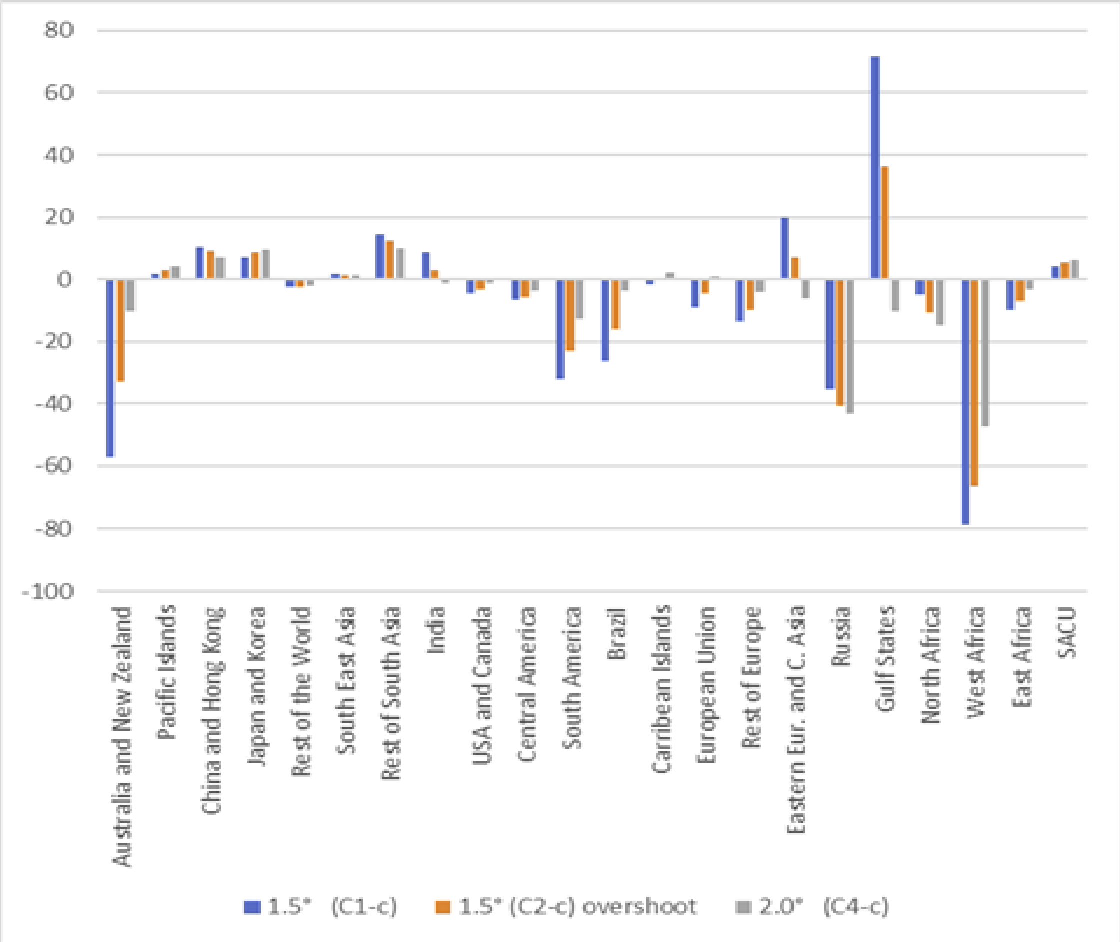
Figure 3 Global temperature goal scenario I, 1.5° pathway: Effects on world market prices



Source: model result;

The exchange rate adjusts to keep the current account balanced. The change depends on changes in import prices, changes in import demand, and export supply. Results show that fossil fuel exporters face a drop in the demand for their exports, so their exchange rates depreciate (their currency becomes less valuable) to maintain the current account balance. The currency depreciation makes imports more expensive which in turn reduces import demand. But it also makes exports more competitive by lowering prices for other regions and stimulates supply. The impact of uniform carbon tax on e**mission intensive regions results in relatively stronger increase in production prices which reinforces the depreciation.** Currency of those regions appreciate which have low emission intensities, which do not export fossil fuel and those that do not participate in emission reduction efforts.

Figure 4 Global temperature goal scenario I – exchange rate effects (% change to reference scenario)



Note: a decreasing exchange rate represents a depreciation, an increase an appreciation. Source: model results

(d) Impact of a uniform carbon tax in global Scenario II & III Maritime and Air Transport GHG Strategies on Regional Production and Import Prices

Similar to global temperature goal scenario I, the maritime and air transport GHG strategies also affects regions differently[8]. Examining the impacts on the regional production, the increased transport costs resulting from the imposition of carbon taxes applied in maritime and air transport sectors, as a consequence of the implementation of emission reduction strategies, exerts pressure on production in all regions. The effect on production is influenced by a complex interplay between trade structure, such as the amount of oil imported and exported, and import shares in general, and the specific production structure of a region (Table 3).

The increase in transport costs affects import prices of goods, and transport costs contribute up to 1 percentage point to the import price changes. The extent of change depends on factors such as relationship between commodity value and volume, the main mode of transportation, and the distance travelled. Globally, the results show a decrease in average import prices for fossil fuels (about 3% for maritime transport and about 11% for air transport). and several service sectors, despite the of increase in transport costs. The prices for manufacturing commodities increase the most (about 0 to 0.7 %).

The GHG emission reduction strategies in maritime and air transport have three opposing effects, first, as direct effects the import prices of good increase due to increase in costs of trading. Second, reduced demand for transport services reduces demand for oil products resulting into decrease in oil prices. This decrease in oil prices is beneficial for sectors that are relatively oil intensive or less reliant on water or air transport as a transportation mode. The production cost of these sectors decreases. Third, increase import prices for manufacturing goods,

8 Results are described in detail in Section B4 of the full report

which are used as intermediates in the production process, increase the cost of intermediate products and production costs increase. This disadvantages those sectors which heavily rely on global value chains that rely on imported intermediates. This effect is particularly pronounced for water transport.

Results from additional simulations, that vary the model setup with respect to the possibility to adapt production technologies, show that the magnitude of effects depends crucially on the availability of carbon saving technology and related implementation costs. Thus, when running the model with reduced adjustment possibilities in investment for the maritime sector, transportation costs can increase by a factor of 5 and results in stronger negative effects on production.

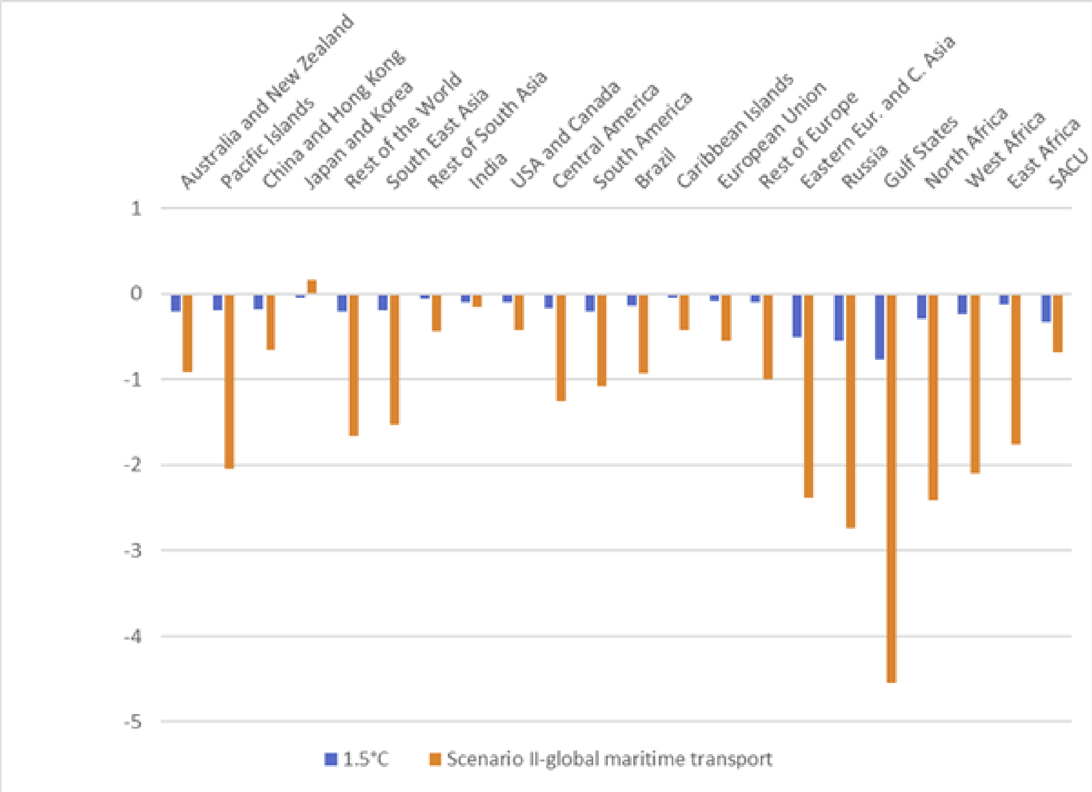
Table 3 Scenario II – Effects on production by region and emissions, 2045 (% deviation from reference scenario)

