Modeling climate-resilient economic development: Quantifying economic effects for Vietnam*

Andrej Drygalla† Katja Heinisch‡ Christoph Schult§

Halle Institute for Economic Research

June 2021

Abstract

The paper addresses the macroeconomic modelling of anticipated climate risks. Specifically, we assess how different economic sectors and different regions are affected by future climate change scenarios, including extreme weather events and damages caused by slow-onset events (e.g. sea-level rise). We develop and apply a Dynamic General Equilibrium Model for Climate Resilient Economic Development (DGE-CRED) to assess future impacts of climate change on the Vietnamese economy and identify effective adaptation options. Besides climate hazard and sector-specific damage functions, the model covers adaptation measures that reduce expected damages. We use the model to assess the impact of building a dyke to guard the Mekong River delta in Vietnam against flooding as a result of climate change. The results show that the dyke construction has positive impact on GDP growth compared to a scenario without a dyke.

Keywords: Dynamic general equilibrium model, climate adaptation
JEL: E17, E27, O11, O13, O21, O44, Q54, R11

*Financial support by the Gesellschaft für Internationale Zusammenarbeit (GIZ) in the context of the research project Climate Resilient Economic Development (CRED) is acknowledged.

†email: andrej.drygalla@iwh-halle.de
‡email: katja.heinisch@iwh-halle.de
§email: christoph.schult@iwh-halle.de

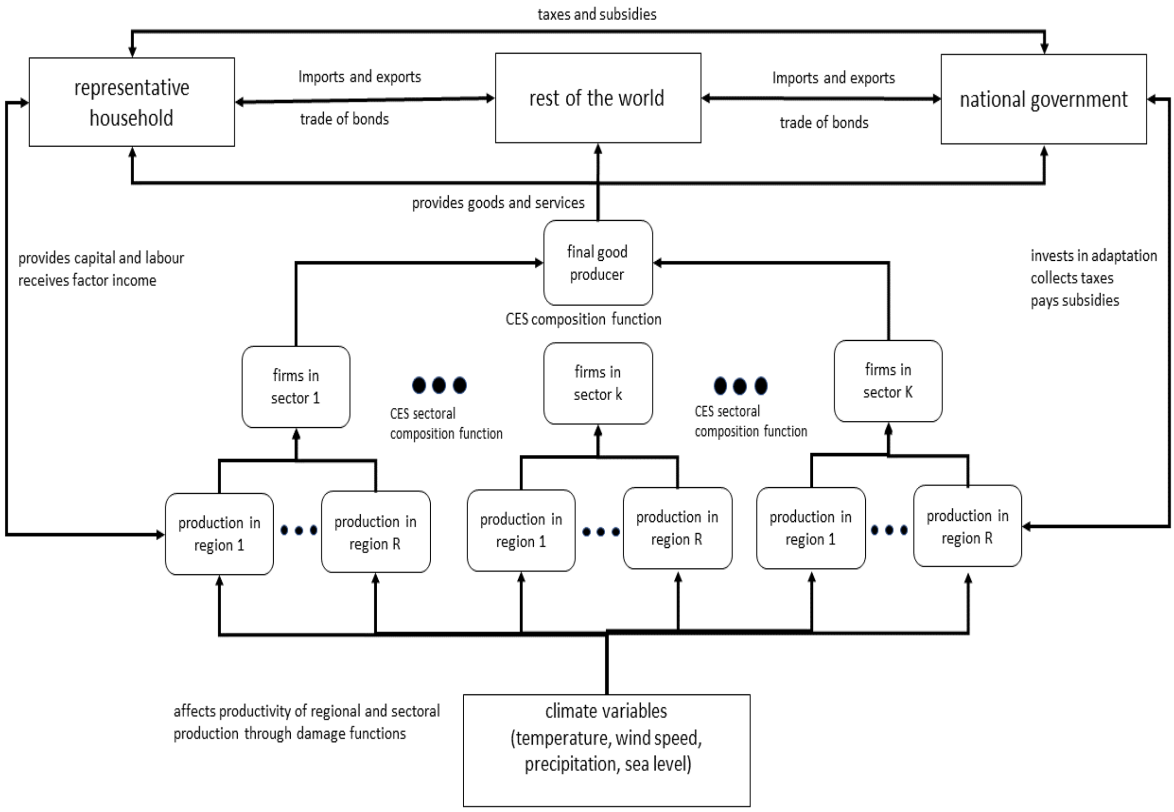
Long Abstract

Projections by the international panel on climate change (IPCC) show that the global average temperature, the sea level and the frequency of weather extremes are likely to change as a consequence of higher greenhouse gas concentration in the atmosphere (Stocker et al., 2013). Previous studies (e.g. Arndt et al., 2015; Wassmann et al., 2004; Chen et al., 2012) show that an increase in temperature, sea-level rise and a higher frequency of weather extremes (e.g. cyclones and droughts) are hazards to future economic development. Vietnam has experienced increases in temperature and sea levels, stronger storms, floods and droughts. Over the past 50 years, the average temperature in the country has increased by approximately 0.5°C, and the sea level has risen by about 20 cm. Hence, Vietnam is highly vulnerable to the impacts of climate change, and climate change has the potential to affect further economic development. Therefore, the design of efficient long-term climate policies is important. Besides mitigation, adaptation is the key tool to moderate potential damages or to even economically benefit from climate change.

