Review on the Policy Advice for Climate Resilient Economic Development (CRED) Project

Status and Potential Future Application of the CRED Approach

Executive Summary

MARCH 2023

Climate change can significantly affect the economic growth and development of countries. Yet, however, there is a lack of experience and approaches around the world in regard to integrating climate risks into macroeconomic forecasts, planning and decision-making. There is therefore an urgent need for methods and tools for assessing the economic impact of climate risks and adaptation measures that can reduce these risks. The Policy Advice for Climate Resilient Economic Development (CRED) project implemented by GIZ on behalf of the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV) aims to address this need. CRED brings national modelling authorities in developing countries together with adaptation and economic experts in Germany, in order to create long-term economic models to assess the macroeconomic impacts of climate change and adaptation measures. CRED has been implemented in three pilot countries (Georgia, Kazakhstan, and Vietnam) from 2019-2023 providing extensive training for model developers and model users. These trained experts then work with authorities in their countries to enable the consideration of climate change impacts and appropriate adaptation measures in their economic planning. Further, CRED has conducted dissemination activities and trainings for experts from other countries, in order to enable the use of macroeconomic models for adaptation planning beyond the pilot countries.

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This report reviews the CRED programme's activities, focusing on the pilot countries of Georgia, Kazakhstan, and Vietnam, as well as model prototype development in Mongolia. The report draws on CRED materials including national reports, policy briefs, and trainings, as well as interviews with CRED partners in the pilot countries. Finally, the report surveys the current macroeconomics of adaptation literature to develop recommendations for further CRED extensions.

Turning to the **review of CRED activities**, the CRED programme is structured along three pillars of i) capacity building for economic modelling; ii) policy advice; and iii) dissemination of the approach.

Regarding the first pillar, the CRED programme developed a macroeconomic modelling framework to assess the effects of climate change and adaptation measures over an entire (national) economy. The approach is compatible with different macroeconomic models, e.g. Input-Output models, Dynamic General Equilibrium (DGE) models. Capacity building has been implemented in several phases and tailored to the needs of the partner countries. Training modules have been developed for different CRED aspects including, climate hazard analysis, monetisation of damages as well as climate and adaptation scenario analysis. Further, CRED trainings provided a platform for a range of public and private sector stakeholders, i.e. ministries, research institutes, universities and think tanks, to exchange data, knowledge and experiences. Finally, a key pillar of CRED capacity building in partner countries is the transfer of the country-specific macroeconomic model ownership to the CRED partner institutions.

Regarding the second pillar, CRED's policy advice and mainstreaming activities aim to bring the macroeconomics of climate change and adaptation into national and sectoral policy-making. Policy advice activities have resulted in concrete mainstreaming outcomes, whereby national policies in pilot countries have included CRED results, e.g. Low Emission Development Strategy (LEDS) in Kazakhstan. Regarding the third pillar, dissemination activities have produced various knowledge products for pilot countries, aimed at communicating the potential macroeconomic costs of climate change and the macroeconomic benefits of investing in adaptation.

Turning to **country-specific activities**, **in Georgia**, the e3.ge model was developed, with adaptation measures analysed chosen by national working groups, focusing on agriculture and tourism-related sectors. CRED activities in Georgia were largely successful in raising awareness of the need to invest in adaptation across different national line ministries, as the results provided the first quantitative economic analysis of adaptation in Georgia. There are thus plans to further build upon the CRED results, for example, in NAP development. Further, the e3.ge model was also applied to evaluate macroeconomic impacts of the COVID-19 pandemic and the Russian war in Ukraine. Finally, a key challenge in Georgian was the lack of existing data on extreme event damages. To address this, CRED initiated processes for data collection, promoting cooperation between ministries and with private sector stakeholders that have potential to last beyond the lifetime of project.

In Kazakhstan, the e3.kz model was developed jointly with Kazakh partners to assess the macroeconomic impacts of climate change and adaptation measures. The e3 framework was an appropriate choice, as an IO model is already maintained by the implementing partner Economic Research Institute (ERI) (GIZ, 2022b). Scenario analysis conducted with e3.kz made use of baseline

scenarios developed for Kazakhstan's Low Emission Development Strategies (LEDS) project. To overcome data gaps, CRED initiated efforts to collect data on extreme weather event damages, establishing communication with various state agencies and sub-national authorities. Climate hazard analysis, priority sectors (i.e. agriculture, energy and infrastructure) and adaptation measures were selected through consultations including Kazakh partners ERI, Zhasyl Damu. Key hazards assessed include droughts; heat waves; extreme precipitation; extreme winds. CRED achieved several mainstreaming successes in Kazakhstan, as newly adopted Low Emission Development Strategy (LEDS) contains a chapter on adaptation based on e3.kz results and e3.kz model has been recommended to be applied in Kazakhstan's roadmap for NDC and adaptation planning. Finally, e3.kz model ownership has also been transferred to national partners.

In Vietnam, CRED developed a dynamical general equilibrium model (DGE) in order to assess the macroeconomic effects of climate change and adaptation. Initial activities involved interactions with the implementing partner, the Ministry of Planning and Investment (MPI) and other national stakeholders and experts, including the Ministry of Agriculture and Rural Development's (MARD) in order to identified available economic data for the DGE-CRED in regions and sectors of interests. Key climate hazards evaluated by DGE-CRED are: temperature increase; forest fires; storms; sea-level rise; landslides. Adaptation measures analysed in the agricultural, housing, forestry and transport sectors. CRED activities successfully raised awareness on adaptation in Vietnam and filled a major gap in the policy analysis toolkit. Future plans include applying regionalised DGE-CRED to provincial action plans for the Vietnam Green Growth Strategy (VGGS), while work to regionalise the model is already underway. Finally, ownership of the DGE-CRED model was officially transferred to CIEM.

In Mongolia, CRED has developed a prototype e3.mn model, with data largely from international sources, and an accompanying e3.mn manual. Further, a 3-day training module was conducted with Mongolian stakeholders both on technical aspects and application of modelling results to salient policy questions. The prototype and training modules are presented in a general way that illustrates the applicability of the e3 approach to different national contexts.

Stakeholders' perspectives in all pilot countries were positive across the three CRED pillars of model development, trainings, and advisory services. Regarding **model development**, pilot country partners emphasised CRED's impact on raising awareness of the economic costs of climate change and the benefits of investing in adaptation. Economic assessment of climate change and adaptation were lacking in pilot countries prior to the CRED programme, and CRED activities successfully brought in sectoral CBAs of adaptation measures to policy discussions, and often provide the first national level assessments of the macroeconomic effects of climate change and adaptation measures. Further, other macroeconomic outcomes analysed by the CRED models were also seen as highly salient to a range of national stakeholders. For instance, analysis of labour effects increased policy interest in adaptation for national line ministries and policymakers. Key challenges regarding the modelling development were common across the pilot countries and involve data collection on climate damages and adaptation benefits.

Regarding **capacity building,** stakeholders emphasised CRED's strengthening of inter-ministerial communication in the public sector. This was particular emphasised in Georgia and Kazakhstan, whereas in Vietnam where the project was comparative smaller, it had less impact in this respect. In Vietnam, it was emphasised that trainings be tailored to the technical level of participants, which is particularly important in the regionalisation of the model and involvement of provincial level stakeholders.

Regarding **future plans**, all pilot countries have plans to work future with their CRED model in policy and planning. **In Georgia**, improving the energy sector modelling to enable policy and long-term strategy development is a prioritised next step. Further, MEPA plans to apply e3.ge in the NAP process, which is expected to be launched in 2023. The e3.ge model may also be used in the preparation of the 5th National Communication to the UNFCCC. **In Kazakhstan**, project partners plan to develop a Road Map for implementing adaptation based on the Adaptation Chapter in the Low Economy Development Strategy (LEDS) that is based on CRED results. Related to this, a more detailed regionalisation of the e3.kz model is being development, which may be completed by Spring 2023. **In Vietnam**, the project partner MPI plans to extend the DGE-CRED model by, first, including more sectors and industries, and second, improving sectoral CBAs with further data collection on climate damages and adaptation measure effectiveness. Further, MPI envisions using the model to support the development of Vietnam Green Growth Strategy (2021-2030) through detailed sectoral analysis to support the development of Road Maps at the provincial level.

Stakeholder's desired extensions of CRED activities are similar across several pilot country. First, extending the modelling to further sectors was identified as a desirable extension across all pilot countries. Second, regionalisation of the models was also expressed as a desirable extension of CRED activities across the pilot countries. Third, there is interest in extending the CRED approach to enable a more detailed analysis of distribution outcomes of adaptation, and particularly, the impact of climate change and adaptation on poverty.

In terms of **assessing the CRED approach**, this report emphasises **several strengths**. First, CRED provides policy-makers with a broad picture of economic impacts of climate change and adaptation measures, addressing a major knowledge gap in developing countries. Often the CRED approach represents the first systematic attempt quantify the economic costs of climate change and adaptation in its partner countries. CRED activities thus raise awareness among key national stakeholders on climate change and the importance of investing in adaptation. Second, CRED activities often initiate systematic data collection processes, which generally require cooperation between different ministries and departments. These interactions improve decision-making and policy and have the potential to be institutionalised beyond the CRED intervention. Third, the CRED approach provides a framework for prioritising adaptation measures for investment. Macroeconomic analysis provides a basis for comparing adaptation measures across different sectors and prioritise these, which is a fundamental challenge in adaptation and NAP development.

Challenges also arose for CRED implementation. First, ensuring that modelling approach and training activities are fit for purpose across different country context has proven challenging. Despite the flexibility of incorporating different modelling approaches, addressing this challenge requires

analysis of a country's data availabilities and technical capacities at the outset of the CRED intervention. Second, building political support and identifying entry-points into policy processes is challenging, yet also essential to ensure that CRED results are taken up in policy. Addressing this challenge involves well designed and managed stakeholder interactions, which requires upfront investments in building relationships in partner countries. Finally, the CRED approach is confronted with challenges of uncertainty that are inherent to long-term decision-making and macroeconomic forecasting. The implication of these uncertainties is that adaptation planning must include space for revisiting and revising adaptation measures and monitoring their contributions to macroeconomic outcomes at regular intervals. Further, this also lends greater importance to ensuring that measures also have (large) positive benefit-cost ratios in the sectors they directly affect and are well aligned with other social and economic development goals.

Regarding **recommendations for future applications** of the CRED approach, the report first suggests how implementation bottlenecks can be overcome. First, explicit assessment of the training and capacity needs in country at the outset of activities is recommended, particularly when sub-national stakeholders are also involved. Second, sharing of experiences, challenges, and best practices between CRED partner countries from the outset of the interventions is recommended. Third, in developing Working Groups on intersectoral adaptation it should be consider how to include other actors beyond national ministries, e.g. universities and civil society organisations, to increase awareness and social acceptance of adaptation measures.

Finally, this report identifies 4 key issue areas to which future applications of CRED could make substantial contributions. A first issue area is analysis of **fiscal impacts of climate change and sovereign risk**. Sovereign risk is a highly salient issue for climate resilient development because a country high levels sovereign risk can restrict governments' access to credit or financial markets. While central bank monetary policy can address these risks, Integrated Assessment Models (IAM) employed to estimate the impact of climate change on growth rates are not precise enough for monetary policy decision. There is a call for an alternative way forward for integrating climate change into central bank decision-making is through detailed, and spatially disaggregate modelling approaches, which CRED is well positioned to address.

A second issue area is analysis of **co-benefits of Nature-based solutions (NbS)**. NbS are being advanced around the world as a measure that can reduce climate risks, while addressing the biodiversity crisis and generating social and economic co-benefits. To date, however there is a lack of research on the macroeconomic effects of NbS. This is a salient knowledge because NbS can address climate policy objectives, and yet also have a range of other significant macroeconomic effects, e.g. on GDP and labour. CRED macroeconomic studies of NbS would potentially break important new ground that could contribute not only to planning in the country in which they are implemented but also to the wider knowledge base on NbS improving policy and decision-making on NbS around the world.

