Analyzing climate change adaptation measures in Georgia

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Introduction

Georgia's geographical location and natural conditions, ranging from complex mountainous landscape to the black sea coastal zone, contribute to a substantial vulnerability to climate change. There are several observable signs of climate change in Georgia during recent decades, among others increasing mean and extreme air temperatures, increased average annual precipitation, and changing rainfall patterns, increased frequency of droughts and hailstorms. These climate change effects are increasingly impacting people's lives and disrupting the Georgian economy. Knowledge of the economy-wide effects of climate change and the implementation of adaptation measures is vital for Georgia in order to set up an appropriate adaptation strategy that focusses on all economic sectors. A multitude of economic sectors will be affected by the impacts of climate change, and adaptation to climate change can in each case ensure that the damage is kept to a minimum and that additional positive impulses are provided to the economy through their implementation. Modeling research allows the determination of climate change effects on macroeconomic indicators like GDP and employment. Furthermore, modeling research is capable to quantify the economy-wide effects of different adaptation measures to elaborate adaptation strategies that support a sustainable development of the economy. The results of the modeling research can be used for the planning in several economic sectors being affected by climate change, including water resources management, agriculture, tourism, and construction of roads, railways, and buildings (USAID 2016).

Methods

We use a macroeconometric input-output model, e3.ge, that was specifically developed in the CRED project for this purpose, to analyze the socioeconomic impacts of various adaptation policies in the country of Georgia (GIZ 2022). More information on CRED and the modelling for climate resilience can be found in Großmann et al. (2022). More details about the approach including a short classification in the literature and in the different model approaches mentioned there is provided by Banning et al. (2023). Adaptation modeling largely builds on model-based policy analysis. Modeling of extreme events can build on disaster research. Disaster Impact Research is a common field of application for IO analysis. There is a large number of research projects in which analyses and assessments of the effects of catastrophic events, such as floods or hurricanes, are undertaken. In many of these studies, IO models are used to estimate the direct costs of reconstruction and the indirect costs resulting from the triggered changes in demand (e. g. Haimes & Jiang 2001, Bockarjova et al. 2004, Cochrane 2004, Okuyama et al. 2004).

Nikas et al. (2019) differentiate six classes of climate-economy models building on various classifications in the literature including macroeconometric IO models. The e3.ge model is a dynamic input-output model that consists of three interlinked model parts (for more information on the modelling concept and methodology also see Großmann et al. (forthcoming)). Macro-econometric (or dynamic) IO models (Almon 1991, 2014; West 1995) build upon the advantages of static IO models but largely resolve their limitations and inherent assumptions, amongst others the absence of time and of capacity constraints (Großmann et al. 2022). At the core of the economic model (1) of e3.ge is a symmetric Georgian input-output table. As no officially published table existed at the beginning of the project, one was derived from the available supply and use tables. 38 economic sectors are differentiated inside the model. Development and linkages of final demand components, such as household and government expenditures, or gross fixed capital formation is estimated econometrically using domestic data. Labor market data is also available from Georgia's National Statistical Office, distinguishing employment in 16 economic sectors and providing aggregated and averages wages. Sectoral employment is linked to output of individual sectors. The energy module (2) consists of the energy balance. The energy consumption depicted in there is directly linked to individual sectors of the input-output table using gross output for industry sectors as well as macroeconomic development and population for transport and the residential sector. The energy mix used as transformation input for the generation electricity can be found in the energy balance as can exports and mainly imports of various energy carriers. It is assumed that electricity demand is met by energy supply: the expansion path of local hydropower is key, as resulting gaps have to be closed by gas imports that are used in fossil power plants. Furthermore, energy-related emissions are calculated using national emission factors for several fossil energy carriers. The environment module (3) contains detailed economic information and data on climate change and adaptation options. Data on past damages from climate change cover extreme weather events. This damage data serves as a benchmark for the economic effects of climate change in Georgia and is projected to the future using data from extensive climate models (joint work with the University of the Balearic Islands).

Evaluation of adaptation measures is performed by conducting scenario analysis. A business-as-usual scenario is contrasted with a scenario that contains the negative impacts of climate change, and another scenario that contains both the impact from climate change and adaptation measures and their presumably positive impact, either by additional investment or by reduced damages.

