Current Status of Macroeconomic Modelling for Climate Resilient Development and Future Perspectives

The CRED approach and its current application

- Policymakers need information to align long-term investment decisions with climate resilient development as stipulated in the Paris Agreement.
- As a response to intensifying climate risks and the need to increase investments in adaptation for national economies, the "Policy Advice for Climate Resilient Economic Development" (CRED) programme (see website) has supported Georgia, Kazakhstan and Vietnam since 2019 in developing **macroeconomic models that capture the economy-wide impacts of climate change**. Furthermore, these models can **assess the economy-wide effects of investing in specific adaptation measures** and thus may guide national adaptation planning.
- **Macroeconomic models are well-established tools for economic policy planning**. Especially Economic ministries use such models to estimate the long-term effects of economic policy measures on key economic indicators (i.e., GDP, employment, consumption, exports/imports).
- The **innovative character** of the CRED approach consists in **integrating climate risks in macroeconomic models** and thereby **improving adaptation planning**. The E3 (economy, energy, emissions) models developed for Kazakhstan and Georgia under the CRED programme cover the demand-and-supply-relationships of an economy and its main connections to the environment, i.e. the use of energy resources and the input of CO_2 emissions into the environment. This integrated modelling approach of the 3Es in one model framework ensures a consistent view of possible transition pathways. Both macroeconomic and sector-specific impacts as well as conclusions on social balance and ecological benefits become apparent. The approach of modelling adaptation is not limited to such macro-econometric E3 models but can be applied with other macroeconomic models as for example in the case of Vietnam where a dynamic general equilibrium (DGE) model[1] is being used. This allows the countries to act in a similar way to Germany and the EU. For the Impact Assessment of the EU Adaptation Strategy 2021, macroeconomic and sectoral effects of climate change and adaptation measures were calculated for the EU countries using macroeconomic models[2]. The modelling is informed by detailed cost-benefit analyses. BMUV and BMWK in Germany are proceeding similarly. Based on a risk and vulnerability analysis, the consequences of climate change and adaptation measures are collected and modelled for the future.[3] Currently, the models can be applied to answer two question types:
    - Questions on the economic vulnerability to climate change (Q1):
        - Looking at the next 30 years, **how does a specific climate hazard** (e.g., increasingly severe droughts) **impact the national economy** (including jobs and GDP), economic sectors and which intersectoral dynamics[4] does it trigger?
        - Which climate hazards will likely harm the national economy the most in the long-term?
    - Questions on benefits/rentability of investments in adaptation measures (Q2):
        - Looking at the next 30 years, **how do investments in a specific adaptation measure** (e.g., irrigation systems) **reduce the economic risks of said climate hazard** and **potentially unlock economic opportunities?**
        - What are the macroeconomic implications of this adaptation measure compared to a scenario without investment in adaptation, what is the effect on CO_2 emissions?
        - Which investments lead to the highest economy-wide benefits?
- The **models are used to compare different scenarios** i.e., scenario analysis. This analysis then allows to answer the questions above. Three **types of situations** are considered:

[1] DGE models allow a systematic analysis of the impact of climate change and adaptation on productivity.
[2] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52021DC0082&from=EN
[3] https://www.adelphi.de/en/publication/klimawirkungs-und-risikoanalyse-2021-f%C3%BCr-deutschland, https://www.bmuv.de/pressemitteilung/hitze-duerre-starkregen-ueber-80-milliarden-euro-schaeden-durch-extremwetter-in-deutschland
[4] Example for an intersectoral effect caused by a climate hazard: Increasing droughts result in lower agricultural production (direct effect), which then leads to production losses in sectors like food production or chemical industry as they rely on the agricultural sector.

