Dynamic General Equilibrium Model – Climate Resilient Economic Development (DGE-CRED)*

Technical Report
Preliminary

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1 Introduction

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 concentrations in the atmosphere all over the world Stocker et al. (2013). Vietnam belongs to the group of countries that are highly vulnerable to climate change, including negative consequences for their economic development. Previous studies (e.g. Arndt et al. 2015, Chen et al. 2012, Wassmann et al. 2004) show quantitatively 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.

However, 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. The map in Figure 1 shows that four of the six 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, i.e. measures that are aimed at reducing the negative impact of climate change on the economy, are thus designed to target different sectors and different production factors independently. Examples include the construction of raising houses on stilts reducing the damage by sea-level rise, replacing conventional asphalt with polymer asphalt concrete to make roads more resilient to extreme temperatures. Labour productivity can be affected by heat waves 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 prioritise and evaluate different adaptation measures. The analysis needs to account for the dynamic nature of the problem, and future benefits need to be expressed in terms of todays' costs. It is also necessary to evaluate the sensitivity of the results to different assumptions made to get reasonable 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 optimising agents provide a consistent framework to assess the impact of different policy measures on variables of interest. Besides their principal purpose, adaptation measures will either reduce productivity in the short run by relocating economic activity or reduce available public funds for other development 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.

We extend the approach by Nordhaus (1993) to model the impact of climate change on different economic sectors and regions of Vietnam. The sector and region-specific damage functions are calibrated according to scientific studies and expert knowledge that quantify the impact of climate variables on the productivity of production factors or the formation of capital. The simulations and cost-benefit analyses that we perform with our model will use the results of meteorology models to define paths for climate variables. Model users are able to 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, consumption, investment etc. The discounted cumulative difference between a scenario without a temperature increase and with a temperature increase is an approximation of the expected costs.

Our model is implemented in the open-source environment Dynare and can be run using Matlab or Octave[1]. Its open-source environment has the advantage that it increases the number of potential model users to acquire the necessary skills and experience to work with the model. Model parameters are calibrated to match (structural) characteristics of the Vietnamese economy. Sectors in the model correspond to economic activities and the classification by the General Statistics Office of Vietnam (GSO). Regions are based on the statistical regions depicted in Figure 1. It is possible to modify the number of sectors and regions by aggregating the official data. This allows to reduce the size of the

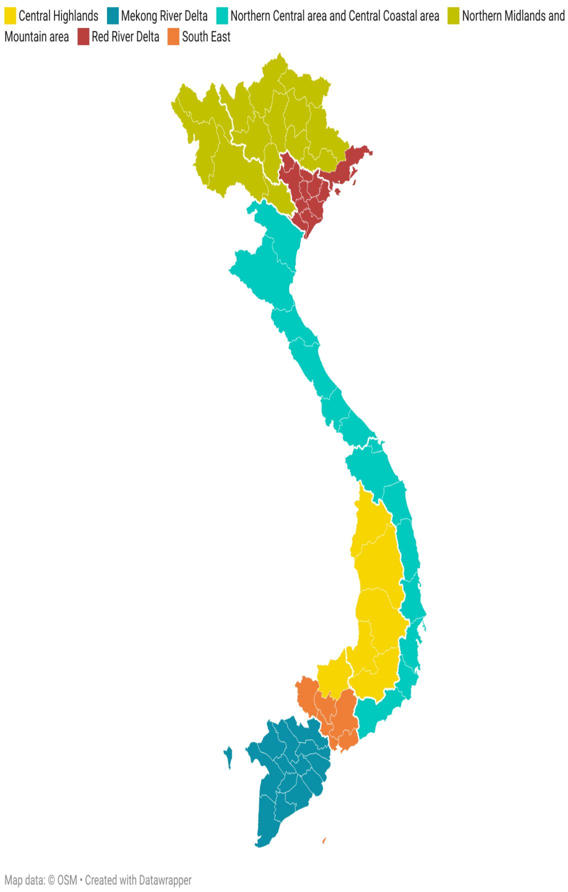
[1]The model is mainly developed for Matlab and using the model with Octave might require several adjustments of the code.

model and makes it easier to test new modifications and features of the model. The core of the model can be extended to feature different aspects of the economy.

In order to evaluate the costs and benefits associated with adaptation measures given the evolution of different climate variables, we first need to define a *Baseline* scenario. It describes the evolution of the Vietnamese economy under the assumption of no additional climate change. Costs associated with climate change are then defined as the difference between the Baseline path and some alternative scenarios with additional climate change. The model thus can serve as a laboratory for policymakers and researchers to conduct experiments by alternating different climate variables and adaptation measures. As the model is designed to illustrate long-run dynamics, it is not meant to predict bumps in the road, e.g. short-run deviations from long-run trends like the most recent downturn caused by the COVID-19 pandemic. However, it is still possible to include short-run fluctuations by adjusting the short-run path of the Baseline scenario according to recent economic developments.[2]

In Section 2 the derivation of the model equations is explicitly described. In Section 3 the implementation of scenarios is explained. Readers who are interested in directly using the model can skip the model description and can directly proceed with Section G.

Figure 1: Map of Vietnam



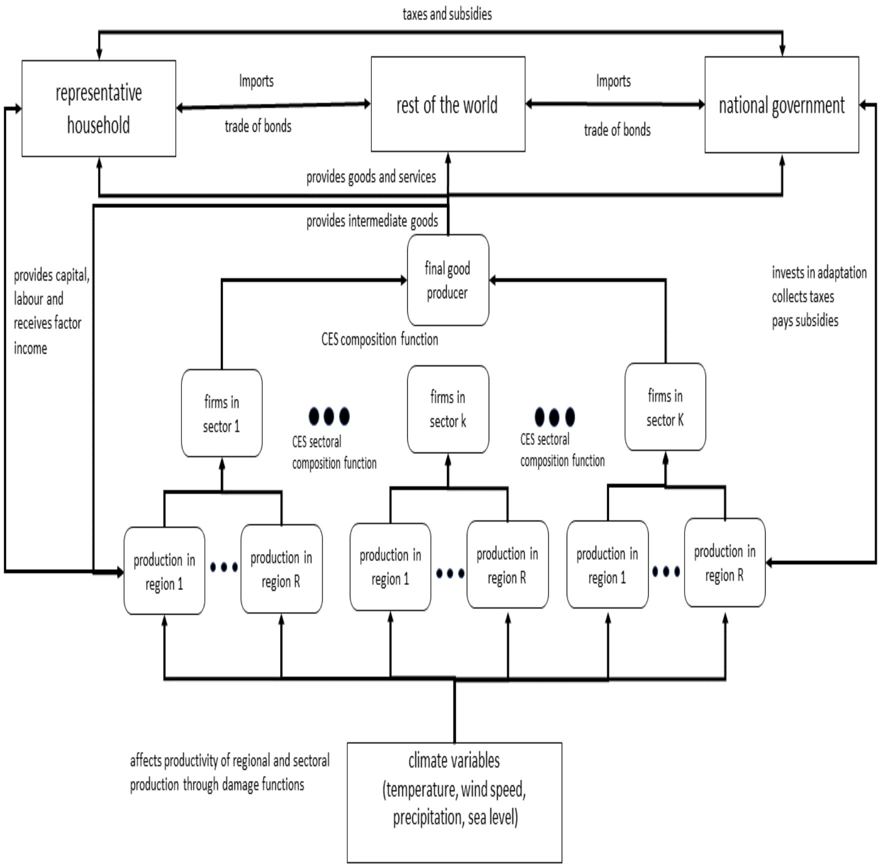
Source: The illustration is based on Boateng (2012).

[2]One easy way to do this is to use the latest economic forecasts as conducted by, e.g. the International Monetary Fund (IMF) in October 2021 in the World Economic Outlook to account for the recent downturn and the subsequent recovery.

2 Model

This report is a guide on how to use the spatial small open economy dynamic general equilibrium model for climate change and adaptation simulations. In general, the model belongs to the class of neoclassical growth models because no nominal rigidities are explicitly considered. Nevertheless, it is possible to extend the model to feature also nominal rigidities. The model structure is depicted in Figure 2. Regional climate variables (e.g. precipitation, wind speed, temperature and sea level) are exogenous

Figure 2: Model structure



Source: own exhibition.

to economic variables. Regional sectoral production functions depend on regional climate variables. The model is meant to reflect small open economies, and hence, the climate system is unaffected by the domestic economic system.

The model consists of an arbitrary number of regions (henceforth denoted by R), aggregate sectors (henceforth denoted by K) and sub-sectors (henceforth denoted by S). Regional differentiation is only provided on the supply side and not on the demand side. Representative households consume goods (henceforth denoted by C), consume housing (henceforth denoted by H), supply capital (henceforth denoted by K) and labour (henceforth denoted by N) to the firms in the regions. Households have access to international capital markets to borrow or lend money by purchasing internationally traded bonds (B). Firms use capital, labour, intermediate goods (henceforth denoted by Q^I) and imports (henceforth denoted by M) to produce goods according to processes that are described by sectoral and region-specific constant elasticity of substitution (CES) production functions. Each sector exports (henceforth denoted by X) a share of its production to the rest of the world.

The government collects taxes (henceforth denoted by τ), consumes (henceforth denoted by G), and can use its funds (henceforth denoted by B^G) to finance adaptation measures (henceforth denoted by G^A) for specific regions and sectors. The link between government expenditure for adaptation purposes and the reduction in realised damage is integrated through exogenous variables. This allows for any functional relationship between adaptation measures and their effectiveness at the cost of lower transparency compared to a functional form.

Table 23 provides a comprehensive list of all variables and parameters. Appendix C reports all equations of the model.

2.1 Climate variables

In order to capture the effect of climate change on the economy it is necessary to include climate variables into the model. By definition, 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), we do not need to model the interaction between economic activity and climate change. Climate variables are independent of other endogenous variables in the model. We model different climate variables by regions based on the simulation results of regional average annual temperature ($tas_{r,t}$), the average precipitation ($pr_{r,t}$), sunshine influx ($sunshine_{r,t}$), relative surface humidity ($hurs_{r,t}$), the average annual wind speed ($SfcWind_{r,t}$), heatwaves ($heatwave_{r,t}$), maximum consecutive dry days ($maxdrydays_{r,t}$), maximum consecutive wet days ($maxwetdays_{r,t}$), storms ($storm_{r,t}$), floods ($floods_{r,t}$), fire ($fire_{r,t}$), landslide ($landslide_{r,t}$) and sea level (SL_t).

$$tas_{r,t} = tas_{0,r} + \eta_{tas\,r,t} \tag{1}$$
$$SfcWind_{r,t} = SfcWind_{0,r} + \eta_{SfcWind_{r,t}} \tag{2}$$
$$pr_{r,t} = pr_{r,0} + \eta_{pr_{r,t}} \tag{3}$$
$$sunshine_{r,t} = sunshine_{0,r} + \eta_{sunshine\,r,t} \tag{4}$$
$$hurs_{r,t} = hurs_{0,r} + \eta_{hurs\,r,t} \tag{5}$$
$$heatwave_{r,t} = heatwave_{0,r} + \eta_{heatwave\,r,t} \tag{6}$$
$$maxwetdays_{r,t} = maxwetdays_{0,r} + \eta_{maxwetdays_{r,t}} \tag{7}$$
$$storms_{r,t} = storms_{0,r} + \eta_{storms\,r,t} \tag{8}$$
$$floods_{r,t} = floods_{0,r} + \eta_{floods_{r,t}} \tag{9}$$
$$fire_{r,t} = fire_{r,t} + \eta_{fire_{r,t}} \tag{10}$$
$$landslide_{r,t} = landslide_{0,r} + \eta_{landslide\,r,t} \tag{11}$$
$$SL_t = SL_0 + \eta_{SL\,t} \tag{12}$$

The approach in eq. 1 to eq. 12 allows to specify the evolution of climate variables according to the projections by meteorological models (e.g. Stocker et al. 2013).

2.2 Demand

The focus of the model is on the supply side. The demand side is represented by a representative household that is consuming and investing. The household receives income from labour and capital allocated to different sub-sectors and regions.

2.2.1 Households

As depicted in Figure 2, representative households h are providing labour and capital to domestic firms f. Households maximize discounted utility over an infinite horizon by choosing consumption $C_t(h)$, capital $K^H_{k,r,t+1}(h)$, investments $I_{k,r,t}(h)$, labour supplied $N_{s,r,t}(h)$, the $H_{t+1}(h)$ housing stock, investments into the housing stock $I^H_t(h)$ and foreign net wealth $B_{t+1}(h)$ to maximize utility constrained by the budget constraint and the law of motion for sectoral and regional capital. Households can be affected by climate change through damages to the capital stock $D^K_{k,r,t}(h)$ and damages to the housing stock $D^H_t(h)$.

Therefore, the Lagrangian eq. 13 of the representative household is

$$
\begin{aligned}
\mathcal{L}^{HH} = \sum_{t=0}^{\infty} \beta^t \Bigg[& \left(\frac{\left(C_t(h)^{1-\gamma} H_t^{\gamma}\right)^{1-\sigma^C}}{1-\sigma^C} - \sum_{s=1}^{S} \sum_{r=1}^{R} A_{s,r,t}^N \phi_{s,r}^L \frac{N_{s,r,t}(h)^{1+\sigma^L}}{1+\sigma^L} \right) \\
& - \lambda_t(h) \Bigg(P_t C_t(h) \left((1+\tau_t^C\right) + P_t^H H_t(h) \left((1+\tau_t^H\right) + \sum_{k=1}^{K} \sum_{r=1}^{R} P_t I_{k,r,t}(h) + B_{t+1}(h) \\
& - \sum_{s=1}^{S} \sum_{r=1}^{R} \left(1-\tau_t^N\right) W_{s,r,t} N_{s,r,t}(h) \\
& - \sum_{k=1}^{K} \sum_{r=1}^{R} P_t K_{k,r,t}^H r_{k,r,t} \left(1-\tau_t^K\right) - \phi_t^B (r_t^f + 1) B_t(h) \Bigg) \\
& - \sum_{k=1}^{K} \sum_{r=1}^{R} \lambda_t(h) \omega_{k,r,t}^I(h) \left\{ K_{k,r,t+1}^H - (1-\delta) K_{k,r,t}^H - I_{k,r,t} \Gamma\left(\frac{I_{k,r,t}}{I_{k,r,t-1}}\right) + D_{k,r,t}^K(h) \right\} \\
& - \sum_{k=1}^{K} \sum_{r=1}^{R} \lambda_t(h) \omega_t^H(h) \left\{ H_{t+1} - \left(H_t \left(1-\delta^H\right) + I_t^H - D_t^H(h)\right) \right\} \Bigg]
\end{aligned}
\tag{13}
$$

Households receive utility by consuming goods and having residential property, where the intertemporal elasticity of consumption is defined by σ^C. The parameter γ reflects the preference for housing or consumption. Disutility from labour is sector and region specific $\phi_{s,r}^L$, the inverse Frisch elasticity σ^L is identical for all sectors and regions. Households spend money either on consumption goods $P_t\, C_t(h)\, (1+\tau_t^C)$, regional and sector-specific investment $P_{s,r,t} I_{s,r,t}(h)$ or they can save in internationally-traded bonds $B_{t+1}(h) > 0$. It is also possible that domestic households borrow money from international investors $B_{t+1}(h) < 0$. They receive income from labour $W_{s,r,t}\, N_{s,r,t}(h)\, (1-\tau_t^N)$, capital renting $P_{s,r,t}\, r_{s,r,t}\, K_{s,r,t}^H(h)\, (1-\tau_t^K)$ and interest payments on lent money $B_t(h) > 0$ or have to pay interest on borrowed money $B_t(h) < 0$. The first order conditions to the problem are the behavioural equations. Households supply labour according to the FOC w.r.t. labour eq. 14 for each sector and region depending on the wage $W_{s,r,t}$ and the marginal disutility of labour for the specific sector and region

$$
\phi_{s,r}^L\, A_{s,r,t}^N\, N_{s,r,t}(h)^{\sigma^L} = \lambda_t(h)\, W_{s,r,t}\, (1-\tau_t^N). \tag{14}
$$

Households also decide how much of their income they consume or invest into capital. The capital stock at the end of period t and the beginning of period $t+1$ is predetermined. The Euler equation eq. 15 is obtained by taking the first derivative of the Lagrangian w.r.t. sector and region-specific capital

$$
\lambda_{t+1}(h)\, \beta \left(P_{t+1}\, r_{k,r,t+1}\, (1-\tau_t^K) + (1-\delta - \sum_{s\in k} D_{s,r,t+1}^K)\, \omega_{s,r,t+1}^I \right) = \lambda_t(h)\, \omega_{k,r,t}^I. \tag{15}
$$

Households face investment adjustment costs $\Gamma(\frac{I_{k,r,t}}{I_{s,r,t-1}}) = 3 - exp\left\{\sqrt{\phi^K/2}\left(\frac{I_{k,r,t}}{I_{s,r,t-1}} - 1\right\}\right) - exp\left\{-\sqrt{\phi^K/2}\left(\frac{I_{k,r,t}}{I_{s,r,t-1}} - \right.\right.$ which are sector and region specific. The specification of the investment adjustment cost function is the same as proposed and estimated by Christiano et al. (2014) for the US. The marginal value of sectoral and regional investment $\omega_{k,r,t}^I$ is determined by

$$
P_t\, \lambda_t(h) = \lambda_t(h)\, \omega_{k,r,t}^I \left(\Gamma(\frac{I_{k,r,t}}{I_{k,r,t-1}}) + \frac{\partial \Gamma(\frac{I_{k,r,t}}{I_{k,r,t-1}})}{\partial (\frac{I_{k,r,t}}{I_{k,r,t-1}})} \frac{I_{k,r,t}}{I_{s,r,t-1}} \right) - \beta \lambda_{t+1}(h)\, \omega_{k,r,t+1}^I \frac{\partial \Gamma(\frac{I_{s,r,t+1}}{I_{k,r,t}})}{\partial (\frac{I_{s,r,t+1}}{I_{k,r,t}})} \left(\frac{I_{s,r,t+1}}{I_{k,r,t}} \right)^2 \tag{16}
$$

Households decide how much they spend on consumption or investments in the housing stock. The FOC of households with respect to consumption is

$$
\lambda_t(h)\, P_t\, (1+\tau_t^C) = (1-\gamma) C_t(h)^{-\gamma} \left(H_t(h)^{\gamma} C_t(h)^{1-\gamma}\right)^{-\sigma^C}. \tag{17}
$$

Further, they decide about the size of the housing stock $H_{t+1}(h)$ they have at the end of period t and at the beginning of period $t+1$. Therefore, the stock of houses is known in period t and is predetermined. The first order condition of the household with respect to housing is

$$\begin{aligned}\lambda_t(h)\,\omega^H{}_t(h) = \beta\,\Big(&\left(1-\delta^H\right)\left(\mathbb{E}_t\lambda_{t+1}(h)\right)\left(\mathbb{E}_t\omega^H_{t+1}(h)\right)\\&+\gamma\,\left(\mathbb{E}_tC_{t+1}(h)\right)^{1-\gamma}\,H_{t+1}(h)^{\gamma-1}\,\left(\mathbb{E}_tC_{t+1}(h)^{1-\gamma}\,\left(H_{t+1}(h)\right)^{\gamma}\right)^{-\sigma^C}\Big)\end{aligned} \tag{18}$$

The first order condition with respect to investment in the housing stock is

$$\lambda_t(h)\,\omega^H{}_t = \lambda_t(h)\,P^H{}_t\,\left(1+\tau^C{}_t\right) \tag{19}$$

2.2.2 Access to international financial markets

Households have access to the international financial market to purchase and sell internationally-traded bonds. However, we only consider net foreign positions.

$$\lambda_{t+1}\,\beta\,\phi^B_{t+1}\left(1+r^f{}_{t+1}\right) = \lambda_t \tag{20}$$

with the world interest rate r^f. The required interest rate is above the world interest rate if the foreign debt ($B_{t+1} < 0$)/ foreign claims ($B_{t+1} > 0$) relative to GDP increases/decreases and future net exports relative to GDP will decrease.

$$\phi^B_{t+1} = exp\left(-\phi^B\,(r^f_{t+1}\,\frac{B_{t+1}+B^G_{t+1}}{Y_{t+1}} + \frac{NX_{t+1}}{Y_{t+1}})\right) \tag{21}$$

We introduce ϕ^B_{t+1} to ensure stability of the system as discussed in Schmitt-Grohé & Uribe (2003). This increases the probability to find a solution with the nonlinear solver.

2.3 Production

A company operating under perfect competition provides domestically used goods Q^U_t as a combination of domestically produced and used goods Q^D_t and imported goods M_t. Imports and domestically produced and used products are combined according to a constant elasticity of substitution production function with distributional parameter ω^F and elasticity of substitution η^F. Domestically produced and used goods Q^D_t are an aggregate of sectoral products $Q^A_{k,t}$ according to a constant elasticity of substitution (CES) production function with distribution parameters $\omega^{Q^A}_k$ and the elasticity of substitution between different sectors η^Q. Similar is the procedure for imports, where sub-sectoral imports $M_{s,t}$ are aggregated according to a CES production function with distribution parameters ω^M_s and elasticity of substitution parameter η^M. Sectoral aggregate products are aggregated using sub-sectoral products $Q^D_{s,t}$. The domestically used sub-sectoral products and exports $X_{s,t}$ are aggregated according to a CES production function from regional sub-sectoral production $Q_{s,r,t}$ with distribution parameters $\omega^Q_{r,s}$ and elasticity of substitution for products from different regions in one sub-sector η^Q_s according to a CES production function.

$$\underset{Q_{s,r,t},M_{s,t}}{max} P_t Q_t^U - \sum_{s,r} P_{s,r,t}^D Q_{s,r,t}^D - \sum_s P_{s,t}^M M_{s,t} \tag{22}$$

$$\text{where } Q_t^U = \left(\omega^{F\,\frac{1}{\eta^F}} M_t{}^{\frac{\eta^F-1}{\eta^F}} + (1-\omega^F)^{\frac{1}{\eta^F}} Q_t^D{}^{\frac{\eta^F-1}{\eta^F}} \right)^{\frac{\eta^F}{\eta^F-1}} \tag{23}$$

$$M_t = \left(\sum_s^S \omega_s^{M\,\frac{1}{\eta^M}} M_{s,t}{}^{\frac{\eta^M-1}{\eta^M}} \right)^{\frac{\eta^M}{\eta^M-1}} \tag{24}$$

$$Q_t^D = \left(\sum_k^K \omega_k^{Q^A\,\frac{1}{\eta^Q}} Q_{k,t}^{A,D}{}^{\frac{\eta^Q-1}{\eta^Q}} \right)^{\frac{\eta^Q}{\eta^Q-1}} \tag{25}$$

$$Q_{k,t}^A = \left(\sum_s^S \omega_s^{Q\,\frac{1}{\eta_k^Q}} Q_{s,t}^D{}^{\frac{\eta^{Q_k}-1}{\eta_k^Q}} \right)^{\frac{\eta_k^Q}{\eta_k^Q-1}} \tag{26}$$

$$Q_{s,t}^D + X_{s,t} = Q_{s,t} = \left(\sum_r^R \omega_{r,s}^{Q\,\frac{1}{\eta_s^Q}} Q_{s,r,t}{}^{\frac{\eta_s^Q-1}{\eta_s^Q}} \right)^{\frac{\eta_s^Q}{\eta_s^Q-1}} \tag{27}$$

$$X_{s,t} = (D_s^X + \eta_{s,t}^X) \left(\frac{P_{s,t}^D}{P_{s,t}^M} \right)^{-\eta^X}. \tag{28}$$

It is important to note that exports are assumed to increase/decrease with a decrease/increase in the relative domestic price to the import price of the specific sector. The time-invariant exogenous demand for exports D_s^X can be adjusted through the exogenous export shock $\eta_{s,t}^X$. We can use the envelope theorem to derive the following first-order condition with respect to products $Q_{s,r,t}$ produced in sub-sector s in region r:

$$P_t \frac{\partial Q_t^U}{\partial Q_t^D} \frac{\partial Q_t^D}{\partial Q_{k,t}^A} \frac{\partial Q_{k,t}^A}{\partial Q_t^D} \frac{\partial Q_{s,t}^D}{\partial Q_{k,t}^A} \frac{\partial Q_{s,t}^D}{\partial Q_{s,r,t}^D} = P_{s,r,t}^D$$

$$P_t\,(1-\omega^F) \left(\frac{Q_t^D}{Q_t^U} \right)^{-\frac{1}{\eta^F}} = P_t^D \tag{29}$$

$$\omega_k^{Q^A} \left(\frac{Q_{k,t}^A}{Q_t^D} \right)^{-\frac{1}{\eta^Q}} = \frac{P_{k,t}^A}{P_t^D} \tag{30}$$

$$\omega_s^{Q^D} \left(\frac{Q_{s,t}}{Q_{k,t}^A} \right)^{-\frac{1}{\eta_k^{Q^A}}} = \frac{P_{s,t}^D}{P_{k,t}^A} \tag{31}$$

$$\omega_{s,r}^{Q^D} \left(\frac{Q_{s,r,t}}{Q_{s,t}} \right)^{-\frac{1}{\eta_s^{Q^D}}} = P_{s,r,t}^D \tag{32}$$

For readability, the model features for each marginal product a relative price.

