Economic impacts of climate change and adaptation in Vietnam

Overview of the "Dynamic General Equilibrium Model for Climate Resilient Economic Development" (DGE-CRED)

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ECONOMIC IMPACTS OF CLIMATE CHANGE AND ADAPTATION IN VIETNAM

OVERVIEW OF THE "DYNAMIC GENERAL EQUILIBRIUM MODEL FOR CLIMATE RESILIENT ECONOMIC DEVELOPMENT" (DGE-CRED)

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Introduction

Vietnam is one of the countries most severely affected by climate change and natural disasters. Weather phenomena related to climate change, such as rising temperatures and sea levels and more frequent occurrences of extreme weather events, including cyclones and typhoons, could have already been observed in recent years. Climate projections by the National Oceanic and Atmospheric Administration (NOAA) indicate even higher average temperatures, increased rainfalls and higher sea levels for the following years. Without any adaptation measures, many areas are at risk of inundation, and all sectors of the economy will be affected; see also Climate Risk Country Profile: Vietnam (2021). The increasing impact of climate change on long-term economic growth and its consequences reinforce the need for approaches to assess the effects of climate risks and potential adaptation strategies on a country's economy. In particular, policymakers would benefit from having access to evidence-based economic projections for Gross Domestic Product (GDP) components such as investment consumption, net exports and government expenditure. To implement appropriate monetary policy measures. These may include shifting investment to more climate resilient sectors and measures to mitigate adverse effects in industries particularly affected by climate change. The inclusion of climate change and potential adaptation measures as variables in macroeconomic models can support the monitoring and evaluation of adaptation measures. For instance, using these modelling results helps tracking the economic impacts of climate risks and evaluating the steps taken to mitigate them (GIZ 2021).

With this background, the "Dynamic General Equilibrium Model for Climate Resilient Economic Development (DGE-CRED)" has been developed at the Halle Institute for Economic Research (IWH) in cooperation with the Central Institute for Economic Management (CIEM) as part of the GIZ global project "*Policy Advice for Climate Resilient Economic Development (CRED) programme*" financed by the German Federal Ministry for the Environment. This model explicitly derives the effects of climate change at the regional and sectoral level for the Vietnamese economy. In particular, it allows analysing of the dynamics of economic variables of interest (e.g. gross value added, investment and consumption) in response to different projections of climate change and associated weather phenomena. In addition, the model can analyse the counteracting effects of adaptation measures and facilitate cost-benefit analysis for policymakers.

In the following, we present a consistent model framework to analyse potential adverse effects of climate change in different regions of Vietnam and sectors of its economy. In a second step, we investigate how variables of interest would evolve instead if adaptation measures were implemented to limit the effects of climate change. It will allow us to perform cost-benefit analyses for selected policy measures explicitly.