	Scenario II		Scenario III	
	Production	*Emissions/ population*	*Production*	*Emissions/ population*
Australia and New Zeala	-0.1	-0.5	-0.2	-5.2
Japan and Korea	-0.1	-0.5	0.6	5.2
USA and Canada	0.0	0.1	-0.2	1.4
European Union	-0.1	-1.5	0.3	-0.5
Rest of Europe	-0.1	-1.8	0	-1.7
Pacific Islands	-0.4	0.1	-0.6	-0.3
Rest of the World	-0.2	-0.1	0.7	4.6
Rest of South Asia	-0.2	-1.0	0.3	3.1
Caribbean Islands	0.0	0.1	0.3	3.3
West Africa	-0.4	-0.8	-0.1	0.9
East Africa	-0.4	-1.3	-0.2	3.7
China and Hong Kong	-0.2	-0.1	0.4	8.7
South East Asia	-0.6	-2.2	-0.5	0.2
India	0.0	0.3	1.6	9.5
Central America	-0.4	-1.2	0.4	5.2
South America	-0.2	-0.1	0	2.2
Brazil	-0.1	-0.4	0.2	3.8
Eastern Eur. and C. Asia	-0.4	-0.3	0.2	3.9
Russia	-0.4	-0.4	-0.3	1.3
Gulf States	-0.7	-0.8	-0.1	3.2
North Africa	-0.3	-0.3	0.7	6.6
SACU	-0.1	0.1	1	7.6

(e) Cost dynamics of leakage in different scenarios

Leakage is increasing costs of fighting climate change. A comparison of the water transport scenario (II), with temperature goal scenario (I) reveals insightful observations. Figure 5 is showing welfare effects of the two scenarios, as the scenarios are targeting different levels of emission reduction the results are depicted relative to a 1% decrease of emissions to allow a comparison of the effects. While efforts to reduce emission reductions within one sector can result in a decrease in global emissions in scenario II, the accompanying leakage phenomenon leads to higher related costs compared to the ambitious 1.5° temperature scenario I. Welfare is up to -1% lower than in the reference scenario for each 1% reduction of global emissions in the ambitious 1.5° temperature scenario and ranges up between +0.2 and –4.5% in the maritime transport scenario. Indeed, leakage effects are increasing global emissions in the air transport scenario.

Figure 5 Leakage is increasing costs: a comparison of effects on welfare (depicted by real household expenditure) between Scenarios I and II



Source: model results

Note: The welfare costs of a 1% reduction in global emissions achieved by different policies, relative to the reference scenario in 2045. Scenario III results in increasing emissions and is therefore not included in the comparison

Similarly, all regions are worse off if single region do not participate, including SIDS and low-income economies. Table 4 shows exemplarily 2.0° that all participating regions are clearly worse off when specific regions do not participate in the uniform carbon tax scheme, as emission reductions are now contributed to by a smaller group of regions, and non-participating regions are increasing emissions as fossil fuel prices decline. In addition, all donor regions are better off when transferring part (5%) of their additional tax income compared to an exemption of certain regions.

As a result, increased inter-country **transfers from richer economies to smaller and poorer economies are better for both donors and recipients than exempting certain regions**. Unrequited transfers to SIDS and low-income economies, earmarked for investment in enhanced technologies, will benefit the donors. The magnitudes and distribution of these transfers are critical. The analyses indicate that an amount considerably more than $(USD) 200 billion per year will be needed to offset the negative effects on SIDS and low-income economies.

The production and export responses of fossil fuel exporters to global mitigation policies will play a crucial role. The implications for Small Island Developing States (SIDS) and low-income economies, which heavily depend on fossil fuel imports, hinge on the extent to which fossil fuel exporters adjust their production and exports. Simply, if fossil fuel output remains constant and fossil fuel prices fall, fuel exporters will see a fall in their income and the incentive to pursue mitigation efforts decreases for all countries. In the short-term, reducing fossil fuel output raises prices and incomes to fossil fuel producers. However, higher fuel prices increase the motivation to mitigate emissions, which reduces the demand for oil - and incomes to fossil fuel producers - in the medium to long term as renewables become relatively cheaper. This dynamic highlight the intricate relationship between production decisions, market forces, and the drive to address climate change, particularly for vulnerable economies reliant on fossil fuel imports.

Table 4: Global temperature goal scenario I, 2.0° pathway - Effects on real household expenditure (% change to reference scenario)

		2.0° pathway		
		standard with transfers (Variant A)	all participate - no transfers (Variant B)	LI-SIDS are not participating (Variant C)
Donor regions (5% of carbon tax income)	AUS and NZL	-8	-8	-10
	JAP and KOR	1	1	0
	USA and CAN	-5	-4	-5
	European Union	-2	-2	-3
	Rest of Europe	-4	-4	-5
Transfer receiving regions	Pacific Islands	-6	-7	-3
	Rest of Asia	-6	-9	-4
	South Asia	2	-2	2
	Caribbean	2	-2	-1
	West Africa	-14	-14	-11
	East Africa	-5	-5	-3
Other regions – not involved in transfers	China and HKG	-7	-7	-9
	South East Asia	-7	-7	-9
	India	-3	-3	-4
	Central America	-6	-6	-8
	South America	-8	-8	-10
	Brazil	-5	-5	-7
	E. Europe,C.Asia	-22	-22	-26
	Russia	-28	-28	-31
	Gulf States	-38	-39	-42
	North Africa	-15	-15	-16
	SACU	-13	-13	-16

C. Impacts of response measures on Maldives

1. Economic impacts of global response measures in the Maldives

The impact analysis for Maldives highlights important considerations for SIDS countries when assessing the implications of global mitigation policies.

Cross-border effects are substantial and have important implications for economies, especially for small open economies with limited capacities to adapt to the changing global economic environment. The results are an illustration of the principle that multiple policy objectives typically require multiple policy instruments, e.g., ‘optimal’ policy instruments to reduce emissions may need to be accompanied by policy instruments that address distributional implications.

The impacts of global response measures reverberate through various aspects of Maldives’ economy, even in absence of direct participation in climate action. These measures influence the pattern of production, trade, consumption and welfare within the country. Global climate response measures, through their effect on international prices, directly influence the costs of imports and prices received for exports in Maldives. These changes in global market dynamics then transmit to the local economy, affecting terms of trade as well as real exchange rates. Consequently, these fluctuations cause domestic changes in production, consumption patterns, carbon emissions, and ultimately household welfare.

As shown in Figure 6, there is increase in imports in Maldives across all temperature goal scenario, primarily driven by cheaper oil imports. Exports also increase, along with welfare, measured by domestic absorption (total consumption by households, government and in the production of capital). However, GDP experiences a decline as the growth in imports exceeds that of exports. These effects are stronger for the 2°C scenario as the fall in oil prices persists until 2045. This demonstrates, even if Maldives do not actively engage in climate action, the interconnectedness of the global economy ensures that the repercussions of such measures are felt locally, impacting various economic indicators and the well-being of households.