A third issue area is analysis of **Loss and Damage from climate change**. To date, the Loss and Damage policy discussion has largely been informed by IAMs assessing financial stability in developed countries. In developing countries, L&D discussions are higher on the policy agenda,

particularly considering recent COP27 decisions on the Loss and Damage financial mechanisms. Extending the macroeconomic assessments of the economic costs of climate change in the CRED approach could thus attract high policy interest in developing countries.

A fourth issue area is analysis of **Just Transitions and Long-term Strategies**. Emerging work on Just Transitions focuses labour and income distribution implications of climate policy, and the energy transition. While the labour effects of climate policies have been explored to an extent, a major knowledge gap exists regarding the distributive effects of climate policy and the energy transition on income, and these gaps are prominent in developing countries. CRED e3 models are thus well positioned to address these gaps, as they are based on Input-Output models for sectoral interaction is a core analytical focus, and further, as e3 models offer the potential to integrate mitigation and adaptation in analysis of Just Transitions.

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1. Introduction

1.1 Background

Climate resilient economic development involves creating and maintaining sustainable economic growth in the face of changing climate conditions. According to the IPCC (2022), “climate resilient development integrates adaptation measures and their enabling conditions with mitigation to advance sustainable development for all”. Climate resilient development thus involves promoting economic activities that align with the principles of sustainable development, including measures to adapt to and mitigate the impacts of climate change.

Climate change can significantly affect the economic growth and development of countries. However, as yet, there is a lack of experience and approaches around the world in regard to integrating climate risks into macroeconomic forecasts, planning and decision-making. There is therefore an urgent need for methods and tools for assessing the economic impact of climate risks and adaptation measures that can reduce these risks. Such approaches involve integrating climate data and impact scenarios with macroeconomic models in order to assess the impacts of climate change and adaptation on key aspects of social and economic development, such as, income and employment.

The Policy Advice for Climate Resilient Economic Development (CRED) project implemented by GIZ on behalf of the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV) aims to address this need by bringing national modelling authorities in developing countries together with adaptation and economic experts in Germany, in order to create long-term economic models to assess the macroeconomic impacts of climate change and adaptation measures. CRED has been implemented in three pilot countries (Georgia, Kazakhstan and Vietnam) from 2019-2023 providing extensive training for model developers and model users. These trained experts then work with authorities in their countries to enable the consideration of climate change impacts and appropriate adaptation measures in their economic planning. The project thus provides advice to ministries on applying findings from the modelling in political decision-making processes and in planning. Further, the CRED project has developed dissemination activities, by sharing project experience, developing communication materials, and conducting short trainings for experts from countries other than Georgia, Kazakhstan and Vietnam, in order to enable the use of macroeconomic models for adaptation planning beyond the pilot countries.

1.2 Objectives

This report reviews the CRED programme’s activities from 2019-2022 focusing particularly on activities in the partner countries of Georgia, Kazakhstan, Vietnam and, on the model prototype development in Mongolia. To do so, the report draws on CRED materials including national reports, policy briefs, sectoral briefs, as well as training materials that include a guidebook for practitioners and handbook for applying the CRED prototype model. Further feedback and insights have been collected through interviews with both implementing and political partners of the CRED project in the pilot countries. These interviews focused on the status of modelling with the country-specific model, future plans, capacity building needs and extension wishes as well as support needed in policy dialogue and dissemination (see Appendix for details). Finally, a brief survey of current literature on the macroeconomics of adaptation and climate change impacts provides a context for recommendations on further extensions of the CRED approach.

This report thus covers the following aspects: Current activities; Stakeholder perspectives; Strengths and weaknesses of the CRED approach; Recommendations for future work.

2. CRED Activities

2.1 Overview

The CRED project is structured along the three pillars of i) capacity building for macroeconomic modelling; ii) policy advice regarding adaptation planning and iii) dissemination of the approach to model the macroeconomic impacts of climate change and adaptation. Below, we detail the macroeconomic approach developed in order describe how adaptation is approached technically. We then discuss how the modelling developed is supported by and informs the pillars of capacity building and policy advice for mainstreaming, before reviewing current activities in the pilot countries of Georgia, Kazakhstan, Vietnam, and Mongolia.

2.2 CRED macroeconomic modelling approach

2.2.1 OVERVIEW

The CRED programme develops a macroeconomic modelling framework that can assess the effects of climate change and adaptation measures over an entire (national) economy. While different macroeconomic models can be applied (e.g. Input-Output models, Dynamic General Equilibrium), the e3 models developed through the CRED modelling framework also comprise an energy sector model, thus energy mix and CO_2 emissions can also be computed for different adaptation scenarios in order to explore implications of different policies and measures for mitigation. Assessment of climate change and adaptation effects on macroeconomic outcomes is achieved through inputting climate hazard scenarios, historical damage data on climate hazards, and information from cost-benefit analyses on adaptation measures into the macroeconomic modelling framework in order to compute the effects on, e.g. GDP, labour, as well as other macroeconomic variables of interest (see Figure 1).

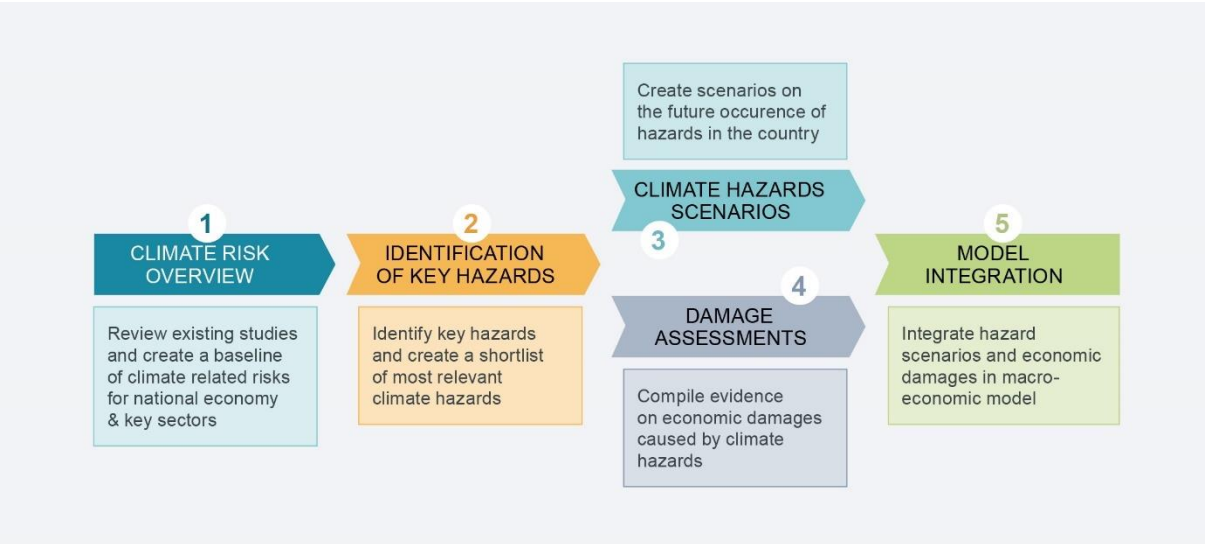

Figure 1. CRED approach to integration of climate hazard scenarios into e3 modelling framework. (Source: GIZ, 2023a)

Generally, the CRED approach is carried out through the following steps:

1. Identify climate hazards and the related impacts in affected sectors.

2. Attribute *direct* economic damages to these climate hazards though various methods including regression analysis, literature review and historical extreme event record.
3. Calculate total damages under future climate scenarios:
    a. Compute a macroeconomic *reference scenario* with no climate change and no adaptation.
    b. Compute a macroeconomic *climate change scenario* (without adaptation): Develop a climate hazard scenario, based on climate projections, climate damage data and expert assumptions regarding the future evolution of damages from extreme weather (Figure 1) and input this into the macroeconomic model. By comparing this scenario to the baseline scenario, *indirect* economic damages of climate change are computed.
    c. Compute a macroeconomic *adaptation scenario*: Develop an adaptation scenario, based on analyses and expert judgement regarding, the input requirements for the adaptation measure (i.e. cost-benefit analyses (e.g. investment costs, economic benefits from the adaptation measure) labour, imports, suitability and relevance of the measure for the national context etc.). By comparing this scenario to the climate change scenario, total *indirect* adaptation benefits are computed.

Adaptation measures are identified for different sectors based on expert consultations (see Pilot country activities below). Note that several adaptation measures can be combined into one adaptation scenario, provided there is sufficient data available. For example, in Kazakhstan, adaptation investments in the reconstruction of canals and reservoirs and drip irrigation were combined into one adaptation scenario. The data needs and potential data sources for each of these scenarios is shown in Table 1.

	Data needs	**Potential data sources**
Reference scenario	Macroeconomic data: • GDP • Imports/Exports • Price information of goods and services • Consumption of goods and services (of households, of government) • Gross fixed capital formation • Employment	National Accounts
	• Annual national input-output tables [IOT] (sectoral data) provide information on the economic relationships between suppliers and producers in the national economy.	IO tables available for 75 countries from OECD and ADB Georgia: MoESD[1]'s supply and use tables (2017-2019)
	• Economic growth forecast: expected growth rates for important economic variables • Population forecasts to 2050	National or international sources (e.g. IMF World Economic Outlook Database)
	• Occurrence of past extreme weather events and recorded economic damages	• EM-DAT database

[1] Ministry of Economy and Sustainable Development (MoESD).

Climate change scenario		• National consultants • Media reports
	• Frequency and intensity of past extreme weather events	Georgia & Kazakhstan: Climate Hazards Analyses by international consultants Navarro, J. S. & Jorda, G. (GIZ 2022a, 2022b)
	• Evolution of climate hazards under RCP 8.5 and RCP 2.6 (or relevant SSPs)	Georgia & Kazakhstan: Climate Hazards Analyses by international consultants Navarro, J. S. & Jorda, G. (GIZ 2022a, 2022b)
Adaptation scenario	• Estimated *direct* costs and other inputs of adaptation measures (e.g. investment costs, labour needs, imports, etc.)	• National statistics (e.g. crop statistics) • Expert judgement • Scientific literature
	• Estimated *direct* monetary benefits of adaptation measures, e.g. reduced damages, increased productivity	• National statistics (e.g. crop statistics) • Expert judgement • Scientific literature

Table 1. Data needs and potential sources for e3 modelling approach. (Source: adapted from GIZ (2022b))

To include adaptation measures in the analysis, a description of a measure's *direct* costs and benefits (i.e., avoided damages from climate hazards or slow on-set events) is needed, as well as other relevant information, e.g. investment costs, labour inputs, import requirements, etc. A measure's adaptation benefits are calculated as the avoided climate-related economic damages from measure, which are derived from the historical record, as well as expert judgement on the effectiveness of measures.

Key challenges here arise from a lack of systematically collected data on damages from weather related extremes in many countries. Often CRED data collection initiatives in pilot countries to address these gaps has led to greater cooperation among public and private stakeholders, raising awareness on adaptation and possibly leading to the institutionalisation of systematic data collection on climate-related data (GIZ, 2022a). Such institutionalisation would be a significant co-benefit of the CRED activities that can support effective policy beyond the lifetime of the specific project activities (see Country activities below).

To calculate the total effects of an adaptation measure, the direct effects of the adaptation measures are input into the macroeconomic model. The CRED approach is compatible with different macroeconomic modelling approaches. One commonly applied approach to assess economic risks from climate change to date are Input-Output (IO) models. The approach has also been adopted in Georgia (e3.ge) and Kazakhstan (e3.kz). A dynamic general equilibrium (DGE-CRED) model has been developed in Vietnam (see Section 2.4 for details). With the input of the direct effects of adaptation measures, the macroeconomic model computes the aggregate macroeconomic effects of the measure(s), in terms of macroeconomic variables, such as, GDP, labour impacts, as well as energy sector impacts, e.g. CO_2 emissions. By comparing the aggregate effects of the scenario including adaptation with the climate change scenario without adaptation, the aggregate macroeconomic effects of adaptation are calculated for a given climate scenario. An example of macroeconomic results of adaptation measures for an irrigation measure in Kazakhstan computed with the e3.kz model is shown in Figure 2.