One type of event prevalent in the past and bound to increase in frequency and severity in the future is extreme heat (Navarro and Jorda Sanchez 2021). The effects of a heatwave on the economy are manifold, Infrastructure, industrial and agricultural productivity, as well as electricity generation and distribution infrastructure are all possibly affected. While data on certain effects might be scarce and their mapping requires some assumptions, the exogenous scenario specifications of the heatwave scenario are: Increased demand for healthcare services due to symptoms caused by heat (based on evidence form Hübler 2014 for Germany); higher demand for beverages (using a 2018 heatwave in Germany for reference); damage to irrigation systems; reduced exports of wine due to burnt grapes as well as reduced agricultural production in general, accompanied by a price increase; productivity in industry is also decreasing due to workers being affected by hot conditions (based on ILO 2019); finally, electricity demand is increased due to higher use of cooling and air conditioning.

When evaluating the impact of adaptation measures, our focus is set on the agricultural sector. With the sector employing about 40% of all workers, its importance to the Georgian economy remains high. Even though it's share on GDP decrease in recent decades, it stands at 7.4% as of 2021 (USAID 2017, GeoStat 2023). At the same time, it is highly vulnerable to the impacts of climate change (MoF 2015). For the purpose of analysis, we limit the negative effects of the heatwave scenario to the damages in agriculture and contrast it with a scenario where adaptation action is taken in form of increased use of irrigation systems. There is already an irrigation strategy set in place in Georgia, which "encompasses the rehabilitation of decayed irrigation infrastructure and the development of a modern data-based professional and participatory irrigation management capacity" (MoA 2017).

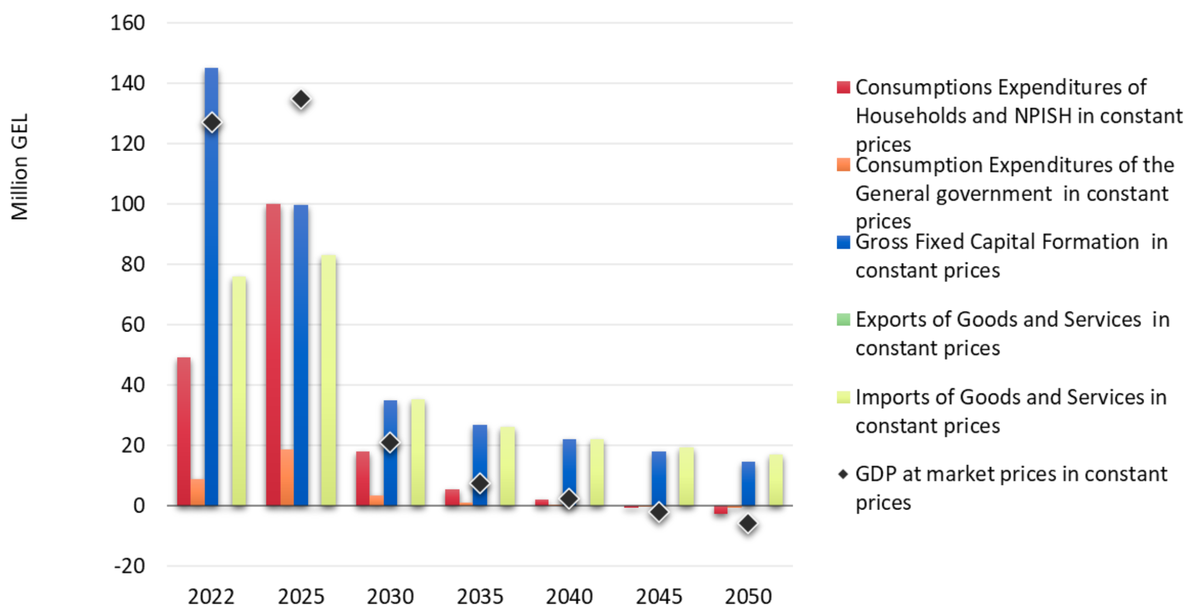
Severe droughts are assumed to occur every 5 years, starting in 2025 with the last year of projection being 2050. Intensifying climate change leads to increasing effects on agriculture over time. The rehabilitation of existing gravity irrigation schemes is done by construction works (e.g., canals, drainage, reservoirs). Water-saving technologies (e.g., drip irrigation systems) will be imported from abroad (China, Turkey and Israel; MoA 2017). Rehabilitation and installation of the irrigation systems is done by the local construction industry in Georgia. The benefits of irrigation systems include increased agricultural productivity and thus increased crop yields in years without severe heat and drought, and reduced damages in years with extreme temperatures. Water availability does not seem to be constraining (MoA 2017).