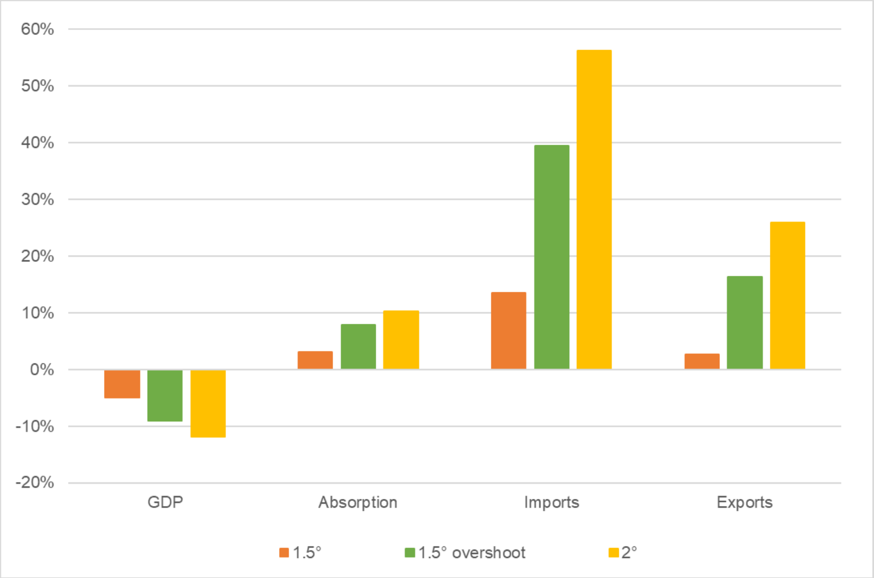
Additionally, the results of global temperature goal scenario I reveals that the terms of trade[9] for Maldives improve across all but the most in stringent climate scenario by 2045 which is also driven by the fall in the world oil price as illustrated in Figure 7. This improvement in terms of trade results in a strong increase in imports, and expansion in production due to the influx of cheaper oil and other imports. Consequently, the wages and capital returns experience an increase as production expands leading to an overall increase in household expenditure across all income brackets, with the exception of the lowest income households. However, it's worth noting that the impact on production, factor returns, and household expenditure is smaller under the 1.5°C simulation. This is attributed to the recovery of the oil prices starting from 2038 onwards, which mitigates the magnitude of changes observed compared to the more stringent climate scenarios. The global response measures aimed to limit global temperature rise enhance the terms of trade in Maldives across all income groups except for the lowest-income households.

Similar to the temperature goal scenario, the implementation of the global maritime response measure has impacts on the Maldivian economy, leading to its contraction and a subsequent decrease in household expenditure. This shrinkage is predominantly attributed to the interaction between the response measure and import costs, particularly those associated with shipping. One aspect of this interaction is the relatively modest impact on oil prices induced by the global maritime response measure, amounting to a decrease of merely 6% in comparison to up to 43% achievable under a global carbon tax. However, despite this reduction in oil prices, the overall effect is not sufficient to offset the amplified import costs arising from escalated shipping expenses. This illuminates that t**he implementation of global maritime response measure results in a smaller Maldivian economy, accompanied by reduced household expenditure.**

Continuing the above analysis, the global air transport response measures affect the Maldivian economy mainly tourism industry due to reduced tourism demand from higher airfares. Unlike the global maritime response measures, the primary mechanism through which the global air transport policy influences the economy is by diminishing tourism demand due to the increased cost of air travel, rather than altering the price of oil imports. This substantial effect on tourism demand triggers a cascade of consequences, prompting a shift in economic activities towards alternative export-oriented sectors. This shift ripples through labour and capital markets, resulting in tangible reduction in consumption for all but the richest households. Furthermore, the implementation of this policy also correlates with a deterioration in almost all SDG indicators, signalling broader socio-economic ramifications (Figure 8). Therefore, it can be inferred that t**he global air transport response measure has substantial impacts on the Maldives' tourist industry and wider economy due to higher airfares.**

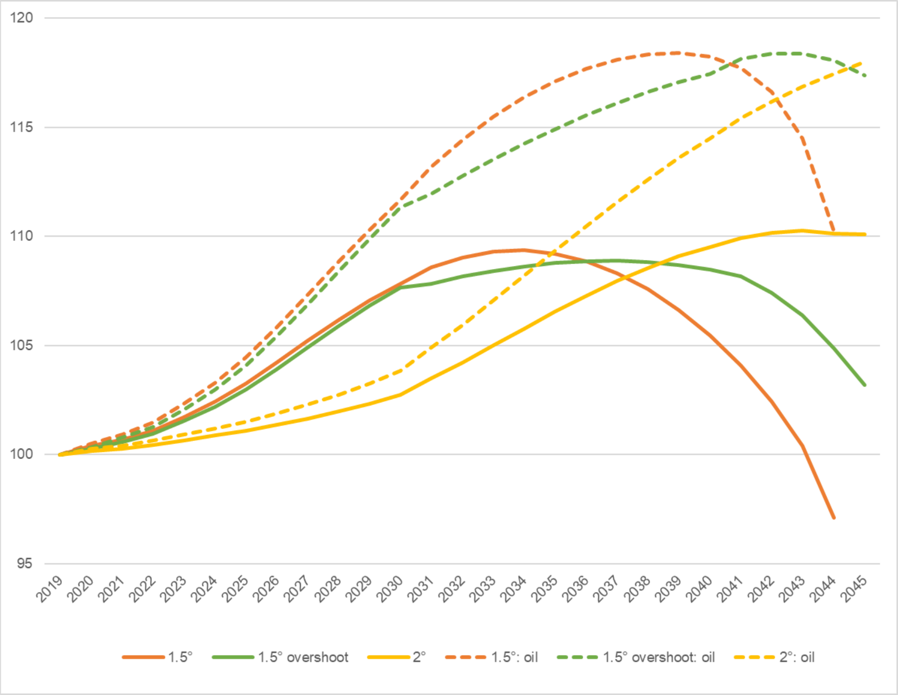
[9] The ratio of world export prices to world import prices weighted by the pattern of trade for Maldives

Figure 6 Macroeconomic impacts of Global temperature goal scenario I in Maldives (percentage change from the reference scenario in 2045 (2044 for 1.5°C simulation), real) without participation



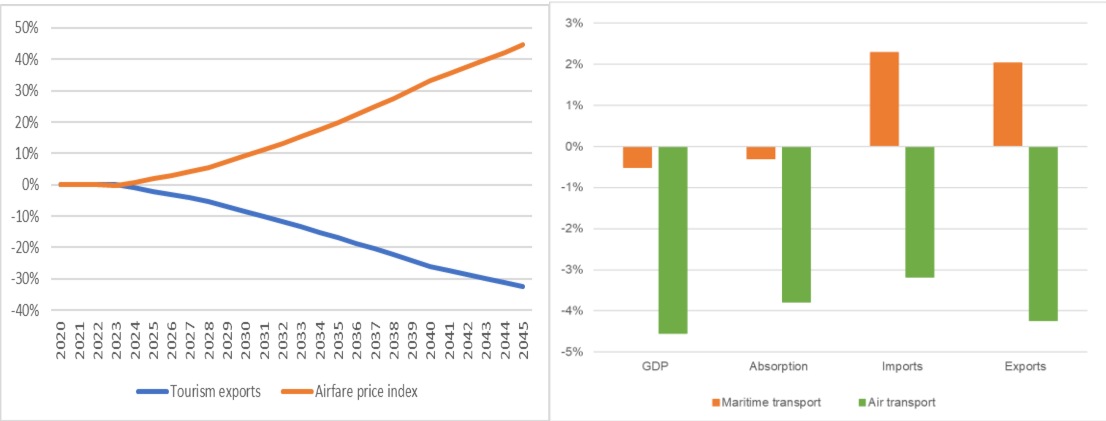
Source: simulation results

Figure 7 Terms of trade average for all products and Oil alone under global carbon tax response measures (index relative to the reference scenario, the index equals 100 when the terms of trade in the scenario and reference scenario are the same)



Source: authors' calculations based on global model results

Figure 8 Left panel: Global airfare price index and export of tourism services by Maldives tourism (left panel, percentage change from reference scenario), Right panel: Macroeconomic impacts of global maritime and air transport response measures (percentage change from the reference scenario in2045).



Source: simulation results

2. Employment Dynamics and Welfare Implications of Global Response Measures in the Maldives

The impact of global response measures on jobs in Maldives is a crucial aspect to consider Considering that the model assumes full employment at all times, the expansion of certain sectors necessitates the reallocation of labour from contracting sectors thereby, reflecting changes in the job market according to changes in the structure of production. Figure 9 and 10 illustrates the effects of global response measures on jobs in Maldives.