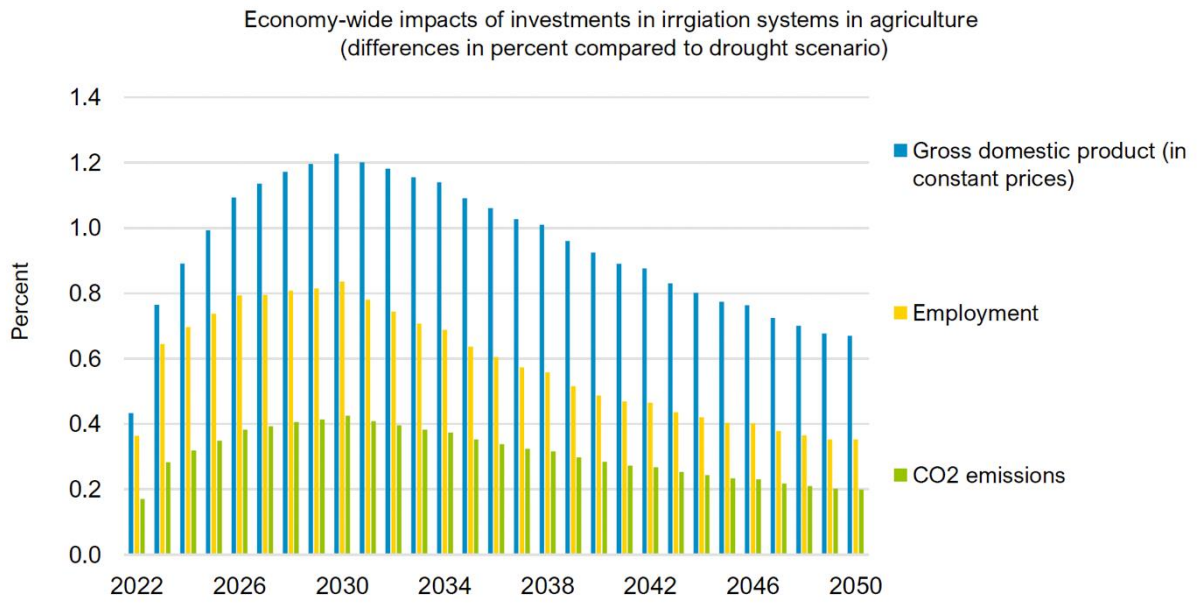

Figure 2. Example results for irrigation system adaptation measure in Kazakhstan. (Source: GIZ, 2022b).

Finally, it is important to note that, for mitigation, climate change impacts may reduce carbon emissions because of reduced economic growth. Conversely, adaptation that is effective and thus leads to increased growth can increase carbon emission without accompanying changes in the energy sector (e.g., shifting towards a greater share of renewables). This can lead to important trade-offs between mitigation and adaptation measures, which can be also explored through the CRED modelling framework in the case of the e3 models. Importantly, adaptation measures that involve carbon sinks (e.g., planting of trees for wind breaks) can sequester emissions, thus contributing to both adaptation and mitigation objectives.

2.3 CRED capacity building and advisory activities

2.3.1 CAPACITY BUILDING OF NATIONAL PARTNERS

Capacity building in the CRED project has been implemented in several phases and tailored to the needs of the partner countries. Training modules have been developed for different aspects of the CRED approach including, climate hazard analysis and monetisation of damages through, e.g., regression analysis, as well as climate and adaptation scenario analysis, implemented through an Dynamic Input-Output Model in Microsoft Excel (DIOM-X) with supplements in R in the case of Georgia and Kazakhstan; and a Dynamic General Equilibrium Model using Matlab in the case of Vietnam.

In each pilot country, different stakeholders are active and have differing levels of knowledge and capacity regarding climate impacts and adaptation, and their relation to macroeconomic forecasting. Therefore, an assessment of stakeholder needs and interests in the pilot countries at the outset of project was needed to inform capacity building activities. An overview of the capacity building activities in the project activities is given in Figure 3 below.

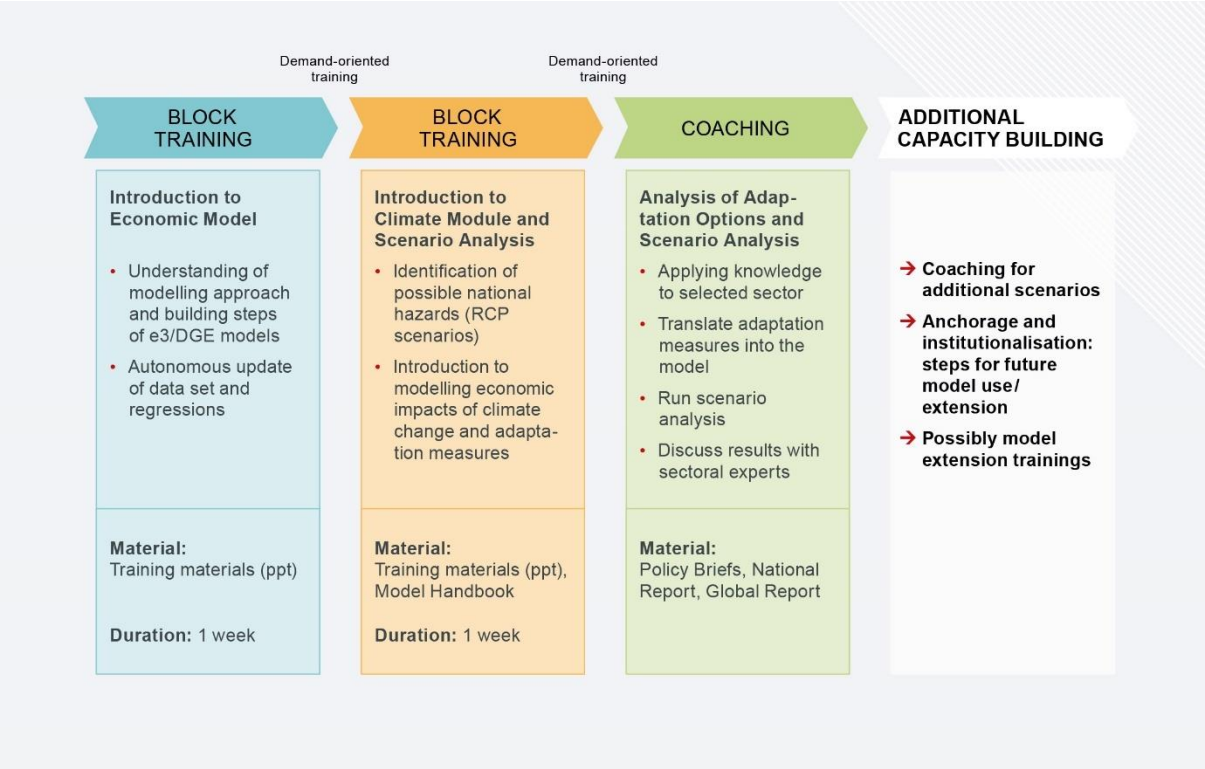

Figure 3. Overview of modelling capacity building and coaching activities for CRED partner countries. (Source: GIZ, 2023a)

CRED's subcontractors, including the Institute of Economic Structures Research (GWS) and the Halle Institute for Economic Research (IWH), conduct trainings in each of the pilot countries. First trainings introduced the economic models and underlying data sets. A second training focused on applying the models for analysing the economic effects of climate change and adaptation. Across all trainings, a differentiation was made between technical model development focus and model applications to policy questions. The latter focus of the trainings was for 'model users', who are identified experts that were envisioned as being able to apply the models for policy analysis and advice, without requiring the programming and coding skills to develop the economic model (GIZ, 2023a). Trainings focused both conceptual and technical aspects of model development in order to equip participants with the knowledge needed to interpret climate change and adaptation scenario results.

Due to restrictions related to the COVID-19 pandemic, trainings were adapted in order to accommodate the need for model building trainings and coaching to be conducted remotely. This was achieved by the CRED program through establishing digital exchange rooms based on Microsoft Teams (GIZ, 2023a). The trainings thus provided a platform for participants from a range of public and private stakeholders, i.e. ministries, research institutes, universities and think tanks, to exchange data, and share their experience and knowledge. These exchanges thus promoted capacity building in partner institutions on both macroeconomic modelling and knowledge management for assessing climate change and adaptation (GIZ, 2023a).

Capacity building and trainings then increased in detail and complexity in tandem with the further development of the economic models over the course of the project. This step-by-step approach of starting with a simple modelling framework is appropriate to ensure that both modelling and training activities are fit for purpose in the partner countries. As discussed below (Section 3.5), future plans in the partner countries aim to build on

this CRED approach adding further regionalisation to the models, e.g. in Vietnam and Kazakhstan, and designing subsequent trainings appropriate to the stakeholders at these sub-national levels.

Finally, a key pillar of CRED approach to building capacity in partner countries is the transfer of ownership of the respective country-specific macroeconomic model to the CRED partner institutions. This promotes an institutionalisation of knowledge and capacity for macroeconomic analysis of adaptation within the partner countries themselves.

2.3.2 POLICY ADVICE AND MAINSTREAMING

CRED's policy advice and mainstreaming activities aim to bring results of macroeconomic modelling of climate change and adaptation into national and sectoral policy-making and decisions. Policy advice activities have produced various knowledge products for pilot countries, e.g., Policy Briefs, Infographics, Country Reports on adaptation. CRED knowledge products communicate modelling results on the potential economic costs of climate change and the macroeconomic effects of investing in adaptation. These materials have been an important tool for raising awareness of key stakeholders (e.g. line ministries) on the urgency of adaptation (see Section 3 below.)

Second, policy advice activities have also resulted in concrete mainstreaming outcomes, whereby national policies in pilot countries have included CRED results. Table 2 gives an overview of the key policy documents in the pilot countries being based on CRED results.

Pilot country	Policy document	CRED contribution	Status
Georgia	National Adaptation Plan (NAP)	Plans to apply e3.ge modelling in NAP development	Launch of NAP planned for 2023
Kazakhstan	Low Emission Development Strategy (LEDS)	Chapter on Adaptation based on CRED results	Adopted
	Environmental Code	Section on Adaptation	Adopted
Vietnam	Vietnam Green Growth Strategy (VGGS)	Plans to apply regionalised DGE-CRED to provincial action plans for VGGS	Ongoing

Table 2. CRED policy mainstreaming activities.

2.4 Country-specific activities

2.4.1 GEORGIA

CRED activities represent the first attempt in Georgia to address adaptation in a cross-sectoral perspective and analyse adaptation effects in a macroeconomic framework. While some sectoral cost-benefit analysis (CBA) of adaptation measures had been conducted prior to CRED, existing analysis of adaptation measures lacked information on GDP and labour effects of measures, and cross-sectoral impacts of adaptation measures. Further, adaptation analysis had largely only addressed the agricultural sector. CRED activities filled these gaps.

In Georgia, the e3.ge model assesses macroeconomic impacts of climate change and adaptation measures. The e3.ge model combines demographic and macroeconomic forecasts, with climate scenarios, and an Input-Output model developed with national accounts data provided by MoESD, to develop scenarios that compute macroeconomic impacts of climate change and adaptation measures. Climate scenarios and projections of future evolution of hazards are based on analysis by the University of the Balearic Islands and expert judgement for issues not resolved by global climate projections, e.g., on the future development of windstorm intensity.

Adaptation measures analysed with e3.ge are shown in Table 3. These measures were chosen for analysis through working groups described below and addressed the agriculture and tourism-related sectors. Currently, the model computes scenarios of macroeconomic impacts of single climate change hazards and adaptation measures, although provided sufficient data is available (e.g. effects of the joint implementation of adaptation measures) multiple adaptation measures can also be analysed (GIZ, 2022a).

