Macroeconomic Modelling for Climate Policy Planning

Impact Analysis with an Excel-based E3 (Economy-Energy-Emission) Model Building Framework

Summary

MAY 2022

There is increasing consensus over the need to integrate economic policy planning and climate change adaptation. The following article presents macroeconomic modelling as a valuable policy tool for climate resilient economic development. Such modelling allows decisionmakers to include long-term direct, indirect, induced and overall socio-economic impacts of climate hazards and respective adaptation measures in their considerations enabling them to reduce risks associated with climate change.

Building on experiences within the global programme "Policy Advice for Climate Resilient Economic Development" (CRED) implemented by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) on behalf of the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV), this article describes a simplified E3 (Economy-Energy-Emission) model prototype based on international datasets to be applied to climate change adaptation related issues.

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Introduction

Macroeconomic models have been successfully used for decades to support evidence-based policymaking. Environmentally extended macroeconomic models become more and more important to evaluate climate change policies. Such models provide a single framework to integrate climate change related issues in order to analyse not only the direct impacts but also the indirect, induced and total socio-economic impacts of both climate hazards and adaptation. However, in developing countries the technical, financial and human capacities to conduct such model-based analysis are often limited.

Within the project "Policy Advice for Climate Resilient Economic Development" (CRED) financed by the German Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV) and implemented by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), E3 (economy-energy-emission) models have been developed for Georgia and Kazakhstan. In combination with scenario analysis, these models are applied to analyse the economy-wide impacts of climate change and adaptation measures (see our knowledge products at GIZ). The results provide valuable information for adaptation planning processes.

Experiences to date with the CRED approach (GIZ 2021[1], GIZ 2022[2]) in Kazakhstan and Georgia show that transferability to other countries is practicable without reinventing the wheel.

This article describes an E3 model prototype as part of the CRED approach which is based on multi-country, international datasets and a simplified E3 model approach to be applied to climate change adaptation related issues. The E3 model prototype serves as a show case and facilitates the transfers of the CRED modelling approach to other countries. As Figure 1 shows, the country-independent part I can be re-used for other countries while part II, in particular economic and climate data, is country-specific. Country-specific scenario results provide a science-based information for policymakers on possible macroeconomic consequences of adaptation actions or inaction.

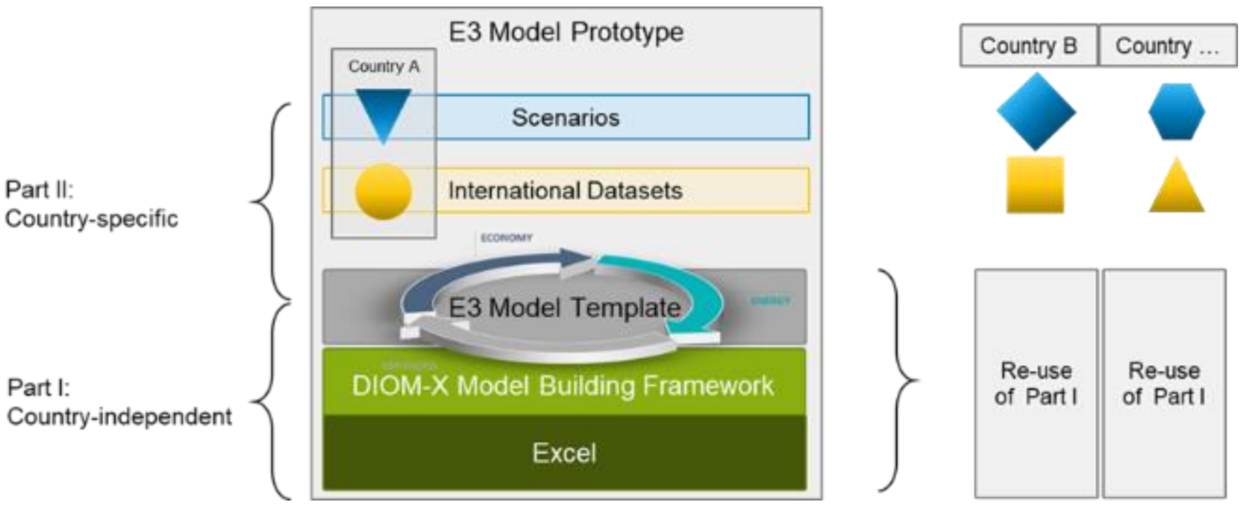

Figure 1: E3 model prototype (Source: GWS)