Costs and benefits from irrigations systems are derived from MoA (2017) and enter the e3.ge model exogenously. The investment required for irrigation systems amounts to 700 million GEL until 2025 and 50 million GEL p.a. afterwards. In the first phase (until 2025) 85% of the investment goes into irrigation channels and 15% goes into drip irrigation systems, while from 2026 onwards 25% of the investment goes into irrigation channels and 75% goes into drip irrigation systems. The benefits are estimated with crop yield increase of 15% from 2025 onwards, increasing linearly in the years leading up to this point. Per assumption the government subsidizes the investment, reducing governmental consumption in other areas.

Results

The following results depict the differences between the irrigation scenario and the scenario without adaptation measures that is limited to the impact of heatwaves on the agricultural sector, that is droughts.

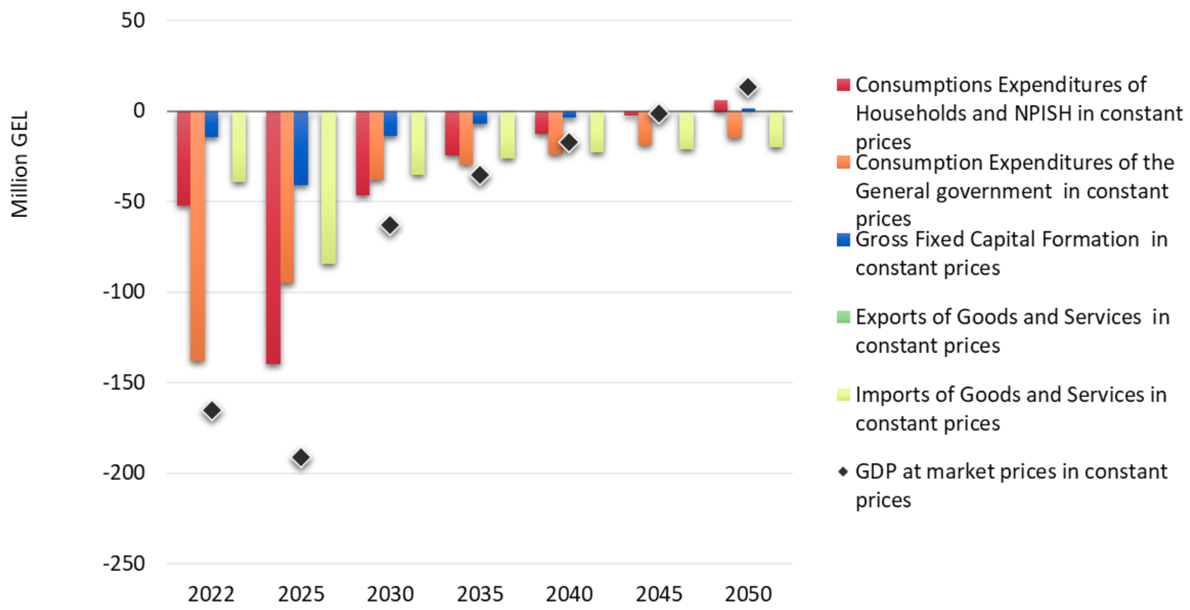
Figure 1: Macroeconomic effects of the additional investment in construction and machinery in the "Irrigation" scenario, selected years, deviations from Drought scenario in million GEL



Source: own results calculated by e3.ge, adapted from GIZ (2022).

The additional investment in construction has a clear positive impact on the economy and the GDP. Initial investments in construction are rather high, reflecting the irrigation strategy, while investments in the following years serve to maintain the quality. After the rehabilitation of the irrigation channels in the year 2025, the annual construction investment is small, but still positive. Since almost 100% of machinery products are imported, imports increase in line with investments in machinery. No local production takes place. This negative effect, however, is limited and thus the overall impact on the GDP remains positive until 2040. With the induced effects of additional investments in the earlier years decreasing overtime while imports not decreasing as fast, the resulting GDP effect is slightly negative in the years afterwards. In the year 2025, GDP is higher by GEL 140 million, corresponding to +0.28%.