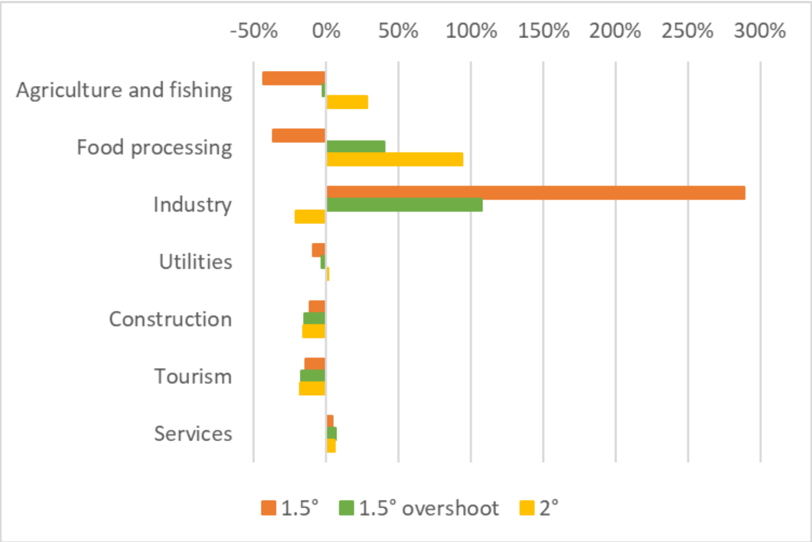
Across the three variations of temperature goal scenario, the expansion of fish and fish processing exports, aimed to raise foreign currency and consequently higher imports, results in a notable influx of workers into the agriculture and fishing sector, and the food processing sector which includes fish processing. Workers move from sectors that are less oil intensive and have less benefits from the falling oil price. However, under the 1.5º simulations, a different trend emerges. The expansion in manufacturing goods and transport services attracts workers into industrial sector diverting them from employment in other sectors. This shift underscores the dynamic nature of employment patterns in response to varying temperature goals, highlighting the need for an adequate policy consideration to ensure equitable outcomes across different sectors and income groups of Maldives.

The results from Maritime scenario and Air transport scenario (Figure 10) reveals that the expansion of fish and fish processing exports will raise foreign currency, which is then used to purchase imports. This expansion draws workers into the agriculture and fishing sector, as well as the food processing sector which includes fish processing. This effect is particularly notable under the CORSIA scenario where labour previously employed in the contracting tourism sector is redirected towards fish and fish processing, implying substantial changes in the Maldives' labour market.

Global response measures have a progressive impact on household welfare in non-participating regions due to the lower oil price. When analysing the impacts of global temperature goal scenario I on households, the result highlighted a key mechanism of global climate response measures with less than global participation i.e. that countries that do not participate benefit from falling oil prices. The implementation of the carbon tax reduces the global demand and price for fossil fuels. Countries, such as Maldives, which do not implement the carbon tax can import more oil at lower prices. This produces an 'externality effect' an indirect, unintended consequence in which global response measures lead to increases in emissions and reduced incentives to invest in renewables (although may be partly offset by targeting transfers towards greening investments).

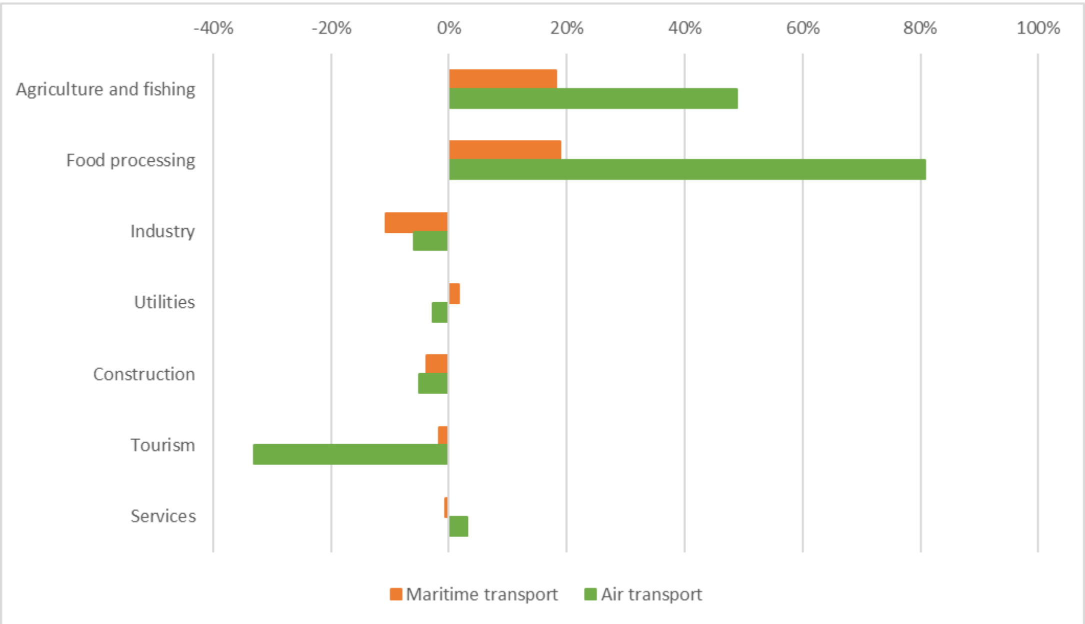
As the main source of household income, changes in wages and capital and land payments, drive changes in household incomes, expenditures and welfare. The impact of these changes on household consumption (welfare) in Maldives, compared to the initial wealth level of the household, is shown in Figure 11. This analysis highlights the impacts of global temperature goal scenario I global response measures across households and identifies vulnerable household groups that may be particularly negatively impacted. In the case of global response measures that lead to falling oil import prices in an oil dependent economy like Maldives, the overall household impact is positive. All households are better off in all but the most stringent climate scenarios, with the poorest households seeing a large increase in welfare. Most households also benefit under the more stringent climate scenarios, but richer households in income quintiles 4 and 5, who derive a larger share of their income from capital, see a reduction in welfare under the 1.5º and 1.5º with overshoot simulations.

Figure 9 Jobs under global carbon tax response measures (percentage change from the reference scenario in 2045, 2044 for 1.5°C simulation)



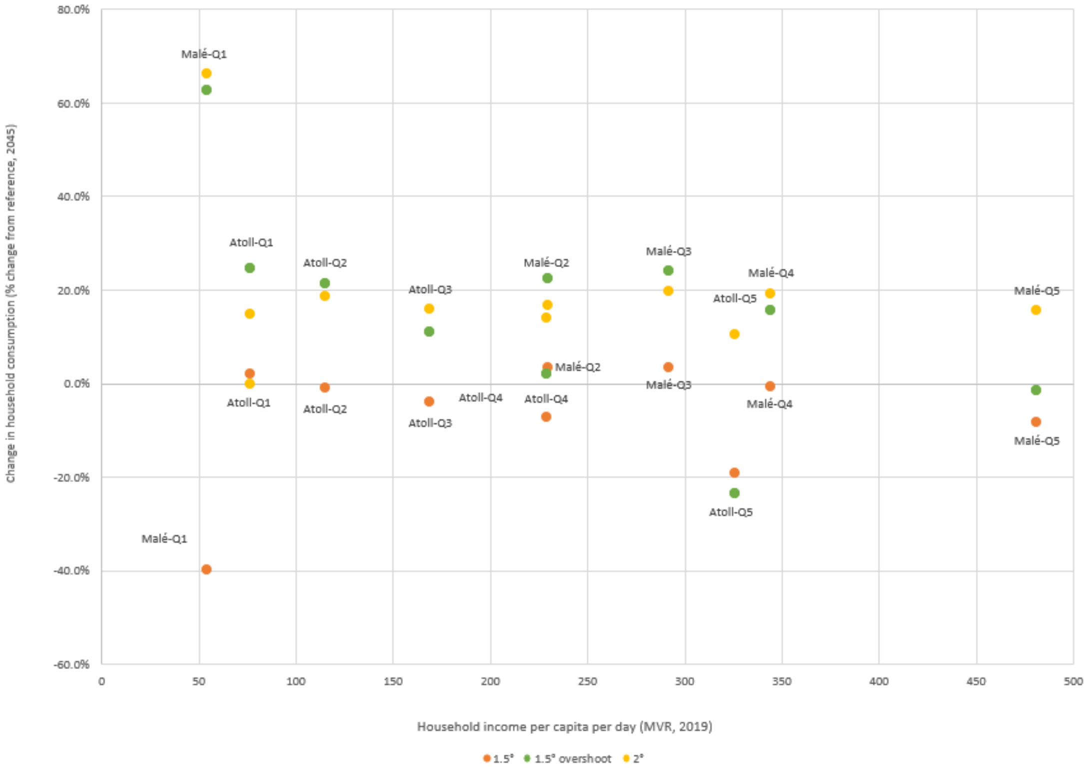
Source: simulation results

Figure 10 Jobs under global maritime and air transport response measures (percentage change from the reference scenario in 2045)



Source: simulation results

Figure 11 Impacts on households from uniform carbon tax as response measures to achieve temperature goal



Source: simulation results. Note: Households are grouped by location and income quintile. The two locations are the capital island of Malé and those on other islands (atolls). There are five income quintiles where quintile 1 (Q1) includes households with the lowest 20% of income and quintile 5 includes households with the highest 20% of income.