At the regional and sectoral level, representative firms are maximizing profits using capital $K_{s,r,t}$ and labour $L_{s,r,t} = N_{s,r,t}\,Pop_t$ provided by households to produce products. They charge a price $P_{s,r,t}^D$ for their products and have to pay households wages $W_{s,r,t}$, interest on rented capital $P_{s,r,t}\,r_{k,r,t}$, taxes related to the wage bill $\tau_{s,r,t}^{N,F}$ and on capital expenditure $\tau_{s,r,t}^{K,F}$. Representative firms have access to a regional and sector specific constant elasticity of substitution production function. The productivity of capital and labour of a firm in one sector and region depends on the climate variables, and the adaption measures by the government represented by a damage function affecting total factor productivity $A_{s,r,t}$ by $D_{s,r,t}$. Further, we also consider climate induced damages affecting labour productivity $D_{N,s,r,t}$. In contrast to Nordhaus (1993), we assume no explicit functional form of the damage functions (eq. 33-35).

$$D_{s,r,t} = \eta^{D}_{s,r,t}. \tag{33}$$
$$D^{N}_{s,r,t} = \eta^{D^N}_{s,r,t}. \tag{34}$$
$$D^{K}_{s,r,t} = \eta^{D^K}_{s,r,t}. \tag{35}$$

Firms in each region and sector have access to a constant elasticity of substitution production function with production factors labour, capital and intermediate products. Eq. 36 states the optimization problem of the firm.

$$\max_{Q^I_{s,r,t}, N_{s,r,t}, K_{s,r,t}} P_{s,r,t}\, Q_{s,r,t} - W_{s,r,t}\, N_{s,r,t}\, Pop_t\, (1+\tau^{N,F}_{s,r,t}) - r_{s,r,t}\, P_{s,r,t}\, K_{s,r,t}\, (1+\tau^{K,F}_{s,r,t}) - P_t\, Q^I_{s,r,t}$$
$$\text{s.t. } Y_{s,r,t} = A_{s,r,t}(1-D_{s,r,t}) \left[{\alpha^N_{s,r}}^{\frac{1}{\eta^{NK}_{s,r}}} \left(A^N_{s,r,t}\,(1-D^N_{s,r,t})\, Pop_t\, N_{s,r,t}\right)^{\rho_{s,r}} + {\alpha^K_{s,r}}^{\frac{1}{\eta^{NK}_{s,r}}} (K_{s,r,t})^{\rho_{s,r}} \right]^{\frac{1}{\rho_{s,r}}},$$
$$\text{where } \rho_{s,r} = \frac{\eta^{NK}_{s,r} - 1}{\eta^{NK}_{s,r}}. \tag{36}$$

$$Q_{s,r,t} = \left[{\omega^I_{s,r}}^{\frac{1}{\eta^I_s}} \left(Q^I_{s,r,t}\right)^{\rho^I_s} + (1-\omega^I_{s,r})^{\frac{1}{\eta^I_s}} (Y_{s,r,t})^{\rho^I_s} \right]^{\frac{1}{\rho^I_s}},$$
$$\text{where } \rho^I_s = \frac{\eta^I_s - 1}{\eta^I_s}. \tag{37}$$

Demand for production factors is given by the first-order condition of the above optimisation problem. The Lagrange multiplier is equal to the price charged by companies.

$$\frac{W_{s,r,t}}{P_{s,r,t}}\,(1+\tau^{N,F}_{s,r,t}) = {\alpha^N_{s,r}}^{\frac{1}{\eta^{NK}_{s,r}}} \left(A_{s,r,t}\,(1-D_{s,r,t})\, A^N_{s,r,t}\,(1-D^N_{s,r,t})\right)^{\rho_{s,r}} \left(\frac{Pop_t N_{s,r,t}}{Y_{s,r,t}}\right)^{-\frac{1}{\eta^{NK}_{s,r}}}$$
$$r_{s,r,t}\,(1+\tau^{K,F}_{s,r,t}) = {\alpha^K_{s,r}}^{\frac{1}{\eta^{NK}_{s,r}}} \left(A_{s,r,t}\,(1-D_{s,r,t})\right)^{\rho_{s,r}} \left(\frac{K_{s,r,t}}{Y_{s,r,t}}\right)^{-\frac{1}{\eta^{NK}_{s,r}}} \tag{38}$$
$$\frac{P_t}{P^D_{s,r,t}} = {\omega^{Q^I}_{s,r}}^{\frac{1}{\eta^I_s}} \left(\frac{Q^I_{s,r,t}}{Q_{s,r,t}}\right)^{-\frac{1}{\eta^I_s}} \tag{39}$$
$$\frac{P_{s,r,t}}{P^D_{s,r,t}} = (1-\omega^{Q^I}_{s,r})^{\frac{1}{\eta^I_s}} \left(\frac{Y_{s,r,t}}{Q_{s,r,t}}\right)^{-\frac{1}{\eta^I_s}} \tag{40}$$
$$\tag{41}$$

We use the more general case of the CES production function rather than the more commonly used Cobb-Douglas production function. The parameter $\eta^{NK}_{s,r}$ allows us to control the response of capital and labour demand to temporary productivity shocks. Temporary productivity shocks are in our setup also weather extremes. Cyclones can destroy the capital stock. Firms can either substitute capital using more labour in the period, e.g. using more labour to replace tractors. Or they need to lay off workers because they are useless without machines, e.g. destruction of factories. The parameter $\eta^{NK}_{s,r}$ allows specifying the reaction of firms.

2.3.1 Government

We are interested in different policy measures taken by the government to adapt to a new climate regime. Government behaviour is not a result of an optimization problem. The government collects taxes from consumption $\tau^C_t\, C_t$, labour income $\sum_k^K \sum_r^R (\tau^N_t + \tau^{N,F}_{s,r,t})\, W_{s,r,t}\, N_{s,r,t}\, Pop_t$ and capital income $\sum_k^K \sum_r^R (\tau^K + \tau^K_{r,s,t})\, P_{s,r,t}\, r_{s,r,t}\, K_{s,r,t}$. In order to finance its activities the government can borrow loans from the rest of the world $B^G_{t+1} < 0$ and has to repay loans and interest from the previous period denominated in foreign currency $(1 + r^f_t)$ identical to the interest rates paid by households. The government budget constraint boils down to eq. 42.

$$G_t + \sum_k^K \sum_r^R G^A_{s,r,t} + G^{A,H}_t + B^G_{t+1} = \sum_k^K \sum_r^R \left\{ (\tau^K_t + \tau^{K,F}_{r,s,t})\, P_{s,r,t}\, r_{s,r,t}\, K_{s,r,t} + (\tau^N_t + \tau^{N,F}_{s,r,t})\, W_{s,r,t}\, N_{s,r,t}\, Pop_t \right\}$$
$$+ (1 + r^f_t)\, S^f_t\, \phi^B_t\, B^G_t \tag{42}$$

Government expenditures can be used to finance adaptation measures in specific sectors and regions $G^A_{s,r,t}$ against climate change. In addition, the government can directly invest in adaptation measures for the construction sector $G^{A,H}_t$ to avoid the destruction of houses owned by households. The effectiveness of adaptation measures might also depend on previous expenditures of the government. Therefore, we consider capital stocks $K^A_{s,r,t+1}$ financed by expenditures on adaptation measures. The depreciation rate $\delta_{K^A,s,r}$ defines necessary maintenance costs, which are assumed to be proportional to the capital stock.

Government expenditures on adaptation measures, taxes on regional and sectoral capital expenditure, and government debt are independent of other variables, or to formulate it differently are discretionary. This allows us to evaluate different policy paths for the future and to model the variables by exogenous processes as stated in eq. 43.

$$\begin{aligned} K^A_{s,r,t+1} &= \eta^A_{s,r,t} \\ K^A_{s,r,t+1} = (1 - \delta_{K^A,s,r})\, K^A_{s,r,t} &+ G^A_{s,r,t} \\ \tau^{K,F}_{s,r,t} &= \tau^{K,F}_{s,r,0} + \eta^{\tau^{K,F}}_{s,r,t} \\ \tau^{N,F}_{s,r,t} &= \tau^{N,F}_{s,r,0} + \eta^{\tau^{N,F}}_{s,r,t} \\ \tau^K_t &= \tau^K_0 + \eta^{\tau^K}_t \\ \tau^N_t &= \tau^N_0 + \eta^{\tau^N}_t \\ \tau^H_t &= \tau^H_0 + \eta^{\tau^H}_t \\ B^G_{t+1} &= B^G_0 + \eta^{B^G}_t \end{aligned} \tag{43}$$

2.3.2 Resource constraint

Households and governments use final domestic goods (denoted by Q_t) produced by firms fewer intermediates goods Q^I_t for consumption, investment, and for exports (denoted by X_t), and can also use imports M_t for consumption and investment. This gives rise to the well-known resource constraint or the expenditure approach to define GDP.

$$P^D_t\, Q_t = P_t\, (Q^I_t + \underbrace{C_t + I_t + G_t + G^{A,H}_t + \sum_s \sum_r G^A_{s,r,t}}_{Y_t} + \underbrace{P^D_t\, X_t - P^M_t\, M_t}_{NX_t}) \tag{44}$$

The aggregation of the budget constraints of the representative households also states that positive net exports are used to increase net financial wealth to the rest of the world.

$$NX_t = B_{t+1} + B^G_{t+1} - (1 + r^f_t)\phi^B_t(B_t + B^G_t) \tag{45}$$

2.4 Rest of the world

The demand for domestic exports and foreign imports is not explicitly modelled in this version of the model. Net exports are total expenditures for imports less total revenue from exports. The trade balance depends on the demand for subsectoral imports and the supply for sub-sectoral exports. Demand for sub-sectoral imports grows with the overall production level in the economy and the price of imports relative to domestic products. Exports depend on the terms of trade defined as the domestic and imported price level. The world interest rate r^f_t determines how much governments and households have to pay back in domestic currency as net lenders or how much they receive as a net borrower from the rest of the world. Here the world interest rate is independent of domestic developments, and only the effective exchange rate adjusts according to eq. 20.

$$NX_t = P_t^D X_t - P_t^M M_t \tag{46}$$

$$P_{s,t}^M = P_{s,0}^M + \eta_{s,t}^{P^M} \tag{47}$$

$$X_{s,t} = (D_s^X + \eta_{s,t}^X) \left(\frac{P_{s,t}^D}{P_{s,t}^M} \right)^{-\eta^X} . \tag{48}$$

Import prices $P_{s,t}^M$ for different sub-sector goods are exogenous and do not respond to endogenous variables. Sub-sector exports are a share of sub-sector production and react to the terms of trade in the sub-sector.

3 Scenario Analysis at the Sectoral Level

For simulations, it is necessary to specify a direct mapping between sectors in the model and the available data. The analysis in the following paragraphs will differentiate between five aggregate sectors and 12 sub-sectors. The specific mapping is reported in Table 18. We use this mapping to reduce the number of state variables in the model. Capital stocks for each aggregate sector are simulated. This implicitly assumes that the capital stock in the aggregate sector can be used in the different sub-sectors. However, the model can also use each sub-sector as an individual sector. Nevertheless, this also allows specifying different substitutability across the sub-sectors. For instance, the capital stock in the service and health sector can be used in both sub-sectors (e.g. computers, cars and beds).

3.1 Calibration

Before we can conduct scenario analysis we need to calibrate the model to reflect the current situation of the Vietnamese economy. We make use of an extended input-output table to reflect the economic structure for the year 2014. We calibrate the production function parameters $\alpha_{s,r}^K$, $\alpha_{s,r}^N$ such that we match for a given elasticity of substitution $\eta_{s,r}^{NK}$ the observed share of the wage bill on gross value added $\frac{W_{s,r,0}\, N_{s,r,0}}{P_{s,r,0}\, Y_{s,r,0}}$ and ensure a correct accounting of factor income by economic activity. Further, we calibrate the sectoral composition production function parameters $\omega_{s,r}^Q$, $\omega_s^Q, \omega_k^{Q^A}$ for a given elasticity of substitution η_s^Q, $\eta_k^{Q^A}, \eta^Q$ to meet the initial gross value added shares $\phi_{s,r,0}^Y = \frac{P_{s,r,0}\, Y_{s,r,0}}{P_0\, Y_0}$ for the year 2014. We further know the share of intermediate products $\frac{P\, Q_s^I}{P_s^D\, Q_s}$ in each sub-sector and assume identical sub-sectoral shares in each region. Therefore, a detailed description of this procedure is reported in Appendix E. We further need to specify how labour supply responds to wage changes. Therefore, we need to specify the value for the inverse Frisch elasticity (σ^L). We take the value 0.5 from Nguyen (2020). Further, the intertemporal elasticity of substitution of consumption is set to $\sigma^C = 1$. The capital stock depreciation rate (δ) is identical across sectors and regions and equals 0.045.[3] We model a very simplified tax system in Vietnam. All tax revenues of the government come from a tax on consumption in the model. The tax rate τ_0^C is set to 20%. This is the relation between total tax income and consumption in Vietnam in the year 2014. There are adjustment costs for the capital stock and for foreign assets. We calibrate the curvature of the adjustment cost functions to be 10 with the parameters ϕ^K and ϕ^B. The discount factor β is equal to 0.9606 and ensures an initial ratio between investment and gross value added of approximately 23%.

For the production functions, it is necessary to assign values for the elasticity of substitution parameters between capital and labour ($\eta_{s,r}^{NK}$), sub-sectoral products for different regions η_s^Q, sub-sectoral products belonging to one sector $\eta_k^{Q^A}$, between sectoral products η^Q and between imports and domestically produced products η^F. We assume a Cobb-Douglas production function for the creation of gross

[3]The value for the depreciation rate is reported in IMF country report No. 18/216.

Table 1: Sub-sectoral elasticity of substitution

Sub-sector	Value (η_s^Q)
Rice	10.00
Agriculture excluding rice	10.00
Aquaculture	10.00
Forestry	10.00
Water	0.01
Energy	10.00
Manufacturing	10.00
Construction	0.01
Transport Water	0.01
Transport Land	0.01
Health	0.01
Services	0.01

Source: own computation.

value added from labour and capital ($\eta_{s,r}^{NK} = 1 \forall s, r$). The elasticity of substitution between intermediate inputs and gross value added is set to $\eta_{s,r}^{I} = 1.01$ and reflects a quasi Cobb-Douglas production function. For the elasticity of substitution between different regions in one sub-sector η_s^Q we distinguish between sub-sectors primarily produce tradable ($eta_s^Q = 10$) or non-tradable sectors ($eta_s^Q = 0.01$). Table 1 reports the elasticity of substitution parameters for each sub-sector. We test the elasticity of substitution between different sub-sectors belonging to one aggregate sector k to be equal to $\eta_k^{Q^A} = 0.01$. Therefore, we estimate the elasticity of substitution between the different sub-sectors in one sector k and use a t-test whether we can reject the null hypothesis of $\eta_k^{Q^A} = 0.01$. We can not reject the null hypothesis for any of the sectors (see Appendix F). The same procedure is applied for the elasticity of substitution between different aggregate sectors η^Q. The elasticity of substitution between foreign and domestic products is calibrated to $\eta^F = 1.83$ and the export price elasticity is set to $\eta^X = 0.83$ (see Christiansen et al. (2011) in Table 6.1 and 6.2 last column reported for Vietnam).

In the initial steady state population is set to $PoP_0 = 0.907280$ and reflects 90.7280.000 persons in Vietnam.[4] Further, we set the initial nominal GDP to $P_0 Y_0 = 1.86$ and reflects a GDP value of 186 billion Dollars.[5]. In 2014, the average weekly hours worked was 43.5[6] of 168 potential hours. In 2014 52,744,000 persons have been employed.[7]. The initial share of hours worked is $N_0 = \frac{43.5}{168} \frac{52{,}744{,}00}{90{,}728{,}000} \approx 0.15$. In 2014 the average housing area in Vietnam was $\frac{H_0}{PoP_0} = 23 \frac{m^2}{Person}$.[8] Investments into the housing stock relative to GDP are set to 0.5%. Investments in the housing stock are expenditures by households for residential buildings.

Table 2 reports the export and intermediate product shares relative to the revenue of the specific sector. They are computed by aggregating all exports and intermediate products used by the respective commodities and industry categories belonging to the sector and dividing them by aggregated total sub-sectoral output. Import shares, in contrast, are expressed as a share of total national imports.

Subsectoral import and export shares define the ratio of net exports to GDP. Further, net exports define the net foreign asset position of the domestic households to the rest of the world. Therefore, the foreign debt level is computed endogenously and can be evaluated against empirical data. In addition to the above-mentioned shares, it is also necessary to have data on regional and sub-sectoral gross value added, employment and labour cost shares. So far, we only have access to national shares reported in Table 3. Therefore it is necessary to approximate the contribution of each region to each sector. For the sub-sector rice, the regional share of the national area of planted paddies in the year 2014 is considered. For other sectors, population shares of each region are used. The shares are reported in Table 4.

[4]Source: General Statistical Office of Vietnam Table E02.01
[5]Source: https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=VN
[6]Source: https://www.ceicdata.com/en/vietnam/average-working-hour-per-week
[7]Source: General Statistical Office of Vietnam Table E02.01
[8]Source: https://vietnamnews.vn/society/349388/vns-average-floor-area-per-person-is-228sqm.html

Table 2: Sub-sectoral exports and intermediate product shares

Sector	Export share ($\phi_s^X = \frac{X_s}{Q_s}$)	Import shares ($\phi_s^M = \frac{P_s^M M_s}{P^M M}$)	intermediate products ($\phi_s^{Q^I} = \frac{P Q_s^I}{P_s^D Q_s}$)
Rice	0.0121	0.0003	0.5592
Agriculture excluding rice	0.1410	0.0407	0.6669
Aquaculture	0.7670	0.0002	0.7111
Forestry	0.3750	0.0446	0.5527
Water	0.0010	0.0001	0.6108
Energy	0.0082	0.0202	0.5776
Manufacturing	0.3368	0.8331	0.8198
Construction	0.0010	0.0001	0.7585
Transport Water	0.1872	0.0001	0.7508
Transport Land	0.1081	0.0049	0.5507
Health	0.0116	0.0030	0.5953
Services	0.1226	0.0526	0.5637

Source: National expert's extended IO table and own computation.

Table 3: Value added, employment and labour cost shares

Sector	VA shares ($\phi_s^Y = \frac{P_s Y_s}{P Y}$)	Employment shares ($\phi_s^N = \frac{N_s}{N}$)	LC shares ($\phi_s^W = \frac{W_s N_s}{P Y}$)
Rice	0.03181	0.100255	0.494986
Agriculture excluding rice	0.07282	0.229508	0.50108
Aquaculture	0.026922	0.084851	0.526193
Forestry	0.0144	0.045386	0.583953
Water	0.00653	0.0027	0.199205
Energy	0.07961	0.0026	0.234692
Manufacturing	0.292172	0.14	0.481682
Construction	0.044659	0.062	0.724319
Transport Water	0.008473	0.002291	0.564652
Transport Land	0.098791	0.026709	0.585345
Health	0.013103	0.0093	0.691108
Services	0.31071	0.2944	0.550248

Source: National expert's extended IO table, GSO and own computation.

Table 4: Regional shares of rice production and population

Region	Share of planted paddy land	Share of population
Red River Delta	0.14	0.23
Northern midlands and mountain areas	0.09	0.13
Northern Central area and Central coastal area	0.16	0.22
Central Highlands	0.03	0.06
South East	0.04	0.17
Mekong River Delta	0.54	0.19

Source: GSO and own computation.

Further, we need to specify initial values for the different climate variables. They are the respective averages across provinces for each region for the year 2015, except for sunshine hours (we sum over all provinces). All initial values are reported in Table 17.

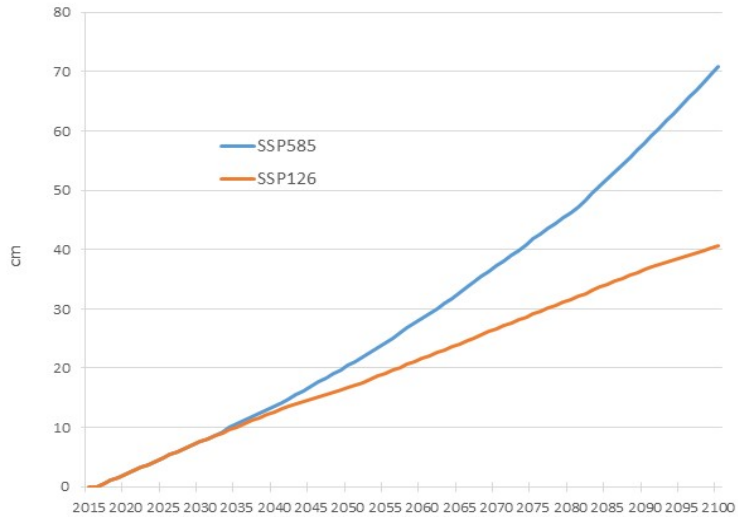
3.2 Baseline

For the Baseline scenario, we assume no impact on climate change on the economy. Further, we compute sectoral productivities $A_{s,r,t}$ to match the reported sectoral growth rates $\frac{P_{s,r,t}\,Y_{s,r,t}}{P_{s,r,t-1}\,Y_{s,r,t-1}}$ from Figure 14. The same is true for labour specific productivity shocks $A^N_{s,r,t}$ to match the reported growth rates for labour supply shares $\frac{\frac{N_{s,r,t}}{N_t}}{\frac{N_{s,r,t-1}}{N_{t-1}}}$ reported in Figure 15. The Vietnamese population is growing at an exogenous rate, according to projections by the General Statistical Office (GSO). The projection is depicted in Figure 16. Further, we assume that the relationship between net exports and GDP ($\frac{NX}{Y}$) is constant at the 2014 level. This is ensured through adjustments in the import price level. The housing stock per capita is constant, and the house price increases as a response to a fixed supply of housing areas.

3.3 Climate Change Scenarios

For the climate change scenarios, we use results provided by the National Oceanic and Atmospheric Administration (NOAA). We explicitly use the simulation results for the shared social path (SSP) scenarios 126 and 585. One of the main hazards to the Vietnamese economy is an increase in the sea level. Projections show that climate change can lead to an increase of the sea level until 2100 by 70 cm (see Figure 3). This implies a higher risk of floods in coastal areas and a higher exposure to cyclones. Further, it might reduce the available land for agriculture and other economic activities.

Figure 3: Sea level



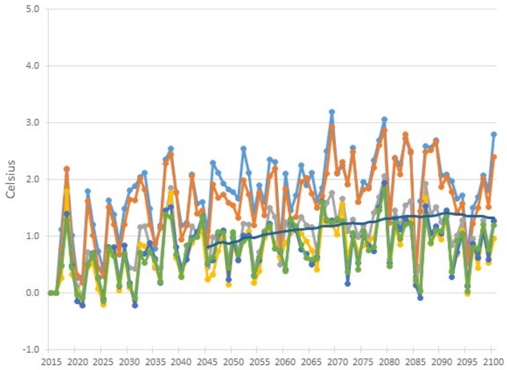
Source: Sea-level rise as reported by Thuc et al. (2016)

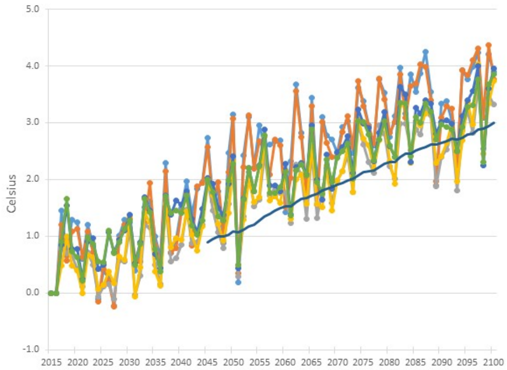
In order to simulate climate change at a subnational level for the respective regions depicted in Figure 1, we need to aggregate the data from a provincial level to a regional level. Therefore, we use the mapping reported in Table 19. The paths for each climate variable from 2015 to 2100 is depicted in Figure 4 for the considered regions. We can see that the SSP 126 scenario can limit an increase in the surface air temperature to roughly 1°C. The graphs show the change in the respective climate variable to the year 2014. We observe a clear upward trending behaviour of the surface temperature in the SSP 585 scenario. Surface precipitation seems to decline in the SSP 585 scenario.

Figure 4: Simulated change in climate variables

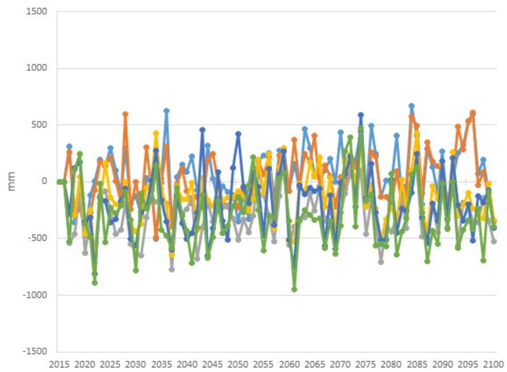
SSP 126 | SSP 585

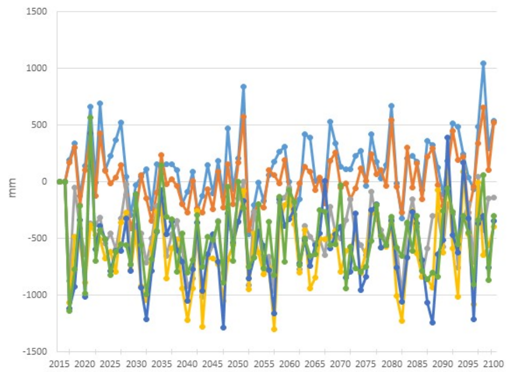
surface temperature



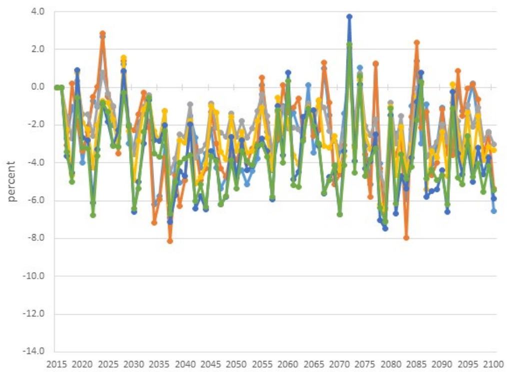


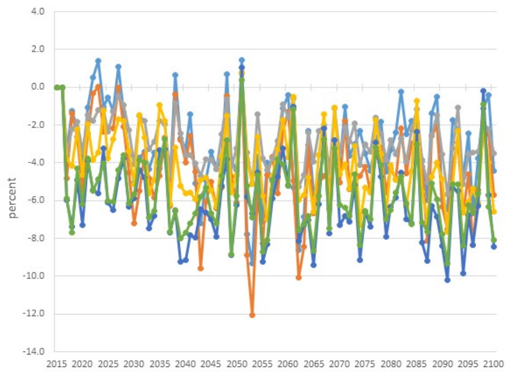
surface precipitation



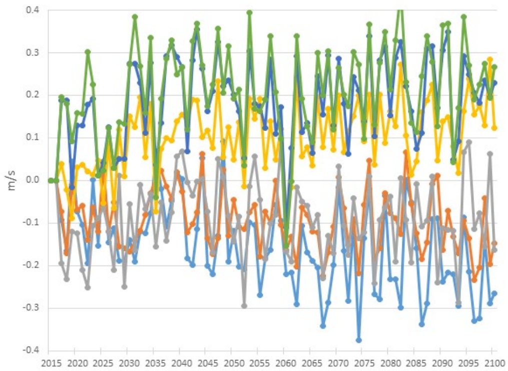


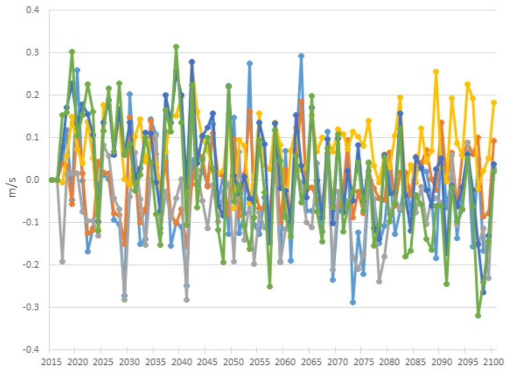
surface relative humidity





surface wind speed





Note: Red River Delta (light blue), Northern midland and mountain area (light red), Northern Central and Central coastal area (grey), Central Highlands (yellow), South East (dark blue), Mekong River Delta (green).
Source: National expert computation based on results from an NOAA.

3.3.1 Rice, Agriculture excluding rice and Aquaculture

We consider two climate hazards to the agricultural sector in Vietnam. The first one is the reduction in crop yields through an increase in the average annual temperature and the second one is the loss of land due to sea-level rise. For our simulation, we need to identify how the hazard will impact the respective sector. In general, we have three different options to incorporate damages into the model. Either we can assume that climate change will impact the total factor productivity, labour productivity or the formation of capital. A reduction of crop yields due to an increase in temperature will reduce the maximum amount of crops produced in a given period using the same amount of production factors. Land loss due to sea-level rise will force farmers to produce with less land. In our setup, this implies that the same number of workers and the same capital stock can only be used in a smaller area. The impact of sea-level rise and temperature increase affects total factor productivity through $D_{1,r,t}$ and $D_{2,r,t}$.