For economic adaptation measures, a regional dimension is important because the impact of climate change on the Vietnamese economy will be different across regions. National statistics differentiate between six different statistical regions in Vietnam: Red River Delta, Northern Midlands and Mountain Areas (North East and North West), North Central and Central Coastal area (North Central Coast and South Central Coast), Central Highlands, South East, and Mekong River Delta. Most of the regions are located at the coast. Hence, the impact of sea-level rise will be different for coastal and non-coastal regions in Vietnam. Further, climate change will affect economic activities like agriculture, forestry and fishery differently than manufacturing. Climate variables have different effects on the production factors labour and capital used in the different economic sectors. Adaptation measures can target different sectors and different production factors. Building a dyke will reduce the damage the sea-level rise on land use. Early warning systems for cyclones are able to reduce the damage to the capital stock. Water management systems are able to tackle the issue of water scarcity due to higher temperatures. Labour productivity will be affected by heatwaves as well. Adaptation measures replacing labour-intensive tasks using more capital intensive production processes are potential adaptation measures. A cost-benefit analysis is necessary to prioritize and evaluate different adaptation measures. This needs to account for the dynamic nature of the problem. It is also necessary to evaluate the sensitivity of the results to different assumptions made in order to achieve robust policy decisions. Further, the analysis needs to be transparent and all the assumptions made are explicitly stated. Structural mathematical models are a suitable tool for this task.

Dynamic general equilibrium models with optimizing agents are a standard tool to assess the impact of different policy measures. All adaptation measures will either reduce productivity in the short-run by relocating economic activity or reduce available public funds for other development measures. Therefore, a general equilibrium framework is necessary to assess the economic implications of different adaptation measures. Investment decisions today will affect the future development of specific sectors. This implies path dependency and requires a dynamic framework. We need to differentiate between different regions and economic activities to account for different regional climate developments (see Figure 1).

Figure 1: Model Structure



Source: own exhibition.

We extend the approach by Nordhaus (1993) to model the impact of climate change through sector- and region-specific damage functions. Damage functions will affect the productivity of all production factors, or only labour productivity or the formation of capital. We know that the impact of Vietnamese economic variables on average annual temperature, precipitation, wind speed, the average intensity of cyclones and droughts are negligible. Our cost-benefit analysis takes into account the results of meteorology models to define paths for climate variables. Different scenarios to evaluate the costs and benefits associated with different climate variables are defined. In a Baseline scenario, the evolution of the Vietnamese economy is presented without any climate change. Costs associated with climate change are defined as the difference between the Baseline path and another scenario with climate change for any target variable like gross domestic product. The model is a laboratory for policymakers and researchers to conduct experiments by alternating different climate variables and adaption measures. Hence, one can quantify upper limits for costs of adaptation measures to reduce damages by climate change. For instance, it is possible to evaluate the impact of temperature increases on different sectors and the overall impact on total gross value added. The discounted cumulative difference between a scenario without a temperature increase and with a temperature increase can be used to determine the upper bound for the costs to reduce the damage caused by a temperature increase.

In order to capture the effect of climate change on the economy, it is necessary to include climate variables into the model. However, a small open economy model does not need to include the impact of domestic economic activity on climate variables. Therefore, in contrast to Nordhaus (1993), it is not required to model the interaction between economic activity and climate change. Climate variables are independent of other endogenous variables in the model. We explicitly model the regional average annual temperature, the average precipitation, the average annual wind speed, the sea level, cyclones and droughts. This approach allows to specify the evolution of climate variables according to the projections by meteorological models (e.g. Stocker et al., 2013).

One typical example of an adaptation measure against climate change and especially sea-level rise are dykes.A dyke is a capital good that requires maintenance and need to be built before the sea level rises in order to be effective. Lenk et al. (2017) show that construction costs of a dyke with one-meter length and one-meter height is about 40,000 Euro. The coastline of the Mekong River Delta is 600 km long. Building a dyke along the coastline of the Mekong River Delta of one-meter height costs roughly 24 billion Euro or roughly 15% of the Vietnamese GDP in 2016. We assume that the damage caused by inundation can be reduced to zero if the height of the dyke exceeds the change in sea level. Otherwise, the full damage materializes. We can translate the monetary value of the dyke into meters, using the estimates by Lenk et al. (2017). If the sea level rises by one meter, the cumulative investments into the dyke have to exceed 24 billion Euro, excluding maintenance costs. Our preliminary results show that a dyke will increase aggregate GDP from the beginning compared to a scenario without a dyke.

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