The DGE-CRED Model

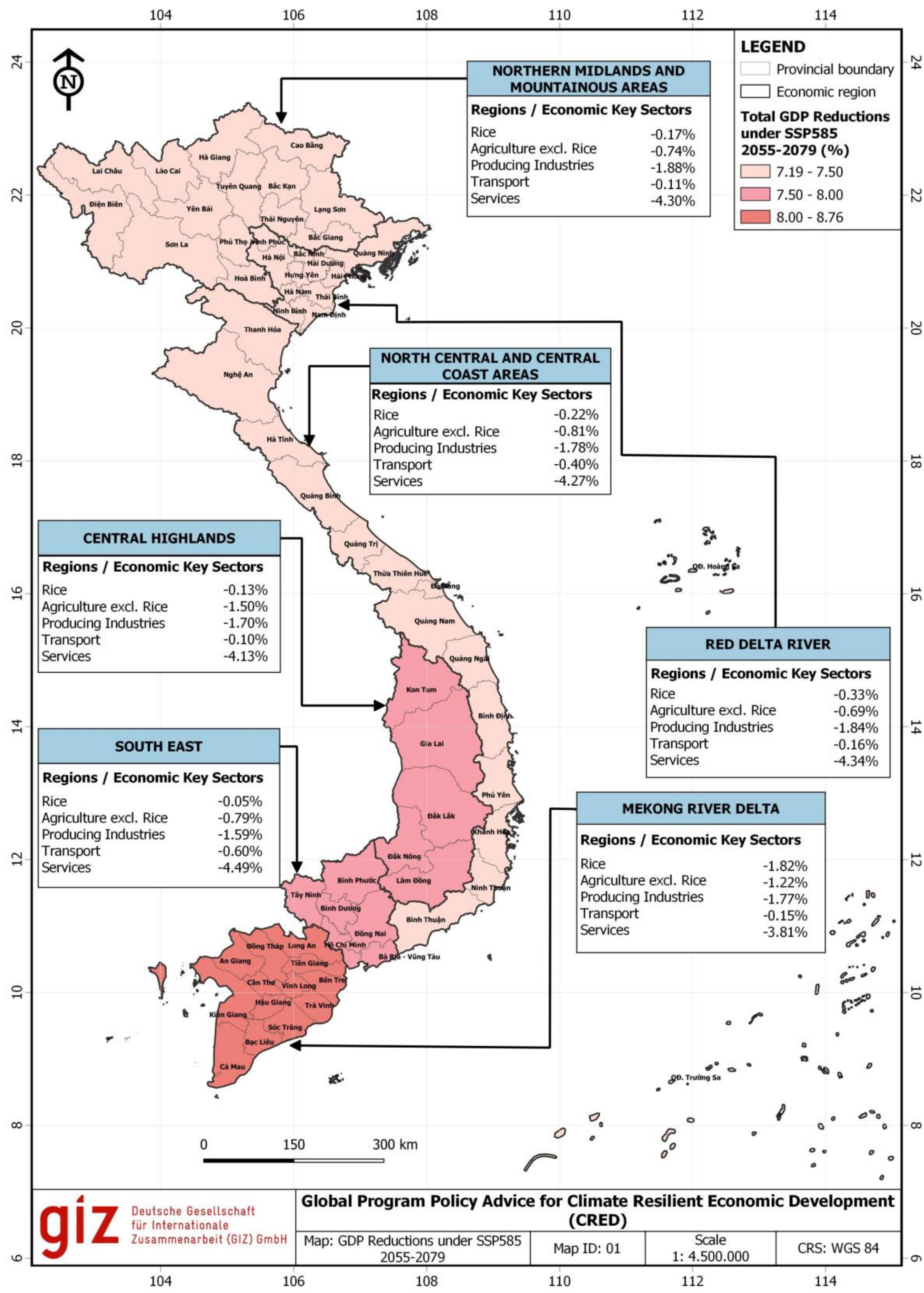
The DGE-CRED model is a dynamic general equilibrium (DGE) model with optimising agents. For instance, firms adjust production levels of goods and services to maximise profits. It is used to analyse the impact of climate change on the Vietnamese economy (including sectoral and total GDP, sectoral and total labour, consumption, investment, exports, imports, and relative prices for each sector) as well as how potential adaptation measures by the government can reduce the damage. DGE models with optimising agents are a standard tool to assess the impact of different policy measures since they allow us to break down the effect of the actions in a very detailed way. The model is constructed as a multi-sector and multi-region model. This approach allows for differentiation between different regions and economic activities to account for various regional climate developments and other characteristics of economic sectors and their specific vulnerability to climate change. This detailed breakdown facilitates the analysis of targeted policy measures. The model is calibrated to represent the regions' current economic structures. Sectors in the model correspond to economic activities and the General Statistics Office of Vietnam (GSO) classification. The following areas are covered: Red River Delta, Northern Midlands and Mountain Areas, North Central and Central Coastal area, Central Highlands, South East, and Mekong River Delta. The model is constructed so that it is easily possible to modify the number of sectors and regions by aggregating the official data. It reduces the model's size and makes testing modifications and new features more accessible.

The model framework follows the standard DGE modelling approach. The link between climate and the economy is modelled using sector and region-specific damage functions based on literature review and new sectoral sub-models developed by Vietnamese experts. Climate variables and weather extremes are linked to the region and sector-specific production functions. They impact total factor productivity and the demand for labour and capital inputs. For example, one can think of cyclones that can destroy capital stock. Firms can then either substitute capital using more work in the respective period. Or they might need to lay off workers because they are unproductive without machines that have been destroyed.

Since the impact of the Vietnamese economy on global climate and climate variables is negligible, we treat them as exogenous. The paths of climate variables are defined with the help of meteorological models based on climate change scenarios, according to the socioeconomic shared pathways (SSPs) developed for the Intergovernmental Panel on Climate Change (IPCC). We model different climate variables by regions based on the simulation results of regional average annual temperature, the average precipitation, sunshine influx, relative surface humidity, the average yearly wind speed, heatwaves, maximum consecutive dry days, maximum consecutive wet days, storms, floods, fires, landslides and sea level.