Temperature: Zhao et al. (2017) provide a meta-study to investigate the impact of climate change on crop yields in the world. We use these results for the different crops and translate them into direct impacts on the Vietnamese economy. Table 5 reports the expected drop in crop yields due to an increase in the average annual temperature. We use available estimates for Vietnam and China. Only for rice, the study explicitly reports an estimate for Vietnam. We see that maise is most vulnerable to an increase in the average annual temperature.

Table 5: Crop yield loss

Crop	Loss ($\%/^{\circ}C$)	Region
wheat	-2.6	China
rice	-3.0	Vietnam
maize	-8.0	China
soybean	-3.1	China

Source: Zhao et al. (2017).

It is straightforward to include the damage on rice induced by climate change into the model. Therefore, we will define the following relationship between the exogenous damage on regional productivity in the rice sector $\eta^D_{1,r,t}$ and regional temperature increase $\eta^{tas}_{r,t}$. The damage on the rice sector is captured by a decline in total factor productivity in the sector by 3% for a 1°C increase (49).

$$D_{1,r,t} = \eta^D_{1,r,t} = 0.03\,\eta^{tas}_{r,t}. \tag{49}$$

For other agricultural sectors, excluding rice, we need to weigh the damage induced by temperature with the respective share of the crop on the overall gross value added generated in the sector. In 2014, starchy root crops were responsible for 6.6% of value added in the agricultural sector. We assume that all crops in this category react identically to an increase in temperature as maize. Oilseed plants contributed 1.7% to the overall value added of the agricultural sector, excluding rice in 2014. All crops in this category will experience a reduction in crop yields as a response to climate change by 3.1%. Therefore we will have the following impact of a temperature increase on the total factor productivity in the agricultural sector, excluding rice. For all other sub-sectors belonging to the agricultural sector, excluding rice, the damage is set to zero.

$$D_{2,r,t} = \eta^D_{2,r,t} = \underbrace{0.006}_{=1-(1-0.031)^{0.017}\,(1-0.08)^{0.0657}} \eta^{tas}_{r,t}. \tag{50}$$

Sea level: In addition to an increase in temperature, the sea-level rise will reduce the available land for agricultural activities. In order to incorporate this effect, we use data on land usage by province. Further, national experts predict the potential loss of land in different categories for different levels of sea-level rise. We compute the share of land loss used for rice production or the agricultural sector excluding rice. For the computation, we use the following steps:

1. First, obtain agricultural production land by province. (Source: GSO Table E01.02)
2. Second, compute land used for rice production in each province using the total national land used for rice production multiplied with the regional share of planted paddy land in each region.
3. Third, subtract the land used for rice from agricultural production land by the province to get land used for agriculture excluding rice.
4. Compute the share of land loss for the different levels of sea-level rise ($ll_{b,r}$ for $b \in [5(j-1), 5j)$ for $j \in (1, \ldots 20)$)

Figure 5 depicts the share of land loss due to different sea-level rise levels. The exposure of the two river deltas is the highest. Over 10% of the land currently used for rice might be lost if the sea level rises by 50 cm in the Red River Delta. The same is true for the Mekong River Delta for the agricultural sector, excluding rice.

We include the effect of sea-level rise on land used with the following modification to the damage functions

$$D_{1,r,t} = \eta^D_{1,r,t} = 0.031\, \eta^{tas}_{r,t} + 1(\eta^{SL}_t \in b) \sum_{b=2}^{20} ll_{b,1,r}, \tag{51}$$

$$D_{2,r,t} = \eta^D_{2,r,t} = \underbrace{0.006}_{=1-(1-0.031)^{0.017}\,(1-0.08)^{0.0657}} \eta^{tas}_{r,t} + \sum_{b=2}^{20} 1(SL_{b-1} \leq SL_t < SL_b)\, ll_{b,2,r}. \tag{52}$$

The reduction in total factor productivity in the agricultural sector is a linear function in temperature and a non-continuous step function based on indicator functions (1) with respect to sea-level rise.

Adaptation: There are different ways to adapt to climate change in the agricultural sector. One way to adapt to climate change is to switch production from the more affected sectors to the less affected sectors or regions in Vietnam. The DGE-CRED model assumes optimising agents. This implies endogenous adaptation to climate change through disinvestment from highly vulnerable to less vulnerable sectors. Further, it is possible to compensate the loss in total factor productivity with more investments into the capital stock. So far, most adaptation measures for the agricultural sector consider private action, which is implicitly modelled by optimising agents.

3.3.2 Forestry

The forestry sector in Vietnam is responsible for 1.6 % of the gross national value added. More than 30 % of the output in the sector is exported to other countries. National experts differentiate between seven types of forests in Vietnam: evergreen broad-leaved forest, coniferous forest, deciduous broad-leaved forest, bamboo forest, flooded forest, plantation forest. Figure 6 shows the distribution forests across Vietnam.

Forest fires are the main hazard to the forestry sector in Vietnam. In order to quantify the impact of climate change on the forestry sector, we need to know the potential change in the frequency of forest fires. Therefore, we use the so-called Keetch-Byran Drought-Index (KBDI).[9] This index is used to predict the risk of forest fires and depends on the daily maximum temperature T^{MAX}_t, annual average rainfall R_0 and a rainfall factor RF_t, depending on the daily rainfall R_t. We use the modified index for tropical ecosystems Taufik et al. (2015)

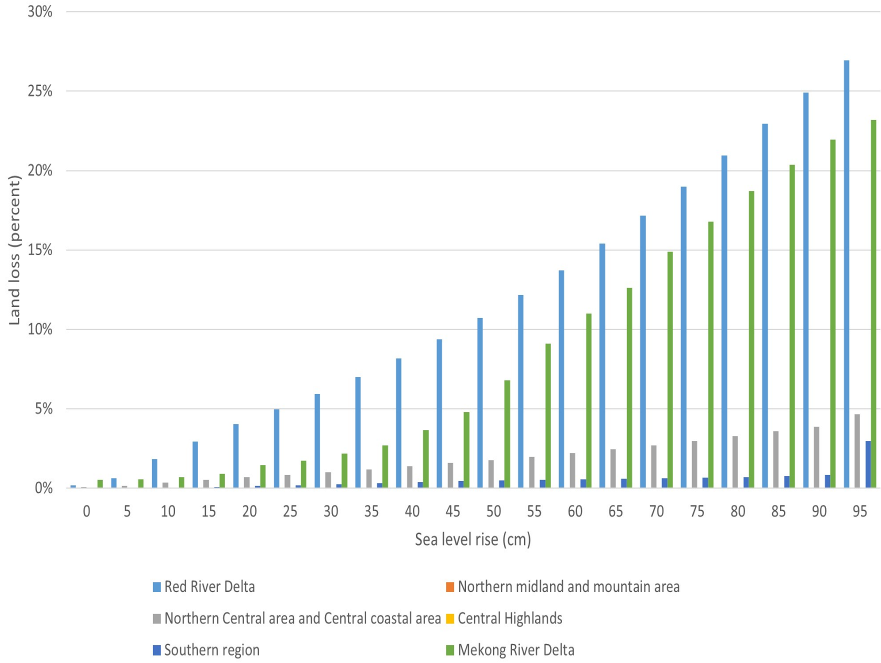
$$KBDI_t = KBDI_{t-1} + \frac{(203 - KBDI_{t-1}) \cdot (0.492 \cdot e^{(0.095 \cdot T^{MAX}_t + 1.6096)} - 4.268) \cdot 10^{-3}}{1 + 10.88 \cdot e^{-0.001736 \cdot R_0}} - RF_t.$$

In the following, we describe how we compute the fire frequency using the daily KBDI index for each province.

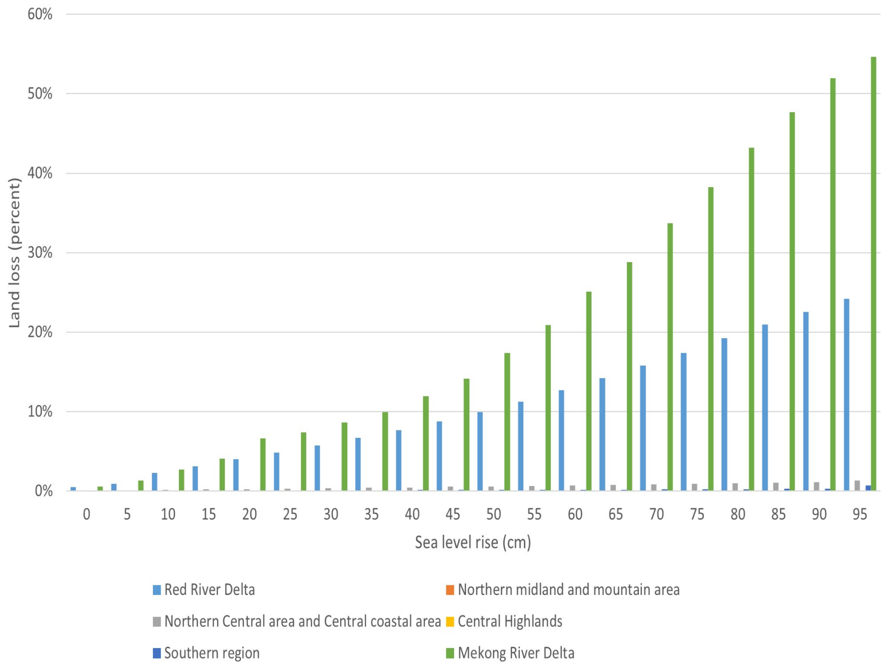
[9] Keetch & Byram (1968) introduces the index to measure the severity of droughts.

Figure 5: Land loss due to sea-level rise

Rice

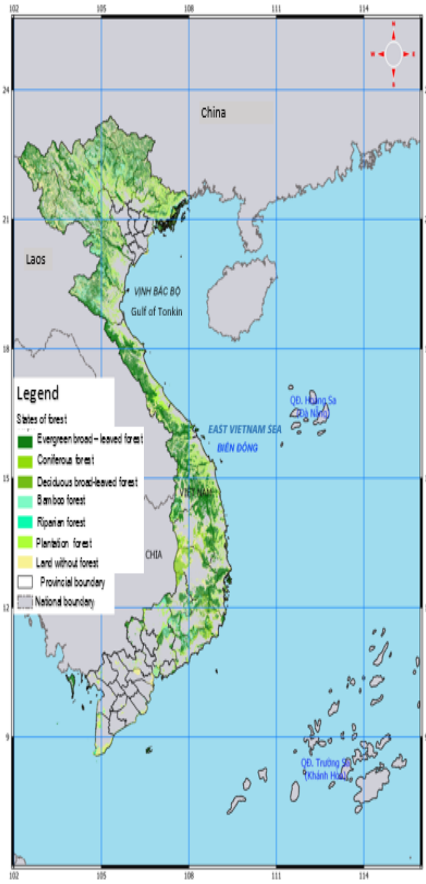


Agriculture excluding rice



Source: National expert, GSO and own computation.

Figure 6: Map of forests in Vietnam



Source: National experts report for the forestry sector.

1. We compute the KBDI for each region using daily surface temperature and daily precipitation. In order to obtain daily predicted precipitation, we use monthly predicted precipitation and use the relative historic daily distribution of precipitation with respect to the average monthly precipitation. In the next step, we compute the daily KBDI for each province. We combine the historically computed KBDI for each province with a dataset of the burned area by the province in Vietnam published by `globalforestwatch.org`. The dataset is used to evaluate the predictive power of the KBDI to forecast fires in Vietnam. The regression results show that the KBDI has predictive power. However, the R^2 is 0.32 and, therefore, indicates only moderate explanatory power. For our simulation study, we will use instead predicted forest fires with a regression analysis conditional probabilities. This allows us to capture the potential impact of climate change on the likelihood of forest fires and, at the same time to get reliable estimates of the number of forest fires to be expected. In the literature, a KBDI index value above 150 indicates good conditions for a forest fire.

2. The dataset from `globalforestwatch.org` reports burned areas on a weekly frequency. We sum up the KBDI for different weeks and compute the probabilities that a fire occurred conditional on a weekly KBDI exceeding $1050 = 150 * 7$ and being below the threshold. We estimate the conditional probability of fire given that the KBDI exceeds the threshold to be $P(fire = 1|KBDI > 150*7) = 0.42$. For the case that the index is below the threshold we estimate $P(fire = 1|KBDI < 150*7) = 0.15$.

3. Now, we use the computed daily KBDI to simulate fires in each week from 2014 onwards until 2100 based on the climate variables for the SSP scenario. A fire occurs with a probability of 42% if the cumulative KBDI for this week exceeded the threshold and only with a probability of 15% if the KBDI is below 150. We sum up overall provinces belonging to one region for each year to get the predicted number of fires for each year.

4. To evaluate the damage forest fires can create on the forestry sector, it is necessary to know the expected loss in forest area due to fire. Therefore, we compute the median area burned for a fire in each region from 2000 to 2014. In case a fire occurs, this area will be burned. Nevertheless, it is necessary to relate this area to the total area of land used for forestry in the region. Therefore, we use the land use data for each province to get the land used for forestry.

5. The damage due to forest fire in the forestry sector for each region is computed by multiplying the number of forest fires $\eta^{fire}_{r,t}$ in the region for the respective year with the fraction of land burned $ll^{fire}_{r,t}$ from the historical database.

$$D_{4,r,t} = \eta^{D}_{4,r,t} = \eta^{fire}_{r,t}\, ll^{fire}_{r,t}. \tag{53}$$

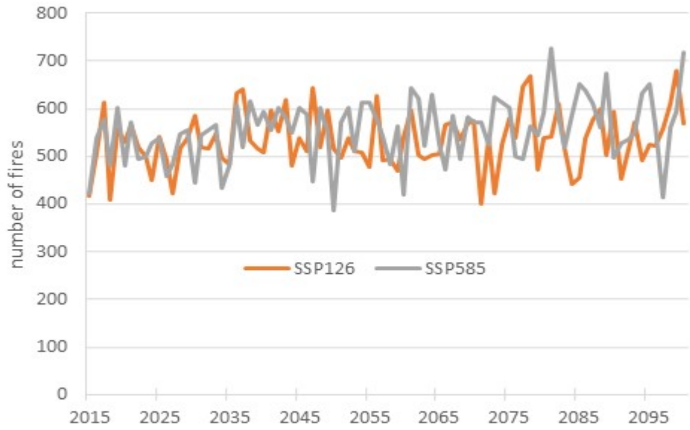
Figure 7 depicts the evolution of forest fires based on the simulation of the KBDI index and the conditional probabilities estimated.

Adaptation: Forest fires mainly happen in plantation forests. According to the Vietnam Administration of Forestry, about 20,000 ha of natural forest burned between 2002 to 2011. In the same period, about 32,500 ha of plantation forest burned. National experts identified five different adaptation measures to reduce the risk of a forest fire. Table 6 reports all adaptation measures. All adaptation measures are evaluated according to their technical feasibility, local approval and based on the previous two categories. We see that from all adaptation measures, the first one received a very high rating. This adaptation measure considers converting single species forests to mixed plantations consisting of native species and with lower fire risk and higher survival rates.

The share of forestry land loss due to forest fires with and without adaptation for each region is tabulated in Table 7. After the implementation of the first adaptation measure, the share of land loss due to forest fire will be lower. The reduction is based on the historically observed ratio between forest fires occurring in natural forests and plantation forests ($\frac{20{,}000ha}{32{,}500} = 61\%$).

The necessary adaptation expenditures are reported in Table 8. They are computed considering the costs of changing one hectare of pure eucalyptus forests to mixed forests with eucalyptus and pine. We assume that the cumulative adaptation measures expressed relative to GDP in 2014 will reduce the

Figure 7: Number of forest fires in Vietnam per year



Source: own computation.

Table 6: Adaptation measures

Adaption measure	Technically feasible	Local approval	Ratings
convert single species forests and plantation forests into mixed plantations	High	High	Very high
specialize in trade of natural forests with higher water retention and moisture retention	High	Low	Medium
integrated fire prevention techniques	High	Medium	High
research on technologies for useful use of forest burning	Medium	Low	Low
strengthen communication and education in forest fire prevention and fighting	Medium	Medium	Medium

Source: National expert report.

Table 7: Forestry land loss due to forest fires

Region	without adaptation	with adaptation
Red River Delta	0.104%	0.064%
Northen Midland and Mountain area	0.003%	0.002%
Northen Central and Central Coastal Area	0.003%	0.002%
Central Highlands	0.016%	0.010%
South East	0.020%	0.012%
Mekong River Delta	0.191%	0.117%

Source: National experts, GSO, globalforestwatch.org and own computation.

burned area for each fire according to the factor computed with the historical data for the period 2001 to 2010. Therefore, the damage induced by a fire is

$$D_{4,r,t} = \eta^D_{4,r,t} = \begin{cases} ll^{fire,na}_{r,t} \, fire_{r,t} & ,\text{if } \sum_{h=0}^{t} G^A_{h,r} < G^A_{Total,r}, \\ ll^{fire,a}_{r,t} \, fire_{r,t} & ,\text{if } \sum_{h=0}^{t} G^A_{h,r} \geq G^A_{Total,r}. \end{cases} \quad (54)$$

After the adaptation measures have been implemented, the burned area per fire in the region reduces to the respective value reported in Table 9. However, the adaptation measures only reduce the burned area after completion of the adaptation measure. The implementation of the adaptation measure, according to the experts, takes ten years.

Table 8: Adaptation expenditures in the forestry sector $\frac{G^A_{r,t}}{P_0 Y_0}$

Period	Red River Delta	Northern Midland and Mountain area	Northen Central and Central Coastal Area	Central Highlands	Southeast	Mekong River Delta
1	0.0140	1.5396	0.8889	0.0000	0.0000	0.0000
2	0.0070	0.7674	0.4431	0.0000	0.0000	0.0000
3	0.0043	0.4706	0.2717	0.0000	0.0000	0.0000
4	0.0018	0.1998	0.1154	0.0000	0.0000	0.0000
5	0.0012	0.1374	0.0793	0.0000	0.0000	0.0000
6	0.0111	1.2178	0.7031	0.0000	0.0000	0.0000
7	0.0001	0.0115	0.0066	0.0000	0.0000	0.0000
8	0.0001	0.0115	0.0066	0.0000	0.0000	0.0000
9	0.0001	0.0115	0.0066	0.0000	0.0000	0.0000
10	0.0117	1.2893	0.7444	0.0000	0.0000	0.0000
Total	0.0515	5.6560	3.2669	0.0000	0.0000	0.0000

Source: National Experts report.
Note: Adaptation expenditures are expressed in relation to 2014 GDP of Vietnam.

Table 9: Forestry land loss due to forest fires

Region	share of forestry land loss without adaptation $ll^{fire,na}_{r,t}$	share of forestry land loss with adaptation $ll^{fire,a}_{r,t}$
Red River Delta	0.104%	0.064%
Northen Midland and Mountain area	0.003%	0.002%
Northen Central and Central Coastal Area	0.003%	0.002%
Central Highlands	0.016%	0.010%
South East	0.020%	0.012%
Mekong River Delta	0.191%	0.117%

Source: National experts, GSO, globalforestwatch.org and own computation.

3.3.3 Housing

The home-ownership rate in Vietnam is above 90%.[10] This implies that the residential buildings are not rented out to firms to provide rental services. They are mainly durable goods consumed by households. Therefore, climate hazards to the housing stock in Vietnam will not affect the capital stock of a specific sector primarily.

Sectoral experts identify two main hazards to the housing stock in Vietnam. Storms destroy regularly houses in Vietnam. The frequency of storms is different across the regions. In the Northern Central area and Central coastal area, there is each year a storm. In the South East and the Mekong River Delta, every third year, there is no storm. In the Red River Delta, in every fourth year, there is no storm. In the Northern midlands and mountain areas and the Central Highlands, every fifth year, there is no storm. We simulate the storm frequency in our model, setting the exogenous variable to one if a storm occurs ($\eta_{r,t}^{Storms} = 1$).

Storms: The damage a storm causes to the housing stock of the region depends on the composition of the housing stock. Official data differentiates between rudimentary, non-permanent, semi-permanent and permanent houses. Roughly 92% of households live in permanent houses, 6% in rudimentary houses, 1.3% in semi-permanent houses and 0.5% in non-permanent houses. For the estimation of the damages for each region, it is assumed that storms or floods will destroy about 10% of the houses. Therefore, the regional damage induced by climate change depends on the number of houses in one region. The destruction of houses in Vietnam due to storms in one year relative to GDP in 2014 is tabulated in Table 10.

Table 10: Houses destroyed by storms

Region	Damage avoided $D_r^{H,pot,storm}$
Red River Delta	0.0063
Northern midlands and mountain areas	0.046
Northern Central area and Central coastal area	0.030
Central Highlands	0.027
South East	0.00015
Mekong River Delta	0.00057

Source: Sectoral experts report and own computation.

We use these values and define them as the potential damage $D_r^{H,pot,storm}$ storms can produce in the region. However, the total damage to the national housing stock is given by

$$D_t^H = \eta_t^{D^H} = \sum_r storms_{r,t}\, D_r^{H,pot,storm}. \tag{55}$$

Sea level: In addition to storms, the sea-level rise will increase the number of floods. This will also destroy parts of the houses in the affected areas. Here, the sectoral experts again assume that roughly 10% of the houses affected by the floods will be destroyed. We obtained the potential damage for a house given a sea-level rise of 50 cm. This level of sea-level rise will only occur at the earliest stage in 70 years in the SSP 585 scenario. It is very unlikely that intermediate levels of sea-level rise have no impact on the housing stock. Therefore, we use the share of land loss in the construction sector for different bins of sea-level rise. We need to assume a uniform distribution of houses across the total land used for construction. We use the share of construction land loss for a specific range of sea-level rise to estimate the costs. Table 11 reports the damages to the housing stock for each region for different sea levels.

Therefore, damages to the housing stock in Vietnam evolve by

$$D_t^H = \sum_r storms_{r,t}\, D_r^{H,pot,storm} + \sum_{b=2}^{20} (1(SL_{b-1} < SL_t \leq SL_b) D_b^{H,SL}). \tag{56}$$

[10]Source: `https://www.globalpropertyguide.com/Asia/Vietnam/Price-History`

Table 11: House destruction by sea-level rise relative to GDP in 2014

SLR in cm (SL_b)	Red River Delta	Northern midland and mountain area	Northern Central area and Central coastal area	Central Highlands	South East	Mekong River Delta	Vietnam $D_b^{H,SL}$
0	0.000	0.000	0.001	0.000	0.000	0.042	0.043
5	0.001	0.000	0.001	0.000	0.000	0.077	0.079
10	0.002	0.000	0.003	0.000	0.000	0.181	0.186
15	0.004	0.000	0.004	0.000	0.001	0.282	0.290
20	0.005	0.000	0.005	0.000	0.001	0.480	0.492
25	0.007	0.000	0.006	0.000	0.002	0.502	0.517
30	0.008	0.000	0.007	0.000	0.003	0.537	0.555
35	0.009	0.000	0.008	0.000	0.004	0.575	0.596
40	0.011	0.000	0.009	0.000	0.005	0.633	0.659
45	0.013	0.000	0.011	0.000	0.006	0.705	0.734
50	0.014	0.000	0.012	0.000	0.007	0.812	0.846
55	0.016	0.000	0.014	0.000	0.008	0.927	0.965
60	0.019	0.000	0.015	0.000	0.009	1.035	1.078
65	0.021	0.000	0.017	0.000	0.010	1.127	1.175
70	0.024	0.000	0.018	0.000	0.011	1.249	1.302
75	0.026	0.000	0.020	0.000	0.012	1.359	1.418
80	0.029	0.000	0.022	0.000	0.014	1.469	1.534
85	0.032	0.000	0.023	0.000	0.015	1.558	1.629
90	0.035	0.000	0.025	0.000	0.016	1.637	1.714
95	0.039	0.000	0.036	0.000	0.024	1.696	1.795

Source: Sectoral experts report and own computation.

Adaptation: For sea-level rise and storms, there are two different adaptation measures. It is possible to build houses with reinforced walls and bricks to reduce the vulnerability of houses to storms. An appropriate measure to reduce the impact of an increase in sea-level rise is to raise a house on stilts. We use the estimated costs and benefits reported in Table 20 and 21 in the Appendix. We will reduce the damages caused by sea-level rise or storms by the respective benefits associated with the necessary cumulative costs for the adaptation measures. Therefore (57), the following equation describes the damages on the housing stock, including adaptation measures.

$$D_t^H = \sum_r (storms_{r,t}\, D_r^{H,pot,storm})(\sum_\tau^t G_\tau^{A,H,Storms} < \sum_\iota^p G_\iota^{A,H,Storms})\ldots \tag{57}$$

$$+ \sum_{b=2}^{20} (1(SL_{b-1} < SL_t \leq SL_b) D_b^{H,SL} * (\sum_\tau^t G_\tau^{A,H,SL} < G_b^{A,H,SL})). \tag{58}$$

If all adaptation measures are implemented, the damage caused by the two climate hazards is completely offset.

3.3.4 Transport

Sea-level rise, temperature, landslides: In Vietnam, the transportation sector is responsible for about 11 % of gross value added. Transportation via roads makes up over 90 %. However, climate change poses a threat to the conditions of the road stock in Vietnam. All damages on the road stock are incorporated through damages to the capital stock of the transport land sub-sector ($D_{10,r,t}^K$). Three different climate hazards have been identified by national experts. First, sea-level rise can flood some of the roads. Second, consecutive days with temperatures above $30^{\circ}C$ and more can destroy the asphalt due to melting. Third, landslides as a response to higher precipitation can destroy part of the roads as well. A further distinction by the national experts have been provided regarding the types of road (national roads, highways and provincial roads) and their vulnerability (very low, low, medium, high, very high). However, for the simulation, we aggregate damages and costs across road types and their vulnerability classification. We assign subjective probabilities for different vulnerability classes to compute expected damages on the road stock. In order to link the climate variables from the meteorological model to the specific hazards identified, we first select suitable proxies for each climate hazard. For high temperatures, we use the maximum number of heatwaves in a year as a proxy. The damages caused on the road stock induced by higher temperatures materialize if heatwaves exceed the 90% quantile of the simulated distribution for the SSP 126 scenario. For the damages induced by landslides, we use the maximum consecutive wet days as a proxy. The sectoral experts provide with the potential damages which alternate across years. This is straightforward for sea-level rise. Here we use the change in sea level to determine the damage on the road stock due to flooding. We computed expected damages across all road types per km^2. In the next step, we multiply the area in km^2 of road loss due to a specific sea-level rise to approximate costs and benefits. Table 22 reports the expected damages for different sea levels.

For the climate hazard high temperatures, we use the maximum number of heatwaves in a year as a proxy. The damages caused on the road stock induced by higher temperatures materialize if heatwaves exceed the 90% quantile of the simulated distribution for the SSP 126 scenario. Table 13 reports the expected damages caused by heatwaves on the road stock relative to 2014 GDP. According to the table, annual heatwaves above the 90 percent quantile will lead to damages of about 0.025% relative to GDP in the Red River Delta.

For the damages induced by landslides, we use the maximum consecutive wet days as a proxy. The sectoral experts provide us with damages which alternate across years. In order to link the damages to an observable climate variable, we first identify the $\frac{1}{30}, \dots, \frac{15}{30}, \dots \frac{30}{30}$ percentiles of the distribution for maximum consecutive wet days for each region. 30 different distinct values for damages induced by landslides in Vietnam are ordered. If the simulated climate maximum consecutive wet days falls into the respective percentile, we choose the corresponding value for the damages reported by the sectoral experts. The respective damages for each percentile are reported in Table 14. Landslides mainly occur in mountainous areas and not at the coastline. Further, the implied damage to the road stock is negligible in relation to GDP.