(1) **climate change is not occurring** (*hypothetical reference scenario*) based on historical economic data, which up to date does not show significant impacts of climate change.
(2) a specific **climate hazard** (e.g., droughts) **intensifies** up to 2050 (*climate change scenario*) based on climate hazards analysis linked to IPCC's current Representative Concentration Pathway (RCP) or Shared Socioeconomic Pathways scenarios (SSP) (see below).
(3) **investments in a measure adapting to said climate hazard** (e.g., irrigation systems) are made (*adaptation scenario*) based on cost-benefit analyses (CBA).

When comparing scenario (1) and (2) it becomes clear how the climate hazard impacts the national economy in the long run (answering question type Q1). For example, our analysis shows that Kazakhstan's GDP is up to 2.4% (resp. 2,028 bn. KZT) lower with intensifying droughts compared to a situation without droughts. Amongst others, this is caused by the need to import more wheat and electricity.

When comparing scenario (2) and (3) we can see how investments in an adaptation measure can influence the long-term economic development under climate change (answer to question type Q2). Following the previous example, the analysis shows that the GDP is annually up to 1.2% (resp. 833 bn. KZT) higher with adaptation investments compared to a drought scenario without adaptation action. This results from intensified construction activity and higher crop yields due to additional irrigation facilities.

- The models are based on the following data:
    - **historical macroeconomic data**: GDP, imports/exports, price information of goods and services, consumption, employment, gross fixed capital formation, labor market
    - **annual national input-output tables** providing sectoral data
    - **economic growth forecasts** (growth rates and population forecasts)
    - **energy and emission data** (energy balances, energy-related CO_2 emissions, energy prices)
    - **historical climate change effects** (occurrence, (economic) damage data)
    - **projected climate hazard occurrence and intensity** based on RCP 8.5 scenario[5] (Georgia and Kazakhstan) or SSP scenarios (Vietnam) [6].
    - **cost-benefit analyses** (CBAs) of adaptation measures
- **Data collection process**: Partner institutions provide the necessary economic data as far as possible. If national data is unavailable, international data represents an alternative. Damage data of the most relevant climate hazards stems from news reports, studies of other donors and partner institutions. In case of missing data, assumptions on economic damages as well as costs and benefits of adaptations measures have been discussed and agreed upon with national experts. Climate hazard projections are based on country-specific climate hazard analyses[7] conducted by experts associated with CORDEX, the Coordinated Regional Climate Downscaling Experiment on behalf of the CRED programme.
- **Need for regular update and systematic damage data collection:** As partners successfully completed model trainings and actively contributed to the process of data collection, discussions on assumptions and integration of climate scenarios into the models, they are generally capable of independently updating and further applying the model and conducting new scenario analyses.
- Ideally, countries should be supported by donors in systematically collecting data on economic damage caused by previous climate hazards and conducting required CBAs for adaptation measures. While the former is already part of the global agenda on disaster risk reduction (i.e., Sendai Framework for Disaster Risk Reduction), the latter will likely also pick up pace as adaptation efforts become more relevant, leading to higher demand for CBAs and thereby increasing their availability. Nonetheless, missing data is a typical bottleneck, and building up data collection capacities should be a priority.
- The model should be updated on an annual basis to include the latest data – ensuring estimates are based on a reliable data foundation. Moreover, annual updating of model data can provide a platform to reflect on the accuracy of prior modelling results.

[5] The data required is also available for RCP 2.6 i.e., the most optimistic scenario assuming all countries stick to the restriction of emissions agreed in the Paris Agreement. Intermediate scenarios have not been considered due to poorer availability of data. A workaround to calculate such an intermediate scenario would be to calculate the mean of the RCP 8.5 and 2.6 scenarios for the different projections.
[6] In the case of Vietnam three SSPs are being considered, representing a range of low and high climate change impacts.
[7] Climate Hazards Analysis for Georgia and Climate Hazards Analysis for Kazakhstan