[1] GIZ (2021): Macroeconomic Models for Climate Resilience. An economic tool for adaptation and development planning

[2] GIZ (2022): Supporting Climate Resilient Economic Development in Kazakhstan. Application of the e3.kz Model to Analyze the Economy-wide Impacts of Climate Change Adaptation.

The E3 modelling approach described in this article comprises a simplified E3 model template and the DIOM-X[3] Excel-based framework which focusses on the development of environmentally enhanced macro-econometric Input-Output (IO) models.

This framework addresses the following issues:

- The underlying multi-country data sets support transferability to many countries.
- The harmonized model structure allows for comparison of results between different countries and supports the international exchange between institutions, governments, and other actors.
- Compared to other modelling approaches, the framework has lower technical hurdles (software and hardware requirements, required IT skills).
- The model building framework DIOM-X and the E3 template are distributed with royalty-free, non-exclusive rights.[4]
- The main application of the E3 model is scenario ("what-if") analysis which does not require any programming skills.
- The E3 model is suitable for introductory lessons regarding macroeconomic analysis of climate change adaptation ("teaser trainings").

E3 Model Template

According to the literature[5], various modelling approaches exist which cover the linkages between the economy and the climate. In principle, key requirements for an economic model to be able to map climate change impacts can be defined as follows:

- Main economic impacts of climate change (e. g. productivity and income losses) must be captured.
- Economic sectors (e. g. agriculture, energy) that are directly affected by climate change must be considered as well as intersectoral dependencies.
- Long-term macroeconomic developments should be captured regarding future climate change impacts as well as adjustment reactions in the years subsequent to a climate event.
- The model must be able to cope with the inherent uncertainties of future development in particular climate change.

The macro-econometric (dynamic) IO modelling approach in combination with scenario analysis is a suitable solution which fulfils the requirements. To identify possible synergies or trade-offs of adaptation and mitigation strategies, the economic model was extended to an E3 model (Figure 2).

[3] **D**ynamic **I**nput **O**utput **M**odelling in E**x**cel.

[4] The DIOM-X framework and the E3 template are intellectual property of GWS (Germany) and may not be used in commercial projects or to develop competitive products.

[5] See e.g., Nikas A, Doukas H, Papandreou A (2019). A Detailed Overview and Consistent Classification of Climate-Economy Models. In: Doukas H, Flamos A, Lieu J (eds) Understanding Risks and Uncertainties in Energy and Climate Policy. Springer. or UNFCCC. https://unfccc.int/topics/mitigation/workstreams/response-measures/integrated-assessment-models-iams-and-energy-environment-economy-e3-models#eq-9