Damages caused by climate change without adaptation to the road stock of a region is represented by (59)

$$\begin{aligned} D^K_{10,r,t} = &\sum_{b=2}^{20} (1(SL_{b-1} \geq SL_t < SL_b) D^{SL,Road}_{b,r}) \dots \\ &+ 1(heatwave_{r,t} > heatwave^{90,SSP126}_r) D^{heatwave,Road}_r \dots \\ &+ \sum_{p=2}^{30} (1(maxwetdays^{p-1,SSP126}_r < maxwetdays_{r,t} \leq maxwetdays^{p,SSP126}_r) D^{landslide,Road,p}_r). \end{aligned} \tag{59}$$

Adaptation: We simulate adaptation measures for each climate hazard. Each adaptation measure is funded by government expenditures $G^{A}_{10,r,t} = G^{A,SL}_{10,r,t} + G^{A,heatwave}_{10,r,t} + G^{A,landlside}_{10,r,t}$ in each region. The adaptation measures will reduce the damage induced by the specific hazards. We distinguish between the three different categories. First, an adaptation measure to tackle the sea-level rise is to elevate the affected roadbed by the respective increase. We assume that the roadbed elevation can be done successively before the sea-level rises. The implementation of the adaptation measure will reduce the potential damage for the respective sea level to zero. Second, the adaptation measure to tackle heatwaves and extraordinarily high temperatures is to replace conventional asphalt concrete with poly mere asphalt concrete. At the moment the project starts, the damage by high temperatures to the road network goes to zero. According to the sectoral experts, the implementation of the adaptation measure only takes two years. This short period justifies this simplification. Third, effective measures against road erosion can mitigate the impact of landslides on the road stock in Vietnam. The implementation takes only a year, and the costs are relative to GDP in 2014 negligible. Equation (60) reports damages with adaptation measures.

$$D^K_{10,r,t} = \sum_{b=2}^{20}(1(SL_{b-1} \geq SL_t < SL_b) D^{SL,road}_{b,r}) 1(\sum_{\tau}^{t} G^{A,SL}_{10,r,\tau} < G^{A,SL,b}_{10,r})) \ldots$$
$$+ 1(heatwave_{r,t} > heatwave^{90,SSP126}_r) D^{heatwave,road}_r 1(\sum_{\tau}^{t} G^{A,heatwave}_{10,r,\tau} < G^{A,heatwave,total}_{10,r,\tau}) \ldots$$
$$+ \sum_{p=2}^{20} 1(maxwetdays^{p-1,SSP126}_r < maxwetdays_{r,t} \leq maxwetdays^{p,SSP126}_r) D^{landslide,road,p}_r) \ldots$$
$$+ 1(\sum_{\tau}^{t} G^{A,landslide}_{10,r,\tau} < G^{A,landslide,total}_{10,r,\tau}) \quad (60)$$

Table 12: Damages caused by sea-level rise to the road stock

SLR	Red River Delta	Northern midland and mountain area	Northern coastal and coastal area	Central Highlands	South East	Mekong River Delta
			Damages/Benefits			
0	0.001	0.000	0.002	0.000	0.001	0.002
5	0.001	0.000	0.004	0.000	0.003	0.004
10	0.001	0.000	0.008	0.000	0.006	0.009
15	0.002	0.000	0.010	0.000	0.010	0.014
20	0.002	0.000	0.013	0.000	0.017	0.023
25	0.003	0.000	0.016	0.000	0.018	0.025
30	0.004	0.000	0.020	0.000	0.020	0.029
35	0.004	0.000	0.023	0.000	0.021	0.031
40	0.005	0.000	0.027	0.000	0.023	0.035
45	0.006	0.000	0.032	0.000	0.024	0.040
50	0.007	0.000	0.036	0.000	0.027	0.044
55	0.008	0.000	0.039	0.000	0.029	0.048
60	0.009	0.000	0.044	0.000	0.032	0.053
65	0.011	0.000	0.048	0.000	0.034	0.058
70	0.012	0.000	0.052	0.000	0.037	0.063
75	0.014	0.000	0.056	0.000	0.040	0.068
80	0.015	0.000	0.062	0.000	0.043	0.074
85	0.017	0.000	0.067	0.000	0.045	0.080
90	0.019	0.000	0.071	0.000	0.048	0.086
95	0.021	0.000	0.083	0.000	0.052	0.095
			Costs			
0	0.001	0.000	0.004	0.000	0.002	0.003
5	0.001	0.000	0.003	0.000	0.003	0.004
10	0.001	0.000	0.008	0.000	0.006	0.008
15	0.001	0.000	0.004	0.000	0.008	0.011
20	0.001	0.000	0.005	0.000	0.014	0.019
25	0.001	0.000	0.006	0.000	0.002	0.003
30	0.001	0.000	0.008	0.000	0.003	0.004
35	0.001	0.000	0.006	0.000	0.002	0.003
40	0.001	0.000	0.007	0.000	0.004	0.005
45	0.002	0.000	0.010	0.000	0.003	0.005
50	0.002	0.000	0.007	0.000	0.005	0.007
55	0.002	0.000	0.007	0.000	0.004	0.006
60	0.003	0.000	0.008	0.000	0.005	0.007
65	0.003	0.000	0.009	0.000	0.004	0.006
70	0.003	0.000	0.007	0.000	0.006	0.008
75	0.003	0.000	0.008	0.000	0.005	0.007
80	0.004	0.000	0.012	0.000	0.006	0.008
85	0.004	0.000	0.009	0.000	0.005	0.007
90	0.004	0.000	0.009	0.000	0.006	0.008
95	0.004	0.000	0.021	0.000	0.008	0.011

Source: Sectoral experts report and own computation.

Table 13: Damages caused by heatwaves on road stock

Period after start	Red River Delta	Northern midland and mountain area	Northern coastal and coastal area	Central Highlands	South East	Mekong River Delta
			Damage by extraordinary heatwaves			
heatwave	0.025	0.071	0.060	0.038	0.024	0.033
			Adaptation benefits			
1	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.000	0.000	0.000	0.000	0.000
3	0.006	0.018	0.015	0.010	0.006	0.008
4	0.006	0.018	0.015	0.010	0.006	0.008
5	0.006	0.018	0.015	0.010	0.006	0.008
6	0.025	0.071	0.060	0.038	0.024	0.033
7	0.006	0.018	0.015	0.010	0.006	0.008
8	0.006	0.018	0.015	0.010	0.006	0.008
9	0.006	0.018	0.015	0.010	0.006	0.008
10	0.025	0.071	0.060	0.038	0.024	0.033
11	0.006	0.018	0.015	0.010	0.006	0.008
12	0.006	0.018	0.015	0.010	0.006	0.008
13	0.006	0.018	0.015	0.010	0.006	0.008
14	-0.008	-0.022	-0.019	-0.012	-0.008	-0.010
15	0.006	0.018	0.015	0.010	0.006	0.008
16	0.006	0.018	0.015	0.010	0.006	0.008
17	0.006	0.018	0.015	0.010	0.006	0.008
18	0.025	0.071	0.060	0.038	0.024	0.033
19	0.006	0.018	0.015	0.010	0.006	0.008
20	0.006	0.018	0.015	0.010	0.006	0.008
21	0.006	0.018	0.015	0.010	0.006	0.008
22	0.025	0.071	0.060	0.038	0.024	0.033
23	0.006	0.018	0.015	0.010	0.006	0.008
24	0.006	0.018	0.015	0.010	0.006	0.008
25	0.006	0.018	0.015	0.010	0.006	0.008
26	-0.008	-0.022	-0.019	-0.012	-0.008	-0.010
27	0.006	0.018	0.015	0.010	0.006	0.008
28	0.006	0.018	0.015	0.010	0.006	0.008
29	0.006	0.018	0.015	0.010	0.006	0.008
30	0.025	0.071	0.060	0.038	0.024	0.033
Period			Costs to extraordinary heatwaves			
1	0.012	0.033	0.029	0.018	0.012	0.016
2	0.018	0.050	0.043	0.026	0.017	0.024

Source: Sectoral experts report and own computation.

Table 14: Damages caused by landslides and cost of adaptation measures

Percentile after start	Red River Delta	Northern midland and mountain area	Northern coastal and coastal area	Central Highlands	South East	Mekong River Delta
3%	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
7%	0.00000	0.00021	0.00000	0.00001	0.00000	0.00000
10%	0.00000	0.00007	0.00000	0.00000	0.00000	0.00000
13%	0.00000	0.00033	0.00000	0.00002	0.00000	0.00000
17%	0.00000	0.00008	0.00000	0.00000	0.00000	0.00000
20%	0.00000	0.00009	0.00000	0.00000	0.00000	0.00000
23%	0.00000	0.00035	0.00000	0.00002	0.00000	0.00000
27%	0.00000	0.00011	0.00000	0.00001	0.00000	0.00000
30%	0.00000	0.00011	0.00000	0.00001	0.00000	0.00000
33%	0.00000	0.00038	0.00000	0.00002	0.00000	0.00000
37%	0.00000	0.00013	0.00000	0.00001	0.00000	0.00000
40%	0.00000	0.00014	0.00000	0.00001	0.00000	0.00000
43%	0.00000	0.00040	0.00000	0.00002	0.00000	0.00000
47%	0.00000	0.00016	0.00000	0.00001	0.00000	0.00000
50%	0.00000	0.00017	0.00000	0.00001	0.00000	0.00000
53%	0.00000	0.00043	0.00000	0.00002	0.00000	0.00000
57%	0.00000	0.00019	0.00000	0.00001	0.00000	0.00000
60%	0.00000	0.00020	0.00000	0.00001	0.00000	0.00000
63%	0.00000	0.00046	0.00000	0.00002	0.00000	0.00000
67%	0.00000	0.00022	0.00000	0.00001	0.00000	0.00000
70%	0.00000	0.00023	0.00000	0.00001	0.00000	0.00000

Table 14: Damages caused by landslides and cost of adaptation measures

Percentile after start	Red River Delta	Northern midland and mountain area	Northern coastal and coastal area	Central Highlands	South East	Mekong River Delta
73%	0.00000	0.00049	0.00000	0.00003	0.00000	0.00000
77%	0.00000	0.00025	0.00000	0.00001	0.00000	0.00000
80%	0.00000	0.00026	0.00000	0.00001	0.00000	0.00000
83%	0.00000	0.00053	0.00000	0.00003	0.00000	0.00000
87%	0.00000	0.00029	0.00000	0.00002	0.00000	0.00000
90%	0.00000	0.00031	0.00000	0.00002	0.00000	0.00000
93%	0.00000	0.00058	0.00000	0.00003	0.00000	0.00000
97%	0.00000	0.00074	0.00000	0.00004	0.00000	0.00000
100%	0.00000	0.00076	0.00000	0.00004	0.00000	0.00000
Year				Cost		
1	0	0.00076	0	0.000048	0	0

Source: Sectoral experts report and own computation.

3.3.5 Scenarios

In addition to the Baseline scenario, we will simulate in total nine different scenarios. Table 15 reports all nine scenarios. The Baseline scenario only considers the evolution of the Vietnamese economy without climate change. The climate change scenarios SSP 126 and 585 represent the evolution of climate variables and their impact on the different sectors, as discussed in the previous sections. For each sub-sector, we implement an adaptation scenario, where we only consider adaptation measures for the respective sector. We do this also for each SSP scenario. This allows us to see the adaptation measures with the highest impact on GDP in Vietnam. This will allow us to identify the sector with the highest potential.

Table 15: Overview of Scenarios

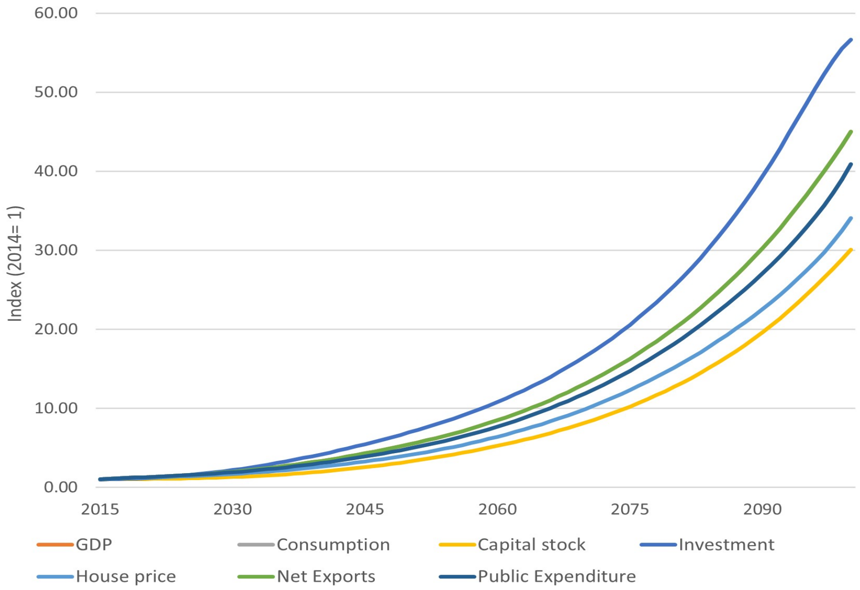
Name	Description
Baseline	Development of the Vietnamese economy without impacts of climate change on the economic development. The net export to GDP ratio remains constant. Sectoral growth rates are depicted in Figure 14. Further, the housing area per person remains the same.
SSP 126	Climate variables evolve according to the shared socio-economic pathway 126. Damages are incorporated for each sub-sector.
SSP 585	Climate variables evolve according to the shared socio-economic pathway 585. Damages are incorporated for each sub-sector.
SSP 126 Adaptation Forestry	Climate variables evolve according to the shared socio-economic pathway 126. Damages are incorporated for each sub-sector and only adaptation measures for the forestry sector are implemented
SSP 126 Adaptation Housing	Climate variables evolve according to the shared socio-economic pathway 126. Damages are incorporated for each sub-sector and only adaptation measures for the housing sector are implemented
SSP 126 Adaptation Transport	Climate variables evolve according to the shared socio-economic pathway 126. Damages are incorporated for each sub-sector and only adaptation measures for the transport sector are implemented
SSP 585 Adaptation Forestry	Climate variables evolve according to the shared socio-economic pathway 585. Damages are incorporated for each sub-sector and only adaptation measures for the forestry sector are implemented
SSP 585 Adaptation Housing	Climate variables evolve according to the shared socio-economic pathway 585. Damages are incorporated for each sub-sector and only adaptation measures for the housing sector are implemented
SSP 585 Adaptation Transport	Climate variables evolve according to the shared socio-economic pathway 585. Damages are incorporated for each sub-sector and only adaptation measures for the transport sector are implemented

3.4 Results

3.4.1 Baseline

The model simulates an exponential growth path through the development of sectoral productivity. This reflects the fact that developing countries increase their productivity by deploying knowledge and production technologies from already developed economies. It implicitly also assumes higher human capital formation. However, this increase in exogenous productivity of the primary production factors capital and labour triggers more investment into the capital stock, which also contributes to the growth of the economy. A higher GDP, in the long run, leads to higher consumption expenditures and government expenditures. Figure 8 shows an increase in all components of GDP. However, investments in the capital stock grow faster than the other components. The growth rate of GDP and net exports coincides by assumption. The house price increases while the housing stock per capita remains constant.

Figure 8: Evolution of key economic indicators



Source: Own computation.

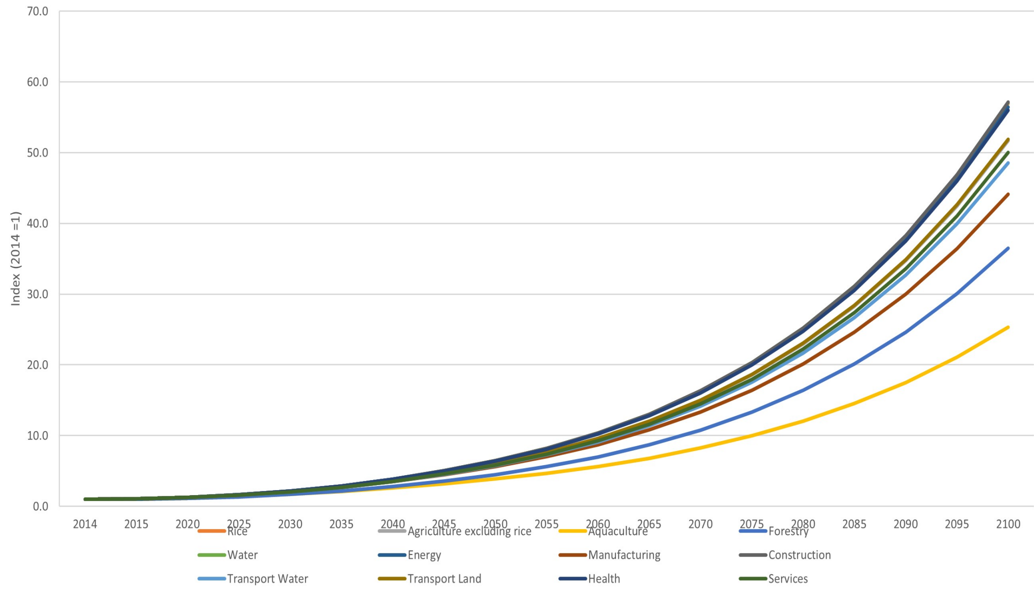
The impact evaluation of different adaptation measures and climate change variables is done with respect to the baseline evolution. This allows evaluating the impact controlling for a change in the composition of sectors. We can see in Figure 9 a faster expansion of the tertiary sector. Especially the services sector will increase. Therefore, Vietnam will move from an economy with a focus on the primary sector to a service-based economy similar to currently developed economies. As a consequence, the share of employment (see Figure 17) in the service industry increases. However, prices in the services sector increase more than in other sectors (see Figure 18).

In the following, we present the results for different scenarios. All figures represent deviations from the baseline results.

3.4.2 Rice and Agriculture

Figure 19 shows the damages for rice in different scenarios. The greatest damage occurs in the Red River Delta, where the damage in rice is about 15% in the SSP 126 and more than 30% in SSP 585. The Central Highland rice production is less affected by climate change. Figure 20 shows the effects on value added for rice in different regions. In line with the magnitude of damages in Figure 19, the effect on value added is the highest in the Red River Delta with a loss of more than 35% in SSP 126 compared to the baseline and even 60% in SSP 585. In the regions with minor damages, value added is even higher with adaptation measures, e.g. the Central Highlands has more than 16% value added compared to the Baseline. First, the region is not affected by a sea-level rise at all. Further, it is expected that production

Figure 9: Evolution of sub-sectoral output



Source: own computation.

is shifted from regions that are affected to the non or less-affected regions. In addition, the regional price is comparatively low compared to the regions where the damages occur.

Figure 21 shows the damages in the sector of agriculture, excluding rice. The greatest damage is expected again in the Red River Delta with damages compared to the Baseline by up to 10% (SPP 126) and 20% (SSP 585), respectively.

Figure 22 shows the loss in gross value added compared to the Baseline for agriculture, excluding the rice sector. In the Red River Delta, gross value added is about 25% in SSP 126 and almost 50% in SSP 585 higher compared to the Baseline. A smaller loss in gross value added is also expected in the Mekong River Delta. In all other regions under investigation, the gross value added is higher compared to the baseline scenario.

3.4.3 Forestry

The expected damages in the forestry sector are shown in Figure 23. The greatest damage is expected in the Red River Delta and Mekong River Delta, with damages compared to the Baseline by up to 10 % to 30 % (SPP 126) and 14 % to 30 % (SSP 585), respectively. Here, it is assumed that already burned areas can burn next year again; if we assume that already burned areas are less likely to burn next year again, the expected damage increases even further. In the Central Highlands, Northern Midland and Mountain area, South East, and the Northern Central area and Central coastal area, the burned area per fire is lower. The share of forest burned in the regions is much lower, with only up to two percent of the forest area burned.

Figure 24 indicates a loss in gross value added for the SSP 126 scenario in the forestry sector compared to the Baseline of more than 60% in the Mekong River Delta and up to 20 % in the Red River Delta. In all other regions under investigation, gross value added is up to 20 % higher compared to the Baseline scenario. Economic activity in the forestry sector shifts away from the more affected regions towards the less-affected regions. A reduction in the forest area in one region leads to lower capacities of the sector. However, at the same time, other regions do not experience such reductions and can produce more wood for the economy. Therefore, the model predicts an expansion of the forestry sector in the less-affected regions. Nevertheless, producer prices of wood will increase.

We simulate in the adaptation scenarios for the forestry sector the switch of forests from single species to multiple species forests. Quantification for the costs is not reported for the Central Highlands, the South East, and the Mekong River Delta. For the other regions, the implementation of the adaptation measure will lead to a reduction of burned area per fire by almost 40%. This has direct consequences for value added in the sub-sector and region. In the Red River Delta, the implementation of the adaptation measures reduces the loss in value added due to climate change in the forestry sector by almost 50 %.

3.4.4 Housing

Figure 25 presents the results for damages to the housing stock, investment into the housing stock, and the evolution of the housing stock. Damages to the housing stock are different for the SSP 126 and SSP 585 scenarios. The main reason for the observed difference are the associated damages with a higher sea level in the SSP 585 scenario compared to the SSP 126 scenario. The reported damages for the SSP 126 scenario is about 60% of Vietnamese GDP in 2014 at the end of the simulation. For the SSP 585 scenario the damage is about 120% of 2014 GDP. The simulated GDP in Vietnam will be 45 times higher at the end of the century than in 2014. This implies that damages caused by climate change to the housing stock are between one and three percent of GDP.

As a consequence to the damages households will invest more into the housing stock in the SSP 126 and SSP 585 scenario compatred to the Baseline scenario. Investments into the housing stock until the end of the centurry in the SSP 126 scenario are at least 100% higher compared to the Baseline scenario. In the SSP 585 scenario investments are even 200% higher compared to the Baseline scenario. These additional investments will reduce other consumption expenditures. However, the impacts on the housing stock itself range between -4% and 4%. Adaptation measures in the housing sector allow to reduce the implied damages to zero. The impact on the housing stock is almost negligible. This implies that damages to the housing stock in Vietnam due to climate change are not the dominant driver for the changes in the housing stock between the SSP and the Baseline scenario. Additional investments into the housing stock on the other side are mainly driven by damages to the housing stock. This has direct consequences for overall consumption expenditures as reported in Section 3.4.6.

3.4.5 Transport

The effects on the transport sector to the capital stock by sea-level rise, temperature, landslides are shown in Figure 26. Again the regions with a coastline are the most vulnerable regions. The most vulnerable region is the Mekong River Delta, where the damage to the road stock in the region is up to 12 % relative to the 2014 GDP in Vietnam in the SSP 585. In the SSP 126 scenario, damages to the capital stock are only 6 % of 2014 GDP at the end of the century. The Northern Central and Central Coastal area is the second most vulnerable region to climate change with regard to road stock. Damages can be as high as 10% percent in terms of 2014 GDP in the SSP 585 scenario. For the SSP 126 scenario, the impact could be 5% until the end of the century – the third most vulnerable region is the South East region, followed by the Red River Delta. The impacts on the road stock in the Northern midland and mountainous region and the Central Highlands are negligible. In the regions without a coastline, storms and landslides are the main hazards to the road stock.

Damages to the road stock will ceteris paribus reduce the capital stock in the transport sector in each region. However, the endogenous investment decision of households and the demand for capital by firms can overcompensate the reduction in the capital stock caused by storms, floods and landslides. Figure 27 shows that initially, the capital stock in the transport sector is lower in the SSP scenarios in the highly affected regions. In the middle and the end of the 21st century, the capital stocks in the transport sector are slightly higher compared to the Baseline scenario. Further, investments into the transport capital stock of less-affected regions will increase in all SSP scenarios. The adaptation measures to reduce the impact of climate hazards in one region has also implications for other regions.

Figure 28 reports the direct implications of climate change to the value added in the transport sector in each region. We see similar qualitative patterns for value added as for the capital stock in the transport sector. This implies that the capital channel dominates all other potential counteracting forces to value added in the transport sector. Figure 29 reports the results for employment in the transport sector for each region. A response to the destruction of the capital stock is an increase in labour input. This implies that a higher labour input reduces the direct impact of the destruction on the capital stock. Therefore, we see a greater reduction in the capital stock compared to value added in almost all regions. Further, we see that adaptation measures in the regions can mute the impact of climate change on the transport capital stock. However, they are not able to completely offset the impacts of climate change on the capital stock.

3.4.6 Macroeconomic effects

To assess the overall macroeconomic effects of climate change, Figures 10 and 13 picture the difference compared to the Baseline scenario. Private consumption will be lower in all climate change scenarios. However, this is not true for GDP as depicted in Figure 11. It is important to highlight that absolute consumption and GDP increase compared to 2014 in all scenarios. Therefore, the living standards of people in Vietnam increased in all scenarios compared to the year 2014.

A response to lower productivity by the optimizing agents is to invest more into the capital stock today to compensate for the loss in productivity tomorrow (see Figure 12). We see that investment increases in both SSP scenarios and all adaptation scenarios. In the SSP 585 scenario, the investment increase is 2% and 1.7% in the SSP 126 scenario compared to the Baseline scenario in 2035. Investments in the capital stock directly reduce the impact on GDP. However, the increase in investment causes a reduction in consumption compared to the Baseline scenario. Employment increases as well. Therefore, we see that the loss in total factor productivity is compensated by using more of the primary production factors, capital and employment.

Net exports increased at the beginning of the 21st century and declined during the middle of the century. The main mechanism here is that domestic prices relative to import prices of products in the same category increase, which reduces foreign demand for the products and eventually leads to fewer exports and more imports. Therefore the trade surplus of Vietnam is lower due to climate change. Adaptation measures in the housing sector seem to be able to counteract the negative impacts of climate change on net exports. It is even possible to have higher net exports with adaptation measures in the housing sector compared to the Baseline scenario. Adaptation measures in the housing sector allow households to invest more into the capital stock rented out to the firms. This will allow the firms to sell more products to the rest of the world at higher domestic prices. This result depends on the export price elasticity, which is below unity and identical across all sub-sectors.

In order to prioritize adaptation measures by sectors we look at the potential of the adaptation measure to reduce the gap in consumption between climate change scenarios and the Baseline scenario. We can establish the following ranking reported in Table 16 for the SSP 585 scenario.

Table 16: Adaptation measures prioritization

	SSP 126		SSP 585	
Rank	before 2055	after 2055	before 2050	after 2050
1	Transport	Housing	Transport	Housing
2	Housing	Transport	Housing	Transport
3	Forestry	Forestry	Forestry	Forestry

Source: Own computation.

We see that until the year 2050, adaptation measures in the transport sector reduce the consumption gap more than adaptation measures in the other two sectors. Further, we see that after the year 2050, the ranking changes. For the years after 2050, adaptation measures in the housing sector reduce the consumption gap more than adaptation measures in the transport sector.

However, the adaptation measures in no sector so far are able to reduce the consumption gap tremendously. Except for the forestry sector, the adaptation measures in each sector are able to reduce the damages caused by climate change to zero. This implies that the main reason for the gap in consumption is not due to the forestry, housing or transport sector. The main cause for the consumption gap is the damages caused by climate change in the agriculture and aquaculture sector.