Benefits from using CRED macroeconomic models

- **The benefits go beyond the results derived from such macroeconomic analysis**. The process around data collection and discussing assumptions across different governmental institutions (e.g., Ministry of Economy, Ministry of Environment) facilitates deepening inter-institutional ties through constructive exchanges. Thus, the CRED approach also contributes to **strengthening the institutional link between climate adaptation and economic policy planning and thereby promotes climate mainstreaming.**
- Building on sectoral cost-benefit analyses for individual adaptation measures, climate-sensitive macroeconomic models allow for **economy-wide cost-benefit analyses of adaptation measures**. As such, they refine the information provided by sectoral cost-benefit analyses and lead to a more complete picture for policymakers i.e., an improved decision basis for policymakers.
- Another huge advantage of developing such models is their **wide applicability**. Essentially, partners may use climate-sensitive macroeconomic models to assess the impact of **any kind of economic shock** (caused by unforeseen circumstances like the occurrence of a pandemic or supply chain issues) on the economy. An illustrative example is the independent adjustment of the e3.ge model by Georgian modelers to assess the impacts of Russia's war on Ukraine on the Georgian economy.
- The CRED programme has piloted the innovative approach of modelling country-specific economy-wide impacts of adaptation. To illustrate the potential of using such climate-sensitive macroeconomic models for policy processes like the development of national adaptation plans (NAPs), the **impact of exemplary adaptation measures** in different sectors (agriculture, energy, infrastructure and tourism) has been assessed. **Policy advice thus far has been geared towards raising awareness about the model's added value for policy planning and preparing its use for future climate strategies and policies**:
  - In Kazakhstan, a chapter on adaptation has been included in the current draft of the low-emission development strategy (LEDS) including results from e3.kz modelling. E3.kz model has also been recommended as a policy supporting tool in Kazakhstan's roadmap for NDC and adaptation planning.
  - The Vietnamese Ministry of Agriculture and Rural Development's (MARD) Green Growth Action Plan benefited from preliminary modelling results in the agricultural sector.
  - In Georgia, the project is anticipating the application of the model for the NAP process, which is expected to be launched in late 2022 or 2023. CRED is facilitating stakeholder discussions between the Ministry of Environmental Protection and Agriculture (MEPA) and the Ministry of Economy and Sustainable Development (MoESD). CRED currently supports dialogues of the land-use department to access financing from the adaptation fund to implement windbreaks as an adaptation measure to intensifying droughts by using e3.ge model results.

Example for Kazakhstan | Adaptation in the agriculture sector

Sectoral cost-benefit analysis of investments in drip irrigation and reconstruction of canals and reservoirs

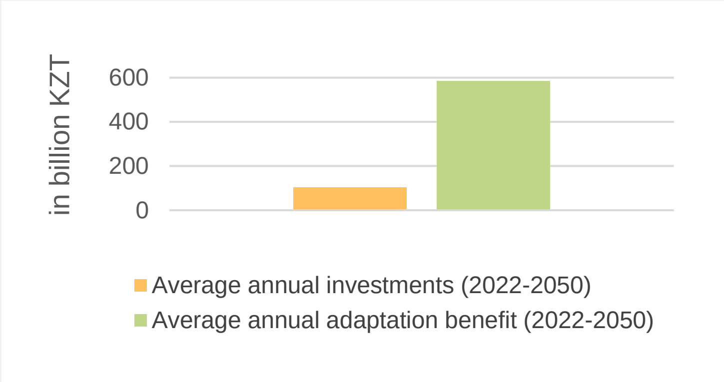


Figure 1: CBA for investments in irrigation systems.