Adaptation measures	Climate change impact	Economic sectors affected
Irrigation systems	Severe droughts	Agriculture
Wind breaks	Extreme wind	Agriculture
(Re-)construction of coastline protection	Sea-level rise	Tourism related sectors
Climate-resilient roads and bridges	Heavy precipitation	Tourism related sectors

Table 3. Adaptation scenarios analysed in e3.ge. Source (GIZ, 2022a).

Stakeholder consultations in Georgia were focused on the two key partners, the Ministry of Environment and Agriculture (MEPA), Georgia's climate adaptation focal point, and the Ministry of Economy and Sustainable Development (MoESD). During the stakeholder consultations the policy and sectoral focus of CRED activities were discussed to select key sectors to prioritise in CRED analysis. Participants included key government stakeholders, primarily from MEPA and MoESD. The modelling approach and results were presented and discussed in sectoral policy workshops. Coaching sessions were offered to model builders, which focused on modelling activities, including model development and capacity building.

CRED activities were largely successful in raising awareness of the need to invest in adaptation across different national line ministries, as the results provided the first quantitative economic analysis of adaptation in Georgia.

Moreover, the CRED approach was attractive due to the perceived need to analyse complementary policies, i.e. in other sectors, and take a cross-sectoral approach to adaptation. Further, as CRED modelling results were in line with other models used in the country, which promoted confidence in the results. There are thus plans to further build upon the CRED results, for example, in the commitment to mainstream CRED results into NAP development (see Table 2, and Section 3.4 below). Further, the e3.ge model was also applied to evaluate the impact of the COVID-19 pandemic and the Russian war in Ukraine on the national economy.

Challenges emerged regarding model development, capacity building and policy advice. Concerning model development, a first key challenge was the lack of existing data on extreme event damages. To address this, CRED initiated processes for data collection, promoting cooperation between ministries and with private sector stakeholders. Indeed, national government stakeholders in Georgia itself were best positioned to address data collection issues, and CRED sparked exchanges and systematic data collection that hold the potential to establish institutions, data sharing protocols, etc. that last beyond the lifetime of project. A second challenge for model development was the technical task of including a detailed energy sector in the model in order to evaluate mitigation measures and their potential trade-offs with adaptation. Addressing this has led to delaying the inclusion of CRED results in the Georgian Green Growth Strategy. Integration of the energy sector is currently being explored in the country (see Section 3.5 below).

For capacity building, challenges emerged due to the COVID-19 pandemic, as restrictions made it difficult to hold in-person trainings, delaying activities. For policy advice, coordination challenges between different national and international stakeholders leading to delays in mainstreaming adaptation into key policy processes. For example, while the CRED analysis is planned to underpin NAP development, the NAP process has not yet started, having been delayed multiple times by international donor funding the process. Despite these challenges, there are several plans to build upon CRED activities (see Section 3.4). Figure 4 proposes possible institutional arrangements on the application of the e3.ge model for climate adaptation planning in Georgia. As stated in the figure, MoESD's Economic Analysis and Reforms Department holds the official ownership of the e3.ge model.

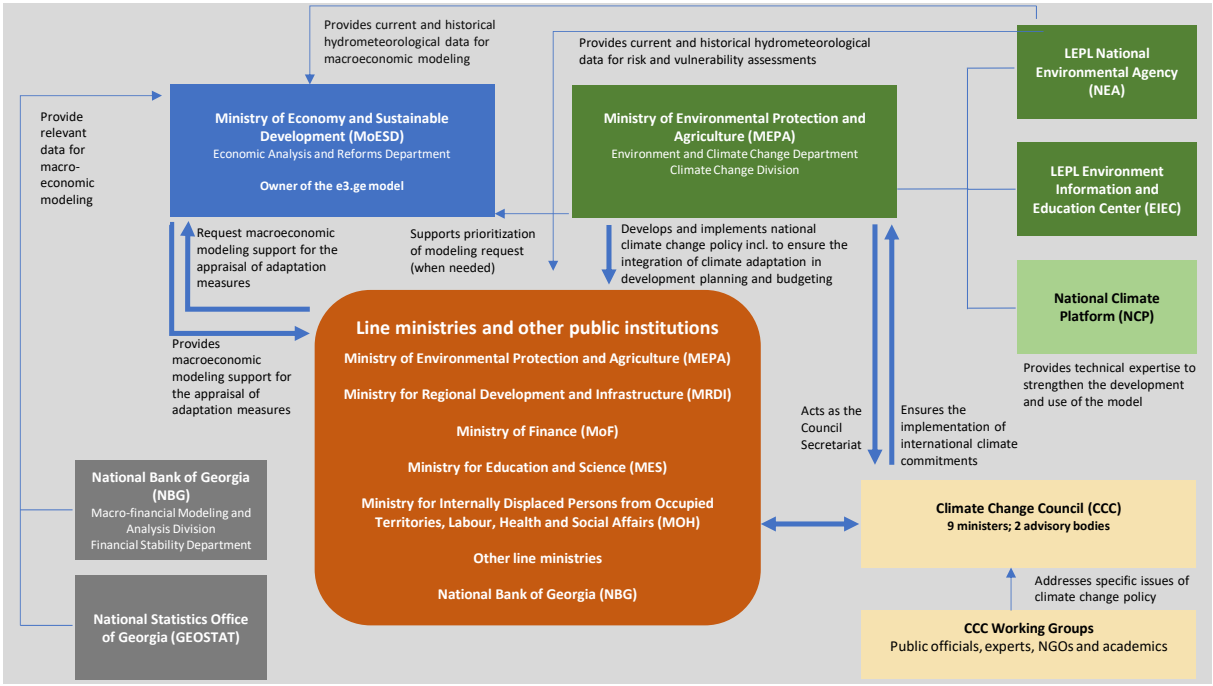

Figure 4. Institutional arrangements for climate change in Georgia. Source (GIZ, 2022a).

2.4.2 KAZAKHSTAN

In Kazakhstan, the e3.kz model was developed jointly with Kazakh partners to assess the macroeconomic impacts of climate change and adaptation measures. The model computes scenarios of macroeconomic impacts of climate change hazards and adaptation measures, by combining demographic and macroeconomic forecasts, with climate scenarios, and an Input-Output (IO) model (see Figure 5). The e3 framework was an appropriate choice, as an IO model is already maintained by the implementing partner Economic Research Institute (ERI) (GIZ, 2022b).

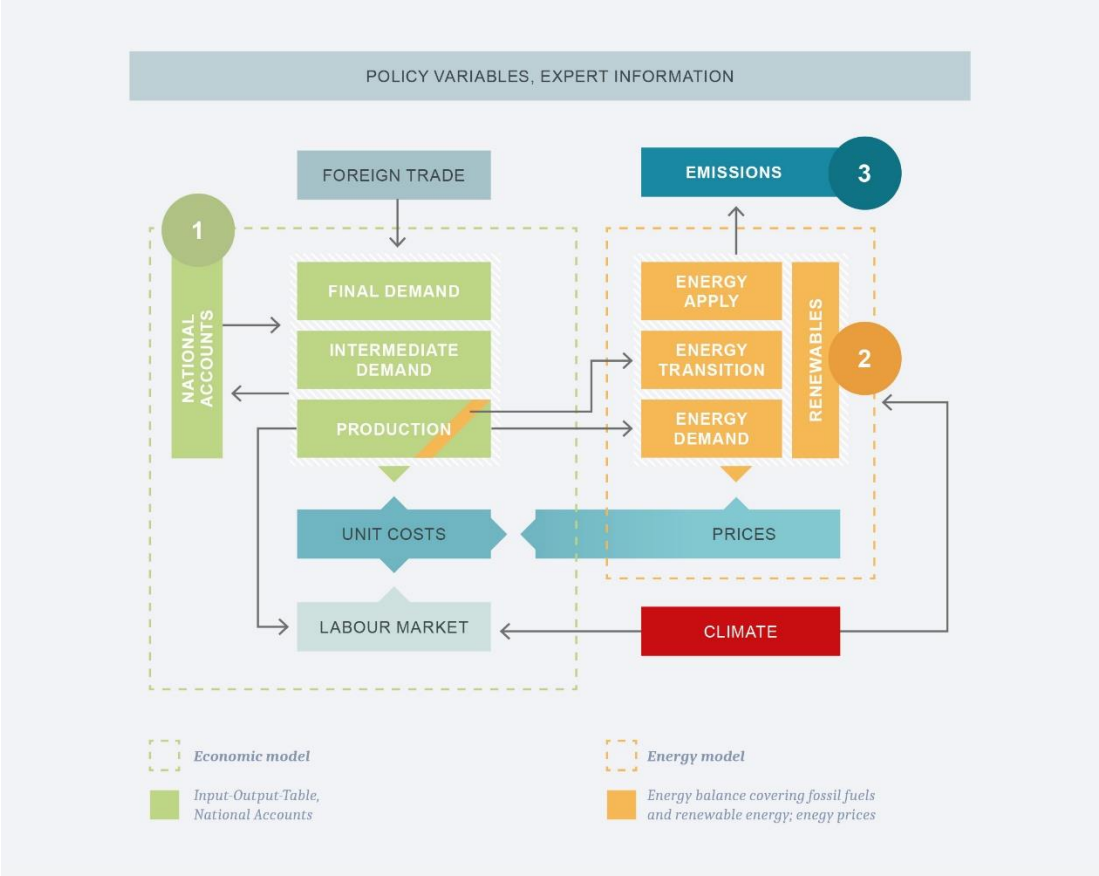

Figure 5. e3.kz model overview. Source: (GIZ, 2022b).

In developing the model, CRED initiated efforts to collect data on extreme weather event damages, for which official methods in Kazakhstan had been lacking. The gaps and inconsistencies in economic data on climate-related event damages was a major hurdle to CRED modelling. To overcome this, communication with various state agencies was established, e.g., Kazhydromet, Committee of Emergency Situations, as well as the Ministry of Agriculture and sub-national level authorities for drought-related data. Data collected through these channels was supplemented by review of media and scientific literature to develop extreme weather event damage data that could be used to develop climate change and adaptation scenario analysis in e3.kz.

Climate change and adaptation impacts are calculated with respect to a reference scenario that reflects expectations about the future economic development in the absence of climate change, which is based on the Business-As-Usual scenario developed for Kazakhstan's Low Emission Development Strategies (LEDS) project. The LEDS objective is to support Kazakhstan's transition to climate neutrality by 2060, and develops GDP growth pathways, energy demand and supply scenarios, which are used in the e3.kz modelling.

Climate scenarios are developed based on RCP 2.6 and RCP 8.5 and supplemented with assumptions developed through expert consultations on the future evolution of specific hazard intensity and frequency in Kazakhstan. Further, the identified climate damages are translated into model parameters, as climate damages effect both the economy and energy modules (see Figure 5). Thus, climate impacts are translated into the model as effects on human behaviour (e.g., household consumption and expenditure), production factors (e.g. employment, prices, intermediate demand, etc.) and infrastructure (see GIZ (2022b) for details). Key hazards assessed include droughts; heat waves; extreme precipitation; extreme winds.

Climate hazard analysis, priority sectors (i.e. agriculture, energy and infrastructure) and adaptation measures were selected through consultations with Kazakh partners ERI, Zhasyl Damu as well as other experts and were supplemented by literature review. A prerequisite for selecting a measure to analyse was that a CBA for the measure (nationally or sectoral) was available, and showed positive benefit-cost ratios.

CRED activities were largely successful in raising awareness on adaptation, as e3.kz modelling showed several important results for adaptation policy. Generally, the adaptation measures assessed showed positive results for GDP in the RCP 8.5 scenario, compared to a baseline with no climate change (GIZ, 2022b). Further, measures that supported the domestic economy, i.e. relying to a lesser extent on imports, showed higher employment gains, which was a key issue for many stakeholders (see Section 3). Finally, the modelling assumed that all funding came from domestic sources. If international climate finance were mobilised to finance adaptation measures, the macroeconomic outcomes would be even more positive.