4 Conclusion and Discussion

4.1 Summary

The DGE-CRED model allows the user to conduct a cost-benefit analysis in a dynamic general equilibrium framework. This requires the translation of damages for each sector in the form of monetary or physical values into values meaningful from a general equilibrium perspective. First, it is necessary to define a baseline scenario to evaluate the impact of climate change and adaptation measures. The baseline scenario requires the definition of sub-sectoral growth rates for value added and employment shares. Further, it is necessary to define the evolution of net exports to GDP, the population stock and the house area. For Vietnam, we define the Baseline scenario according to the results of another CGE model provided by national economists.

Users need to decide through which channel a hazard will impact the economy. So far, we include the potential of climate hazards to cause damages to total factor productivity of the sub-sector, labour productivity or the formation of the capital stock and housing stock.

We show in the application for Vietnam that one can include biophysical damages, such as crop yield loss land losses due to sea-level rise into productivity losses for different sectors. Further, we show how to incorporate estimated monetary damages to the capital stock and housing stock. It is possible to implement damages as a fraction of current GDP or as a fraction of initial GDP. The most appropriate approach depends on the specific adaptation measure considered.

Our results for Vietnam suggest that adaptation measures in the transport sector should have priority to reduce the consumption gap until the middle of the 21st century and afterwards adaptation measures for the housing sector. However, we see that neither the considered adaptation measures in the transport, housing or forestry sector can reduce the consumption gap in a relevant magnitude. This implies that the main source of consumption reductions in Vietnam due to climate change is caused by the damages induced on the agricultural and aqua-cultural sectors. Policymakers in Vietnam should therefore focus on adaptation measures for the agricultural and aqua-cultural sector. So far, the simulation results only consider endogenous adaptation measures. Such adaptation measures include the relocation of production factors from more affected to less affected regions and an increase in the employment to production factors to compensate for productivity losses.

4.2 Discussion

Our application allows us to evaluate the impact of adaptation measures on other sectors not explicitly considered in the initial cost-benefit analysis. Further, it is not necessary to make assumptions about prices, interest rates and other variables as usually done by standard partial equilibrium cost-benefit analysis. The current version of the model relies on the assumption of rational agents with perfect foresight. Policymakers need to acknowledge the assumption and its implications for the interpretation of the results.

Modelling representative households with a clear preference structure and model consistent expectations implies that the transition path of the model represents the most efficient transition path. It rules out the impact of uncertainty on the decisions of the agents. Under risk, aversion investment behaviour will be more cautious compared to a world without a scenario. Further, backward-looking expectations will also reduce the speed of adjustment. Therefore, we can expect that the adjustment process will take longer.

Researchers and policymakers need to inform the public as good as possible about the current scientific basics of climate change and potential adaptation measures. Further, policy measures need to be implemented in a transparent and commonly understandable way. This is necessary to enable agents in the economy to make rational decisions. The credibility of the stability in the implementation of policy measures is a further prerequisite to making long-run planning possible.

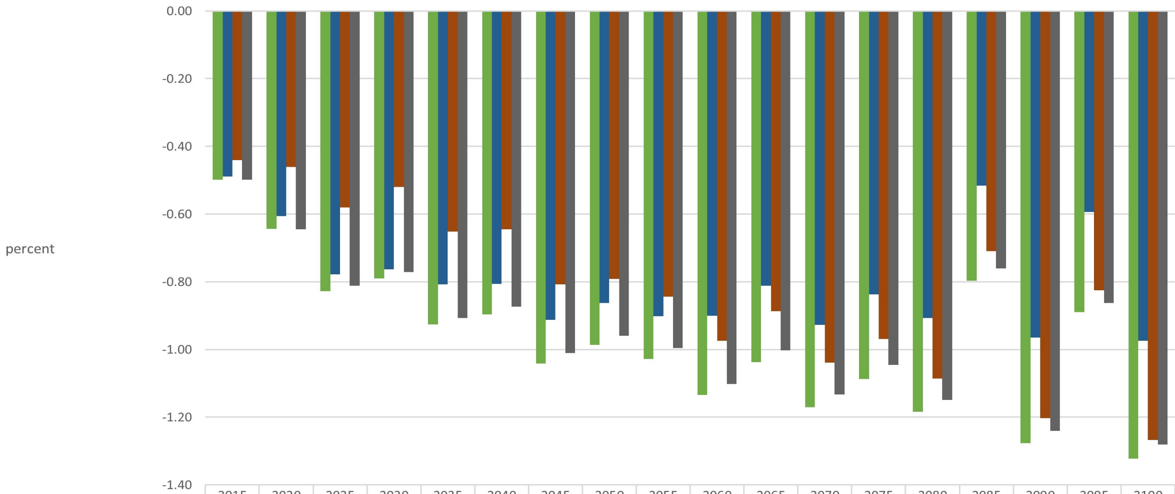
Future versions of the model can allow for a share of irrational agents forming expectations either solely on the past and with a behaviour described by simple heuristics. Nevertheless, it is noteworthy that Cobb-Douglas production functions and utility functions imply constant expenditure shares. Therefore, the implied response is already a simple rule which implies that agents adjust their quantities purchased of a product such that the share on total expenditures is constant.

A further modification for future versions of the model is the explicit incorporation of the implied increase in demand for different sub-sectoral products induced by adaptation expenditures. For instance, one could explicitly account for the higher demand for construction services to employ adaptation measures in the construction sector. It is also possible to make the demand regional specific.

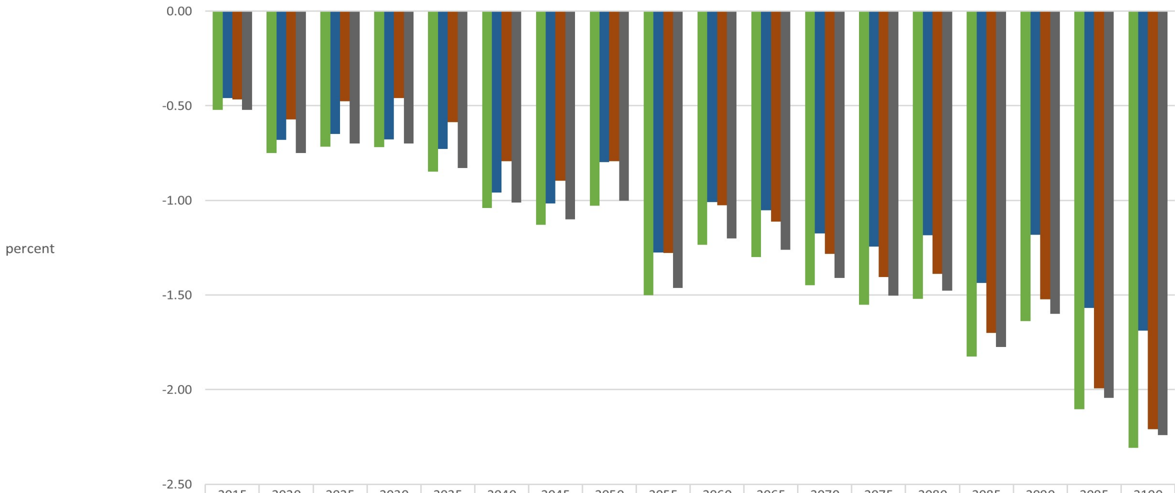
Mitigation policies are not yet explicitly considered. There are potential interdependencies between mitigation and adaptation policies to climate change. It is clear that adaptation measures in the forestry sector will help to store GHG emissions and therefore increase the carbon budget of the world. Here we did not consider the impact of reducing burned forest area on the storage of CO_2 emissions.

The proposed model is meant to be a point of departure for future research to implement in a transparent and replicable way potential damages induced by climate change and adaptation measures to reduce the damages. The results can be used to conduct a cost-benefit analysis to prioritize adaptation measures between and within sectors.

Figure 10: Key macroeconomic indicators: Consumption



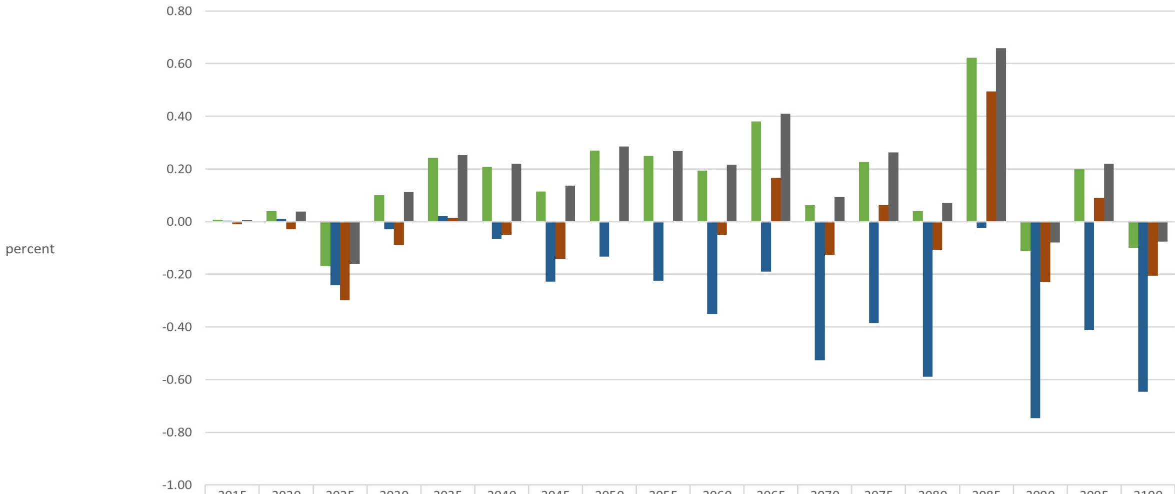
	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	-0.499	-0.644	-0.828	-0.790	-0.926	-0.896	-1.041	-0.987	-1.028	-1.135	-1.037	-1.170	-1.088	-1.183	-0.796	-1.277	-0.890	-1.323
SSP 126 Adaptation Housing	-0.489	-0.606	-0.778	-0.764	-0.808	-0.807	-0.912	-0.863	-0.902	-0.900	-0.812	-0.927	-0.837	-0.907	-0.516	-0.965	-0.594	-0.975
SSP 126 Adaptation Transport	-0.441	-0.460	-0.580	-0.520	-0.652	-0.644	-0.808	-0.791	-0.844	-0.975	-0.887	-1.039	-0.969	-1.085	-0.709	-1.202	-0.825	-1.268
SSP 126 Adaptation Forestry	-0.499	-0.646	-0.811	-0.772	-0.908	-0.874	-1.011	-0.959	-0.996	-1.102	-1.002	-1.133	-1.046	-1.148	-0.760	-1.241	-0.863	-1.281



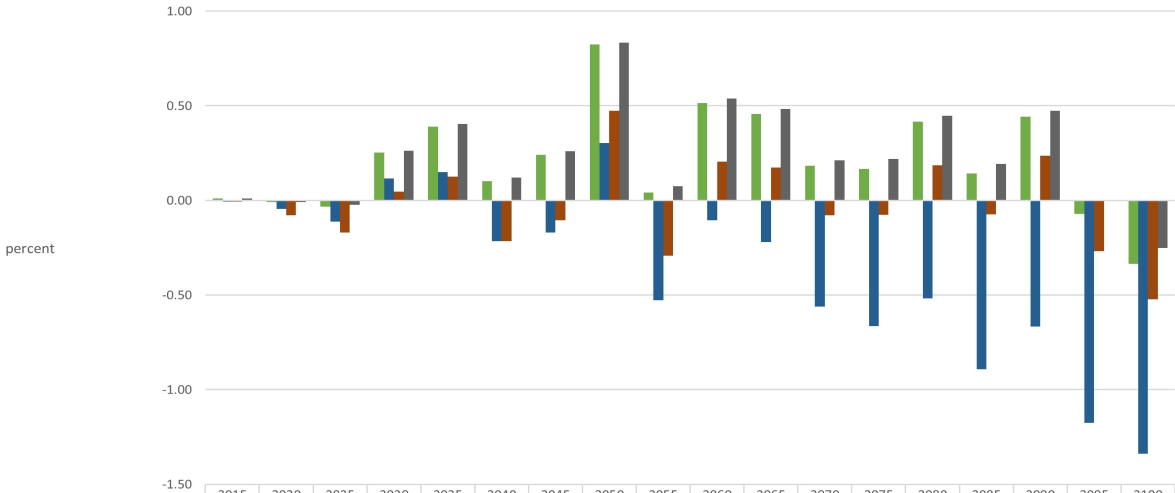
	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	-0.522	-0.749	-0.715	-0.718	-0.848	-1.040	-1.129	-1.027	-1.500	-1.234	-1.299	-1.447	-1.552	-1.520	-1.824	-1.637	-2.103	-2.306
SSP 585 Adaptation Housing	-0.460	-0.679	-0.649	-0.678	-0.729	-0.960	-1.017	-0.798	-1.275	-1.008	-1.051	-1.175	-1.245	-1.184	-1.435	-1.183	-1.567	-1.687
SSP 585 Adaptation Transport	-0.465	-0.572	-0.476	-0.459	-0.588	-0.793	-0.896	-0.793	-1.277	-1.025	-1.112	-1.282	-1.404	-1.387	-1.701	-1.522	-1.992	-2.209
SSP 585 Adaptation Forestry	-0.522	-0.750	-0.700	-0.700	-0.829	-1.012	-1.101	-1.001	-1.462	-1.200	-1.262	-1.410	-1.504	-1.477	-1.775	-1.600	-2.044	-2.241

Source: own computation.

Figure 11: Key macroeconomic indicators: GDP



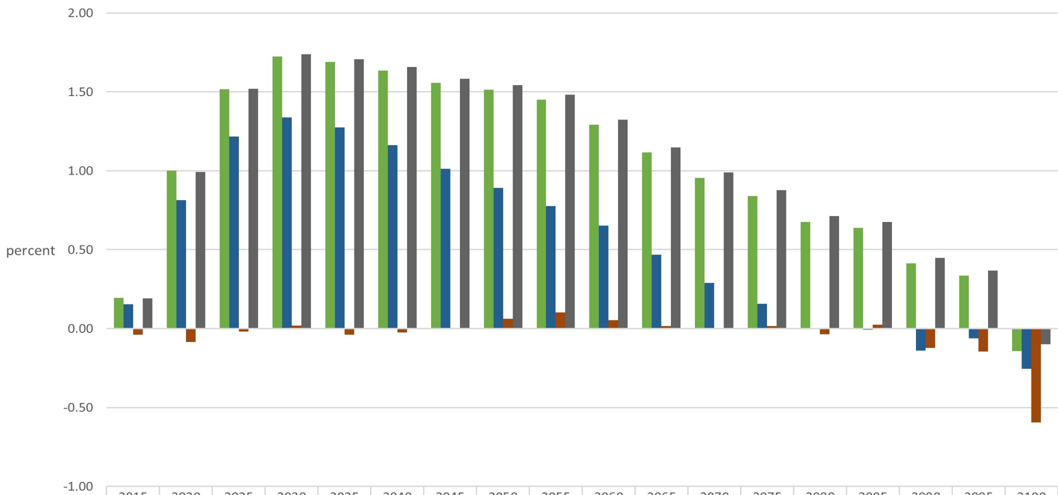
	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	0.006	0.040	-0.169	0.101	0.243	0.208	0.113	0.270	0.250	0.193	0.380	0.062	0.226	0.040	0.623	-0.113	0.200	-0.101
SSP 126 Adaptation Housing	0.003	0.011	-0.241	-0.028	0.021	-0.066	-0.229	-0.133	-0.225	-0.350	-0.189	-0.526	-0.386	-0.589	-0.024	-0.746	-0.410	-0.647
SSP 126 Adaptation Transport	-0.011	-0.029	-0.299	-0.088	0.014	-0.050	-0.142	0.002	-0.002	-0.051	0.166	-0.128	0.063	-0.107	0.494	-0.230	0.090	-0.205
SSP 126 Adaptation Forestry	0.006	0.038	-0.160	0.112	0.253	0.220	0.137	0.285	0.269	0.216	0.409	0.094	0.263	0.070	0.659	-0.080	0.220	-0.076



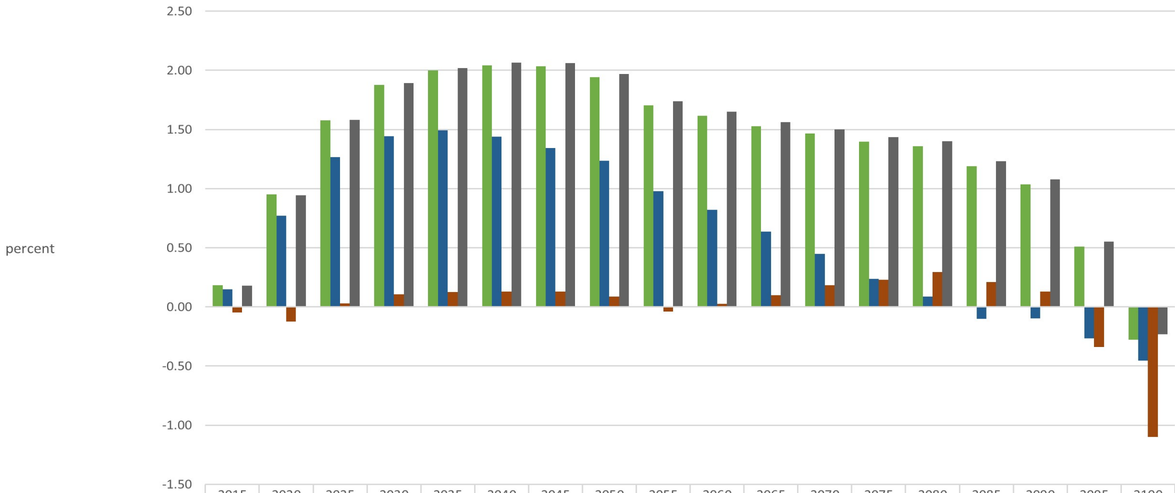
	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	0.011	-0.008	-0.033	0.254	0.390	0.100	0.241	0.823	0.043	0.514	0.456	0.182	0.166	0.416	0.142	0.443	-0.072	-0.334
SSP 585 Adaptation Housing	-0.008	-0.045	-0.111	0.115	0.149	-0.214	-0.169	0.303	-0.528	-0.106	-0.219	-0.560	-0.663	-0.518	-0.893	-0.667	-1.176	-1.339
SSP 585 Adaptation Transport	-0.006	-0.078	-0.169	0.047	0.125	-0.215	-0.104	0.474	-0.291	0.206	0.173	-0.079	-0.077	0.186	-0.075	0.237	-0.267	-0.523
SSP 585 Adaptation Forestry	0.011	-0.010	-0.024	0.262	0.403	0.121	0.261	0.833	0.076	0.537	0.482	0.211	0.218	0.447	0.194	0.473	-0.004	-0.252

Source: own computation.

Figure 12: Key macroeconomic indicators: Investment



	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	0.195	1.000	1.516	1.725	1.689	1.635	1.556	1.514	1.451	1.293	1.117	0.956	0.840	0.676	0.637	0.412	0.335	-0.142
SSP 126 Adaptation Housing	0.156	0.813	1.217	1.337	1.276	1.163	1.013	0.891	0.776	0.651	0.468	0.289	0.157	-0.002	-0.008	-0.139	-0.063	-0.254
SSP 126 Adaptation Transport	-0.037	-0.085	-0.018	0.019	-0.038	-0.023	0.001	0.061	0.102	0.053	0.015	-0.003	0.015	-0.036	0.024	-0.122	-0.146	-0.594
SSP 126 Adaptation Forestry	0.192	0.992	1.519	1.738	1.707	1.656	1.582	1.543	1.481	1.323	1.149	0.990	0.877	0.713	0.674	0.448	0.369	-0.100

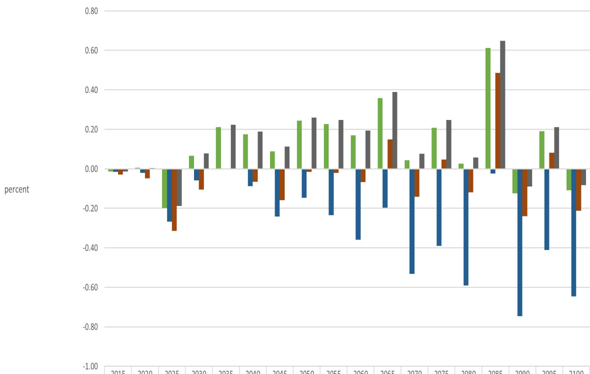


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	0.181	0.953	1.578	1.877	2.001	2.043	2.036	1.941	1.704	1.614	1.528	1.467	1.396	1.359	1.188	1.037	0.511	-0.278
SSP 585 Adaptation Housing	0.147	0.770	1.265	1.443	1.494	1.437	1.344	1.234	0.977	0.819	0.636	0.447	0.238	0.086	-0.099	-0.098	-0.265	-0.453
SSP 585 Adaptation Transport	-0.046	-0.123	0.029	0.105	0.125	0.131	0.129	0.087	-0.039	0.025	0.099	0.182	0.231	0.293	0.208	0.131	-0.338	-1.098
SSP 585 Adaptation Forestry	0.179	0.945	1.580	1.890	2.018	2.066	2.062	1.970	1.736	1.648	1.564	1.502	1.434	1.400	1.232	1.077	0.553	-0.234

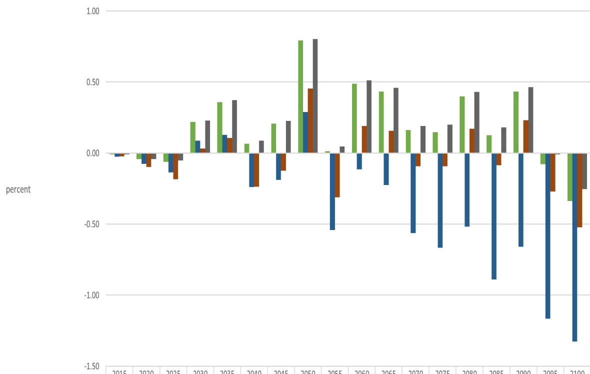
Source: own computation.

Figure 13: Key macroeconomic indicators: Output, net exports, employment

Output

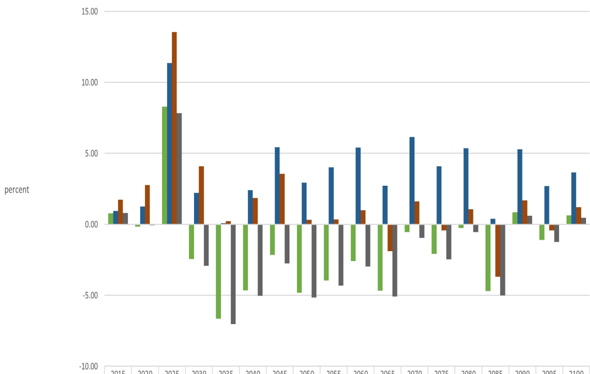


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	-0.013	0.006	-0.199	0.066	0.211	0.176	0.088	0.244	0.227	0.169	0.358	0.043	0.208	0.026	0.612	-0.124	0.190	-0.109
SSP 126 Adaptation Housing	-0.016	-0.021	-0.267	-0.058	0.000	-0.088	-0.241	-0.146	-0.234	-0.359	-0.197	-0.532	-0.391	-0.591	-0.023	-0.747	-0.411	-0.647
SSP 126 Adaptation Transport	-0.028	-0.049	-0.314	-0.105	-0.003	-0.066	-0.158	-0.015	-0.020	-0.068	0.150	-0.142	0.048	-0.119	0.485	-0.240	0.082	-0.212
SSP 126 Adaptation Forestry	-0.013	0.004	-0.189	0.078	0.222	0.189	0.113	0.260	0.246	0.193	0.388	0.076	0.247	0.057	0.649	-0.090	0.211	-0.083

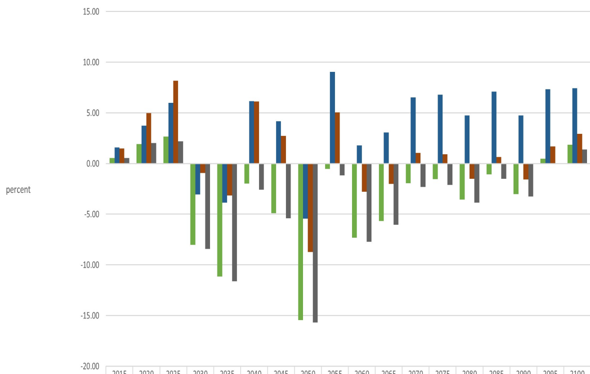


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	-0.009	-0.042	-0.063	0.219	0.358	0.064	0.206	0.792	0.012	0.488	0.432	0.161	0.147	0.398	0.126	0.433	-0.078	-0.337
SSP 585 Adaptation Housing	-0.026	-0.076	-0.136	0.086	0.128	-0.238	-0.190	0.289	-0.542	-0.115	-0.226	-0.564	-0.666	-0.518	-0.890	-0.659	-1.165	-1.327
SSP 585 Adaptation Transport	-0.024	-0.099	-0.183	0.032	0.107	-0.236	-0.125	0.454	-0.311	0.189	0.157	-0.094	-0.092	0.172	-0.087	0.230	-0.270	-0.524
SSP 585 Adaptation Forestry	-0.009	-0.044	-0.053	0.228	0.372	0.086	0.227	0.802	0.046	0.512	0.460	0.191	0.200	0.431	0.180	0.465	-0.008	-0.253

Net exports

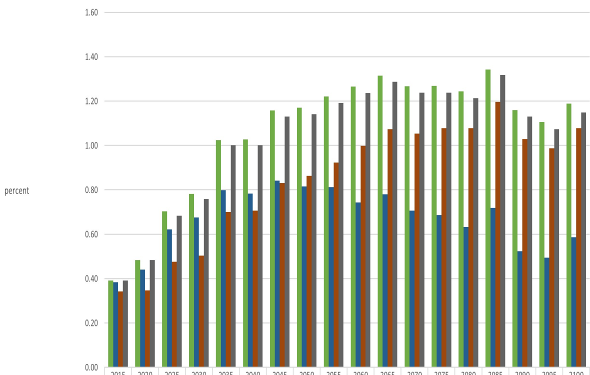


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	0.780	-0.161	8.295	-2.437	-6.655	-4.658	-2.156	-4.822	-3.952	-2.590	-4.666	-0.560	-2.074	-0.250	-4.713	0.850	-1.103	0.620
SSP 126 Adaptation Housing	0.946	1.246	11.361	2.207	0.064	2.408	5.425	2.933	4.023	5.408	2.704	6.146	4.071	5.343	0.377	5.277	2.686	3.641
SSP 126 Adaptation Transport	1.738	2.772	13.533	4.073	0.222	1.861	3.559	0.321	0.337	0.986	-1.893	1.601	-0.427	1.060	-3.697	1.671	-0.421	1.199
SSP 126 Adaptation Forestry	0.786	-0.071	7.825	-2.920	-7.040	-5.042	-2.746	-5.155	-4.310	-2.975	-5.074	-0.948	-2.481	-0.540	-5.016	0.601	-1.244	0.468

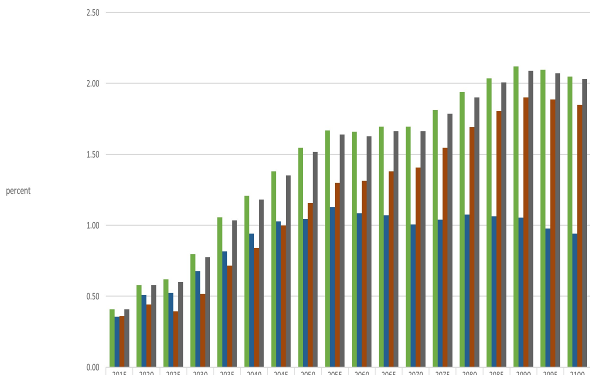


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	0.542	1.922	2.668	-8.045	-11.168	-1.980	-4.912	-15.465	-0.546	-7.336	-5.681	-1.944	-1.556	-3.551	-1.062	-3.012	0.459	1.861
SSP 585 Adaptation Housing	1.568	3.748	5.968	-3.065	-3.858	6.142	4.183	-5.448	9.050	1.797	3.051	6.509	6.784	4.747	7.081	4.744	7.318	7.423
SSP 585 Adaptation Transport	1.476	4.974	8.162	-0.930	-3.157	6.113	2.720	-8.731	5.049	-2.801	-2.018	1.032	0.893	-1.504	0.643	-1.570	1.672	2.910
SSP 585 Adaptation Forestry	0.548	2.013	2.195	-8.424	-11.640	-2.588	-5.414	-15.693	-1.159	-7.715	-6.058	-2.304	-2.109	-3.857	-1.498	-3.242	0.017	1.391

Employment



	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	0.391	0.484	0.702	0.781	1.024	1.027	1.158	1.170	1.220	1.266	1.315	1.267	1.268	1.244	1.342	1.159	1.106	1.188
SSP 126 Adaptation Housing	0.383	0.440	0.622	0.676	0.798	0.783	0.841	0.815	0.813	0.743	0.779	0.706	0.686	0.633	0.718	0.523	0.494	0.586
SSP 126 Adaptation Transport	0.343	0.346	0.475	0.504	0.700	0.706	0.830	0.863	0.923	0.997	1.073	1.053	1.078	1.078	1.197	1.030	0.987	1.078
SSP 126 Adaptation Forestry	0.391	0.484	0.684	0.759	1.001	1.001	1.130	1.141	1.191	1.237	1.287	1.237	1.238	1.214	1.318	1.130	1.074	1.149



	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	0.409	0.580	0.620	0.797	1.057	1.208	1.381	1.547	1.669	1.658	1.695	1.695	1.813	1.939	2.036	2.121	2.096	2.047
SSP 585 Adaptation Housing	0.356	0.510	0.525	0.678	0.817	0.940	1.027	1.045	1.129	1.086	1.070	1.007	1.040	1.075	1.065	1.055	0.977	0.940
SSP 585 Adaptation Transport	0.361	0.442	0.393	0.516	0.715	0.841	0.998	1.157	1.299	1.314	1.381	1.407	1.547	1.692	1.805	1.902	1.887	1.849
SSP 585 Adaptation Forestry	0.408	0.580	0.602	0.776	1.034	1.180	1.353	1.518	1.639	1.628	1.664	1.664	1.786	1.903	2.008	2.088	2.073	2.030

Source: own computation.