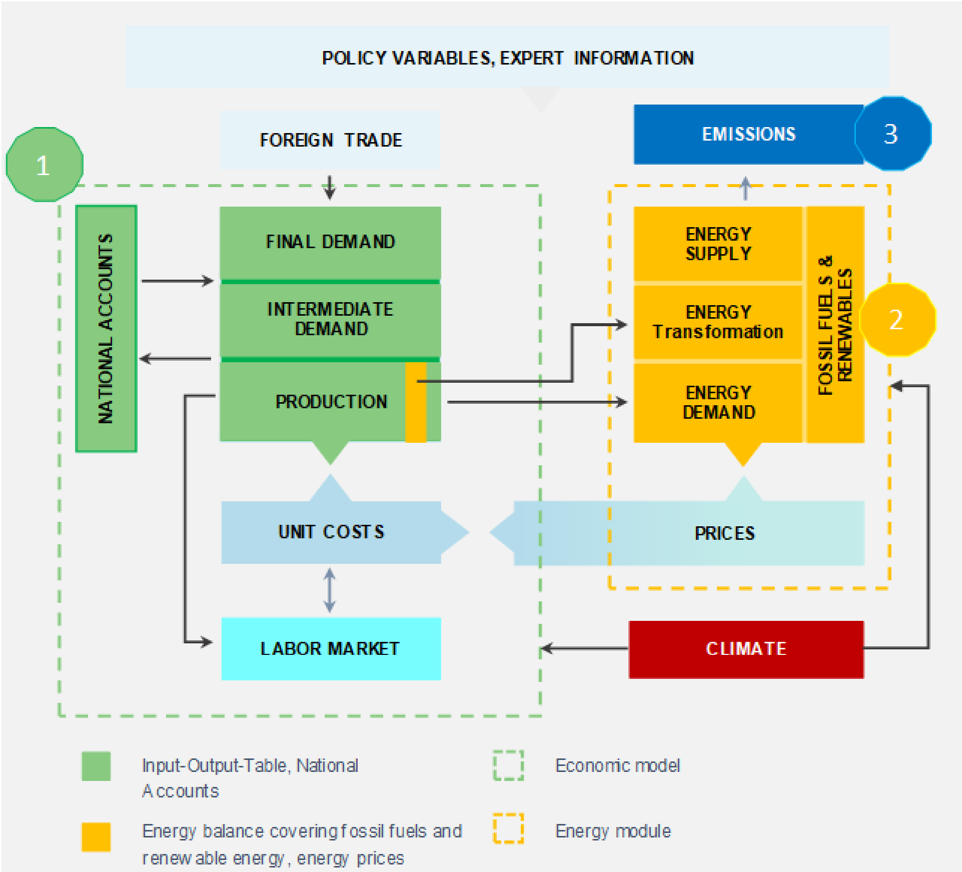

Figure 2: E3 model template overview (Source: GWS)

Due to its IO foundation, the **economic model** covers several economic sectors, their interlinkages as well as the domestic and foreign drivers for economic growth. Demand and supply of the economy as well as prices are part of the model which allows to integrate various impacts of climate change such as lower sectoral labour productivity, higher cooling needs due to high temperatures as well as the effects of adaptation measures such as the associated investments. Climate impacts are either given by sector- and country-specific bottom-up models or by observed past and current climate change related damages. Macroeconomic analysis of adaptation measures is built upon sector-specific cost-benefit analyses.

The **energy module** describes the relations within the energy sector in greater detail than in the economic model. It depicts the energy demand, supply and transformation by different fossil fuels and renewables as stated in the energy balance. The representation of fossil fuel combustion in physical units allows for a better illustration of the combustion-related CO_2 emissions which are covered in the **emission module**. Reductions in the use of fossil fuels caused by deployment of renewable energy or increased energy efficiency can be seen in CO_2 savings.

In contrast to static models – which compare a situation before and after a change (comparative static analysis) – the dynamic IO model is time-dependent and considers a possible economic development path until 2050.

The main data prerequisite for the E3 model template are (a series of) IO tables which are available for 75 countries from OECD and ADB (Figure 3 and Appendix 1: IOT country coverage). Other economic data such as GDP by components, employment, and wages as well as energy balances and greenhouse gas emission data are needed for an E3 model as well.