CRED achieved several mainstreaming successes in Kazakhstan (see Table 2). First, the Low Emission Development Strategy (LEDS), adopted in early 2023, contains a chapter on adaptation based on e3.kz modelling results. Second, the e3.kz model has been recommended as a policy supporting tool in Kazakhstan's roadmap for NDC and adaptation planning. Third, the Environmental Code also now contains a section on adaptation, which can also be attributed to the raised profile of adaptation in the country due to CRED activities.

Finally, it should be noted that e3.kz model ownership has been transferred to national partners, e.g. ERI. This facilitates potential extensions of the modelling that are currently being implemented or considered, including a regionalisation of the e3.kz and an extension of the energy module (see Chapter 3.5 below).

2.4.3 VIETNAM

In Vietnam, the CRED approach comprised the development of dynamical general equilibrium model (DGE) in order to assess the macroeconomic effects of climate change and adaptation. In contrast to the computable general equilibrium (CGE) modelling framework used to address many national policy questions in Vietnam, the DGE framework is able to integrate climate change impacts, and further provides greater sectoral detail needed to represent various adaptation measures. The DGE-CRED model was thus used to calculate the macroeconomic climate change costs and adaptation benefits in Vietnam, and further provide input into the development of the Vietnam Green Growth Strategy (VGGS) and its action plan.

In contrast to IO models, which are macro-econometric models that develop relationships between different sectors based on historical national accounts data, DGE models use representative optimizing agents to assess the impact of different policy measures (see Figure 6). The DGE-CRED model develops 6 economic regions in Vietnam allowing to spatially differentiate climate hazards between the regions and analyse how different sectoral productivities evolve under varying climate conditions (GIZ, 2023b).

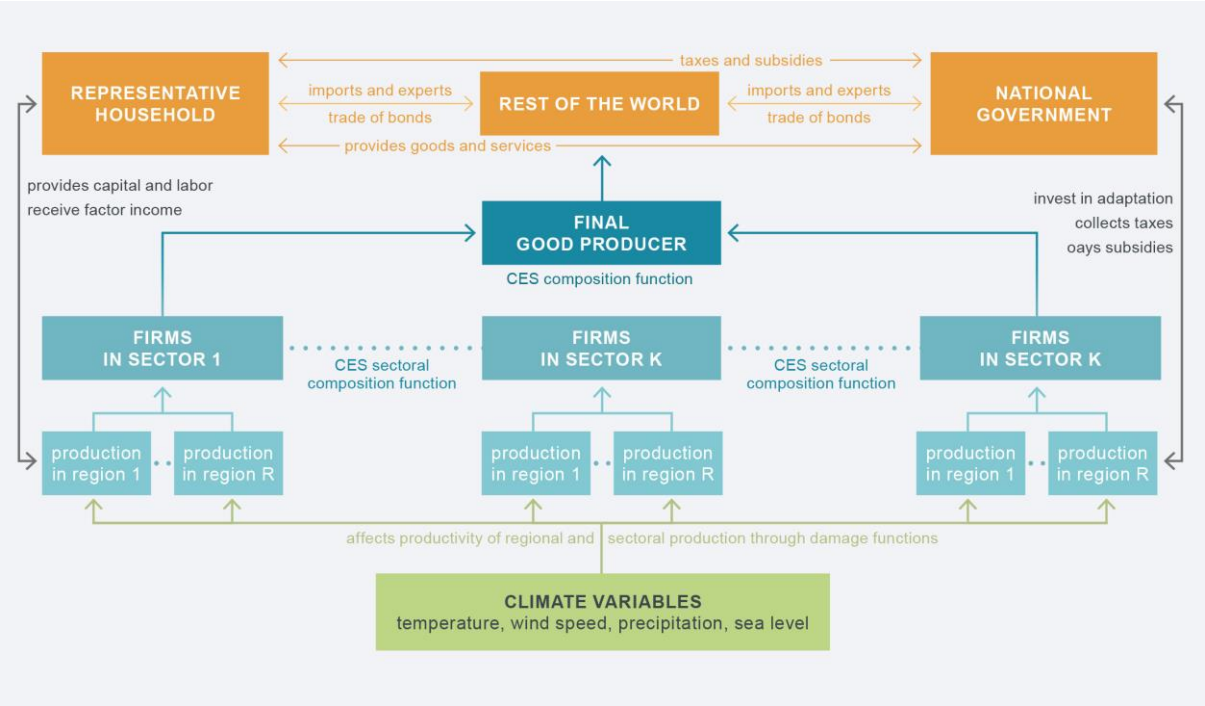

Figure 6. DGE-CRED model developed for Vietnam. (Source: GIZ, 2021b).

The first stage of activities involved stakeholder interactions with the implementing partner, the Ministry of Planning and Investment (MPI) and other national stakeholders and experts. CRED has also facilitated stakeholder discussions in Vietnam with the Ministry of Agriculture and Rural Development's (MARD), and this also led to the Green Growth Action Plan benefitting from preliminary modelling results in the agricultural sector.

Another key aspect of this first stage was the identification available data for the DGE-CRED model including economic variables such as output, prices, or employment levels in the different Vietnamese regions and sectors of interests. Much of the required data was collected from national experts and government statistics sources. However, data gaps also emerged with respect to economic, climate and adaptation variables and thus available data had to be supplemented with assumptions based on expert judgement and literature review.

To assess climate change impacts, the model uses sector and regional damage functions that represent a relationship between climate hazards (i.e. weather extremes) and labor and capital productivity. Climate hazards thus impact production at regional and sectoral levels in the model (GIZ, 2023b). Climate scenarios are developed based on IPCC Shared Socioeconomic Pathways (SSP) scenarios representing low, medium and high global emissions pathways that can be used to project changes in climate variables at a regional level in Vietnam until the end of the 21st century. To compute the macroeconomic impacts of climate change, the DGE-CRED model compares the macroeconomic outcomes using these climate scenarios to the macroeconomic outcomes using baseline scenario that assumes that no climate change. The key climate hazards evaluated in the scenario analysis are: temperature increase; forest fires; storms; sea-level rise; landslides.

To assess adaptation measures, the DGE-CRED model can also include adaptation measures for sectors and compare the impacts of these under climate change scenarios to climate change scenarios with no adaptation, along macroeconomic dimensions such as, consumption, investments, government expenditure, net exports, housing expenditures and GDP. Adaptation measures analysed in the agricultural, housing, forestry and

transport sectors. The design of adaptation measures in the model were based on reports of national experts, which however also presented challenges for translating and implementing in the model (GIZ, 2023b).

Of the evaluated adaptation measures dike system upgrades was the only measure able to substantially reduce climate damages, although all measures evaluated were able to reduce economic damages in excess of their costs. One further interesting result was that some adaptation measures actually reduced GDP and investment in the short term because avoided damages, e.g. avoided flood losses from building a sea-wall, reduced economic activity for reconstruction. However, the same measures led to high consumption for households illustrating that a range of macroeconomic indicators beyond only GDP are important for evaluating adaptation measures (GIZ, 2023b).

CRED activities in Vietnam were also successful in raising awareness on adaptation and filled a major gap in the policy analysis toolkit by providing a macroeconomic model that could integrate climate change and adaptation effects. CRED was however a relatively small-scale intervention in Vietnam compared to other climate initiatives in the country (mainly led by the Ministry of Natural Resources of Vietnam) and thus has not yet achieved concrete policy mainstreaming results. However, a positive outcome are the plans to apply regionalised DGE-CRED to provincial action plans for VGGS, as the DGE-CRED is perceived as an appropriate tool for the detailed regional analysis required for developing these action plans. Further work is also ongoing to regionalise the model, which will also increase the ability of the DGE-CRED model to support regional and provincial adaptation planning (see Section 3.4). Ownership of the DGE-CRED model was officially transferred to CIEM. CIEM will apply the model on behalf of MPI for regional planning.

2.4.4 MONGOLIA

In Mongolia, CRED has developed a prototype e3.mn model for the country that, similar to the general CRED framework applied in other pilot countries, can address the questions:

- What could be possible economic impacts from climate change?
- Which adaptation measures help to reduce the economic risks of climate change?

The e3.mn prototype provides environmentally extended economic models in combination with scenario analysis that enables (GIZ, 2022c):

- Evaluation of the impacts of climate change (“climate change scenarios”)
- Evaluation and comparison (sets of) policies (“climate change adaptation scenarios”)
- Detection of not only direct but (unwanted) feedback effects
- Exploration of benefits and trade-offs of policies

Accompanying the prototype is a fully elaborated e3.mn manual that provides detailed guidance on developing and using the model (GIZ, 2022c). Further, a 3-day training module was conducted with Mongolian stakeholder to provide initial support both on technical aspects of model development and application of the modelling results to salient policy questions. The training modules cover scenario development for baseline, climate change, and adaptation scenarios implemented in the model’s Excel based framework (DIOM-X). The training covered a number of key conceptual issues in economic analysis of adaptation including inputs (i.e. data or assumptions) needed for the adaptation scenario development, including future evolution of extreme event frequency and intensity; and the effectiveness of adaptation measures assessed; and costs of the adaptation measures. Further, the training provided technical guidance on, for example, how to generate climate damage functions through regressions implemented in R programming language.

The e3.mn prototype has to date been developed with data largely based on international sources (GIZ, 2022c). The prototype and the accompanying training modules are presented in a general way that illustrates the applicability of the e3 approach to different national contexts for analysing adaptation. Using the e3.mn prototype model, short virtual trainings with a duration of two and four hours were offered to experts interested in the approach of modelling the macroeconomic impacts of climate change and adaptation investments serving the aim to promote a broader application of the CRED approach. The prototype and training materials thus provide useful dissemination materials for demonstrating the relevance of the approach to other potentially interested developing countries.

3. Stakeholder perspectives

3.1 Overview

Overall, stakeholders in all pilot countries view the CRED programme's work positively in terms of advancing adaptation work through its model development, trainings, and advisory services. In all three pilot countries, plans are in place to further work with the model and extend it for use with key policy questions in the country (see Section 3.5.). Challenges encountered were also common across the three countries. We discuss these perspectives with examples from each country below.

3.2 Model development

Regarding the modelling development, pilot country partners were similarly very positive regarding its ability to raise awareness regarding the economic costs of climate change and the benefits of investing in adaptation. Across all three pilot countries, there was a lack of economic assessment of climate change costs or adaptation prior to the CRED programme. CRED activities were successful in bringing not only sectoral CBAs of adaptation measures into policy discussions, but also often providing the first national level assessments of the macroeconomic effects of climate change and adaptation measures. In Georgia, for example, e3.ge modelling results were seen to strengthen both cross-sectoral adaptation policy efforts as well as in the key sectors of agriculture and infrastructure, as they provided credible quantitative insights on the economic costs of climate change, and the macroeconomic benefits of investing in adaptation. As CRED results are quantitative and research-based, they were perceived as credible supplementary evidence by line ministries, providing arguments for acting on adaptation.

Further, other macroeconomic outcomes of adaptation analysed by the CRED models were also seen as highly salient to a range of national stakeholders. In particular, analysis of the labour effects of adaptation measures was of high interest to public stakeholders, e.g., in Kazakhstan. Labour effects analysed in the modelling results were seen to increase policy interest in adaptation for national line ministries and policymakers.

Key challenges regarding the modelling development were common across the pilot countries and involve data collection on climate damages and adaptation benefits.

3.3 Capacity building

Another perceived strength of the CRED approach reported by stakeholders, in addition to the model development itself, was the strengthening of inter-ministerial communication in the public sector. In Georgia, for example, stakeholders reported that CRED activities brought together various line ministries, the National

Bank of Georgia, and the Ministry of Economy and Sustainable Development, in constructive dialogues on climate change policy, as well as, on data sharing required by the project. The CRED programme thus helped to re-establish and solidify connections, for example, between stakeholders of the same university cohorts, that had otherwise relatively little contact with one another.

In contrast to that CRED's capacity building activities in Vietnam had different impacts. Compared to other activities, e.g., the VGGS elaboration, CRED activities were relatively small. Thus, the impact in terms of building relations and inter-governmental interactions was not yet seen as very significant. However, there is a larger potential for building relationships between stakeholders at the national level, and between national and regional or provincial levels, particularly if the CRED model is applied to develop the Road Maps for the VGGS.