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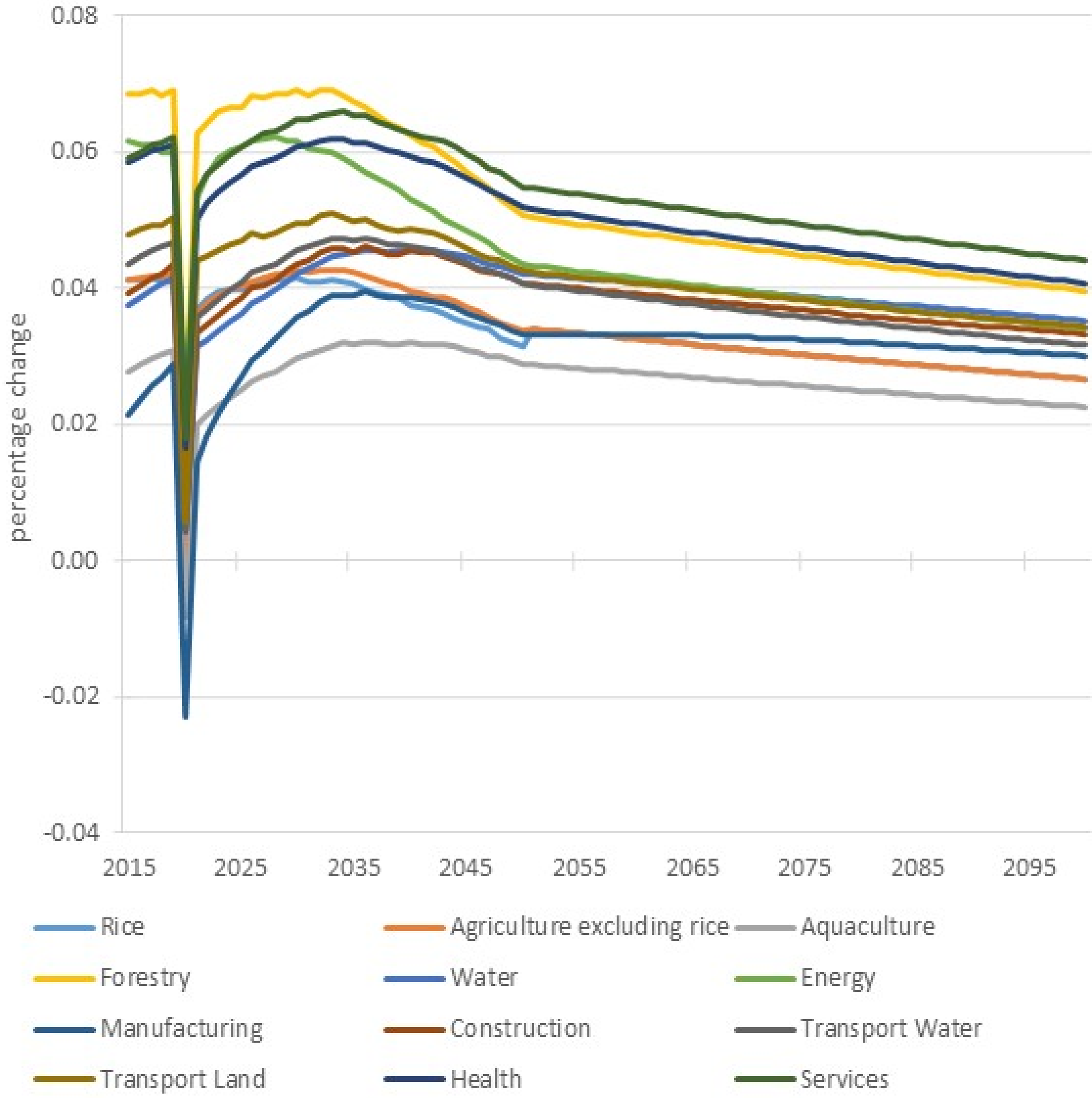
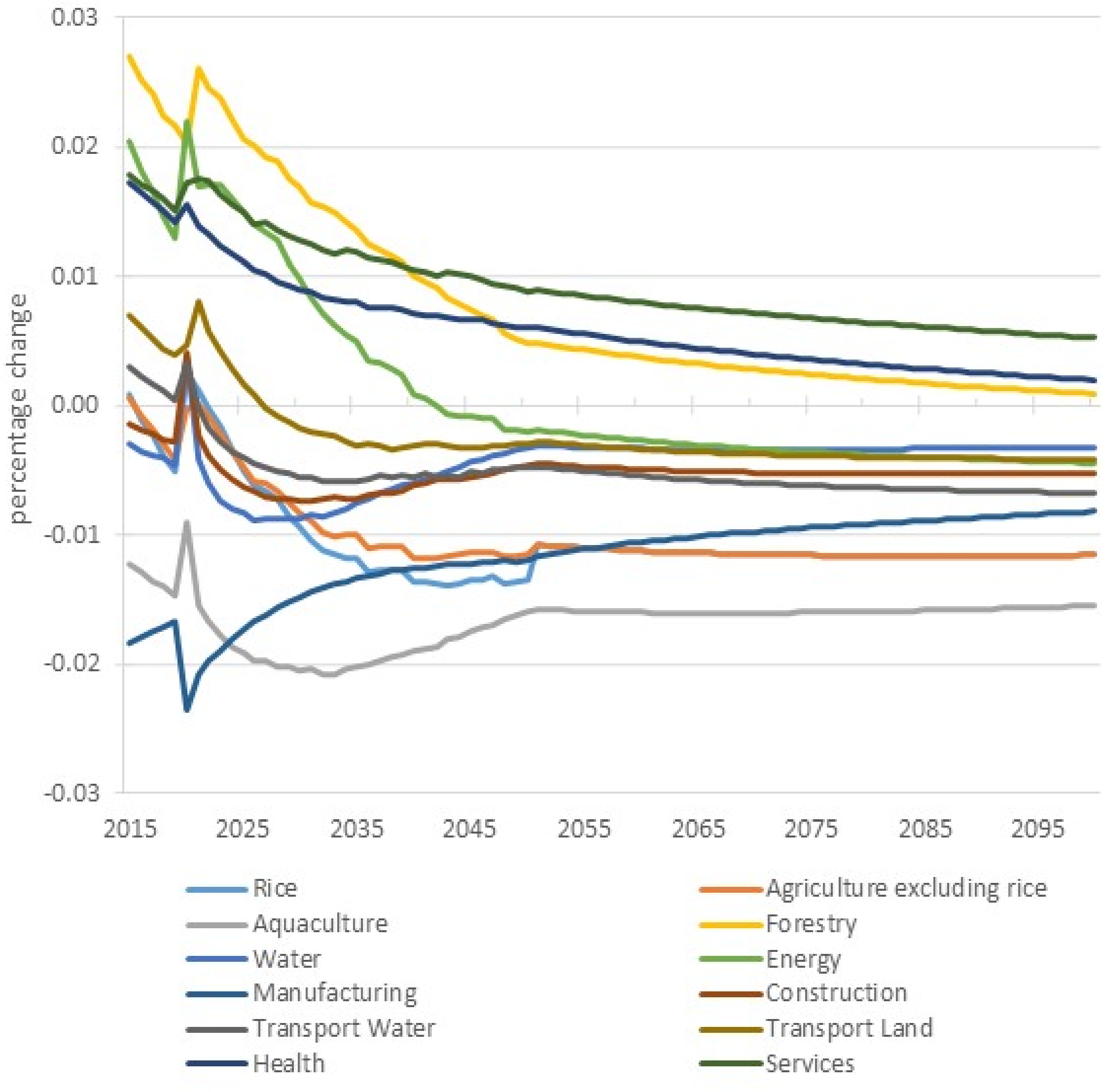
A Figures

Figure 14: Sectoral growth rates in Vietnam



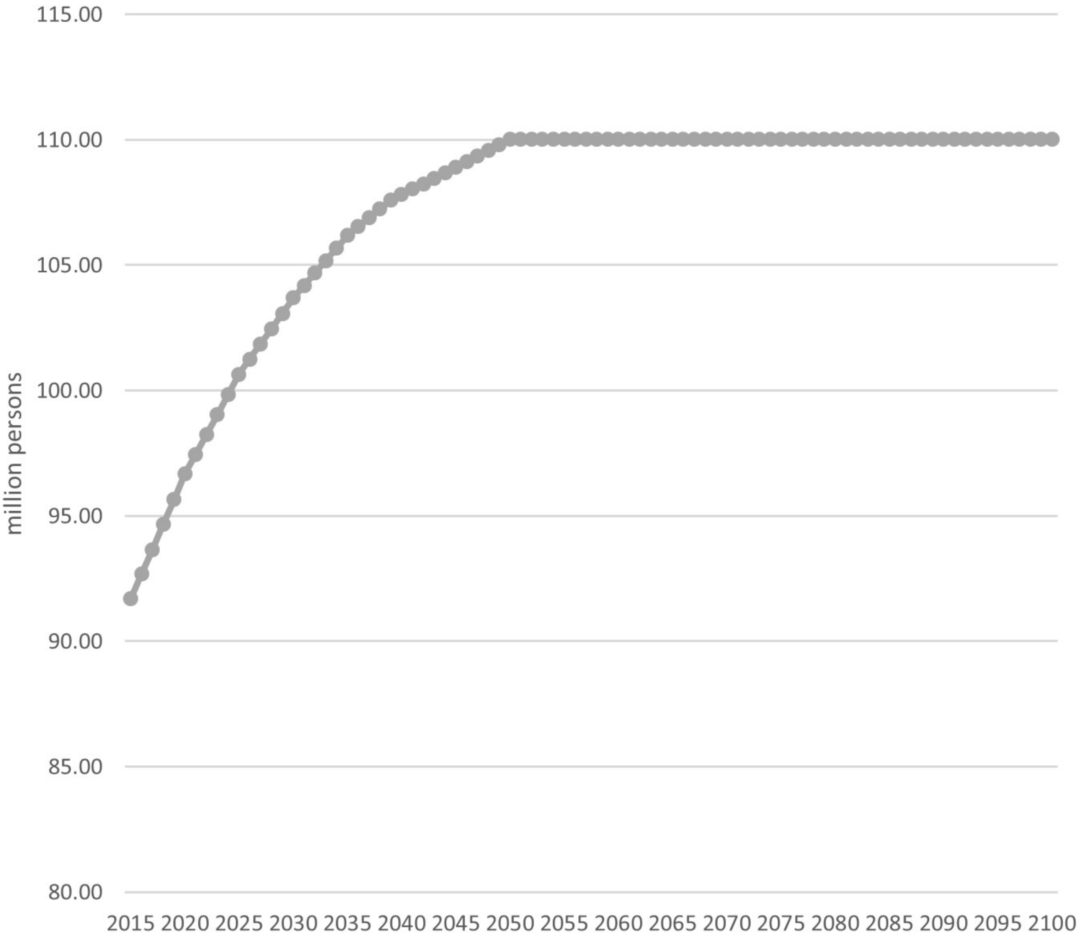
Source: Computation of national expert and own computations.

Figure 15: Sectoral growth rates of the labour share in Vietnam



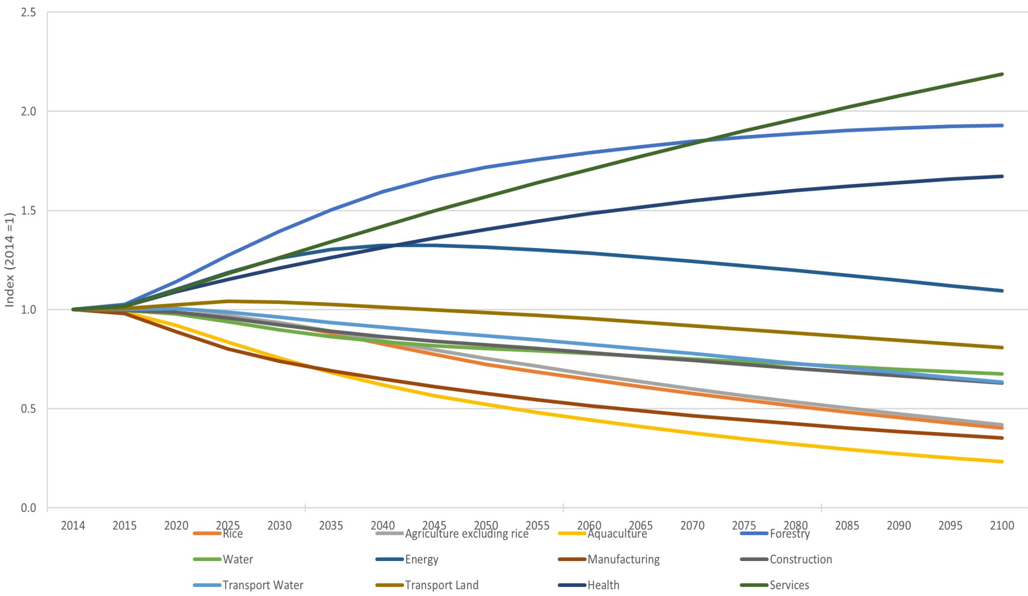
Source: own computation.

Figure 16: Population projection for Vietnam



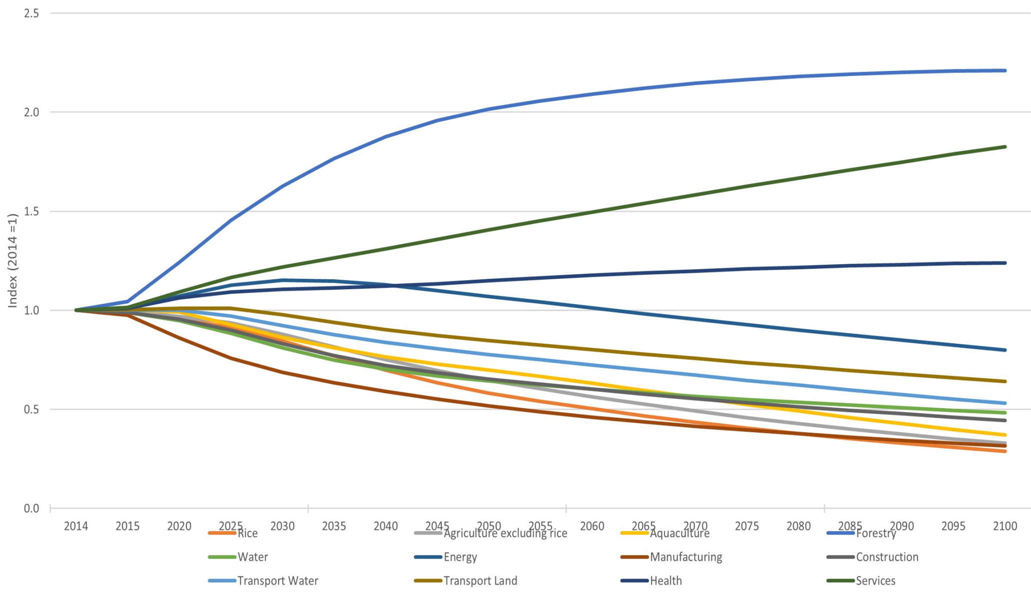
Source: GSO and United Nations medium fertility variant in Table A.1.

Figure 17: Evolution of sub-sectoral employment



Source: own computation.

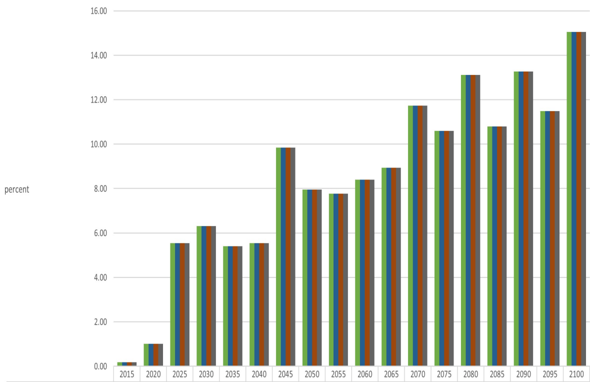
Figure 18: Evolution of sub-sectoral prices



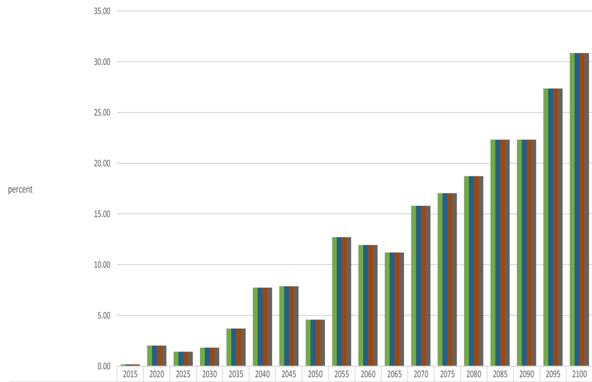
Source: own computation.

Figure 19: Damages rice

Red River Delta

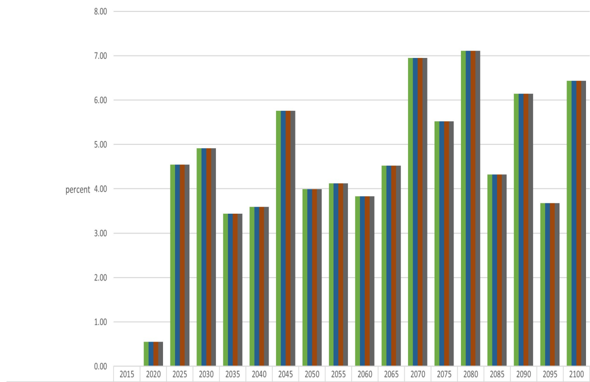


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	0.19	1.01	5.54	6.31	5.41	5.54	9.84	7.96	7.76	8.40	8.94	11.73	10.59	13.12	10.80	13.26	11.49	15.06
SSP 126 Adaptation Construction	0.19	1.01	5.54	6.31	5.41	5.54	9.84	7.96	7.76	8.40	8.94	11.73	10.59	13.12	10.80	13.26	11.49	15.06
SSP 126 Adaptation Transport	0.19	1.01	5.54	6.31	5.41	5.54	9.84	7.96	7.76	8.40	8.94	11.73	10.59	13.12	10.80	13.26	11.49	15.06
SSP 126 Adaptation Forestry	0.19	1.01	5.54	6.31	5.41	5.54	9.84	7.96	7.76	8.40	8.94	11.73	10.59	13.12	10.80	13.26	11.49	15.06

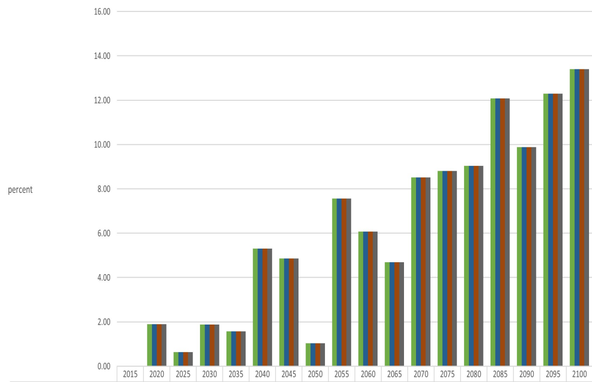


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	0.19	2.01	1.43	1.84	3.71	7.73	7.87	4.59	12.72	11.94	11.18	15.79	17.03	18.73	22.32	22.31	27.35	30.85
SSP 585 Adaptation Construction	0.19	2.01	1.43	1.84	3.71	7.73	7.87	4.59	12.72	11.94	11.18	15.79	17.03	18.73	22.32	22.31	27.35	30.85
SSP 585 Adaptation Transport	0.19	2.01	1.43	1.84	3.71	7.73	7.87	4.59	12.72	11.94	11.18	15.79	17.03	18.73	22.32	22.31	27.35	30.85
SSP 585 Adaptation Forestry	0.19	2.01	1.43	1.84	3.71	7.73	7.87	4.59	12.72	11.94	11.18	15.79	17.03	18.73	22.32	22.31	27.35	30.85

Northern midlands and mountain areas

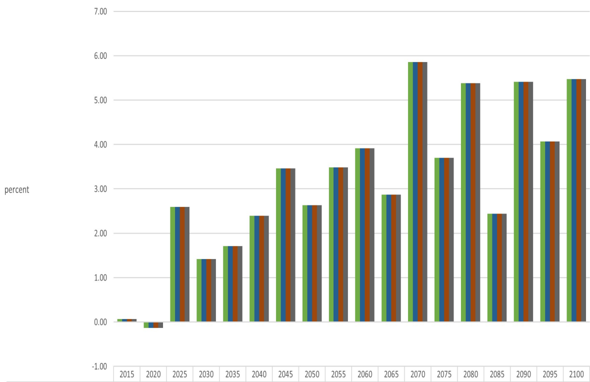


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	0.00	0.55	4.55	4.92	3.44	3.59	5.76	3.99	4.12	3.83	4.53	6.95	5.52	7.11	4.32	6.14	3.68	6.43
SSP 126 Adaptation Construction	0.00	0.55	4.55	4.92	3.44	3.59	5.76	3.99	4.12	3.83	4.53	6.95	5.52	7.11	4.32	6.14	3.68	6.43
SSP 126 Adaptation Transport	0.00	0.55	4.55	4.92	3.44	3.59	5.76	3.99	4.12	3.83	4.53	6.95	5.52	7.11	4.32	6.14	3.68	6.43
SSP 126 Adaptation Forestry	0.00	0.55	4.55	4.92	3.44	3.59	5.76	3.99	4.12	3.83	4.53	6.95	5.52	7.11	4.32	6.14	3.68	6.43

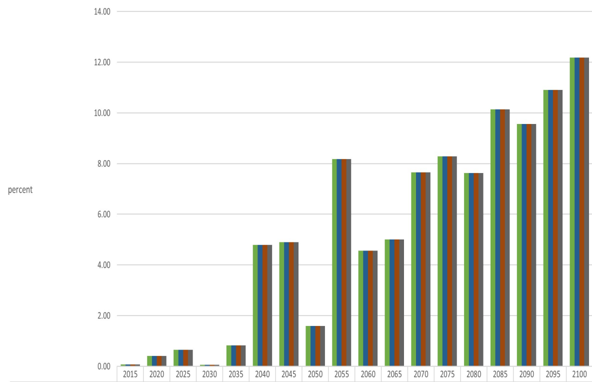


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	0.00	1.89	0.63	1.88	1.57	5.30	4.86	1.04	7.55	6.07	4.70	8.52	8.80	9.03	12.08	9.88	12.29	13.40
SSP 585 Adaptation Construction	0.00	1.89	0.63	1.88	1.57	5.30	4.86	1.04	7.55	6.07	4.70	8.52	8.80	9.03	12.08	9.88	12.29	13.40
SSP 585 Adaptation Transport	0.00	1.89	0.63	1.88	1.57	5.30	4.86	1.04	7.55	6.07	4.70	8.52	8.80	9.03	12.08	9.88	12.29	13.40
SSP 585 Adaptation Forestry	0.00	1.89	0.63	1.88	1.57	5.30	4.86	1.04	7.55	6.07	4.70	8.52	8.80	9.03	12.08	9.88	12.29	13.40

Northern Central area and Central coastal area



	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	0.06	-0.14	2.59	1.42	1.71	2.39	3.46	2.63	3.49	3.91	2.87	5.86	3.70	5.38	2.44	5.41	4.06	5.47
SSP 126 Adaptation Construction	0.06	-0.14	2.59	1.42	1.71	2.39	3.46	2.63	3.49	3.91	2.87	5.86	3.70	5.38	2.44	5.41	4.06	5.47
SSP 126 Adaptation Transport	0.06	-0.14	2.59	1.42	1.71	2.39	3.46	2.63	3.49	3.91	2.87	5.86	3.70	5.38	2.44	5.41	4.06	5.47
SSP 126 Adaptation Forestry	0.06	-0.14	2.59	1.42	1.71	2.39	3.46	2.63	3.49	3.91	2.87	5.86	3.70	5.38	2.44	5.41	4.06	5.47

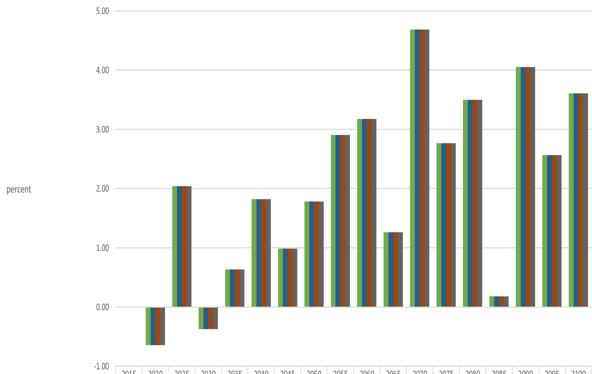


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	0.06	0.41	0.64	0.05	0.83	4.78	4.90	1.59	8.18	4.56	5.01	7.65	8.29	7.63	10.14	9.55	10.91	12.19
SSP 585 Adaptation Construction	0.06	0.41	0.64	0.05	0.83	4.78	4.90	1.59	8.18	4.56	5.01	7.65	8.29	7.63	10.14	9.55	10.91	12.19
SSP 585 Adaptation Transport	0.06	0.41	0.64	0.05	0.83	4.78	4.90	1.59	8.18	4.56	5.01	7.65	8.29	7.63	10.14	9.55	10.91	12.19
SSP 585 Adaptation Forestry	0.06	0.41	0.64	0.05	0.83	4.78	4.90	1.59	8.18	4.56	5.01	7.65	8.29	7.63	10.14	9.55	10.91	12.19

Source: own computation.