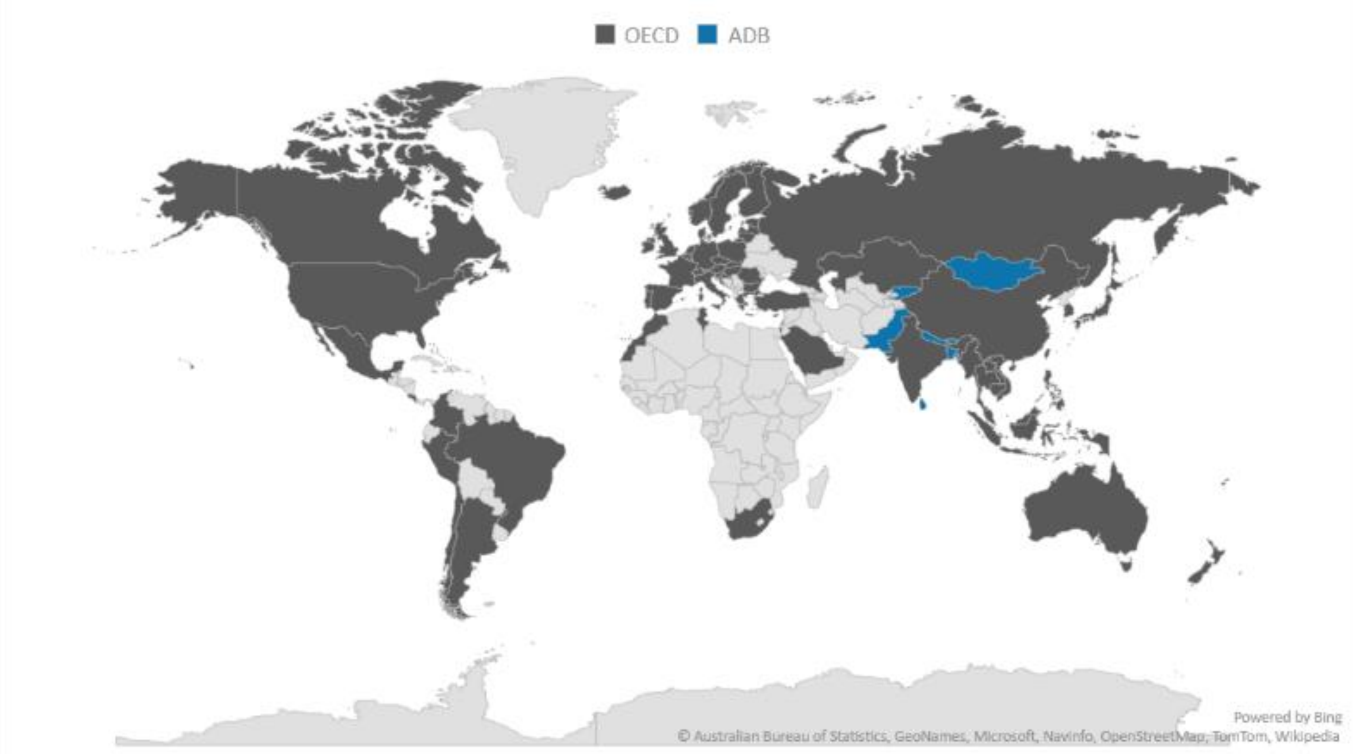

Figure 3: Country Coverage IOT (Source: OECD, ADB (For some countries IOTs are available from both data providers))

Model Building Framework DIOM-X

The E3 models are developed in Microsoft (MS) Excel using the model building framework DIOM-X. This framework is built upon the programming language Visual Basic for Applications (VBA) which is part of the MS Office suite of applications.

Using the integrated programming environment of the MS Office suite in combination with DIOM-X offers several advantages[6]:

- Many potential model builders and model users have at least fundamental knowledge in using MS Excel for data processing and evaluation.
- Most professionally used computers are equipped with the MS Office application suite and thus are already prepared for model development with DIOM-X. This reduces both investments in software and setup requirements.
- A model which is fully built with this framework can be easily shared or distributed to other

[6] Großmann, A., Hohmann, F. (2019). Static and Dynamic Input-Output Modelling with Microsoft Excel. SHAIO Conference Paper 2019, Osnabrück.

users because the full model data set (both historical and projected data), model equations and results are stored in a single MS Excel workbook.

- The time needed to build an E3 model is greatly reduced by reusing existing knowledge in operating MS Excel which is important for projects with tight time and/or budget restrictions.
- Each aspect of such a model can be examined, adapted, and enhanced. The full set of data, equations, model, and framework programming statements are accessible within one workbook ("white box" approach) which ensures transparency of the overall approach

DIOM-X provides the necessary programming routines to process time series data and to iteratively solve a system of model equations. The equations formulated in the VBA programming language are readable even for non-programmers.