The model is implemented in the open-source environment Dynare and can be run using MATLAB. The open-source character of the model minimises the costs of acquiring the necessary skills and experience to work with the model and facilitates knowledge transfer.

Figure 1: GDP reduction under SSP 585 (severe climate change) in 2055-2079 for key regions and economic sectors



Source: GIZ and IWH.

Sectoral Models and Linkages with Core Model

Sectoral damage functions reflect expert knowledge in the agriculture, forestry, housing construction, transport, drainage and dyke sector. The agricultural industry is disaggregated into rice, other annual crops, fruit trees, dry rubber, coffee, other perennial crops, livestock and farming services. In particular, the output of the sectoral models is used to estimate direct damages to describe the most relevant impact channels from climate change. An extended input-output table reflects the economic structure for 2014, representing the most recent version available for the required disaggregation by sectors.

TABLE 1: IMPACT CHANNELS AND ADAPTATION OPTIONS

Sector	Direct Damage (Estimation)		Adaptation	
Forestry	▪ deforestation through forest fires	▪ heat stress affects labour productivity	▪ mixed plantation	
Rice, other annual crops, fruit trees, dry rubber, coffee, other perennial crops, livestock and agricultural services	▪ sea-level rise and temperature increase affect total factor productivity ▪ crop yield model simulation for rice and fruit tree in the Mekong River Delta ▪ crop yield model simulation for coffee and dry rubber in the Central Highlands		▪ endogenous adaptation to climate change through disinvestment from highly vulnerable to less vulnerable sectors. ▪ private action is implicitly modelled by optimising agents. ▪ land use planning for harvesting different types of coffee in Vietnam.	▪ building a dyke to secure against sea-level rise ▪ build sustainable urban drainage systems to shield against flood damages to the housing stock, road infrastructure, and loss in working hours
Housing	▪ storm and sea level affect the housing stock		▪ build houses with reinforced walls and bricks ▪ raise a house on stilts	
Transport	▪ sea level, temperature and landslide affect the capital stock		▪ roadbed elevation ▪ polymer asphalt ▪ effective measures against road erosion	
Industry	▪ Capital loss caused by sea level rise			
Aquaculture, Utilities, Construction, Health and Services				

Source: Own illustration based on sectoral reports.

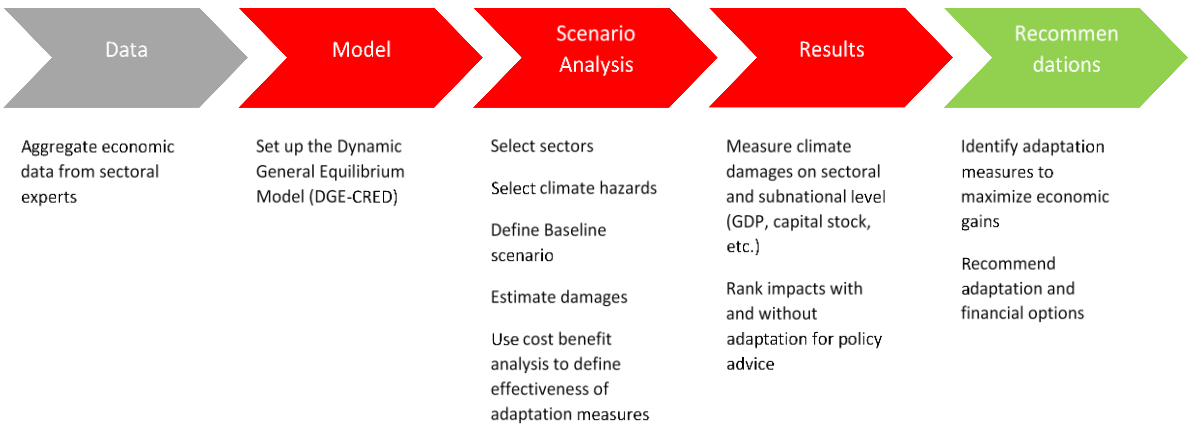
Scenarios for Simulations

The DGE-CRED model is simulated using a baseline scenario and several alternative scenarios for each SSP where adaptation measures are implemented. The hypothetical baseline is based on the assumption that climate change has no economic impact. Sectoral productivities are computed to match specific sectoral growth rates that result in a future economic structure congruent with current projections and expert opinions[1]. The same applies to labour-specific productivity shocks to compare the reported growth rates for labour supply shares. According to forecasts by the GSO, the Vietnamese population is growing at an exogenous rate.