3. Navigating interplay between global response measures and SDGs

The interplay between lower oil prices and emissions is evident in all scenarios, where reduced fuel costs intersect with shifts in production, resulting in emissions surpassing reference scenario levels. However, the consequences extend beyond mere emissions dynamics; lower oil prices also dampen the impetus for investment in renewable energy sources, complicating efforts to achieve NDC emission reduction targets.

Another consequence of global climate response measures for non-participating countries, particularly apparent in the case of the Maldives as an oil-importing, import-dependent nation, is the additional hurdles encountered in meeting NDC targets when lower fossil fuel prices drive up emissions. This challenge is exacerbated for SIDS and low-income economies characterized by limited economic diversity and heightened exposure to international markets.

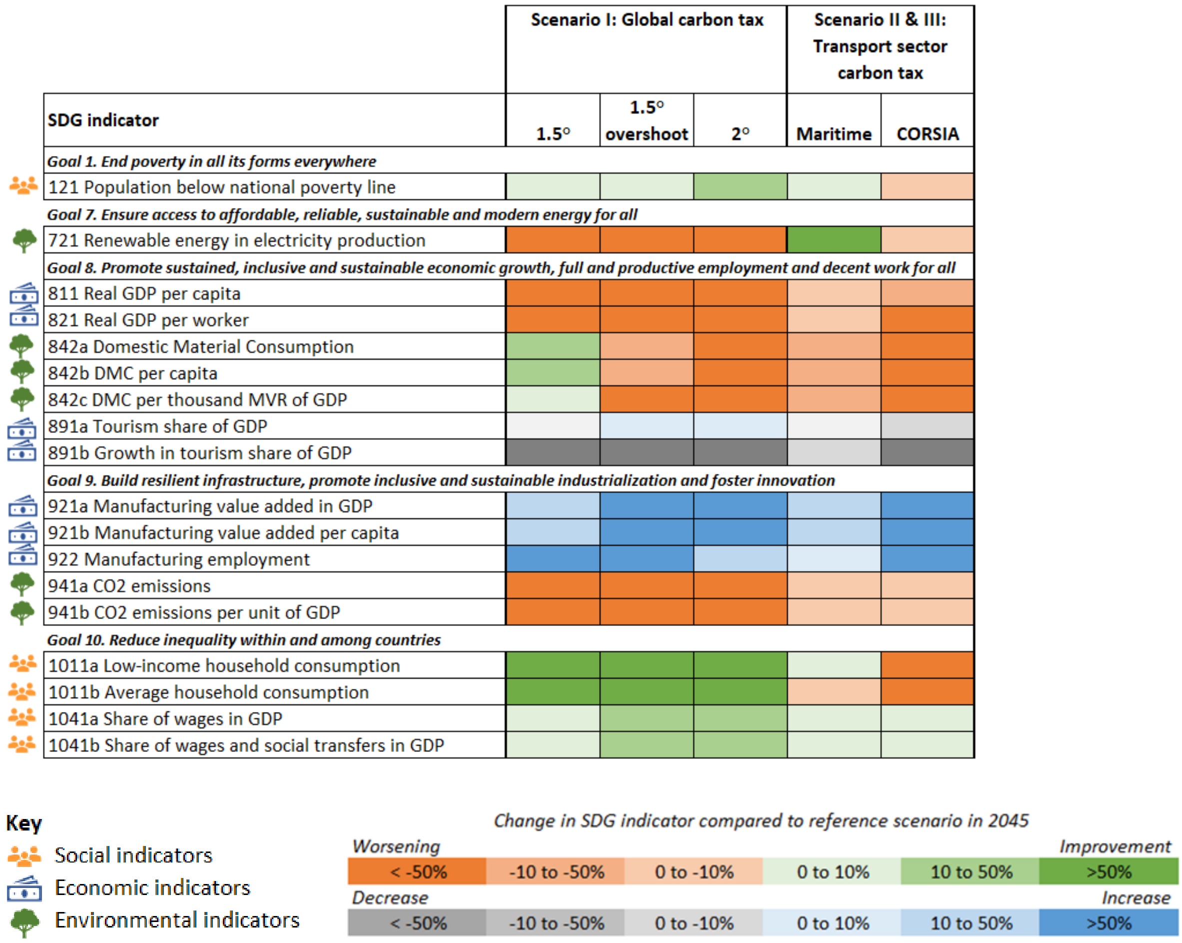
Given these circumstances, the capacity of such economies to adapt to shifts in global economic dynamics is significantly constrained. While global modelling exercises provide valuable insights, it's essential to recognize the unique circumstances and challenges faced by individual countries. Lower oil prices lead to higher emissions in both transport scenarios. Lower fuel costs combine with changes in production to increase emissions above reference scenario levels.

Lower oil prices reduce the incentive to invest in renewables and make reaching NDC emissions reductions more difficult. A consequence of global climate response measures for non-participating countries is that it will take additional efforts to reach their NDCs when lower fossil fuel prices lead to higher emissions. These effects are particularly clear for Maldives as an oil-importing, import dependent country.

SIDS and low-income economies that are characterised by limited economic diversity and are highly exposed to international markets will have less capacity to adjust to changes in the global economic markets. The global modelling exercise is running with an aggregation specifically designed for SIDS countries. The nuances available to policy makers in individual countries will vary enormously but some general principles are clear. . Nevertheless, overarching principles emerge, highlighting the vulnerability of the Maldives, due to the high dependence of Maldives on tourism, imported fossil fuels, and international transport services, exposes the country to cross-border impacts of global response measures.

Further, the findings reveal that the global response measures directed towards limiting global temperature rise inadvertently enable non-participating regions to advance their SDGs, albeit at the cost of environmental objectives. From the impacts of global temperature goal scenario I in Maldives, it becomes evident that the higher the targeted global temperature rise, the more the regression is observed in environmental SDG indicators. At the same time, more progress is observed on social and economic indicators progress as shown in Figure 11. This progression and regression are driven by the fall in world oil prices resulting from reduction in fossil fuels demand. Consequently, within global temperature goal scenario I, a strong expansion in production occurs in response to lower input costs. This expansion in production leads to significantly higher emissions, particularly in sectors heavily reliant on oil imports, as the reduced costs make expansion more economically viable. In essence, global response measures aimed at limiting global temperature rise allow non-participating regions/countries to make progress in social and economic SDGs at a cost to environmental goals.

Figure 12 SDG impacts of global response measures in 2045 (2044 for 1.5°C scenario)



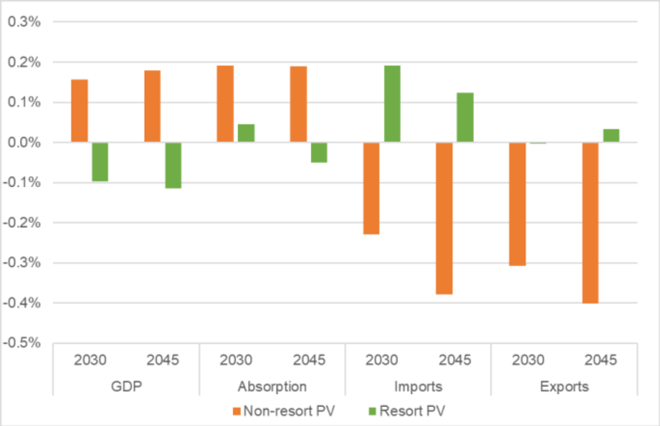
4. Socio-economic impacts of domestic response measures

The results from NDC scenarios show that expanding renewable energy sources has a positive effect on reducing emissions while having minimal impacts on the broader economy. Specifically, when domestic response measures are implemented to increase the share of renewables in the energy mix to 15% in both the tourism and non-tourism sectors, the resulting impacts on the economy are relatively minor (Figure 13) compared to the global climate change response measures discussed earlier (section C-1). The smaller impact on the economy is due to the fact that the change in the energy mix primarily targets one sector: electricity production. As a result, the effects are more contained within this specific sector and do not have significant ripple effects across the entire economy.