The main application "what-if" analysis does not require any programming skills. The corresponding quantified assumptions are entered in the timeline of the "scenario" worksheet and evaluated by the DIOM-X framework at model runtime. The framework offers different options to tweak scenario settings: Values calculated by the model may be replaced, multiplied by a factor or attached to a growth rate. Such tweaks may be applied to single years or time spans for which the framework automatically interpolates the values, if needed.

The full data set – both historical and projected data – is automatically stored in a dedicated worksheet each time a scenario has been calculated. In addition to the values, this sheet contains the variable names and their descriptions which greatly simplifies further data processing, e.g., creation of graphs or customized tables.

Climate Change Adaptation Scenarios

An E3 model can be applied to simulate the macroeconomic effects of climate change scenarios and adaptation measures. This so-called scenario (or "what-if") analysis is used to answer questions such as "What are the macroeconomic impacts of a certain climate hazard?" or "What are the macroeconomic impacts of sector-specific adaptation measures?" A scenario comprises a set of quantified assumptions that are assigned to appropriate E3 model variables. These initial impacts cause chain reactions in the E3 model. Model results show not only the direct effects but also indirect and induced effects as well as the macroeconomic consequences.

The analysis of climate change adaptation starts with the development of **climate change scenarios** including e.g. extreme weather events (EWEs) and their economic impacts (e.g. reduced labour productivity or cost to reconstruct damaged infrastructure). Climate change scenarios are based on the reference scenario without considering climate change.

The reason to explicitly consider the effects of climate change is that they are not very apparent in current and historical macroeconomic data. Either climate change did not cause any observable impacts to the economy or could not even be detected as an impact from climate change because repairing climate change damages may result in positive GDP effects (so called defensive spending). In addition, the damage may have been avoided or reduced by adaptation measures.

Afterwards, **adaptation scenarios** are created including measures that are minimizing or even preventing adverse climate change impacts. Comparing climate change and corresponding adaptation scenarios reveal the economy-wide and sector-specific impacts (in terms of e.g., GDP growth, employment) of preventive measures (Figure 4).

The main prerequisites to analyse the macroeconomic impacts of climate change adaptation are:

- **Climate scenarios with a regional breakdown**[7] and the future evolution of climate hazards,
- Identification of the **most vulnerable sectors**, relevant interfaces and affect chains of climate hazards,
- Past and current **economic damages**[8] (and benefits, if appropriate) due to climate change, and
- Costs and benefits (in terms of damage reduction) of sector-specific adaptation measures[9].

On the one hand, the evaluation of the scenario results with the E3 model reveals what could happen under climate change and on the other hand which adaptation measures are highly effective and have positive effects on the economy, employment, and the emissions. The results can be used by policymakers as a decision-making basis to support adaptation planning.[10]