In Vietnam, a first course in the capacity building stream was aimed at experts with technical knowledge and was thus less applicable for policy-focused partners. The MPI partner suggests that future trainings assume a lower level of technical knowledge, particularly for courses conducted at the provincial level.

Provincial level trainings are worthwhile given the need to develop provincial level Road Maps for the VGGS. Design of these trainings should however take account of particular circumstances and needs. At the provincial level in Vietnam, awareness of climate change is low, and there is a need to explain for users, the very fundamental question of why adaptation should be considered at all, and to do so in non-technical language. Further, allocation sufficient travel and time resources for provincial level stakeholders is important, given that internet connectivity issues are likely to limit the effectiveness of online trainings.

3.4 Future plans for in-country CRED applications

In Georgia, there are plans to further apply and extend the e3.ge model in several areas. First, as energy security is a national policy priority in Georgia, improving the energy sector modelling to enable policy and long-term strategy development is a prioritised next step. CRED partners are working with a World Bank team to further develop the modelling approach for use in developing the Green Growth Strategy. This requires extending and improving the energy sector module and its integration with other sectors in the model, as well as, building more explicit links between the energy sector and macroeconomic economic indicators. Second, regarding adaptation in particular, MEPA plans to apply the e3.ge approach and results in the NAP process, which is expected to be launched in 2023 after several delays. Third, the e3.ge model may also be used in the preparation of the 5th National Communication to the UNFCCC. Fourth, e3.ge modelling results could support the development and monitoring of the National Energy and Climate Action Plan. To do so, there is a need to further extend the modelling with a more detailed representation of the energy sector, as mentioned above.

In Kazakhstan, there are plans to build on CRED activities in several areas. Foremost, project partners plan to develop a Road Map for implementing adaptation based on the Adaptation Chapter in the Low Economy Development Strategy (LEDS) that is based on CRED results. The Road Map is intended to have a 10-year horizon and requires more detailed region information than current provided in the e3.kz results. Second, related to this, there are also plans that are already underway to develop a more detailed regionalisation of the e3.kz model. The regionalisation will be completed by Spring 2023 and will be used to support the development of the Adaptation Road Map. It may also be applicable for regional authorities in Kazakhstan. Third, there are plans to advance legislative work based on the Ecological Code which now contains a general chapter on adaptation. This work which will elaborate legislation relevant for adaptation in more detail may also provide further entry points for mainstreaming adaptation into policy once it is in place.

In Vietnam, the project partner MPI envisions extending the DGE-CRED model in two ways. First, from a technical modelling perspective there are plans to include more sectors and industries in modelling. Further, sectoral CBAs also need to be improved with further data collection on climate damages and adaptation measure effectiveness.

Second, building on these technical extensions, MPI envisions using the model to support the development of Vietnam Green Growth Strategy (2021-2030). While the first VGGS adopted in 2014 was of a general nature setting out objectives, the current VGGS phase requires the specification of concrete policy options and measures quantitatively. A principle building block of the VGGS implementation strategy is the development of Road Maps at the provincial level to integrate VGGS with the national Social and Economic Development Plan. DGE-CRED modelling can support this through detailed sectoral analysis. Further data collection and calibration may enable the DGE-CRED model to evaluate macroeconomic outcomes and mitigation impacts to support the development of Road Maps at the provincial level.

3.5 Desirable extensions of the CRED activities

Avenues for desirable extensions of CRED activities are common across several pilot country stakeholders. First, extending the modelling to further sectors was identified as a desirable extension across all pilot countries. In Georgia, the energy sector is the priority for model extension followed by the forestry and water resources sectors. In Kazakhstan, interest was expressed for extending the modelling through more detailed energy sector representation. Similarly, in Vietnam, extending the modelling to further sectors and industries is an expressed priority.

Second, regionalisation of the models was also expressed as a desirable extension of CRED activities across the pilot countries. In Kazakhstan, regionalisation is already underway, and this will support the development of adaptation road map development (see Section 3.4). In Vietnam, MPI project partners noted that extensions of DGE-CRED model could make it much more influential on policy in the country. Because Vietnam, which has a much larger population than either of the other two pilot countries, is focused on provincial level implementation and road mapping of its VGGS, the further regionalisation of the DGE-CRED model is highly desirable and would be fully applicable to the VGGS implementation tasks.

Third, there is interest in extending the CRED approach to enable a more detailed analysis of distribution outcomes of adaptation in Georgia, and particularly, the impact of climate change and adaptation on poverty. Indeed, adaptation measures may increase GDP but have undesirable effects on distribution, and this should be explored with metrics beyond GDP in the modelling.

4. Assessment of the CRED approach

4.1 Strengths of overall approach

A major strength of the CRED approach is that it gives broader picture of economic impacts of climate change and adaptation measures. While a significant literature has addressed adaptation options at a sectoral level (Bisaro et al., 2016; Kind et al., 2017; Vousdoukas et al., 2020), only a few approaches have applied a macroeconomic perspective to adaptation, and these largely focus on the global scale or on developed countries (Aaheim et al., 2012; Patt et al., 2010; Vrontisi et al., 2022). Further, while progress on adaptation planning is being made in many countries, e.g. through NAPs, NDCs, a key information gap existing on the costs and benefits of adaptation measures (Tompkins et al., 2018). CRED addresses these gaps, generating

information on costs and benefits of adaptation across the national economy that can meaningfully advance adaptation in developing countries. Indeed, often the CRED approach represents the first systematic attempt quantify the economic costs of climate change and adaptation in its partner countries. CRED activities thus raise awareness among key national stakeholders on climate change and the importance of investing in adaptation. Further, modelling the macroeconomic effects of adaptation measures may also be conducive to attracting adaptation finance from international donors, who are a major source of finance in the adaptation domain (see Section 5 below).

Another strength of the CRED approach is that the macroeconomic model development necessitates generating data on the costs and benefits of adaptation measures at a sectoral level. Systematically collecting this data is a benefit in itself because data on climate-related damages is beneficial for decision-making in a range of sectors. Further, as the required data (e.g. on climate-related economic damages) is often lacking in developing countries, CRED activities often initiate and support systematic data collection processes. These processes generally require cooperation between different ministries and departments, and these interactions can also serve to improve decision-making and policy. Moreover, these processes have the potential to be institutionalised beyond the CRED intervention, leading to greater integration of adaptation in decision-making and improved cross-sectoral decision-making for climate resilient economic development.

Another benefit of the CRED approach is that it provides a framework for prioritising adaptation measures for investment. Generally, public budgets for adaptation are constrained, as noted in all partner countries, and thus there is a need to prioritise among adaptation measures. Macroeconomic analysis provides a basis for comparing adaptation measures across different sectors and prioritise these, which is a fundamental challenge in adaptation and NAP development. It should be noted however that the scenario analysis 'what-if' approach has some limitations, which are discussed in the next section.

4.2 Challenges in implementing the approach

While there are clear strengths to the CRED macroeconomic approach to adaptation, several challenges arise in implementing the approach.

One challenge that arises due to ambition of making the CRED approach applicable for different developing country contexts is ensuring that modelling approach and training activities are fit for purpose (i.e., appropriate to capacity levels and data availability in the country). The CRED approach is flexible enough to incorporate different modelling approaches, as illustrated through the IO and DGE models implemented in the current pilot countries. Nonetheless, each approach has specific data needs and technical capacity requirements. Addressing this challenge requires analysis of a country's data availabilities and technical capacities at the outset of the CRED intervention.

Another challenge is building high-level political support for adaptation and identifying entry-points for mainstreaming adaptation into policies (GIZ, 2022a; GIZ, 2022b). Building political support and identifying entry-points into policy processes is essential to ensure that CRED results, and adaptation measures, are taken up in policy. Further, these entry points provide description of the policy questions that are important to national decision-makers, and thus inform the direction of model development. At the same time, building political support for adaptation requires economic arguments for investing adaptation of the kind that the CRED modelling produces. Thus, identifying entry points and building political support must be pursued in parallel with the model development, with modelling resulting being used to build support and identify relevant policy questions, which can then in turn lead to further development and refinement of the modelling.

Due to this two-way interaction between identifying policy entry points and model development, addressing each of these challenges should involve well designed and managed stakeholder interactions. This requires upfront investments in building relationships in order to ensure the success of model development in producing policy relevant results that are then mainstreamed into key policies, strategies and decisions.

Finally, from a decision-making perspective, the CRED approach is confronted with challenges that are inherent to long-term decision-making and macroeconomic forecasting. The first of these challenges relates to prioritising adaptation measures in long-term strategies. Climate adaptation decisions, and long-term strategies that CRED modelling can address more broadly, involve long time horizons, for which it is difficult to prioritise and select measures based only a single scenario of the future (e.g. RCP8.5). Ideally, for such long-term measures, an optimal measure could be selected based on the highest expected value of the measures over a range of plausible scenarios. This is however not possible for adaptation decisions with long time horizons, as probabilities cannot be attached to different climate scenarios, and therefore calculating a measure's expected value over different scenarios is not possible (Kleindorfer et al., 1993).

Thus, while the CRED approach can help to build an investment case for adaptation, or identify, for example, no regrets options that bring benefits across all scenarios, option prioritisation should be treated with caution. This view is reflected in the CRED materials that make clear the 'what-if' reasoning that underpins the scenario analysis in the CRED approach. Further, this view should be emphasised for decision-makers in providing policy advice, as the adaptation benefits that materialise for a given option will ultimately depend in part on which climate (and socio-economic) scenario materialise in the future.

A second challenge for adaptation decision-making are the inherent uncertainties in macroeconomic forecasting that underpin the CRED approach. This challenge is particularly apparent for Georgia, a small country that has been subjected to several shocks over the past decades (e.g. political instability, war, pandemic), as price and foreign exchange volatility, which affect a range of other macroeconomic variables, are characteristic of the country. The implication of these inherent uncertainties for decision-making is that adaptation planning must include space for revisiting and revising adaptation measures, and monitoring their contributions to macroeconomic outcomes at regular intervals. Further, this also lends greater importance to ensuring that measures also have (large) positive benefit-cost ratios in the sectors they directly affect (as these are less sensitive to macroeconomic factors), and are also well aligned with other social and economic development goals. These implications hold for adaptation decision-making using macroeconomic forecasting more broadly, and particularly in the case of small, open, developing economies.

4.3 Macroeconomic model development

A strength of the CRED model development approach is its accessibility in that it can be applied in a range of different country contexts. This accessibility is due to a number of factors. First, data needs for implementing an e3 modelling framework can generally be met in most countries from existing sources. 75 countries have the demand and supply tables needed to develop an IO model-based framework, while macroeconomic, demographic and climate scenarios are available at national levels from international sources (see Section 2). Second, the approach can be tailored to the capacity and resources of the country. For countries where macroeconomic modelling capacity is further developed more sophisticated DGE models may also be developed, as in the case of Vietnam. Third, the DIOM-X framework of the e3 models can be implemented lowers the technical capacity barriers to entry for use and development of the model, as coding capacities are not required.

Despite this accessibility, challenges commonly arise from the need to describe adaptation measures in a manner conducive to the macroeconomic modelling. Foremost, data collection related to the monetisation of climate change impacts and adaptation benefits is a challenge across all pilot countries. Generally, for developing countries, data on economic damages of extreme weather events is either lacking or not systematically collected in many countries. In some cases, gaps can be filled using international datasets such as EM-DAT. However, in the case of the CRED pilot countries, this was not sufficient for generating the sectoral CBAs needed to input into the macroeconomic modelling frameworks. Further, data needed to described adaptation measures as required by the macroeconomic models (e.g. investment costs, employment in affected sectors, imports, etc.) were also often lacking. To address these gaps, pilot countries employed statistical techniques as well as expert judgement to develop assumptions needed for monetisation of adaptation costs and benefits.