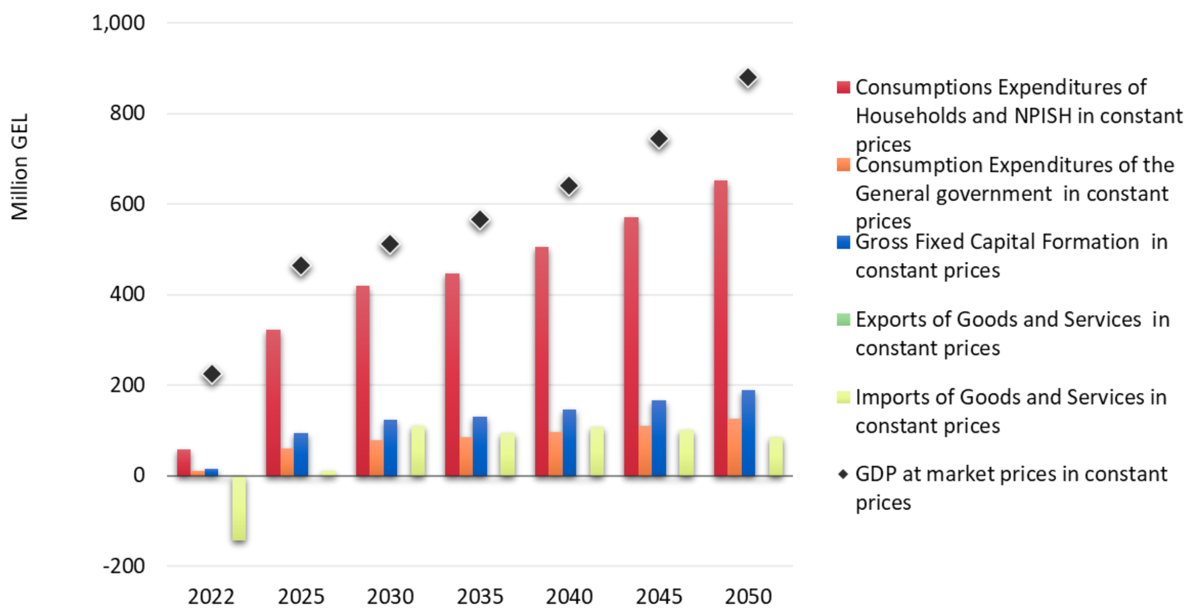
Figure 2: Macroeconomic effects of reduced government expenditures in the Irrigation scenario, selected years, deviations from Drought scenario in million GEL



Source: own results calculated by e3.ge, adapted from GIZ (2022).

With the government subsiding irrigation systems, other governmental expenditures must be reduced. The amount of investment needed for the adaptation measure (construction, machinery) are deducted 1:1 from other consumption expenditures. Thus, Figure 2 illustrates the isolated effect of a reduction in government consumption expenditures. The effect on the GDP is negative (GEL -200 million in 2025; -0.4%) and getting smaller over time, since the amount of investment is decreasing.