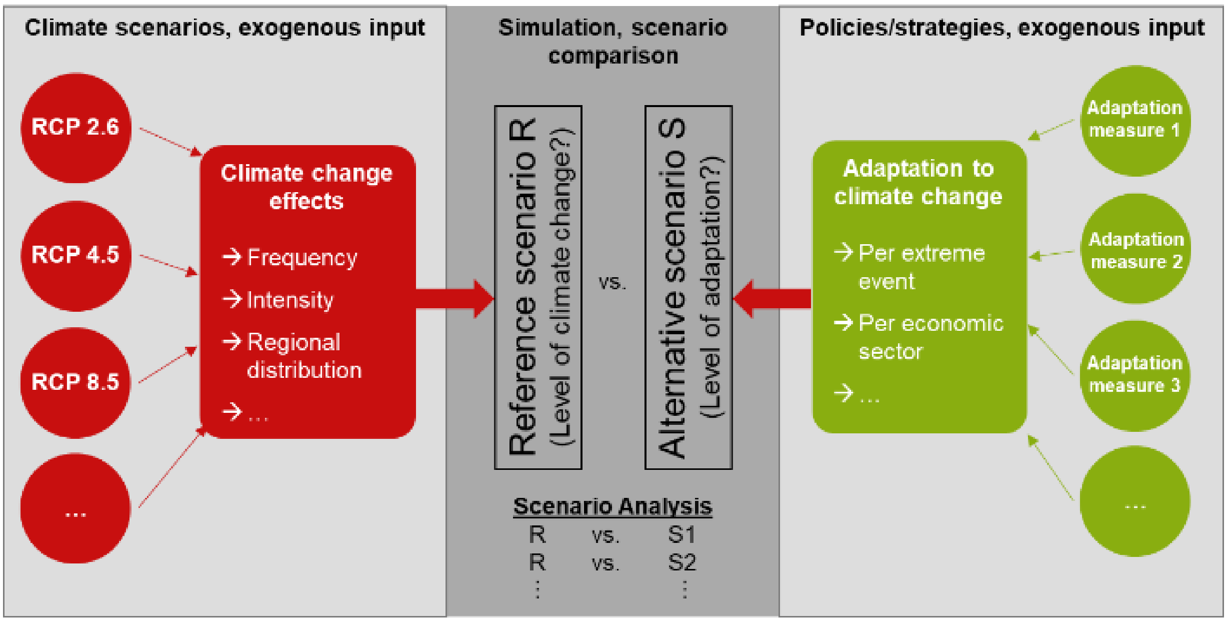

Figure 4: Comparison of climate change and adaptation scenarios (Source: own illustration).

[7] E.g., https://cordex.org/ and https://interactive-atlas.ipcc.ch/regional-synthesis

[8] E.g., Disaster Information Management System (https://www.desinventar.net/DesInventar/); Emergency Events Database (www.emdat.be/); CLIMADA (https://wcr.ethz.ch/research/climada.html)

[9] Collections of case studies and data on climate impacts and adaptation options are provided for example at https://climate-adapt.eea.europa.eu/; https://climatescreeningtools.worldbank.org/resources; https://www.gfdrr.org/en; https://www.adaptation-undp.org/; https://econadapt-toolbox.eu/

[10] GIZ (2021). Macroeconomic Models for Climate Resilience. An economic tool for adaptation and development planning.

Appendix

Appendix 1: IOT country coverage

AR	Argentina	ES	Spain	LA	Lao PDR	PT	Portugal
AT	Austria	FI	Finland	LK	Sri Lanka	RO	Romania
AU	Australia	FJ	Fiji	LT	Lithuania	RU	Russian Federation
BD	Bangladesh	FR	France	LU	Luxembourg	SA	Saudi Arabia
BE	Belgium	GB	United Kingdom	LV	Latvia	SE	Sweden
BG	Bulgaria	GR	Greece	MA	Morocco	SG	Singapore
BN	Brunei Darussalam	HK	Hong Kong SAR, China	MM	Myanmar	SI	Slovenia
BR	Brazil	HR	Croatia	MN	Mongolia	SK	Slovak Republic
BT	Bhutan	HU	Hungary	MT	Malta	TH	Thailand
CA	Canada	ID	Indonesia	MV	Maldives	TN	Tunisia
CH	Switzerland	IE	Ireland	MX	Mexico	TR	Turkey
CL	Chile	IL	Israel	MY	Malaysia	TW	Taiwan, China
CN	China	IN	India	NL	Netherlands	US	United States
CO	Colombia	IS	Iceland	NO	Norway	VN	Vietnam
CR	Costa Rica	IT	Italy	NP	Nepal	ZA	South Africa
CY	Cyprus	JP	Japan	NZ	New Zealand		
CZ	Czech Republic	KG	Kyrgyz Republic	PE	Peru		
DE	Germany	KH	Cambodia	PH	Philippines		
DK	Denmark	KR	Korea, Rep.	PK	Pakistan		
EE	Estonia	KZ	Kazakhstan	PL	Poland		

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