Furthermore, it is observed that that scenario aligned with NDCs results in lower emissions compared to those under the broader global response measures. This indicates that domestic measures aimed at transitioning to renewable energy sources can contribute to emissions reduction goals outlined in international agreements like the Paris Agreement, in contrast to the potential increase in emissions resulting from global responses to climate change. (Figure 14)

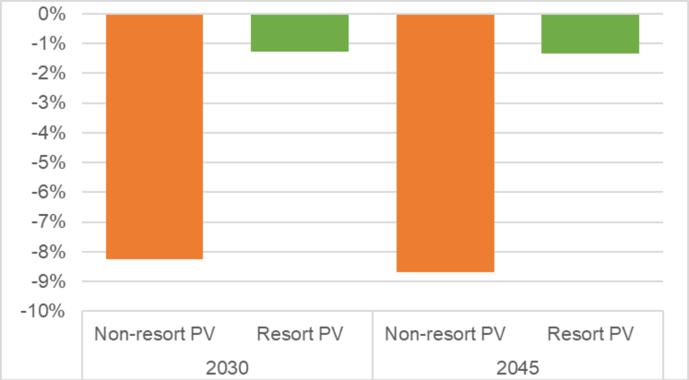
The comparison with two NDC scenarios further highlights that scaling up the share of renewable energy by increasing PV systems in non-tourism sector (non-resort PV) results in a significant reduction in emissions (Figure 14) compared to PV installation in tourism sector (resorts). This reduction is primarily driven by the abolition of the 9% subsidy on diesel-based electricity production. In essence, by eliminating the subsidy, there is less financial incentive to use fossil fuels for electricity generation and the adoption of cleaner energy sources like PV systems is encouraged.

Figure 13 Macroeconomic impacts of domestic response measures (percentage change from the reference scenario in 2030 and 2045)



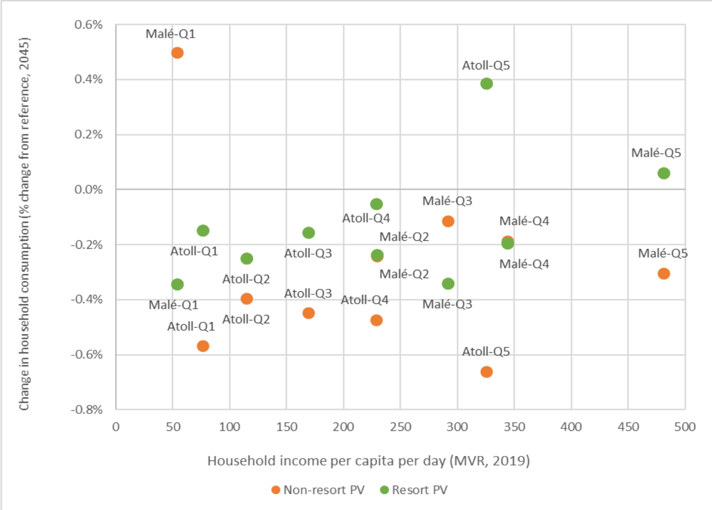
Source: simulation results

Figure 14 Emissions resulting from domestic response measures (percentage change from the reference scenario in 2030 and 2045, CO_2 equivalent)



Source: simulation results

Figure 15 Household impacts of domestic response measures (2045)



Source: simulation results

The high emission reductions are achieved at the cost of household's welfare as significant reduction in household welfare is observed in non-resort scenario. This reduction is driven by higher product costs, broadly lower wages and capital returns, and the increase in the general GST rate aimed at funding investments in PV. However, when we compare these results with global scenarios. the magnitude of the impact on welfare is less pronounced than under the global response measures. Only three households experience an increase in welfare: the poorest Malé household which is shielded from the impact on factor incomes by government transfers, and the two richest households, which benefit from higher capital returns in the Resort scenario. (Figure 15)

5. Navigating interplay between domestic response measures and SDGs

Impact of NDC scenarios on SDGS shows that the transition in the energy mix leads to a decrease in household welfare, while environmental indicators generally show improvement as shown in Figure 16. Although, the poverty rate remains stable under the Resort PV scenario, it slightly deteriorates under the Non-resort PV scenario. The impact on economic and environmental indicators, other than emissions, is mixed. In contrast to the global temperature goal and transport response measures, these impacts arise from direct domestic consequences, rather than cross-border effects.

The results underscore the critical strategic imperative for the Maldives to transition towards renewable energy sources. Given the current land availability (including roofs) and economic conditions in the Maldives, achieving an energy mix comprising 15% renewables appears not only feasible but also essential for the country's sustainable development. However, sustaining this transition and overcoming potential challenges, such as land area loss due to climate change, will require significant investments in innovative technologies. In this regard, embracing solutions like floating photovoltaic (FPV) and ocean energy holds promise for further expanding the renewable energy portfolio, thereby enhancing the Maldives' energy resilience and reducing its vulnerability to external shocks such as fluctuating oil prices.

Moreover, strategic policy interventions aimed at reducing the country's reliance on fuel imports are paramount, not only for enhancing energy security but also for bolstering economic stability and environmental sustainability. Nonetheless, it's crucial to approach this transition with caution, considering the susceptibility of renewable infrastructure to extreme weather events. Thus, adopting a diversified portfolio approach to renewables, inclusive of other technologies like tidal energy where feasible, is deemed necessary to mitigate risks and ensure long-term energy sustainability. Furthermore, there is intricate interplay between the Maldives' energy trajectory and global fossil fuel markets, emphasizing the need for comprehensive analyses to anticipate and respond effectively to various market scenarios. Ultimately, the overarching goal is to navigate the transition towards renewable energy while simultaneously addressing climate vulnerabilities and promoting sustainable development in the Maldives.

Figure 16 SDG impacts of domestic response measures (2045)

SDG indicator	NDCs: Increase share of renewables in the energy mix	
	Non-resort PV	Resort PV
Goal 1. End poverty in all its forms everywhere		
121 Population below national poverty line		
Goal 7. Ensure access to affordable, reliable, sustainable and modern energy for all		
721 Renewable energy in electricity production		
Goal 8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all		
811 Real GDP per capita		
821 Real GDP per worker		
842a Domestic Material Consumption		
842b DMC per capita		
842c DMC per thousand MVR of GDP		
891a Tourism share of GDP		
891b Growth in tourism share of GDP		
Goal 9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation		
921a Manufacturing value added in GDP		
921b Manufacturing value added per capita		
922 Manufacturing employment		
941a CO2 emissions		
941b CO2 emissions per unit of GDP		
Goal 10. Reduce inequality within and among countries		
1011a Low-income household consumption		
1011b Average household consumption		
1041a Share of wages in GDP		
1041b Share of wages and social transfers in GDP		

Key

Social indicators

Economic indicators

Environmental indicators

Change in SDG indicator compared to reference scenario in 2045

Worsening					*Improvement*
< -50%	-10 to -50%	0 to -10%	0 to 10%	10 to 50%	>50%
Decrease					*Increase*
< -50%	-10 to -50%	0 to -10%	0 to 10%	10 to 50%	>50%

III. Chapter 3: Informing policy decisions with research findings

The aim of this chapter is to illustrate how the findings of this study can serve as valuable tools in addressing key inquiries essential for informing policy decisions made by stakeholders and decision-makers.

1. Can Maldives achieve its NDCs without extra climate policies?

The results suggest that market forces alone will not facilitate the transition towards share of renewable energy share required for the Maldives to fulfil its NDC commitment. Projections from reference scenario indicate that the existing market incentives are insufficient to bring the necessary shift in the energy mix for emission reductions, necessitating policy interventions. The need to fund changes in the energy sector will make substantial demands on investible funds. The government will need to play a role in incentivising and possibly financing investments in renewables. Moreover, if economic growth, and consequently electricity demand, surpasses projections, there will be a heightened need for stronger expansion in renewables.

2. **Will all parts of the economy be affected by climate policies?**

Climate policy impacts will induce changes across all sectors of the economy, each adjusting at varying rates. Structural shifts in production will evolve gradually, primarily driven by incentives aimed at restructuring the energy sector, particularly in electricity production. Employment patterns will undergo transformation, while changes in consumption patterns typically manifest swiftly. Trade patterns will change partly due to changes in relative import and export prices and partly due to changes in exchange rates. Changes in relative exchange rates will significantly impact the economy in terms of trade and other international transactions.