- Costs refer to the investments required
- Benefits are considered in terms of higher agricultural output

Macroeconomic assessment of investments in irrigation system reconstruction and expansion

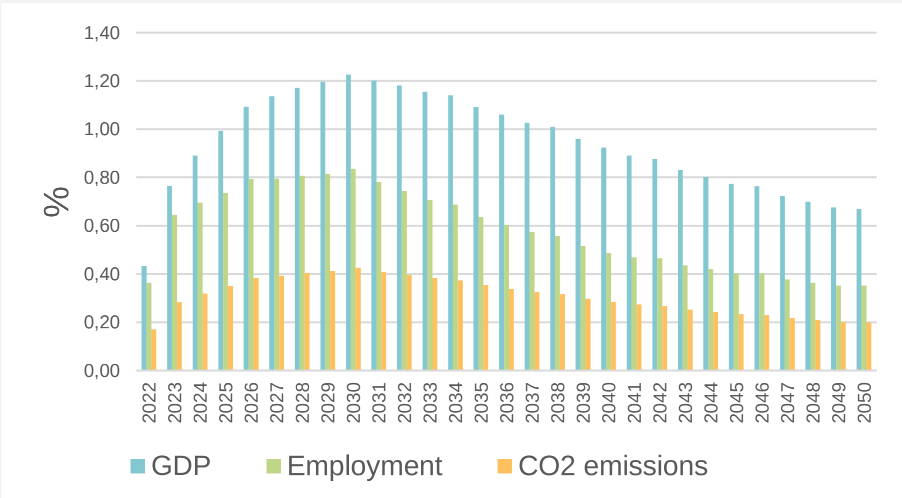
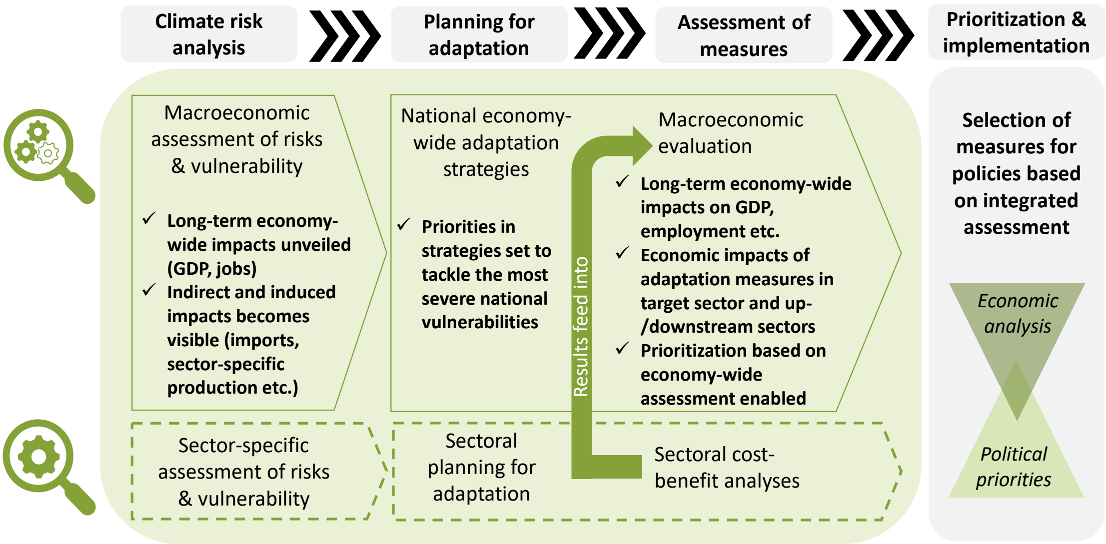


Figure 2: Economy-wide impacts of irrigation measures (compared to scenario without adaptation).