4.4 Capacity building

As discussed above in Section 2.3.1, CRED takes a structured approach to capacity building on model development and application, designing a set of training and coaching modules to be implemented in pilot countries from the project outset.

One strength of the capacity building approach was to ensure that initial trainings were based on a modelling framework that remained in a simplified form. Only after necessary capacities were built up with national partners, further detail and complexities were added to the model to address the relevant policy questions. Through this training approach that proceeding step-by-step in building up the level of detail in the model along with the required capacities, risks that the model would not be taken up for policy questions was reduced. Thus, taking the e3.kz example, current plans for regionalising the model are in place, now that sufficient technical capacities have been established with the project partners (GIZ, 2022b). Similarly, in Vietnam, where further regionalisation is also planned, this structured and step-by-step approach will be important for ensuring that trainings are designed appropriate to the level of provincial stakeholders that will be involved in the regional applications. Indeed, the MPI partner suggests that future trainings assume a lower level of technical knowledge for courses conducted at the provincial level.

A challenge that arose with regard to the capacity building approach that was particularly prominent in Kazakhstan, but has broader relevance, is the potential ‘brain drain’ that occurs when trained project members leave partner institutions for other opportunities. In Kazakhstan, it was noted that a competitive IT sector posed a risk here. Brain drain is a significant risk to project effectiveness as it is difficult to train new partners within time and resource constraints of CRED in-country activities (GIZ, 2022b). This can be address through careful planning of resources and timing, as well as developing in-house training capacities in partner organisations to ensure that knowledge on macroeconomic modelling of adaptation is institutionalised and does not only reside with a few individuals in an organisation.

5. Recommendations for future work

This section provides recommendations for future applications of CRED activities based on a review of past CRED activities and stakeholder interviews conducted with in-country partners (see Annex). First, we review bottlenecks in implementation of the current approach and suggest how these can be overcome. Then, drawing on the wider literature on climate resilient development and adaptation planning, we suggest some areas for future applications of the CRED approach.

5.1 Addressing bottlenecks in implementation of current approach

One aspect that could improve future CRED in-country activities is an explicit assessment of the training and capacity needs in country at the outset of activities. Partner feedback common to more than one pilot country was that the technical capacity was lacking for some training participants. Upfront training needs assessment would help to inform the design of capacity building activities and ensure that modules developed target stakeholders with sufficient technical modelling knowledge. Further, such a training needs assessment is also important where CRED supported activities will involve sub-national stakeholders (e.g. Vietnam) or private sector stakeholders. For example, in Vietnam, where future plans involve the further regionalisation of the model in order to support provincial planners, capacity levels of stakeholders differ significantly from the national level, and a clear assessment of these levels and training needs would be highly beneficial.

Another aspect that could improve project implementation is a sharing of experiences, challenges, and best practices between CRED partner countries from the outset of the interventions. Across all partner countries, broadly similar challenges have been faced with respect to data collection and sectoral CBAs and sharing experiences on how these issues are currently addressed and plans for addressing them, as well as related adaptation policy and planning practices, is likely to be beneficial for all CRED partners. While such exchanges were organised within the CRED activities, these took place rather towards the end of the project (due to the travel restrictions resulting from the COVID-19 pandemic) rather than at the outset, when it may be more beneficial.

Another bottleneck arises with respect to stakeholder interactions and identifying key entry points for adaptation. Identifying policy entry points, as pointed out in CRED Policy Briefs, requires building high level political buy-in, which is in turn a process of relationship building with key policymakers. Crucial to this process have been the facilitated dialogues (incl. coachings) with national stakeholders that provided the opportunity to discuss the selection of priority sectors for adaptation and data collection on economic dimensions of adaptation as well as to present the modelling approach and respective results. Such exchanges among national stakeholders could be institutionalized as Working Groups, which should be established as soon as possible and, optimally, at the outset of the intervention. Further, extending such Working Groups to include other actors beyond national ministries to include, e.g. universities and civil society organisations, would be potentially beneficial for increasing political buy-in by including a broader range of societal stakeholders in the process. Establishing broad-based Working Groups, early on, would provide sufficient time for interactions needed to identifying policy entry points for adaptation and for facilitating the institutionalisation of data collection process on adaptation beyond the CRED intervention lifetimes.

Another potential bottleneck in CRED implementation is the issue of data transparency, as proprietary data and institutional mandates can prevent the publishing of data needed for model developed or that is produced in the model itself. One key step in addressing data transparency issues is the transfer of model ownership to institutions in the partner countries themselves, which has taken place in the current phase of activities. Such

an approach promotes both country ownership and addresses data transparency issues and should continue to be pursued in the future.

5.2 Analysis of fiscal impacts of climate change and sovereign risk

One potential area for future application of CRED macroeconomic modelling and policy advice is for managing climate-related sovereign risk, i.e. risk that a national government is not able to meet its financial obligations. Sovereign risk is a highly salient issue for climate resilient development because a country perceived to be at high sovereign risk has greater difficult and increased costs to access credit or financial markets. This can decrease the government's financial capacity to make investments required to meet socio-economic development objectives.

Research on the macroeconomic impacts of climate change and sovereign risk is a newly emerging topic of particular interest for central banks (Batten et al., 2020; Kling et al., 2018; Volz et al., 2020). Indeed, there is an emerging recognition that extreme weather events can have economic impacts that constitute a significant risk for fiscal sustainability, particularly for smaller developing economies (Volz et al., 2020).

Climate change affects the economy through extreme weather events that induce both supply-side and demand-side shocks that, though short-term, can have long lasting effects on growth and public finances (Batten et al. 2020). Supply-side shocks include price volatility due to reduced outputs (e.g. reduced crop yields) and damaged infrastructure. Demand side shocks include loss of wealth for individuals and reduced consumption. Further, weather related damages are more likely to lead to demand shocks, and thus larger macroeconomic impacts, if losses are uninsured (Aerts et al., 2014).

In addition to shocks from extreme weather events and gradual warming can cause enduring structural changes in the economy and also affect growth rates (Volz et al. 2020). A national economy's long-run growth potential is a fundamental consideration for the sustainability of its public finances. Thus, reductions in economic capacity and reduced growths rates pose sovereign risk to governments in countries highly exposed to climate change.

While central bank monetary policy can address these risks, highly aggregated damage functions employed in Integrated Assessment Models (IAM) to estimate the impact of climate change on growth rates are not precise enough for monetary policy decisions (Batten et al., 2020). There is a call for an alternative way forward for integrating climate change into central bank decision-making is through detailed, and spatially disaggregate modeling approaches, that make use of climate science and econometrics at a level of granularity that can capture regional variation of climate impacts. Such detailed sector-level impact analysis providing quantitative estimates of demand and supply shocks are required before central banks can incorporate these effects into their monetary policy analysis (Batten et al. 2020, Volz et al. 2020).

A promising area of future CRED work is thus further developing such sectoral detail and granularity, which is already included to an extent, in the CRED family of models (IO, DGE). Such extensions could make a valuable contribution to the analysis of sovereign risk and monetary policy decision-making.

It should be noted further that the financial sector can also amplify risks from supply and demand shocks described above, e.g., when credit portfolios of individual financial institutions or the financial sector as a whole are over exposed to climate risks (Volz et al. 2020). Central banks around the world, e.g., ECB and Bundesbank, are developing models and approaches to analyse these risks, and CRED project partners, e.g. the National Bank of Georgia have expressed interest in better understanding the interactions of the financial sector with macroeconomic impacts of climate change through, e.g. sectoral modelling. While it is not clear

that the CRED macroeconomic modelling tools in their current iteration can address such financial sector issues, it is worth noting this aspect as one of high relevance for future extensions associated with assessing sovereign risk.

5.3 Analysis of co-benefits of nature-based solutions

Nature-based solutions (NbS) are being advanced around the world as a measure that can reduce climate risks, while addressing the biodiversity crisis and generating social and economic co-benefits. Despite the growing interest in NbS, significant knowledge gaps remain regarding on their effectiveness in various sectors (Kumar et al., 2021), and their economic efficiency (UNEP, 2020). These gaps are beginning to be addressed through major global initiatives and research projects exploring the effectiveness of NbS in reducing flood risks, drought risks, as well as their co-benefits through studies on financial flows generated (Kok et al., 2021), and effects on property prices (Mutlu et al., 2023).

To date, however there is a lack of research on the macroeconomic effects of NbS. This is a salient knowledge gap for mitigation and adaptation decision-making because NbS can address both these climate policy objectives, and yet can also have a range of other significant macroeconomic effects. For example, NbS often improve real estate values in their surroundings through improving environmental amenities, and there is little research on how improved amenity values feed through into the national economy or investigating the labour effects of NbS implementation. The latter is a particularly important dimension to explore given the potentially lower labour intensity of many types of NbS measures compared to conventional measures. For example, in the coastal management sector, upfront construction investments and resources are likely to be less intensive for NbS (e.g. beach nourishment or dune restoration) compared to hard solutions such as dike or sea-wall construction. Alternatively, in the agricultural sector, the labour implications of NbS such as, no till agriculture or agro-forestry are less clear, and may be usefully explored through a macroeconomic framework. Certainly, such studies would break important new ground that would potentially contribute not only to planning in the country in which they are implemented but also to the knowledge base on NbS that would improve policy and decision-making on NbS around the world.

5.4 Analysis of Loss and Damage

To date, the Loss and Damage policy discussion has largely been informed by IAMs analysing the expected damages under different climate change scenarios of extreme events such as river flooding in Europe (Jongman et al., 2014) and comparing these to existing disaster risk financing mechanisms (Hochrainer-Stigler et al., 2015; Schinko et al., 2017). Further, there is emerging work exploring the impacts of flood damages on financial intermediation and real economy in Japan (Hashimoto and Sudo, 2022), and on the macroeconomic costs of relocation and out-migration due to sea-level rise (Bachner et al., 2022).

Existing work has generally been conducted in the context of assessing financial stability in developed countries, where financial stability is higher on the policy agenda than L&D. In developing countries, L&D discussions are higher on the policy agenda, particularly considering the recent COP27 decisions on Loss and Damage financial mechanisms. Extending the macroeconomic assessments of the economic costs of climate change currently being addressed through the scenario analysis conducted in the CRED approach is another view of extension that could attract high policy interest in developing countries.

Conceptual and definitional discussions on L&D have evolved in the international climate policy arena over many years and are generally considered highly contested (Calliari et al., 2019). Thus, a well-tailored macroeconomic modelling approach to consider L&D may need to consider international stakeholders (e.g. UNFCCC, Climate Finance Institutions, etc) to insure the policy relevance of the analysis to the current L&D institutional arrangements. Further, the current CRED models could be extended to sectors and mechanisms that may have significant macroeconomic effects but have yet not been analysed in detail in the past and ongoing CRED activities. For example, the macroeconomic impacts of community relocations, e.g., due to sea-level rise or desertification, may be a useful extension of the current modelling frameworks for L&D questions.

5.5 Analysis of Just Transitions and Long-term Strategies

Emerging work on Just Transitions focuses on the need explore the labour and income distribution implications of climate policy, and the shift towards renewable energy sources in the energy mix in particular. To date, various approaches have been taken to assessing labour and income distribution effects of climate policy, including IAMs, IO, DGE and hybrid approaches. While each approach has strengths and weaknesses, recent reviews note that, while the labour effects of climate policies have been explored to an extent, a major knowledge gap exists regarding the distributive effects of climate policy and the energy transition on income. Moreover, these gaps are prominent in developing countries. Further, current approaches, and particularly IAMs, tend to narrowly focus on the energy sector as the source of all changes, rather broadly focussing on how different sectors interact (García-García et al., 2020).

The CRED e3 models are thus well positioned to address these gaps, as they are based on Input-Output models for sectoral interaction is a core analytical focus. Further, as e3 models include energy and emissions, they offer the potential to integrate mitigation and adaptation in analysis of Just Transitions in long-term strategies. While the national focus of IO-based models is sometimes listed as a limitation of the model (García-García et al., 2020), planned extensions of the CRED models in the pilot countries to regionalisation are promising for overcoming these limitations. This positions CRED macroeconomic modelling well for advancing analysis and policy advice in support of Just Transitions.