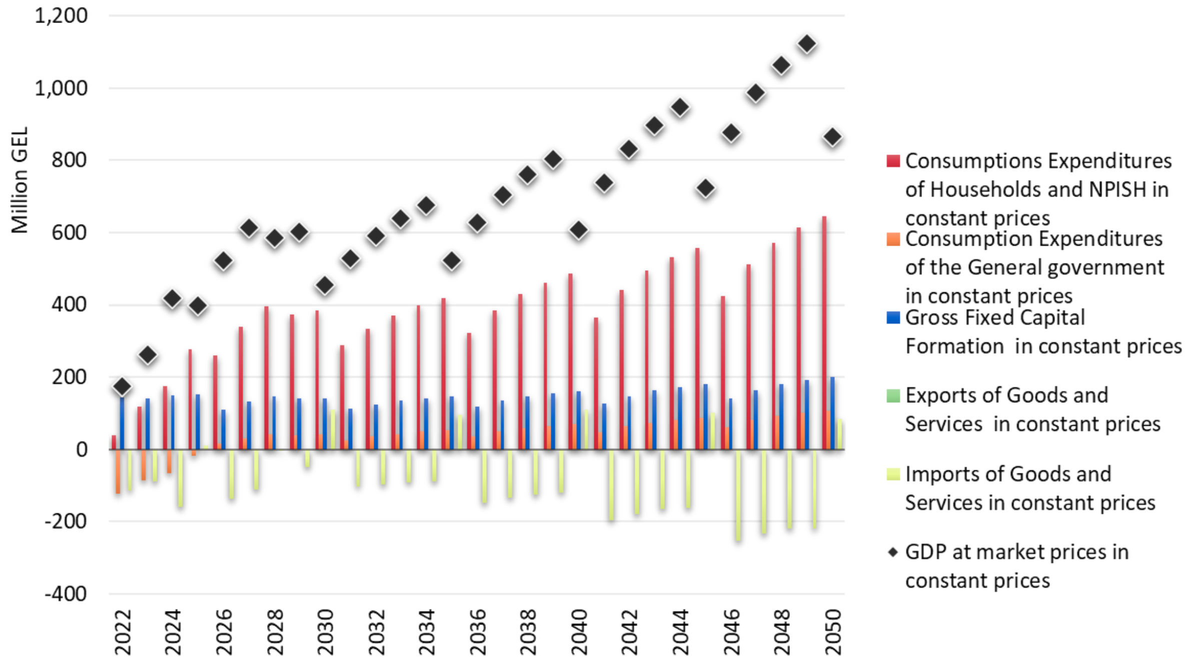
Figure 3: Macroeconomic effects of increased productivity in agriculture in the Irrigation scenario, selected years, deviations from Drought scenario in million GEL



Source: own results calculated by e3.ge, adapted from GIZ (2022).

The increasing productivity in agriculture has the highest impact on the economy (see Figure 3). In years without a drought (which is assumed to occur every 5 years, beginning in 2025), the irrigated arable land becomes larger and therefore the crop yield increases. In years with a drought, the resulting damages are reduced. Compared to the scenario with only climate change, the imports of agricultural products can be reduced and the production in the agricultural sector increases. The overall effect on imports results on the one hand from additional imports due to higher consumption and investment and on the other hand from reduced imports of agricultural products. The production is increasing not only in the agricultural sector, but also in those sectors delivering inputs for the agricultural sectors and those sectors using agricultural products as an input. The positive impact of the increased productivity in agriculture is the main determinant of the overall macroeconomic effects (see Figure 4).

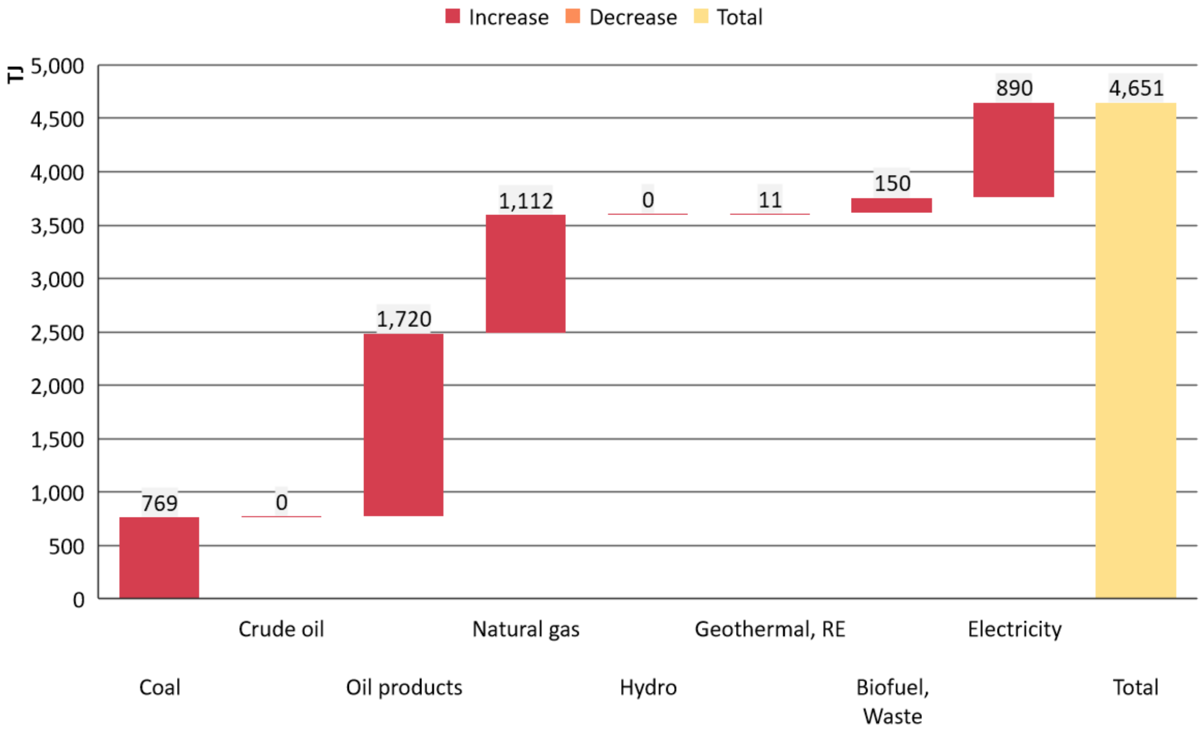
Figure 4: Macroeconomic effects of the Irrigation scenario, selected years, deviations from Drought scenario in million GEL