Additional interventions may be necessary to address the implications of climate policies. The analyses highlight the need for governments to proactively manage fiscal policies to ensure stability of the government's budget and, to mitigate income distribution effects to some extent. The implications of changes in different tax instruments will be important. Where the relative incomes of poor households and the wage rates of lower skilled workers are adversely impacted by the costs of mitigation policies, domestic policy interventions to address these implications may be important to avoid social discord.

3. **Can cross-border impacts lead to improvements in all aspects of sustainable development (economic, social and environmental)?**

There are strong trade-offs between environmental and social and economic goals. The 'externality effect' of global response measures with less than global participation brings about a conflict of goals. Non-participation in global response measures gives countries an opportunity to capitalise on lower oil prices to make progress towards social and economic goals. This comes at a cost to environmental goals and makes achieving a country's NDCs more difficult by expanding emissions and reducing the incentives to invest in renewables, although this may be partly offset by targeting transfers towards greening investments. These effects are clear for Maldives as an oil-importing, import dependent country. Maldives has the policy option to introduce a carbon tax or other duty to 'choke off' some of the cheaper oil imports, thereby reducing the expansion in emissions.

4. **What is likely to happen if oil-producers respond to falling prices by restricting supply?**

The cross-border impacts of global response measures in Maldives are driven by changes in oil prices. The responses of fossil fuel exporters will be critical for both net importers and net exporters. These responses are unknown, and therefore the need for analyses of the consequences of a range of responses by fossil fuel exporters is crucial. If oil-producers respond to falling prices by restricting supply, oil prices are likely to be higher (although may still be lower than in the reference scenario). The economic and social benefits of the lower oil price will be reduced and the increase in emissions will be lower i.e., the trade-off between social and economic benefits and environmental costs will be smaller.

Speeding up the energy transition insulates Maldives from changes in world oil markets. A strategic policy intervention to change the energy mix towards renewables lessens the Maldives' dependence on fuel imports which would insulate the country from oil price rises should oil exporters respond to falling global prices by restricting supply. The increase in energy security from the decoupling from global oil markets should be weighed together with the possibility of extreme weather events damaging PV infrastructure which may be more vulnerable to damage than diesel generators. A portfolio approach to renewables that include other technologies such as tidal, where possible, is therefore desirable.

5. **Can a reform of the fossil fuel subsidy help Maldives achieve its NDCs?**

Reforming the fossil fuel subsidy for electricity production offers scope for greater emissions reduction. Removing the fossil fuel subsidy on diesel-based electricity production reduces emissions and increases the incentive to invest in renewables. The impact on household welfare should be considered and policy interventions put in place for vulnerable households.

6. **Are there any concerns about the transition towards renewables for Maldives?**

A shift in the renewable energy mix is feasible with currently available land area but alternative technologies may be needed to expand PV further when land area is threatened by rising sea levels. The expansion in PV to achieve an energy mix of 15% is likely achievable given current land area (including roofs). However, concerns about land area loss due to climate change and the increasing availability of new technologies, suggest that floating photovoltaic (FPV) could allow for further expansions in PV, assuming that the shading effect of FPV on marine life is benign, alongside ocean energy technologies.

7. Would Maldives benefit from participating in global maritime and air transport climate policies?

The main impact of global maritime and air transport climate policies in Maldives comes from the participation of other countries outside Maldives in the policies. Maldives uses international maritime transport to import goods and international air carriers to bring tourists to the islands, both of which are subject to the transport climate policies. If Maldives remains outside CORSIA, Maldivian, the Maldives' airline would not see a climate-policy driven increase in airfares. However, despite Maldivian covering some markets including China and India, it is unlikely to be scalable enough to offer a carbon-tax exempt option for most inbound tourists. Another option would be for Maldives to participate in CORSIA to reinforce its commitment to tackling climate change and to consider a revision of the GST rate on tourism to reduce the non-flight component of the holiday cost. An exploration of this option, including its implication for government revenue, should be analysed in depth ahead of any policy change.

8. What role can the tourism sector play in the transition?

A clear tourism and diversification strategy is key. It has been recommended that small island developing states strengthen the link between the agricultural and hospitality sectors (Pratt, 2015), however increasing this interdependency further increases the reliance on tourism such that threats to tourism ripple through the rest of the economy. In Maldives, resorts provide 16% of total demand for fish and 34% of total demand for passenger transport services thus the contraction of the tourism sector under CORSIA will have effects beyond the tourist industry. The potential for negative impacts on a key sector within the narrow economic base of Maldives requires action to protect the sector and explore opportunities for economic diversification. Options for the tourism sector include a focus on more price insensitive high value tourism and an expansion of the digital economy offers options for diversification (World Bank, 2022).

The tourism sector is directly affected by global response measures. Efforts to limit emissions from the hard to abate aviation sector directly affect tourism demand via higher airfares. This in turn affects tourist numbers to Small Islands Developing States (SIDS), many of which rely on tourism income. This mechanism is also relevant to oil-producing countries considering diversifying their economies via investments in tourism.

9. What factors should countries consider in planning their transition strategies?

The following seven factors influence the extent to which climate policies are likely to affect an economy:

1. The extent to which a country is tied into international oil markets, either as an importer or exporter.
2. The extent to which a country is reliant on shipping for imports and exports.
3. The extent to which a country is reliant on income from tourism.
4. Whether a country is participating or not in a global response measure
5. Whether current policies are sufficient to bring about the energy transition or further policies are needed to support the transition
6. Whether there is scope to reform domestic energy subsidies
7. Whether it is feasible for renewables to meet expected future energy demands.

IV. Chapter 4: Lessons learnt for use of economic models for policy making

This chapter discusses the challenges and lessons learned in three key areas: engagement, data, and capacity building. It examines the obstacles faced and insights gained while working towards the objectives of customizing and implementing two CGE models, designing a user-friendly modelling interface, creating a Social Accounting Matrix, and conducting staff training. The chapter outlines the primary challenges encountered and offers recommendations based on the lessons learned.

A. Stakeholder engagement

The benefits of value of impact analysis using modelling tools must be demonstrated prior to engaging with stakeholders. A key challenge is to demonstrate the returns to investment in modelling tools. Country partners are asked to invest their time, resources, data and personnel in developing the tool. It is important to explain the strengths and weaknesses of the CGE approach and what they can expect to gain from their investment. Additionally, explaining how these tools complement other quantitative and qualitative methodologies is important. A high-level presentation at the start of a project illustrates the insights that can be gained, using examples from previous studies, and the benefits of close collaboration by country partners.

The use of user-friendly interface for modelling tool enhances stakeholder engagement and collaboration. Firstly, the MIRO_UNFCCC interface enabled stakeholders to interact with more complex models with a reduced training requirement. This increased accessibility fosters transparency and trust by demystifying the modelling 'black box'. Secondly, the process of setting up, running and interpreting scenarios take users through the process of considering potential impacts and promotes the consideration of unintended consequences of both domestic and international policies. Thirdly, users can explore a wider range of scenarios, enriching the research output beyond those that can be included in a written impact assessment report. Fourthly, the interface provides an accessible entry point to CGE simulations for stakeholders who are interested in investing in models for their own economies. Finally, the utilization of common models through the interface encourages discussion and collaboration among multiple stakeholders, facilitating a shared approach to impact assessment.

Engaging experts as consultants is needed to effectively utilize advanced toolkits in the short term to build national capacity. While low-income countries or small island developing states may face challenges in independently utilizing advanced toolkits, such as the one discussed, in the short term, engaging consultants can provide essential support. However, it is imperative for these countries to simultaneously prioritize building the capacity of national policy analysts to ensure sustainable utilization and ownership of the toolkit in the long term.

Close collaboration between consultants and the country partner is essential to ensure representative results. The accuracy of CGE model findings depends on the quality of data and the degree to which the model, assumptions and scenarios reflect the situation in the country. Close collaboration between local policy advisors and analysts is important in obtaining accurate data, framing appropriate policy responses and effectively communicating insights to policy makers.

Involving a country team of domestic climate change specialists during the project fosters ownership of results and skill development. Ownership of results and skill development are important elements for utilizing results in policy making. The collaborative work of a country team of domestic climate change specialists with consultants during the project builds trust. Long-term ownership of the results and insights from the toolkit requires the allocation of domestic resources to national statistical agencies and capacity building for national policy analysts.