References

Aaheim, A., Amundsen, H., Dokken, T., Wei, T., 2012. Impacts and adaptation to climate change in European economies. Global Environmental Change 22, 959–968. https://doi.org/10.1016/j.gloenvcha.2012.06.005

Aerts, J.C., Botzen, W.W., Emanuel, K., Lin, N., de Moel, H., Michel-Kerjan, E.O., 2014. Evaluating flood resilience strategies for coastal megacities. Science 344, 473–475.

Bachner, G., Lincke, D., Hinkel, J., 2022. The macroeconomic effects of adapting to high-end sea-level rise via protection and migration. Nat Commun 13, 5705. https://doi.org/10.1038/s41467-022-33043-z

Batten, S., Sowerbutts, R., Tanaka, M., 2020. Climate Change: Macroeconomic Impact and Implications for Monetary Policy, in: Walker, T., Gramlich, D., Bitar, M., Fardnia, P. (Eds.), Ecological, Societal, and Technological Risks and the Financial Sector, Palgrave Studies in Sustainable Business In Association with Future Earth. Springer International Publishing, Cham, pp. 13–38. https://doi.org/10.1007/978-3-030-38858-4_2

Bisaro, A., Swart, R., Hinkel, J., 2016. Frontiers of solution-oriented adaptation research. Reg Environ Change 16, 123–136. https://doi.org/10.1007/s10113-015-0766-5

Calliari, E., Surminski, S., Mysiak, J., 2019. The Politics of (and Behind) the UNFCCC's Loss and Damage Mechanism, in: Mechler, R., Bouwer, L.M., Schinko, T., Surminski, S., Linnerooth-Bayer, J. (Eds.), Loss and Damage from Climate Change: Concepts, Methods and Policy Options, Climate Risk Management, Policy and Governance. Springer International Publishing, Cham, pp. 155–178. https://doi.org/10.1007/978-3-319-72026-5_6

García-García, P., Carpintero, Ó., Buendía, L., 2020. Just energy transitions to low carbon economies: A review of the concept and its effects on labour and income. Energy Research & Social Science 70, 101664. https://doi.org/10.1016/j.erss.2020.101664

GIZ, 2023a. Handbook on Macroeconomic Modelling for Climate Resilience [Homm, S.]. Bonn and Eschborn.

GIZ, 2023b. Economic Impacts of Climate Change and Adaptation in Vietnam. Overview of the "Dynamic General Equilibrium Model for Climate Resilient Economic Development" (DGE-CRED). [Drygalla, A., Heinisch, K., Schult, C.]. Bonn and Eschborn.

GIZ, 2022a. Supporting Climate Resilient Economic Development in Georgia. Application of the e3.ge Model to Analyse the Economy-wide Impacts of Climate Change Adaptation [Flaute, M., Reuschel, S., Lutz, C., Banning, M. & Hohmann, F.]. 2022, Bonn and Eschborn.

GIZ, 2022b. Supporting Climate Resilient Economic Development in Kazakhstan. Application of the e3.kz Model to Analyse the Economy-wide Impacts of Climate Change Adaptation [Großmann, A., Hohmann, F., Lutz, C. & Reuschel]. 2022, Bonn and Eschborn

GIZ, 2022c. Handbook for the e3 Prototype Model in Mongolia. [Grossmann, A., Hohmann, F.]. 2022, Bonn and Eschborn.

GIZ, 2021a. Macroeconomic Models for Climate Resilience: An economic tool for adaptation and development planning. GIZ Global Programme on Policy Advice for Climate Resilient Economic Development.

GIZ, 2021b. Project Brief: Managing the Economic Risks of Climate Change. GIZ Global Programme on Policy Advice for Climate Resilient Economic Development.

Hashimoto, R., Sudo, N., 2022. Transmission of Flood Damage to the Real Economy and Financial Intermediation: Simulation Analysis using a DSGE model. Bank of Japan Working Paper Series.

Hochrainer-Stigler, S., Mechler, R., Mochizuki, J., 2015. A risk management tool for tackling country-wide contingent disasters: A case study on Madagascar. Environmental Modelling & Software 72, 44–55. https://doi.org/10.1016/j.envsoft.2015.06.004

IPCC, 2022. Summary for Policymakers, in: H. O. Portner, Roberts, D.C., Constable, A. (Eds.), Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (Eds.)]. Cambridge University Press, Cambridge, UK.

Jongman, B., Hochrainer-Stigler, S., Feyen, L., Aerts, J.C., Mechler, R., Botzen, W.W., Bouwer, L.M., Pflug, G., Rojas, R., Ward, P.J., 2014. Increasing stress on disaster-risk finance due to large floods. Nature Climate Change 4, 264–268.

Kind, J., Wouter Botzen, W.J., Aerts, J.C., 2017. Accounting for risk aversion, income distribution and social welfare in cost-benefit analysis for flood risk management. Wiley Interdisciplinary Reviews: Climate Change 8. https://doi.org/10.1002/wcc.446

Kleindorfer, P.R., Kunreuther, H.G., Schoemaker, P.J., 1993. Decision sciences: an integrative perspective. Cambridge University Press.

Kling, G., Lo, Y.C., Murinde, V., Volz, U., 2018. Climate Vulnerability and the Cost of Debt (SSRN Scholarly Paper No. ID 3198093). Social Science Research Network, Rochester, NY. https://doi.org/10.2139/ssrn.3198093

Kok, S., Bisaro, A., de Bel, M., Hinkel, J., Bouwer, L.M., 2021. The potential of nature-based flood defences to leverage public investment in coastal adaptation: Cases from the Netherlands, Indonesia and Georgia. Ecological Economics 179, 106828. https://doi.org/10.1016/j.ecolecon.2020.106828

Kumar, P., Debele, S.E., Sahani, J., Rawat, N., Marti-Cardona, B., Alfieri, S.M., Basu, B., Basu, A.S., Bowyer, P., Charizopoulos, N., Gallotti, G., Jaakko, J., Leo, L.S., Loupis, M., Menenti, M., Mickovski, S.B., Mun, S.-J., Gonzalez-Ollauri, A., Pfeiffer, J., Pilla, F., Pröll, J., Rutzinger, M., Santo, M.A., Sannigrahi, S., Spyrou, C., Tuomenvirta, H., Zieher, T., 2021. Nature-based solutions efficiency evaluation against natural hazards: Modelling methods, advantages and limitations. Science of The Total Environment 784, 147058. https://doi.org/10.1016/j.scitotenv.2021.147058

Lutz, C., Flaute, M., Großmann, A., Heinisch, K., Hohmann, F., Schult, C., Banning, M., 2022. Lessons Learned from Piloting Macroeconomic Modelling for Climate Resilience in Georgia, Kazakhstan and Vietnam. GWS.

Mutlu, A., Roy, D., Filatova, T., 2023. Capitalized value of evolving flood risks discount and nature-based solution premiums on property prices. Ecological Economics 205, 107682.

Patt, A.G., van Vuuren, D.P., Berkhout, F., Aaheim, A., Hof, A.F., Isaac, M., Mechler, R., 2010. Adaptation in integrated assessment modeling: where do we stand? Climatic Change 99, 383–402. https://doi.org/10.1007/s10584-009-9687-y

Schinko, T., Mechler, R., Hochrainer-Stigler, S., 2017. A methodological framework to operationalize climate risk management: managing sovereign climate-related extreme event risk in Austria. Mitig Adapt Strateg Glob Change 22, 1063–1086. https://doi.org/10.1007/s11027-016-9713-0

Tompkins, E.L., Vincent, K., Nicholls, R.J., Suckall, N., 2018. Documenting the state of adaptation for the global stocktake of the Paris Agreement. Wiley Interdisciplinary Reviews: Climate Change 9, e545. https://doi.org/10.1002/wcc.545

UNEP, 2020. Economics of Nature-based Solutions: Current Status and Future Priorities.

Volz, U., Beirne, J., Preudhomme, N.A., Fenton, A., Mazzacurati, E., Renzhi, N., Stampe, J., 2020. Climate Change and Sovereign Risk. SOAS University of London. https://doi.org/10.25501/SOAS.00033524

Vousdoukas, M.I., Mentaschi, L., Hinkel, J., Ward, P.J., Mongelli, I., Ciscar, J.-C., Feyen, L., 2020. Economic motivation for raising coastal flood defenses in Europe. Nat Commun 11, 2119. https://doi.org/10.1038/s41467-020-15665-3

Vrontisi, Z., Charalampidis, I., Lehr, U., Meyer, M., Paroussos, L., Lutz, C., Lam-González, Y.E., Arabadzhyan, A., González, M.M., León, C.J., 2022. Macroeconomic impacts of climate change on the Blue Economy sectors of southern European islands. Climatic Change 170, 27. https://doi.org/10.1007/s10584-022-03310-5

Annex

Interview schedule

Country	Institution	Interview date
GEO	Head of Economic Analysis and Reforms Department, Ministry of Economy and Sustainable Development of Georgia (MoESD)	16.12.22
GEO	Deputy Head of Economic Analysis and Reforms Department, Ministry of Economy and Sustainable Development of Georgia (MoESD)	16.12.22
GEO	Senior specialist, Climate Change Division, Environment and Climate Change Department, Ministry of Environmental Protection and Agriculture of Georgia (MEPA)	20.12.22
KAZ	Director of the Center of ESG Expertise, Economic Research Institute (ERI)	11.1.23
KAZ	Deputy Chairman of the Board Economic Research Institute (ERI)	16.1.23
KAZ	Head of Climate Change Adaptation Unit of the Department of Climate Policy and Green Technology, Ministry of Ecology, Geology and Natural Resources of the Republic of Kazakhstan (MEGNR)	20.1.23
VIE	CIEM	
VIE	DSENRE	5.1.23

CRED Review: Interview guide

This interview guide is intended to explore work done under CRED from 2019-2022 in the partner countries, and explore the potential for future development. **Interviews are expected to be ca. 45 minutes**. Interviews need not strictly adhere to the structure below, but should rather be flexible to explore any topics considered important, but not covered in the guide below. Thanks very much for your time and contribution.

I. Status of modelling with the country-specific model

1. How would you describe the current status of the CRED modelling in your country?
2. Which decisions or planning processes do you address with the CRED macroeconomic modelling?
3. What are the particular **strengths** of the CRED approach for informing these decisions or processes?
4. What are the particular **weaknesses** of the CRED approach for informing these decisions or processes?
5. What alternatives approaches or tools are available for informing these decisions or planning processes?

II. Capacity building needs

1. How would you describe the capacity building and training activities in CRED?
2. What worked well?
3. What were the main challenges or difficulties in the capacity building and training?
4. Were there particular areas (modelling, costing, sectoral analysis, etc) where capacity needs are greater?
5. What changes would you make to the capacity building and training activities in CRED?

III. Support needed in policy dialogue and dissemination

1. How would you describe the policy dialogue and dissemination in CRED?
2. At which stage in the process were key decision-makers and stakeholders involved, and what was the strategy for involving these stakeholders?
3. What worked well in the policy dialogue and dissemination?
4. What are the main challenges or difficulties in the policy dialogue and dissemination?
5. What changes would you make to the policy dialogue and dissemination in CRED?

IV. Future plans

1. What are your future plans for applying the CRED modelling approach in your country?
2. Which decisions or planning processes do you aim to address with these activities?
3. Are there any barriers you foresee in carrying these activities forward? If so, what are these?
4. What strategies can you pursue to overcome these barriers? And what support would be needed to do so?

V. Desirable extensions of the CRED approach

1. What extensions of the CRED modelling framework would be desirable for your work? (e.g. introduction of other sectors, climate scenarios, etc.)
2. Who are the main stakeholders and what are the main policy processes that would be targeted by this work?
3. What are the main challenges for advancing such extensions?

VI. Conclusion

1. Are there any other aspects regarding the CRED approach that you feel are important to discuss and have not yet been covered?

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