- The results from the CBA are fed into the model and are thereby reflected in the results.
- Investments in the agricultural water infrastructure result per year in a maximum of **1.2% higher GDP (resp. KZT 833 bn.)** and **up to 0.8% higher employment corresponding to up to 78,000 additional jobs** (compared to a situation without adaptation).
- Investments in **irrigation systems increase agricultural output – also in years when droughts are not occurring.** Other sectors along the value chain are **indirectly, positively affected e.g., food producers** (compared to a situation without adaptation). Positive effects can be expected in the construction sector which profits from the rehabilitation and expansion of water canals and reservoirs. This information demonstrates one of the advantages of macroeconomic assessments compared to CBAs: they go beyond the benefits of the agricultural output from the adaptation measures and **include the effects in linked sectors**.
- A higher growth path without further climate protection measures as seen here leads to annual increases of energy demand and energy-related CO_2 emissions of up to 0.4% (compared to a situation without adaptation). The identification of potential **trade-offs with mitigation efforts** is crucial so that additional mitigation actions may accompany such adaptation measures.

Outlook and potential of the CRED approach

- The **CRED programme laid the foundation** in the pilot countries to **use the models systematically from the beginning in future policy processes**. Over the course of the project, accompanying such a policy process proved challenging. For example, the NAP process in Georgia has been delayed multiple times. In the case of Kazakhstan, the low emission development strategy (LEDS) is based on a different economic model, which only allows soft linking with the e3.kz model developed with CRED support.
- In the future, the models can be applied to **guide national and sectoral adaptation planning and respective investment decisions**. Ideally, the starting point for this should be a **specific investment project, like a long-term strategy (LTS) or a NAP**.
- *Figure 3* visualizes the added value of macroeconomic models for such processes. A comprehensive risk and vulnerability analysis should be the starting point. **Macroeconomic assessments enhance the understanding of the country's vulnerability to climate impacts**. They unveil how the economy as a whole in terms of GDP and jobs is affected, but also how indirect and induced effects unfold. For example, during a drought, energy production (hydro and thermoelectric power plants) can drop. This can then require higher energy imports which then lead to a reduced GDP. Based on this information, **national adaptation strategies can set priorities to mitigate the most severe vulnerabilities**.
- In the next step, concrete adaptation measures are assessed to decide which of them to include in the strategy. A prerequisite is conducting sectoral cost-benefit analyses to understand the sectoral impacts of the different adaptation measures. The cost component of the CBAs includes assumptions on the necessary investments and related interest payments. Different financing options (public, private international climate finance) should be taken into account, including different interest rates that would apply. These CBAs are then fed into macroeconomic models to assess the economy-wide impacts of these measures. Different financing options could be considered by different assumptions. For the macroeconomic analysis, it is primarily important whether financial resources are additional (from abroad) or whether they possibly crowd out other investments at home.
- Macroeconomic analyses further support the prioritization of measures to be included in these policies, as they consider long-term economy-wide impacts. These impacts include effects of investments in adaptation of the targeted sector (e.g. agriculture) and in up- and downstream sectors (e.g. construction, food industry). Contrasting sectoral to macroeconomic analyses shows that macroeconomic approaches deliver key information beyond a sectoral analysis. Thereby, they unveil a more complete picture on economic implications allowing to embed adaptation investments in the broader framework of the national economy.



- However, when selecting adaptation measures for implementation, other criteria resulting from political

Figure 3: Added value of macroeconomic modelling for assessing adaptation measures.

priorities are also taken into account as Figure 4 illustrates. Political priorities, which cannot be analyzed with the abovementioned economic instruments (i.e., biodiversity considerations, reduction of pollution, mitigation) complement the economic assessments. The combination of both macroeconomic analyses and socio-ecological considerations lead to an integrated appraisal of adaptation measures and climate resilient economic development.