Further, it is assumed that the relationship between net exports and GDP remains constant at the 2014 level. It is ensured through adjustments in the import price level. The housing stock per capita is stable, and the house price increases due to a fixed supply of housing areas. All model parameters are set to reflect the characteristics of the Vietnamese economy in 2014.

The model uses results from the Meteorological Research Institute (MRI) for climate change scenarios. We explicitly use the simulation results for the shared social path (SSP) scenarios 119, 245 and 585, i.e. with low, medium and high mitigation challenges, respectively. In contrast to the baseline, the climate change scenarios model the evolution of climate variables and their impact on the different sectors. An adaptation scenario for the SSP scenarios is implemented for vulnerable sectors, where only adaptation measures for the respective industry are considered. It allows identifying the adaptation measures with the highest impact on GDP, consumption and investment in Vietnam. Further, this allows identifying the adaptation measure with the highest potential when minimising the adverse effects of climate change on the Vietnamese economy.

Figure 2: CRED Process: Macro-economic modelling for evidence-based policy making



Source: GIZ and IWH.

[1] Projection in 2050, shares of the Primary sectors: 11%, Secondary: 39%, Tertiary: 50%; in 2100: 7%, 30%, 63%.

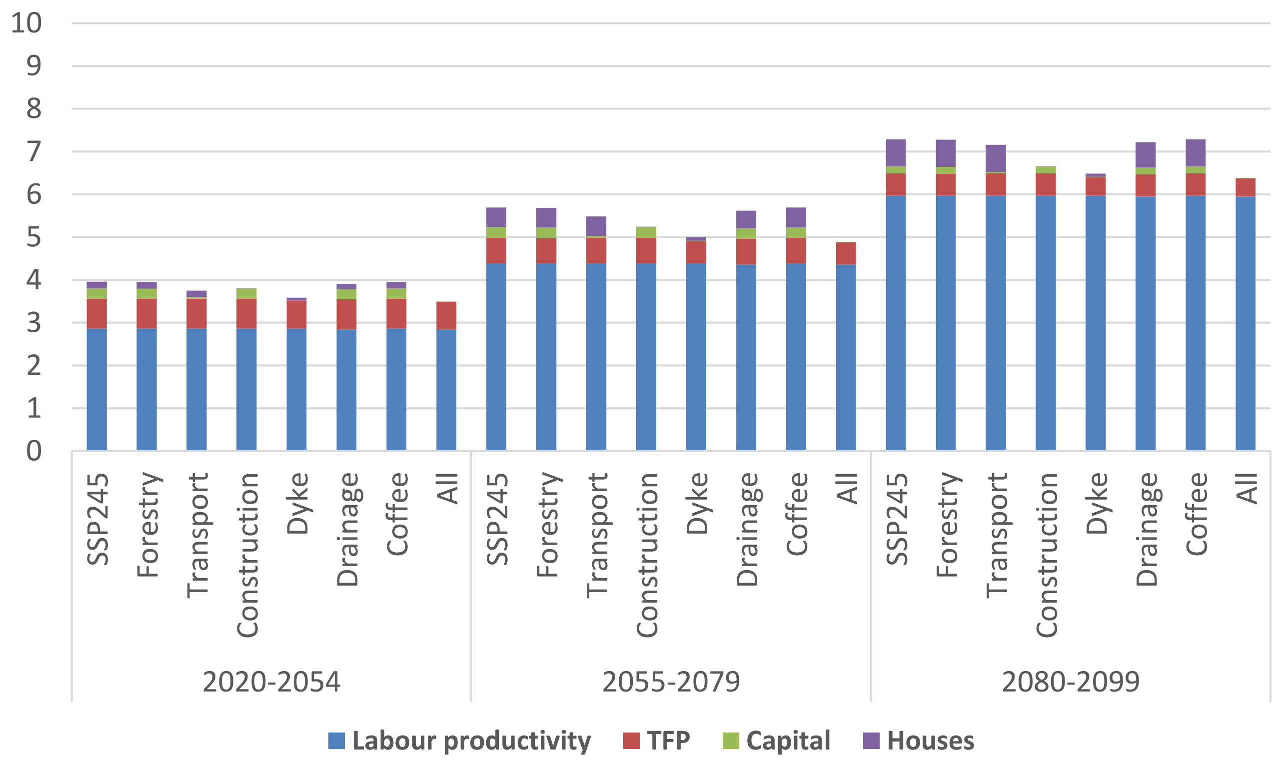
(**Primary**: Agriculture, Aquaculture, Forestry, Water; **Secondary**: Energy, Manufacturing, Construction; **Tertiary**: Transport, Health, Services).