Damages rice (continued)

Central Highlands

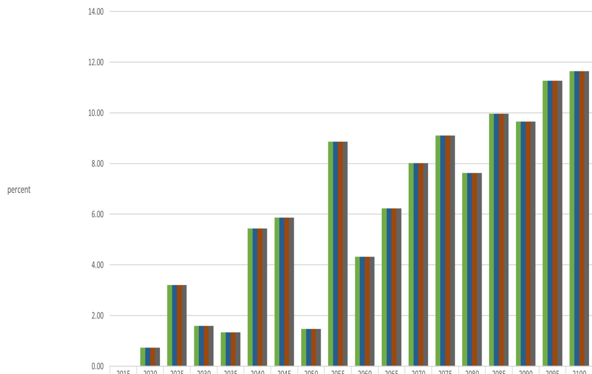


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	0.00	-0.64	2.04	-0.37	0.64	1.82	0.99	1.78	2.91	3.18	1.26	4.68	2.76	3.50	0.18	4.05	2.56	3.61
SSP 126 Adaptation Construction	0.00	-0.64	2.04	-0.37	0.64	1.82	0.99	1.78	2.91	3.18	1.26	4.68	2.76	3.50	0.18	4.05	2.56	3.61
SSP 126 Adaptation Transport	0.00	-0.64	2.04	-0.37	0.64	1.82	0.99	1.78	2.91	3.18	1.26	4.68	2.76	3.50	0.18	4.05	2.56	3.61
SSP 126 Adaptation Forestry	0.00	-0.64	2.04	-0.37	0.64	1.82	0.99	1.78	2.91	3.18	1.26	4.68	2.76	3.50	0.18	4.05	2.56	3.61

	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	0.00	0.01	1.16	-0.18	0.38	4.33	5.18	1.43	8.23	3.93	4.70	6.45	7.81	5.78	8.86	7.95	8.93	9.19
SSP 585 Adaptation Construction	0.00	0.01	1.16	-0.18	0.38	4.33	5.18	1.43	8.23	3.93	4.70	6.45	7.81	5.78	8.86	7.95	8.93	9.19
SSP 585 Adaptation Transport	0.00	0.01	1.16	-0.18	0.38	4.33	5.18	1.43	8.23	3.93	4.70	6.45	7.81	5.78	8.86	7.95	8.93	9.19
SSP 585 Adaptation Forestry	0.00	0.01	1.16	-0.18	0.38	4.33	5.18	1.43	8.23	3.93	4.70	6.45	7.81	5.78	8.86	7.95	8.93	9.19

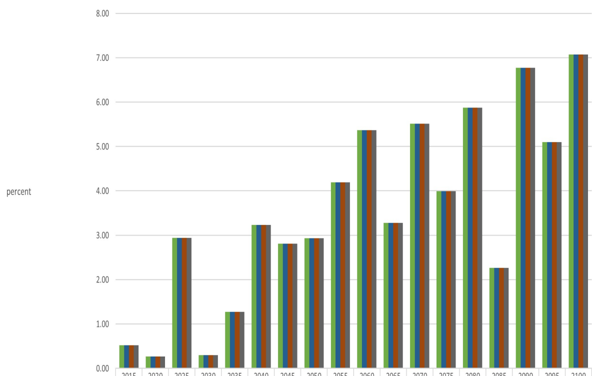
South East

	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	0.00	-0.64	2.42	-0.67	0.57	1.81	1.80	1.80	3.23	3.80	2.03	4.01	2.72	4.16	0.00	4.70	2.93	3.93
SSP 126 Adaptation Construction	0.00	-0.64	2.42	-0.67	0.57	1.81	1.80	1.80	3.23	3.80	2.03	4.01	2.72	4.16	0.00	4.70	2.93	3.93
SSP 126 Adaptation Transport	0.00	-0.64	2.42	-0.67	0.57	1.81	1.80	1.80	3.23	3.80	2.03	4.01	2.72	4.16	0.00	4.70	2.93	3.93
SSP 126 Adaptation Forestry	0.00	-0.64	2.42	-0.67	0.57	1.81	1.80	1.80	3.23	3.80	2.03	4.01	2.72	4.16	0.00	4.70	2.93	3.93

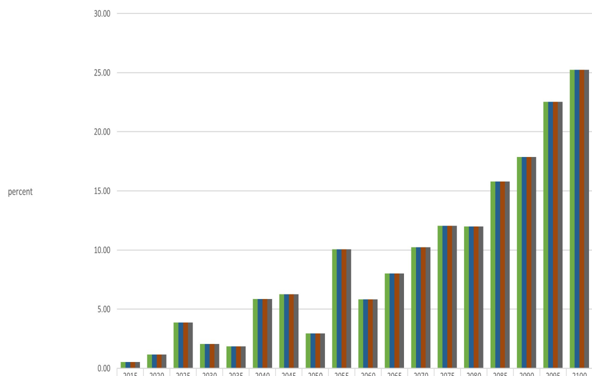


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	0.00	0.73	3.21	1.59	1.34	5.43	5.86	1.46	8.86	4.32	6.22	8.02	9.10	7.63	9.96	9.65	11.26	11.65
SSP 585 Adaptation Construction	0.00	0.73	3.21	1.59	1.34	5.43	5.86	1.46	8.86	4.32	6.22	8.02	9.10	7.63	9.96	9.65	11.26	11.65
SSP 585 Adaptation Transport	0.00	0.73	3.21	1.59	1.34	5.43	5.86	1.46	8.86	4.32	6.22	8.02	9.10	7.63	9.96	9.65	11.26	11.65
SSP 585 Adaptation Forestry	0.00	0.73	3.21	1.59	1.34	5.43	5.86	1.46	8.86	4.32	6.22	8.02	9.10	7.63	9.96	9.65	11.26	11.65

Mekong River Delta



	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	0.52	0.26	2.94	0.30	1.27	3.23	2.81	2.93	4.19	5.37	3.27	5.51	3.99	5.87	2.27	6.77	5.10	7.07
SSP 126 Adaptation Construction	0.52	0.26	2.94	0.30	1.27	3.23	2.81	2.93	4.19	5.37	3.27	5.51	3.99	5.87	2.27	6.77	5.10	7.07
SSP 126 Adaptation Transport	0.52	0.26	2.94	0.30	1.27	3.23	2.81	2.93	4.19	5.37	3.27	5.51	3.99	5.87	2.27	6.77	5.10	7.07
SSP 126 Adaptation Forestry	0.52	0.26	2.94	0.30	1.27	3.23	2.81	2.93	4.19	5.37	3.27	5.51	3.99	5.87	2.27	6.77	5.10	7.07

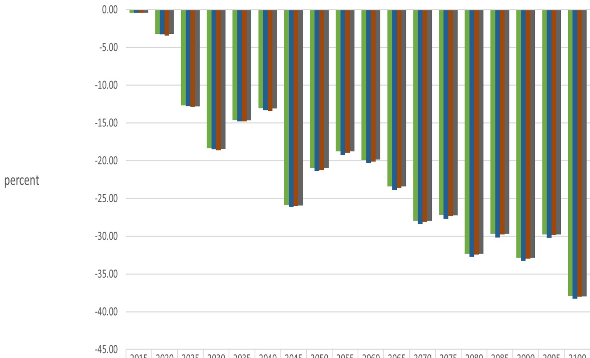


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	0.52	1.16	3.87	2.06	1.85	5.85	6.27	2.96	10.07	5.83	8.03	10.22	12.04	12.00	15.79	17.86	22.52	25.23
SSP 585 Adaptation Construction	0.52	1.16	3.87	2.06	1.85	5.85	6.27	2.96	10.07	5.83	8.03	10.22	12.04	12.00	15.79	17.86	22.52	25.23
SSP 585 Adaptation Transport	0.52	1.16	3.87	2.06	1.85	5.85	6.27	2.96	10.07	5.83	8.03	10.22	12.04	12.00	15.79	17.86	22.52	25.23
SSP 585 Adaptation Forestry	0.52	1.16	3.87	2.06	1.85	5.85	6.27	2.96	10.07	5.83	8.03	10.22	12.04	12.00	15.79	17.86	22.52	25.23

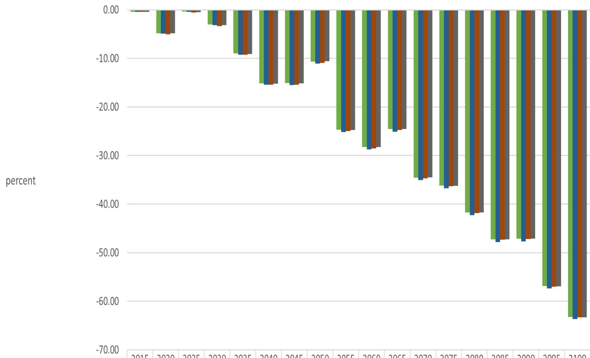
Source: own computation.

Figure 20: Value added rice

Red River Delta

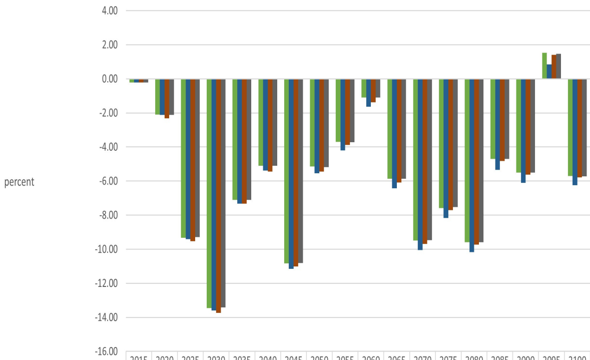


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	-0.41	-3.23	-12.70	-18.36	-14.62	-13.06	-25.87	-21.00	-18.78	-19.87	-23.41	-27.96	-27.21	-32.32	-29.69	-32.88	-29.77	-37.95
SSP 126 Adaptation Housing	-0.41	-3.25	-12.76	-18.49	-14.81	-13.32	-26.13	-21.33	-19.20	-20.31	-23.87	-28.40	-27.67	-32.76	-30.16	-33.30	-30.24	-38.31
SSP 126 Adaptation Transport	-0.41	-3.44	-12.88	-18.62	-14.82	-13.39	-26.01	-21.25	-18.94	-20.11	-23.59	-28.12	-27.31	-32.43	-29.77	-32.96	-29.85	-38.01
SSP 126 Adaptation Forestry	-0.41	-3.22	-12.82	-18.46	-14.68	-13.08	-25.92	-20.97	-18.75	-19.85	-23.40	-27.96	-27.23	-32.32	-29.70	-32.86	-29.77	-37.95

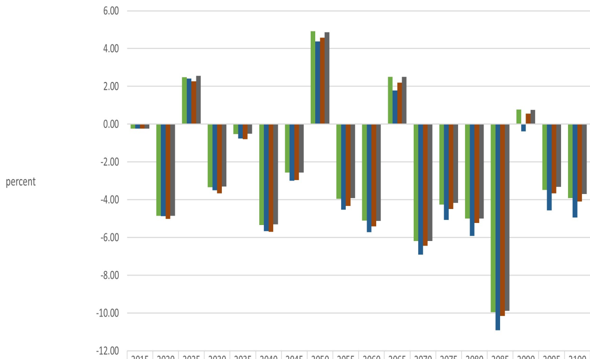


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	-0.42	-4.86	-0.33	-3.02	-9.00	-15.12	-15.09	-10.65	-24.69	-28.26	-24.54	-34.53	-36.17	-41.74	-47.23	-47.09	-56.89	-63.26
SSP 585 Adaptation Housing	-0.43	-4.88	-0.41	-3.18	-9.23	-15.41	-15.47	-11.11	-25.13	-28.73	-25.07	-35.03	-36.71	-42.30	-47.79	-47.70	-57.38	-63.65
SSP 585 Adaptation Transport	-0.43	-5.04	-0.54	-3.35	-9.25	-15.44	-15.43	-10.95	-24.97	-28.50	-24.77	-34.71	-36.33	-41.88	-47.35	-47.21	-56.97	-63.33
SSP 585 Adaptation Forestry	-0.42	-4.85	-0.46	-3.13	-9.09	-15.19	-15.11	-10.59	-24.72	-28.25	-24.51	-34.51	-36.21	-41.74	-47.26	-47.08	-56.90	-63.28

Northern midlands and mountain areas

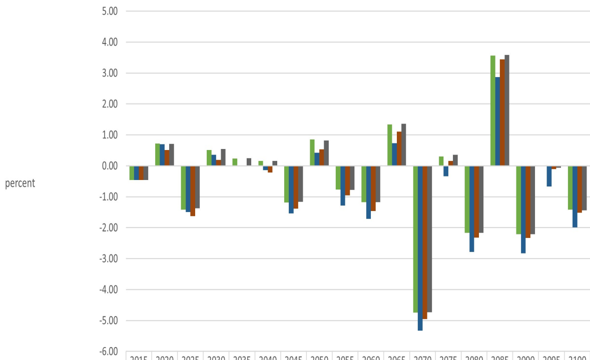


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	-0.22	-2.10	-9.33	-13.46	-7.11	-5.09	-10.84	-5.15	-3.70	-1.09	-5.87	-9.49	-7.58	-9.59	-4.71	-5.51	1.52	-5.70
SSP 126 Adaptation Housing	-0.22	-2.13	-9.40	-13.60	-7.32	-5.37	-11.15	-5.55	-4.20	-1.63	-6.44	-10.04	-8.17	-10.17	-5.35	-6.11	0.85	-6.24
SSP 126 Adaptation Transport	-0.22	-2.31	-9.52	-13.74	-7.32	-5.45	-11.01	-5.45	-3.88	-1.38	-6.09	-9.69	-7.71	-9.73	-4.82	-5.63	1.41	-5.79
SSP 126 Adaptation Forestry	-0.22	-2.11	-9.29	-13.43	-7.10	-5.10	-10.81	-5.18	-3.71	-1.10	-5.87	-9.48	-7.54	-9.59	-4.69	-5.51	1.46	-5.72

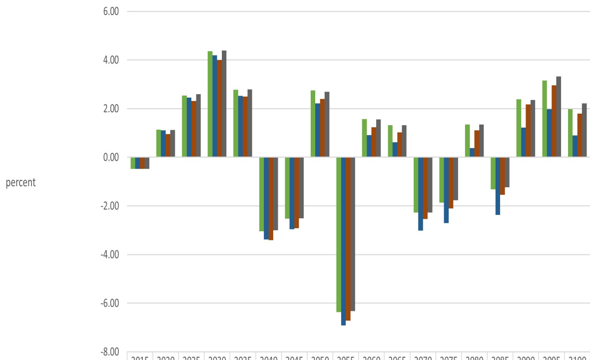


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	-0.23	-4.84	2.49	-3.33	-0.52	-5.34	-2.56	4.93	-3.96	-5.11	2.51	-6.18	-4.26	-5.00	-9.95	0.77	-3.47	-3.92
SSP 585 Adaptation Housing	-0.23	-4.87	2.41	-3.49	-0.77	-5.67	-3.00	4.39	-4.53	-5.72	1.79	-6.90	-5.07	-5.91	-10.91	-0.38	-4.57	-4.93
SSP 585 Adaptation Transport	-0.23	-5.02	2.28	-3.66	-0.79	-5.70	-2.95	4.57	-4.32	-5.42	2.20	-6.44	-4.50	-5.23	-10.15	0.56	-3.66	-4.10
SSP 585 Adaptation Forestry	-0.23	-4.86	2.55	-3.31	-0.50	-5.30	-2.56	4.86	-3.92	-5.12	2.50	-6.19	-4.17	-5.00	-9.87	0.75	-3.32	-3.69

Northern Central area and Central coastal area



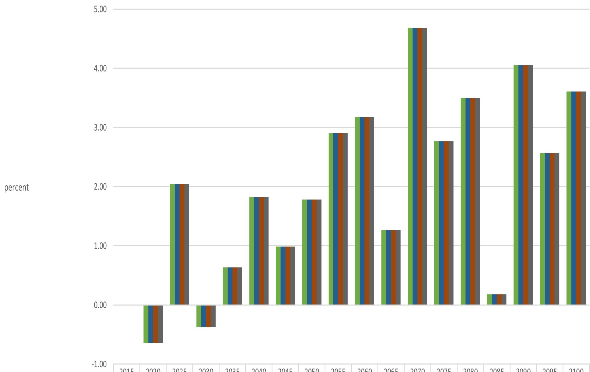
	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	-0.46	0.72	-1.42	0.51	0.23	0.16	-1.19	0.85	-0.76	-1.17	1.34	-4.75	0.30	-2.16	3.56	-2.21	0.00	-1.42
SSP 126 Adaptation Housing	-0.46	0.70	-1.49	0.35	0.01	-0.14	-1.54	0.42	-1.28	-1.71	0.74	-5.33	-0.33	-2.79	2.87	-2.83	-0.66	-1.99
SSP 126 Adaptation Transport	-0.46	0.51	-1.63	0.19	0.00	-0.22	-1.38	0.53	-0.96	-1.46	1.11	-4.96	0.16	-2.32	3.44	-2.33	-0.11	-1.52
SSP 126 Adaptation Forestry	-0.46	0.71	-1.37	0.55	0.24	0.16	-1.16	0.82	-0.78	-1.18	1.36	-4.73	0.35	-2.16	3.58	-2.21	-0.06	-1.44



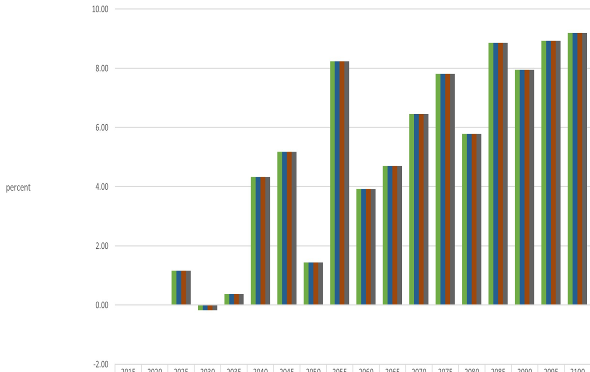
	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	-0.47	1.13	2.53	4.36	2.77	-3.04	-2.52	2.75	-6.37	1.57	1.32	-2.27	-1.87	1.35	-1.32	2.39	3.15	1.98
SSP 585 Adaptation Housing	-0.47	1.11	2.45	4.19	2.52	-3.37	-2.96	2.22	-6.92	0.91	0.61	-3.02	-2.70	0.37	-2.37	1.21	1.98	0.90
SSP 585 Adaptation Transport	-0.47	0.95	2.32	4.00	2.49	-3.41	-2.91	2.40	-6.72	1.23	1.02	-2.54	-2.11	1.10	-1.54	2.17	2.96	1.79
SSP 585 Adaptation Forestry	-0.47	1.12	2.59	4.39	2.79	-3.00	-2.52	2.69	-6.33	1.55	1.31	-2.28	-1.77	1.35	-1.23	2.36	3.32	2.22

Value added rice (continued)

Central Highlands



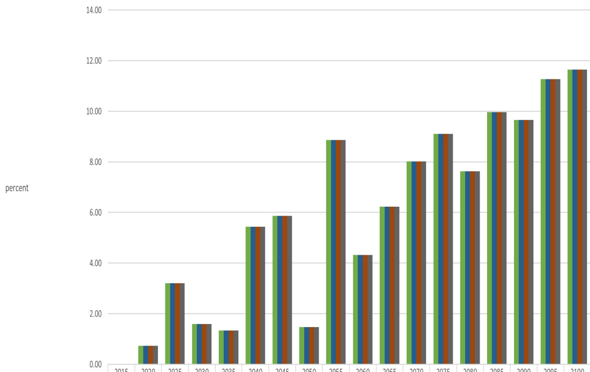
	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	0.00	-0.64	2.04	-0.37	0.64	1.82	0.99	1.78	2.91	3.18	1.26	4.68	2.76	3.50	0.18	4.05	2.56	3.61
SSP 126 Adaptation Construction	0.00	-0.64	2.04	-0.37	0.64	1.82	0.99	1.78	2.91	3.18	1.26	4.68	2.76	3.50	0.18	4.05	2.56	3.61
SSP 126 Adaptation Transport	0.00	-0.64	2.04	-0.37	0.64	1.82	0.99	1.78	2.91	3.18	1.26	4.68	2.76	3.50	0.18	4.05	2.56	3.61
SSP 126 Adaptation Forestry	0.00	-0.64	2.04	-0.37	0.64	1.82	0.99	1.78	2.91	3.18	1.26	4.68	2.76	3.50	0.18	4.05	2.56	3.61



	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	0.00	0.01	1.16	-0.18	0.38	4.33	5.18	1.43	8.23	3.93	4.70	6.45	7.81	5.78	8.86	7.95	8.93	9.19
SSP 585 Adaptation Construction	0.00	0.01	1.16	-0.18	0.38	4.33	5.18	1.43	8.23	3.93	4.70	6.45	7.81	5.78	8.86	7.95	8.93	9.19
SSP 585 Adaptation Transport	0.00	0.01	1.16	-0.18	0.38	4.33	5.18	1.43	8.23	3.93	4.70	6.45	7.81	5.78	8.86	7.95	8.93	9.19
SSP 585 Adaptation Forestry	0.00	0.01	1.16	-0.18	0.38	4.33	5.18	1.43	8.23	3.93	4.70	6.45	7.81	5.78	8.86	7.95	8.93	9.19

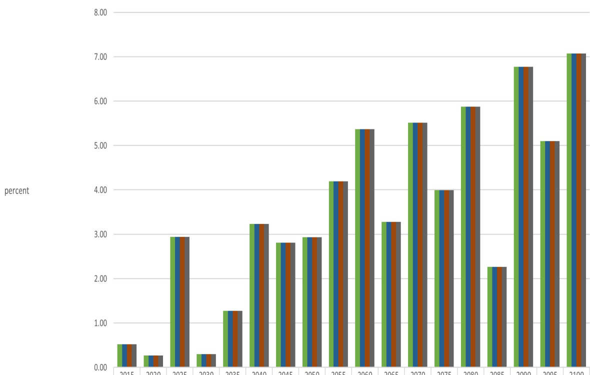
South East

	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	0.00	-0.64	2.42	-0.67	0.57	1.81	1.80	1.80	3.23	3.80	2.03	4.01	2.72	4.16	0.00	4.70	2.93	3.93
SSP 126 Adaptation Construction	0.00	-0.64	2.42	-0.67	0.57	1.81	1.80	1.80	3.23	3.80	2.03	4.01	2.72	4.16	0.00	4.70	2.93	3.93
SSP 126 Adaptation Transport	0.00	-0.64	2.42	-0.67	0.57	1.81	1.80	1.80	3.23	3.80	2.03	4.01	2.72	4.16	0.00	4.70	2.93	3.93
SSP 126 Adaptation Forestry	0.00	-0.64	2.42	-0.67	0.57	1.81	1.80	1.80	3.23	3.80	2.03	4.01	2.72	4.16	0.00	4.70	2.93	3.93

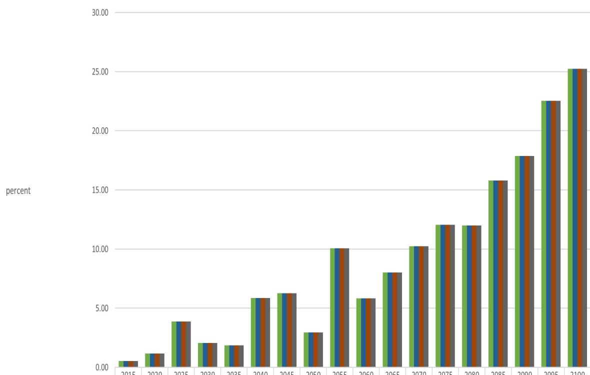


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	0.00	0.73	3.21	1.59	1.34	5.43	5.86	1.46	8.86	4.32	6.22	8.02	9.10	7.63	9.96	9.65	11.26	11.65
SSP 585 Adaptation Construction	0.00	0.73	3.21	1.59	1.34	5.43	5.86	1.46	8.86	4.32	6.22	8.02	9.10	7.63	9.96	9.65	11.26	11.65
SSP 585 Adaptation Transport	0.00	0.73	3.21	1.59	1.34	5.43	5.86	1.46	8.86	4.32	6.22	8.02	9.10	7.63	9.96	9.65	11.26	11.65
SSP 585 Adaptation Forestry	0.00	0.73	3.21	1.59	1.34	5.43	5.86	1.46	8.86	4.32	6.22	8.02	9.10	7.63	9.96	9.65	11.26	11.65

Mekong River Delta



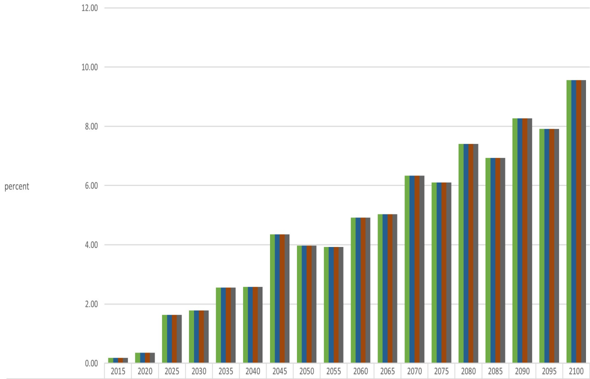
	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	0.52	0.26	2.94	0.30	1.27	3.23	2.81	2.93	4.19	5.37	3.27	5.51	3.99	5.87	2.27	6.77	5.10	7.07
SSP 126 Adaptation Construction	0.52	0.26	2.94	0.30	1.27	3.23	2.81	2.93	4.19	5.37	3.27	5.51	3.99	5.87	2.27	6.77	5.10	7.07
SSP 126 Adaptation Transport	0.52	0.26	2.94	0.30	1.27	3.23	2.81	2.93	4.19	5.37	3.27	5.51	3.99	5.87	2.27	6.77	5.10	7.07
SSP 126 Adaptation Forestry	0.52	0.26	2.94	0.30	1.27	3.23	2.81	2.93	4.19	5.37	3.27	5.51	3.99	5.87	2.27	6.77	5.10	7.07