Source: own results calculated by e3.ge, adapted from GIZ (2022).

GDP increases by up to 1% (up to GEL 1,000 million) in one year in the period under review. Positive effects on GDP from additional investment result in lagged positive effects on consumption and investment, which in turn also have a positive impact on other economic sectors and thus on the GDP. Consumption expenditures increase by up to 0.9% (up to GEL 640 million; see Figure 4) in a single year in the period under review. Since the government subsidizes the irrigation systems, the government's consumption expenditures are reduced elsewhere. The biggest economic effects are to be expected from the increase in production in agriculture due to the additional irrigation. Although there are still crop losses due to droughts and high temperatures, damages can be significantly reduced.

Figure 5: Effects of the "Irrigation" scenario on final energy consumption, 2040, deviations from the Drought scenario in TJ



Source: own results calculated by e3.ge, adapted from GIZ (2022).

The changes for the various energy carriers are dependent on the fuel-specific energy consumption in the economic sectors. Agriculture and construction as well as up- and downstream industries are mainly benefitting from this adaptation measure causing in particular a higher demand for oil products (e.g., 1,700 TJ in 2040; 0.9%), natural gas (1,100 TJ; 0.7%) and electricity (890 TJ; 0.6%). The increase in energy consumption is consequently linked to an increase in energy-related emissions.

Conclusion and discussion

As many countries around the world, Georgia is at risk to face the impacts of climate change in form of more frequent extreme weather events in the future. Adaptation measures can dampen their impact but requires effort in form of investment and physical implementation of measures beforehand. Macroeconomic effects of adaptation measures in Georgia are overall positive. As a higher gross domestic product (GDP) can result due to several factors, it is important to have a closer look on the underlying causes to evaluate individual measures. A positive GDP effect can be observed even in scenarios without adaptation for the years where damage occurs. Nevertheless, the so-called defensive spending on repairing, reconstruction and increased consumption behind the positive impact can be interpreted as inherently undesirable as the positive effect is due to the fact that damage has previously been caused by storms, heavy rains or in this case heatwaves. In contrast, adaptation to climate change ensures that, e.g. additional annual construction activity will also generate a positive GDP effect and, at the same time, damages caused by extreme weather events will be lower. This can be illustrated by the example of heatwaves: Buildings heat up and people are less productive; more energy is demanded for cooling reasons; more beverages are consumed; people experience health problems. While declining productivity has a negative impact on the economy, increased beverage consumption and increased demand for health services can have a positive economic impact. Analyzed extreme weather events also include strong wind and heavy precipitation while adaptation measures range from irrigation and windbreaks to infrastructural programs and coastline protection.

This model is the first macroeconometric model with input-output core applied in Georgia. The model was closely developed together with the Georgian Ministry for Economy and Sustainable Development. All information and data entering the model were continuously discussed beyond that with additional stakeholders and national institutions, such as the Ministry for Environmental Protection and Agriculture, the National Bank of Georgia, and several NGOs. One objective of the project, that was fulfilled, was to rely on domestic data sources and only use international data where no other estimates are available. The model results will be now used in policy-making processes in Georgia to evaluate the economic effects under a bandwidth of climate change scenarios and adaptation options. They provide the quantitative background to decide upon effective policy instruments that lead to resilient economic development.

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