The provision of a clear statement of international and domestic policy objectives with respect to climate change improved the toolkit. Clear guidance on policy goals helped to shape policy scenarios and encourage active engagement with the analyses. Having a well-defined set of objectives facilitated more targeted and meaningful analysis within the toolkit, ultimately contributing to better-informed decision-making processes related to climate change policies.

B. Data

The process of modelling starts with the data. The key challenge is to ensure the data are available and of good quality. Parties interested in undertaking similar analyses are encouraged to make an inventory of the currently available data and compare it with the requirements below. A program of data collection can be developed to fill in any missing gaps.

- The database for the global model is likely, for the foreseeable future, to be the Global Trade Analysis Project (GTAP) database. The data for the country model will be case specific.

- The database for the country model is a Social Accounting Matrix. A Social Accounting Matrix is a record of income and expenditure transactions in a country in a given year. Ideally the year should be representative of a stable time in the country, e.g. not during COVID, conflict, famine etc.
- Minimum data requirements: If a SAM is not available, the minimum data should be consolidated national accounts and domestic supply and use tables from the national statistical agency supplemented by household incomes and expenditure and labour force surveys, environmental accounts, and detailed tax data.
- Data quality is important. Data quality determines the quality of results from the toolkit. The production of national accounts by the national statistical agency is central to the quality of the economic analysis and ownership of the results and insights. Ideally the core economic data is a detailed Social Accounting Matrix (SAM) produced by the national statistical agency.

C. Capacity Building

- Domestic capacity is needed if domestic policy analysts are to provide in-house analysis to domestic policy advisors. The key challenge is to identify, and develop domestic capacity, where needed. Without substantial domestic capacity countries will experience difficulties owning the results and insights.
- Knowledge about the strengths and weaknesses of models is central to ensuring the results and insights can inform policy decisions.
- Basic training in modelling techniques should be undertaken at the beginning of the project cycle. This would provide domestic analysts with information to enhance engagement with the project.
- Funding for capacity building should be provided by the domestic agency/agencies that employ the policy analysts. This would increase the probability that managers provide time and resources for participants in the capacity building programme.

D. Use of modelling tools for policy making

Models are useful tools as they can eliminate logical inconsistencies. They help to extract information from data which can then be transformed into knowledge. Models are a framework that help to recognise and structure complex problems and think through the consequences. They are used to quantify effects and help to choose between decision options.

8. **Economy wide models like CGE models are strong in showing interlinkages between markets where one might not necessarily make connections.** Modelling results highlight areas of concern, prompting further investigation into why certain regions, households, or markets are more affected than others. By illuminating dominant relationships, model results assist in directing policy focus towards critical areas. For instance, the Maldives case study reveals that the impacts of the carbon tax and global maritime response measure are primarily influenced by changes in world oil prices. Similarly, the reduction in tourism demand under the global air transport scenario redirects employment opportunities to fishing and fish processing, sectors that benefit from lower oil prices.

9. **Assumptions employed in modelling are often criticised, but they help us think about how the world develops.** A CGE model is based on assumptions that are founded in economic theory. When a scenario outcome seems unreasonable, it highlights areas where current behaviour and economic structure result in an unlikely outcome in the future. And, thus, identifies inconsistencies in current structures and behaviour. This is where we most likely need to expect changes in behaviour or markets. Questioning the assumptions is an important process to opening discussion about transformation. For example, the case study simulations show clearly the limits of market-based policies (carbon taxes) to reach reductions necessary to stay within the 1.5° pathway (with or without overshoot). The model reports very high costs, which may be labelled unreasonably high for a number of regions.

This does not mean the model is wrong. It means that we need more changes than currently assumed in the scenarios to make the transition, and highlights regions and sectors where transition is most needed. Model results thus highlight the need for governments to actively support diversification of the economy, highlight the relevance and value of R&D, and raise awareness about support for technological change.

The simulations could include additional technological change to support economies in adjusting to the economic impact of reducing emissions. But the architecture of future structural change is highly uncertain and introducing unknown technologies to the system risks assuming ‘manna from heaven’ unless the technological change is based on R&D expenditures and additional investment. The model accounts for responses to changing prices inside the borders of the current production and demand system. However, we do not simulate a full transformation of the economic system in the global model. As it is not the focus of this current study, the global modelling exercise does not include possible response policies such as supply responses and other policies aiming at transferring the economy to another production system and inducing structural change. The study highlights that the level of technological change brought about by market forces alone will not bring about the shift to new production systems and additional policies are needed to drive the large-scale shifts needed.

10. **The model analysis discloses policy inconsistencies and trade-offs.** The global scenario, for example, investigates different possibilities on how to limit the burden of global response measures on developing countries. Results clearly show the trade-off related to exempting regions from the uniform carbon tax. While exempted regions are better off, the subsequent leakage effect (a policy induced relocation of carbon emissions to non-participating countries), increases the burden on participating regions. Results show that it is less costly for participating regions to transfer a part of the tax income to support transition in developing countries. The analysis for Maldives highlights trade-offs between environmental and social goals, as well as potential policy mismatches such as levying import duty on oil and subsidising the use of oil in electricity production.

11. **Investigating the model database helps to understand the economic structure of economies.** The national and global database is a matrix representation of national account statistics. The database is crucial as a basis for modelling and also provides useful insights on the economic structure of a country and relationships between countries. It can identify relevant areas for strategic development or government activity. For example, Maldives is highly import dependent being wholly reliant on imports for diesel fuel, minerals (a key input into the construction industry), and machinery. Aside from fish, Maldives is highly dependent on imports for food including dairy products (import dependency ratio 100%) and grain mill products (93%). There are linkages between domestically produced goods and the large tourism sector with resorts providing 16% of total demand for fish and 34% of total demand for passenger transport services. The import dependence and strong link between food and tourism increases the vulnerability of the economy to tourism-based shocks such as the global air transport response measure.

12. **The use of a model structures thinking about complex problems.** Participating in the process of setting up a scenario and model for an analysis in a general equilibrium framework is valuable to structure discussions and start thinking about impacts. When translating a policy into a policy scenario, decisions about a number of design details are required that the modeller requires to run a scenario. Design details can include, for example: the type of the policy and the size of change; which parts of the economy, and subsets thereof, are targeted (households, commodities, sectors); does the scenario simulate an increase or decrease, should a counterfactual be simulated; the time horizon under review. The scenario design typically involves thorough background research including the collection of expected outcomes. This requires reasoning through the economic intuition underlying the model and develops the understanding of the relevant aspects of the formulation and representation of policies. This leads to an improved understanding about the problem under review and the identification of possible knowledge gaps or inconsistencies even before the model is run.

Thinking through the scenario reveals expected costs and benefits of a policy. It helps interpreting results and drawing policy recommendations. For example, lack of adequate information about the foreign labour force was identified during the SAM construction, despite being more than a third of the total workforce of Maldives. Identifying gaps brings awareness of the limitations of the model and indicates where future gains can be made to improve it. In addition, in CGE models, the imposition of response measures imposes additional constraints on the economic systems. In the scenario setup of the case study the model results report only economic effects related to the implementation of specific response measures, the costs of climate change, or benefits of mitigation are not included. These costs of taking action need to be weighed against costs of climate change - the cost of not taking action or delaying action. Less ambitious pathways will also result in higher adaptation costs from global warming. These higher adaptation costs can be simplified under two categories: first, environmental impacts that are hard to reverse,e.g., projected sea level rises, human health, etc., and second, higher temperatures require more and earlier action for mitigation, and are related to economic costs, such as, accelerated scrappage of electricity generation plant, reductions in living standards needed to fund accelerated investment programmes, etc.

13. **Economy wide models such as CGE models can help to understand impacts of policies that are planned and compare impacts of alternative policies.** The model is designed and well suited to answer "what if" type of questions. The tool can for example be used to investigate a variety of scenarios and assumptions to understand which element of the policy design is important for the outcome. For example, the role of oil prices as the main driver of changes in the terms of trade for Maldives, is shown by comparing the oil price only effect with the overall effect (see Figure 7). Another way to use the model can be to use it as a tool for sensitivity analysis to evaluate performance in a variety of futures, such as the global generic carbon tax associated to a variety of pathways, of 1.5°, 1.5° with overshoot, 2° and 2.5°.

V. References

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