This modelling approach explicitly differentiates between two types of adaptation. Firstly, there is an endogenous reaction of optimising agents to climate change. If, for example, climate change adversely affects production in one region and reduces the profitability of production factors, agents will automatically move to sectors and areas that are less affected, i.e. where the same input factors can be used more productively. Secondly, the government can use its funds to finance adaptation measures for specific regions and sectors. The link between government expenditure for adaptation purposes and the reduction in realised damage is integrated through exogenous variables. It allows for any functional relationship between adaptation measures and their effectiveness at the cost of lower transparency than a functional form.

Results and Recommendations

All the information and data received for the vulnerable sectors have been used to set up and run the DGE-CRED model. Therefore, the results reflect the current assessment of climate change impacts on different economic sectors by sectoral experts. This knowledge needs to be updated regularly to incorporate the current research frontier.

Figure 3: Expected damages in Vietnam relative to GDP



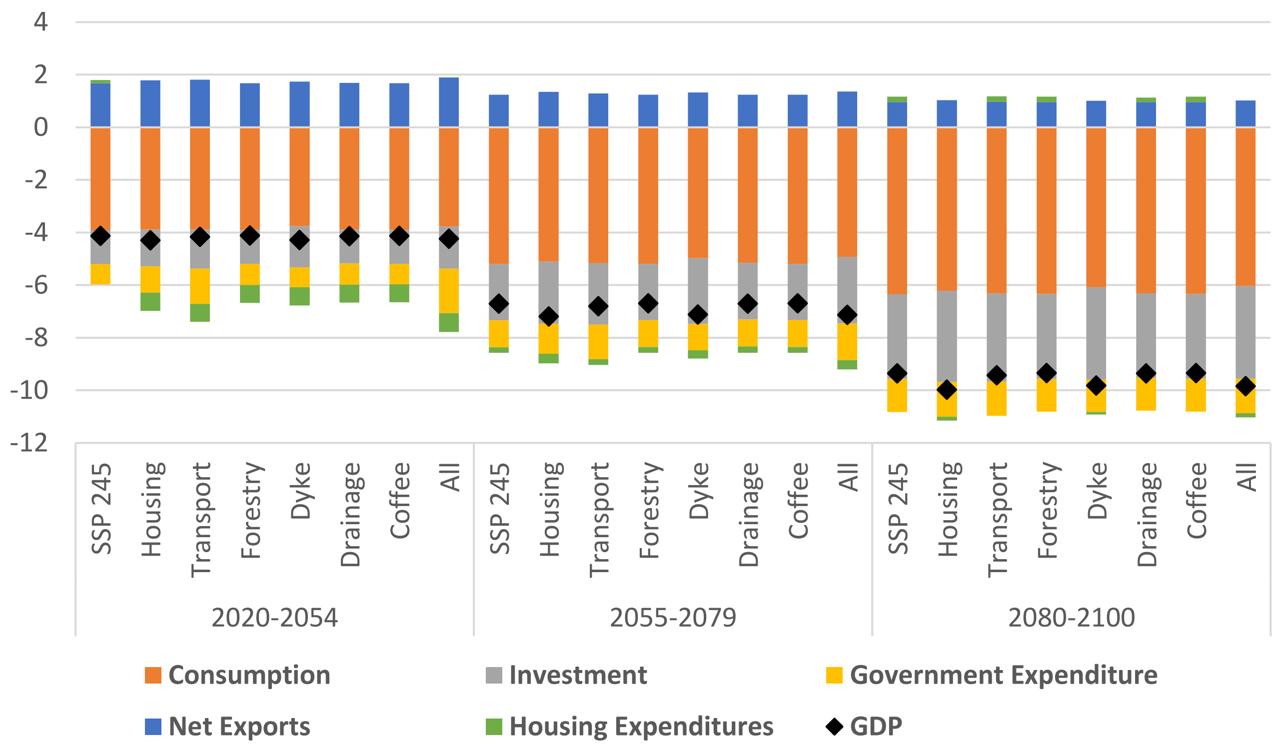
Source: IWH calculations.