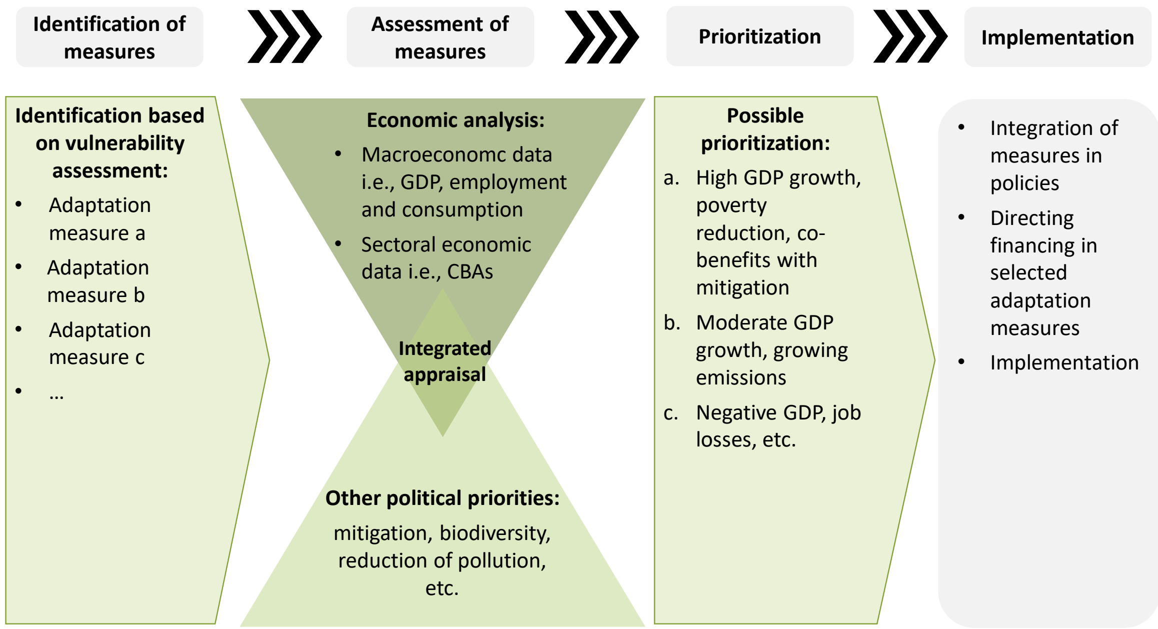


Figure 4: From identification to implementation of different adaptation measures.

- The national economy as a whole benefits from investment decisions that consider the medium to long-term implications of climate impacts and corresponding adaptation strategies to reduce climate risks. NAPs benefit from an economically sound foundation and can become concrete policy roadmaps on how to establish climate resilient development. Institutions providing climate finance benefit from more reliable estimates on long-term effects of adaptation measures. Sectoral stakeholders (i.e., businesses, subnational policymakers) receive information on economic trajectories and can also adapt their business plans and investments.

- Besides ministries, central banks are increasingly interested in climate change and the possible effects on the financial sector. This concerns the credit portfolios of individual banks as well as the financial sector as a whole. ECB and Bundesbank are developing their own models for this purpose, which increasingly recognise the importance of a differentiated sectoral representation for the issue[8]. The Georgian central bank is also interested in the issue and would like to better understand the associated risks. The sectoral modelling by the MoESD could be a good addition here. Ultimately, the challenge of climate change requires an overarching approach by different ministries such as environment, economy, finance, energy, and other institutions. The macroeconomic models can be an important building block for their cooperation.
- The **models can be extended** to include **further sectors and adaptation measures,** to cover **mitigation measures**, and **subnational regional units**. Potentially, they could also look at scenarios which combine multiple climate hazards or look at a set of adaptation measures and their aggregate effects. This requires additional data and more complex scenario development.
- The models are owned and run by partner countries and become part of the national policymaking repertoire. The importance of modelling results will likely increase due to global climate policy priorities such as climate finance, and climate insurance. Thus, countries applying for climate finance with their project proposals backed up with macroeconomic modelling results may increase the likelihood of funding. Disaster Risk Reduction may also benefit from CRED's long-term modelling results and increase cost efficiency by reducing long-term risks and exposure.

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[8] https://www.bundesbank.de/resource/blob/884240/552ff52a08a00f711c038c4b8ef69dd5/mL/2022-01-klimawandel-klimapolitik-data.pdf