We differentiate between four main types of direct damage (Figure 3). First, we consider damages to the housing stock in Vietnam. Storms and floods induced by sea-level rise destroy the housing stock in Vietnam. Direct damages to the capital stock in Vietnam reflect the destruction of the road stock or factories in the manufacturing sector through landslides, floods and heatwaves. A variety of damages is comprised under total factor productivity (TFP) shocks. Direct damages to TFP affect the productivity of labour and capital simultaneously. It includes land loss, lower crop yields caused by higher temperatures or the destruction of forests due to forest fires. The main hazard to the Vietnamese economy is the loss of labour productivity due to heat stress. The implemented adaptation measures mainly focus on reducing the capital stock, housing, or land losses caused by sea-level rise. Our simulation results indicate that climate change can reduce Vietnam's annual GDP on average by 5 percent in the 2050s.

While Arndt, Tarp, & Thurlow (2015) estimate low reductions in GDP due to climate change in the 2050s,our results are consistent with Espagne et al. (2021), who estimate climate change to prompt a decline between 1.8 and 4.5% of Vietnam's GDP by 2050. World Bank Group (2022) even estimates a reduction in annual GDP in the 2050s by roughly 10% of GDP. The range of results for the SSP 245 scenario shows that the impact channels are still very uncertain. Therefore, it is necessary to understand the causes of the observed differences better.

The results suggest that the main reason for the observed decline in annual GDP is a loss in consumption followed by investment. The contribution of housing and government expenditure is relatively low. Net exports increase compared to the Baseline scenario. One reason for the observed increase is the low price elasticity of export demand. Demand for Vietnamese products from other countries in the world does not fall one to one with an increase in the relative price of domestic goods.

Figure 4: GDP components



Source: IWH calculations.

Since consumption and leisure are the main determinants of welfare in the model, adaptation measures should be designed to reduce the welfare gap represented by the loss of consumption opportunities and the necessary sacrifice in leisure. Suppose adaptation measures designed for specific sectors have to be prioritised. In that case, this should be done according to their potential to reduce the gap in consumption between climate change scenarios and the Baseline scenario (Figure 4). We see that adaptation measures to make the dyke system more resilient reduce the consumption gap more than adaptation measures in the other sectors.

TABLE 2: PRIORIZATION OF ADAPTATION MEASURES

SSP 119 (-3.57)		SSP 245 (-5.75)		SSP 585 (-7.47)	
Coffee	-3.48	Forestry	-5.82	Coffee	-7.38
Forestry	-3.47	Drainage	-5.79	Forestry	-7.37
Transport	-3.47	Coffee	-5.79	Transport	-7.36
Drainage	-3.46	Housing	-5.72	Drainage	-7.35
Housing	-3.40	Transport	-5.70	Housing	-7.25
Dyke	-3.31	Dyke	-5.59	Dyke	-7.17

Source: IWH calculations

However, neither the considered adaptation measures in the dyke, drainage, transport, housing, coffee or forestry sector can fully close the consumption gap in a relevant magnitude. It implies that the main reason for the gap in consumption is not due to the forestry, housing or transport sector. The main source of the consumption gap is the damage caused by climate change in the agriculture and aquaculture sector. Those damages are only partly offset by the adaptation measures in the dyke sector. However, currently, we consider dyke improvements for a sea level of 50 cm and not above. Based on our results, the policy recommendation for prioritised adaptation measures favours adaptation measures to upgrade the dyke system.

Nevertheless, the analysis shows that climate change mainly influences labour productivity in Vietnam. Therefore, developing from a labour-intensive to a capital-intensive economy is an important adaptation strategy. It is essential to invest in human capital to equip Vietnam's future and current labour force with a suitable skill set, to reduce labour intensity in Vietnam. It requires investment in vocational training and the education system. Future assessments of climate change impacts in Vietnam need to explicitly address adaptation measures to reduce the impact of labour productivity.

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