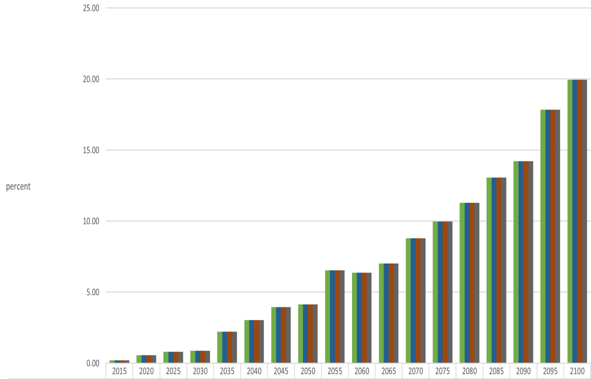
	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	0.52	1.16	3.87	2.06	1.85	5.85	6.27	2.96	10.07	5.83	8.03	10.22	12.04	12.00	15.79	17.86	22.52	25.23
SSP 585 Adaptation Construction	0.52	1.16	3.87	2.06	1.85	5.85	6.27	2.96	10.07	5.83	8.03	10.22	12.04	12.00	15.79	17.86	22.52	25.23
SSP 585 Adaptation Transport	0.52	1.16	3.87	2.06	1.85	5.85	6.27	2.96	10.07	5.83	8.03	10.22	12.04	12.00	15.79	17.86	22.52	25.23
SSP 585 Adaptation Forestry	0.52	1.16	3.87	2.06	1.85	5.85	6.27	2.96	10.07	5.83	8.03	10.22	12.04	12.00	15.79	17.86	22.52	25.23

Figure 21: Damages agriculture excluding rice

Red River Delta

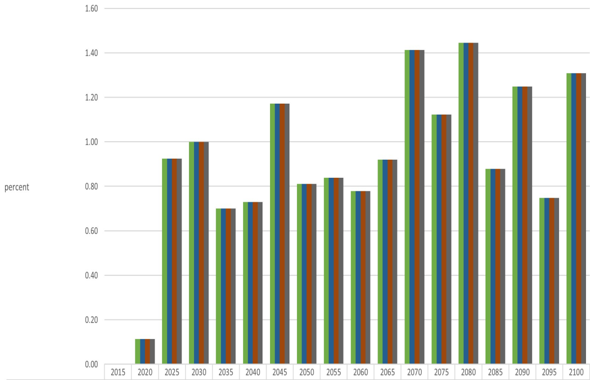


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	0.19	0.35	1.63	1.79	2.55	2.58	4.35	3.97	3.93	4.92	5.03	6.34	6.10	7.40	6.93	8.27	7.91	9.56
SSP 126 Adaptation Housing	0.19	0.35	1.63	1.79	2.55	2.58	4.35	3.97	3.93	4.92	5.03	6.34	6.10	7.40	6.93	8.27	7.91	9.56
SSP 126 Adaptation Transport	0.19	0.35	1.63	1.79	2.55	2.58	4.35	3.97	3.93	4.92	5.03	6.34	6.10	7.40	6.93	8.27	7.91	9.56
SSP 126 Adaptation Forestry	0.19	0.35	1.63	1.79	2.55	2.58	4.35	3.97	3.93	4.92	5.03	6.34	6.10	7.40	6.93	8.27	7.91	9.56

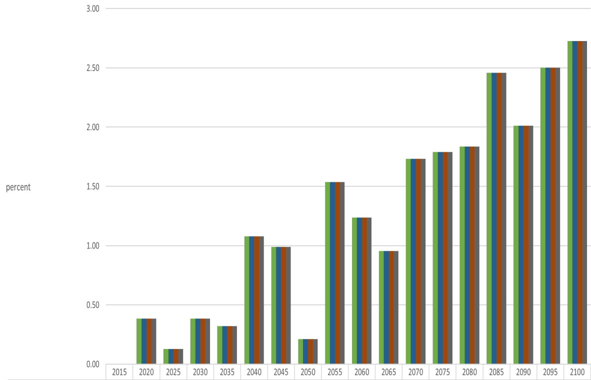


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	0.19	0.56	0.80	0.88	2.21	3.03	3.95	4.14	6.54	6.38	7.01	8.78	9.96	11.28	13.07	14.22	17.84	19.94
SSP 585 Adaptation Housing	0.19	0.56	0.80	0.88	2.21	3.03	3.95	4.14	6.54	6.38	7.01	8.78	9.96	11.28	13.07	14.22	17.84	19.94
SSP 585 Adaptation Transport	0.19	0.56	0.80	0.88	2.21	3.03	3.95	4.14	6.54	6.38	7.01	8.78	9.96	11.28	13.07	14.22	17.84	19.94
SSP 585 Adaptation Forestry	0.19	0.56	0.80	0.88	2.21	3.03	3.95	4.14	6.54	6.38	7.01	8.78	9.96	11.28	13.07	14.22	17.84	19.94

Northern midlands and mountain areas

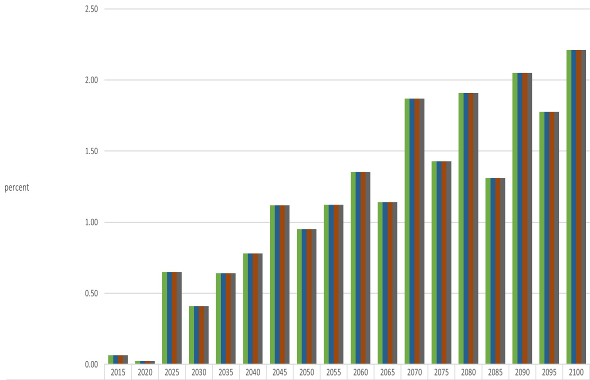


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	0.00	0.11	0.92	1.00	0.70	0.73	1.17	0.81	0.84	0.78	0.92	1.41	1.12	1.45	0.88	1.25	0.75	1.31
SSP 126 Adaptation Housing	0.00	0.11	0.92	1.00	0.70	0.73	1.17	0.81	0.84	0.78	0.92	1.41	1.12	1.45	0.88	1.25	0.75	1.31
SSP 126 Adaptation Transport	0.00	0.11	0.92	1.00	0.70	0.73	1.17	0.81	0.84	0.78	0.92	1.41	1.12	1.45	0.88	1.25	0.75	1.31
SSP 126 Adaptation Forestry	0.00	0.11	0.92	1.00	0.70	0.73	1.17	0.81	0.84	0.78	0.92	1.41	1.12	1.45	0.88	1.25	0.75	1.31

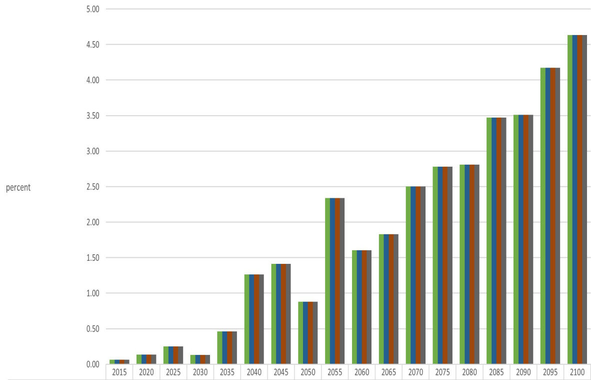


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	0.00	0.38	0.13	0.38	0.32	1.08	0.99	0.21	1.54	1.23	0.95	1.73	1.79	1.84	2.46	2.01	2.50	2.72
SSP 585 Adaptation Housing	0.00	0.38	0.13	0.38	0.32	1.08	0.99	0.21	1.54	1.23	0.95	1.73	1.79	1.84	2.46	2.01	2.50	2.72
SSP 585 Adaptation Transport	0.00	0.38	0.13	0.38	0.32	1.08	0.99	0.21	1.54	1.23	0.95	1.73	1.79	1.84	2.46	2.01	2.50	2.72
SSP 585 Adaptation Forestry	0.00	0.38	0.13	0.38	0.32	1.08	0.99	0.21	1.54	1.23	0.95	1.73	1.79	1.84	2.46	2.01	2.50	2.72

Northern Central area and Central coastal area



	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	0.06	0.02	0.65	0.41	0.64	0.78	1.12	0.95	1.12	1.35	1.14	1.87	1.43	1.91	1.31	2.05	1.78	2.21
SSP 126 Adaptation Housing	0.06	0.02	0.65	0.41	0.64	0.78	1.12	0.95	1.12	1.35	1.14	1.87	1.43	1.91	1.31	2.05	1.78	2.21
SSP 126 Adaptation Transport	0.06	0.02	0.65	0.41	0.64	0.78	1.12	0.95	1.12	1.35	1.14	1.87	1.43	1.91	1.31	2.05	1.78	2.21
SSP 126 Adaptation Forestry	0.06	0.02	0.65	0.41	0.64	0.78	1.12	0.95	1.12	1.35	1.14	1.87	1.43	1.91	1.31	2.05	1.78	2.21

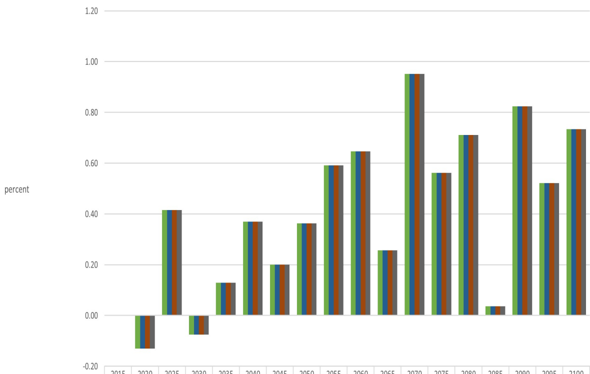


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	0.06	0.13	0.25	0.13	0.46	1.27	1.41	0.88	2.34	1.60	1.83	2.50	2.78	2.81	3.47	3.51	4.17	4.63
SSP 585 Adaptation Housing	0.06	0.13	0.25	0.13	0.46	1.27	1.41	0.88	2.34	1.60	1.83	2.50	2.78	2.81	3.47	3.51	4.17	4.63
SSP 585 Adaptation Transport	0.06	0.13	0.25	0.13	0.46	1.27	1.41	0.88	2.34	1.60	1.83	2.50	2.78	2.81	3.47	3.51	4.17	4.63
SSP 585 Adaptation Forestry	0.06	0.13	0.25	0.13	0.46	1.27	1.41	0.88	2.34	1.60	1.83	2.50	2.78	2.81	3.47	3.51	4.17	4.63

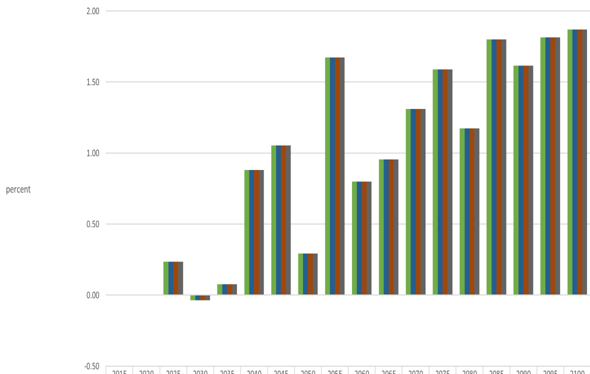
Source: own computation.

Damages agriculture excluding rice (continued)

Central Highlands



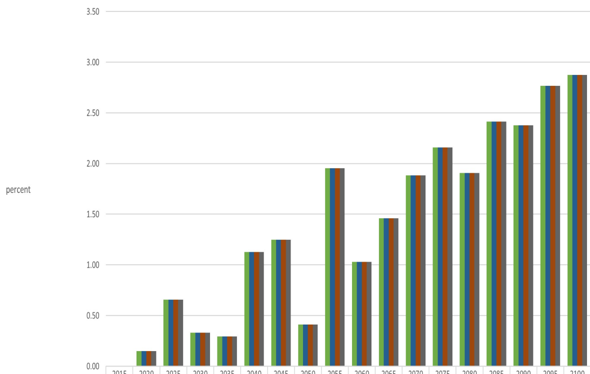
	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	0.00	-0.13	0.41	-0.08	0.13	0.37	0.20	0.36	0.59	0.65	0.26	0.95	0.56	0.71	0.04	0.82	0.52	0.73
SSP 126 Adaptation Housing	0.00	-0.13	0.41	-0.08	0.13	0.37	0.20	0.36	0.59	0.65	0.26	0.95	0.56	0.71	0.04	0.82	0.52	0.73
SSP 126 Adaptation Transport	0.00	-0.13	0.41	-0.08	0.13	0.37	0.20	0.36	0.59	0.65	0.26	0.95	0.56	0.71	0.04	0.82	0.52	0.73
SSP 126 Adaptation Forestry	0.00	-0.13	0.41	-0.08	0.13	0.37	0.20	0.36	0.59	0.65	0.26	0.95	0.56	0.71	0.04	0.82	0.52	0.73



	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	0.00	0.00	0.24	-0.04	0.08	0.88	1.05	0.29	1.67	0.80	0.96	1.31	1.59	1.17	1.80	1.62	1.82	1.87
SSP 585 Adaptation Housing	0.00	0.00	0.24	-0.04	0.08	0.88	1.05	0.29	1.67	0.80	0.96	1.31	1.59	1.17	1.80	1.62	1.82	1.87
SSP 585 Adaptation Transport	0.00	0.00	0.24	-0.04	0.08	0.88	1.05	0.29	1.67	0.80	0.96	1.31	1.59	1.17	1.80	1.62	1.82	1.87
SSP 585 Adaptation Forestry	0.00	0.00	0.24	-0.04	0.08	0.88	1.05	0.29	1.67	0.80	0.96	1.31	1.59	1.17	1.80	1.62	1.82	1.87

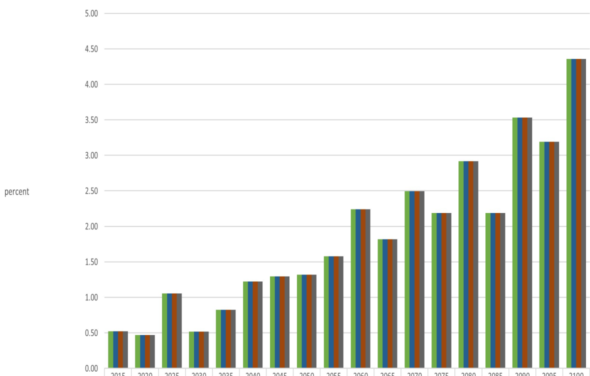
South East

	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	0.00	-0.13	0.50	-0.13	0.14	0.39	0.42	0.42	0.71	0.89	0.53	0.97	0.71	1.04	0.20	1.21	0.85	1.11
SSP 126 Adaptation Housing	0.00	-0.13	0.50	-0.13	0.14	0.39	0.42	0.42	0.71	0.89	0.53	0.97	0.71	1.04	0.20	1.21	0.85	1.11
SSP 126 Adaptation Transport	0.00	-0.13	0.50	-0.13	0.14	0.39	0.42	0.42	0.71	0.89	0.53	0.97	0.71	1.04	0.20	1.21	0.85	1.11
SSP 126 Adaptation Forestry	0.00	-0.13	0.50	-0.13	0.14	0.39	0.42	0.42	0.71	0.89	0.53	0.97	0.71	1.04	0.20	1.21	0.85	1.11

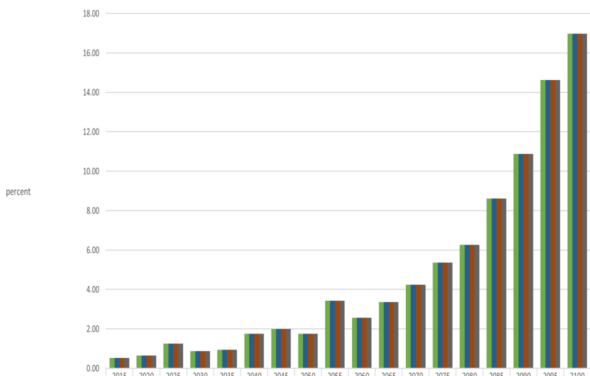


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	0.00	0.15	0.66	0.33	0.29	1.13	1.25	0.41	1.95	1.03	1.46	1.88	2.16	1.91	2.41	2.38	2.77	2.87
SSP 585 Adaptation Housing	0.00	0.15	0.66	0.33	0.29	1.13	1.25	0.41	1.95	1.03	1.46	1.88	2.16	1.91	2.41	2.38	2.77	2.87
SSP 585 Adaptation Transport	0.00	0.15	0.66	0.33	0.29	1.13	1.25	0.41	1.95	1.03	1.46	1.88	2.16	1.91	2.41	2.38	2.77	2.87
SSP 585 Adaptation Forestry	0.00	0.15	0.66	0.33	0.29	1.13	1.25	0.41	1.95	1.03	1.46	1.88	2.16	1.91	2.41	2.38	2.77	2.87

Mekong River Delta



	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	0.52	0.47	1.05	0.52	0.82	1.22	1.30	1.32	1.58	2.24	1.82	2.50	2.19	2.92	2.19	3.53	3.19	4.36
SSP 126 Adaptation Housing	0.52	0.47	1.05	0.52	0.82	1.22	1.30	1.32	1.58	2.24	1.82	2.50	2.19	2.92	2.19	3.53	3.19	4.36
SSP 126 Adaptation Transport	0.52	0.47	1.05	0.52	0.82	1.22	1.30	1.32	1.58	2.24	1.82	2.50	2.19	2.92	2.19	3.53	3.19	4.36
SSP 126 Adaptation Forestry	0.52	0.47	1.05	0.52	0.82	1.22	1.30	1.32	1.58	2.24	1.82	2.50	2.19	2.92	2.19	3.53	3.19	4.36

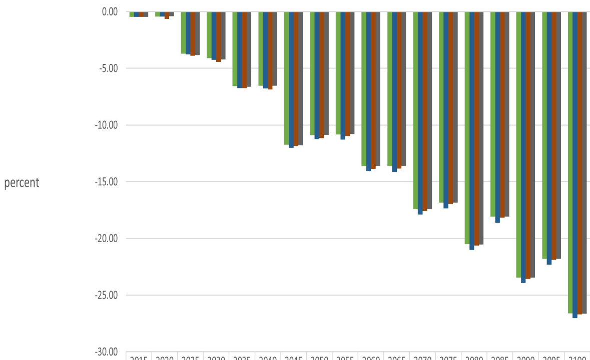


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	0.52	0.65	1.24	0.88	0.94	1.75	2.00	1.75	3.42	2.56	3.36	4.23	5.37	6.26	8.61	10.87	14.62	16.98
SSP 585 Adaptation Housing	0.52	0.65	1.24	0.88	0.94	1.75	2.00	1.75	3.42	2.56	3.36	4.23	5.37	6.26	8.61	10.87	14.62	16.98
SSP 585 Adaptation Transport	0.52	0.65	1.24	0.88	0.94	1.75	2.00	1.75	3.42	2.56	3.36	4.23	5.37	6.26	8.61	10.87	14.62	16.98
SSP 585 Adaptation Forestry	0.52	0.65	1.24	0.88	0.94	1.75	2.00	1.75	3.42	2.56	3.36	4.23	5.37	6.26	8.61	10.87	14.62	16.98

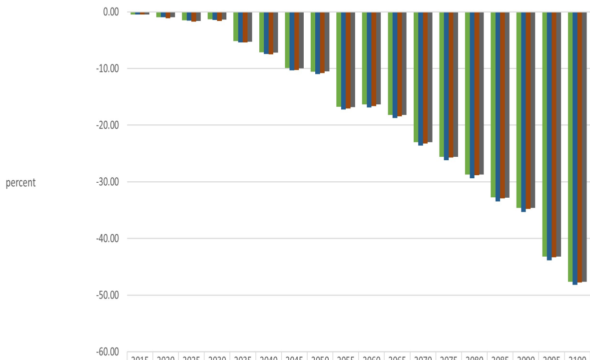
Source: own computation.

Figure 22: Value added agriculture excluding rice

Red River Delta

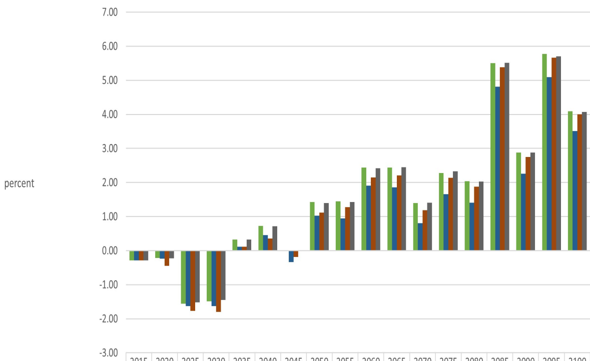


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	-0.47	-0.42	-3.70	-4.11	-6.55	-6.52	-11.72	-10.89	-10.83	-13.63	-13.64	-17.40	-16.84	-20.51	-18.07	-23.46	-21.80	-26.62
SSP 126 Adaptation Housing	-0.47	-0.44	-3.76	-4.25	-6.75	-6.78	-12.01	-11.24	-11.28	-14.07	-14.13	-17.88	-17.34	-21.00	-18.61	-23.93	-22.31	-27.03
SSP 126 Adaptation Transport	-0.46	-0.65	-3.90	-4.42	-6.75	-6.87	-11.87	-11.16	-10.98	-13.87	-13.83	-17.58	-16.95	-20.64	-18.16	-23.56	-21.89	-26.69
SSP 126 Adaptation Forestry	-0.47	-0.42	-3.82	-4.23	-6.61	-6.55	-11.78	-10.86	-10.81	-13.61	-13.63	-17.40	-16.85	-20.52	-18.08	-23.45	-21.81	-26.63

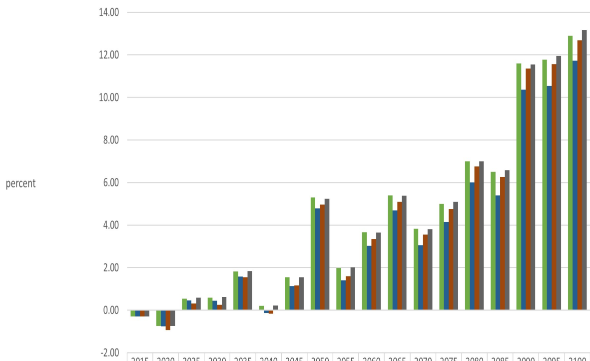


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	-0.48	-0.95	-1.51	-1.30	-5.18	-7.15	-9.93	-10.56	-16.79	-16.36	-18.21	-23.03	-25.57	-28.70	-32.76	-34.63	-43.23	-47.67
SSP 585 Adaptation Housing	-0.48	-0.97	-1.59	-1.45	-5.40	-7.46	-10.31	-10.99	-17.25	-16.88	-18.76	-23.60	-26.17	-29.36	-33.45	-35.35	-43.85	-48.21
SSP 585 Adaptation Transport	-0.48	-1.15	-1.72	-1.64	-5.42	-7.49	-10.28	-10.84	-17.09	-16.63	-18.45	-23.24	-25.74	-28.86	-32.90	-34.76	-43.33	-47.77
SSP 585 Adaptation Forestry	-0.48	-0.94	-1.63	-1.40	-5.27	-7.23	-9.95	-10.52	-16.83	-16.35	-18.19	-23.01	-25.61	-28.70	-32.79	-34.62	-43.23	-47.68

Northern midlands and mountain areas

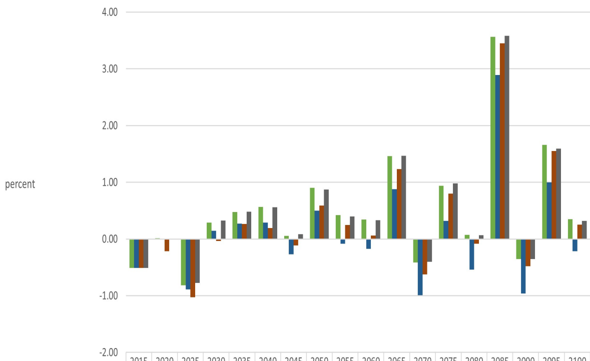


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	-0.29	-0.21	-1.56	-1.48	0.32	0.73	-0.01	1.43	1.45	2.43	2.44	1.40	2.28	2.04	5.50	2.88	5.78	4.09
SSP 126 Adaptation Housing	-0.29	-0.23	-1.63	-1.63	0.12	0.45	-0.34	1.02	0.94	1.90	1.86	0.81	1.65	1.41	4.81	2.26	5.09	3.51
SSP 126 Adaptation Transport	-0.28	-0.44	-1.77	-1.80	0.11	0.35	-0.18	1.12	1.28	2.14	2.21	1.18	2.14	1.88	5.38	2.75	5.66	4.00
SSP 126 Adaptation Forestry	-0.29	-0.22	-1.51	-1.45	0.33	0.72	0.01	1.40	1.42	2.42	2.44	1.41	2.32	2.03	5.51	2.88	5.70	4.07

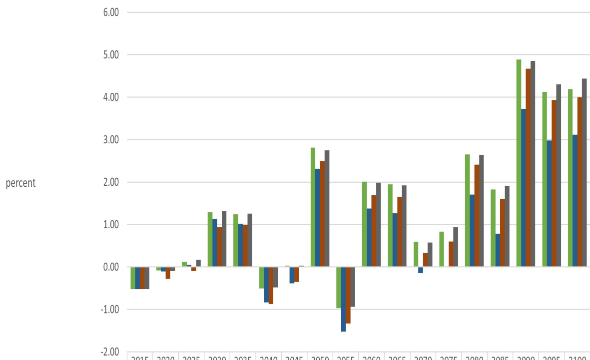


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	-0.30	-0.74	0.53	0.59	1.82	0.20	1.55	5.30	1.97	3.67	5.39	3.82	5.00	7.00	6.49	11.59	11.77	12.89
SSP 585 Adaptation Housing	-0.30	-0.76	0.46	0.44	1.59	-0.13	1.13	4.79	1.41	3.02	4.69	3.06	4.15	6.01	5.40	10.36	10.54	11.72
SSP 585 Adaptation Transport	-0.30	-0.93	0.32	0.25	1.56	-0.17	1.16	4.97	1.60	3.34	5.09	3.55	4.75	6.75	6.26	11.36	11.57	12.68
SSP 585 Adaptation Forestry	-0.30	-0.75	0.58	0.61	1.83	0.23	1.55	5.23	2.01	3.64	5.38	3.81	5.10	6.99	6.58	11.55	11.95	13.17

Northern Central area and Central coastal area



	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	-0.51	0.01	-0.82	0.29	0.48	0.57	0.06	0.90	0.42	0.34	1.46	-0.41	0.94	0.07	3.57	-0.35	1.66	0.35
SSP 126 Adaptation Housing	-0.51	-0.01	-0.89	0.14	0.27	0.29	-0.27	0.50	-0.08	-0.18	0.88	-0.99	0.32	-0.54	2.89	-0.96	1.00	-0.22
SSP 126 Adaptation Transport	-0.51	-0.22	-1.03	-0.03	0.26	0.19	-0.11	0.59	0.25	0.06	1.23	-0.62	0.80	-0.08	3.45	-0.48	1.55	0.25
SSP 126 Adaptation Forestry	-0.51	0.00	-0.77	0.32	0.48	0.56	0.08	0.87	0.40	0.33	1.47	-0.40	0.98	0.07	3.58	-0.36	1.59	0.32

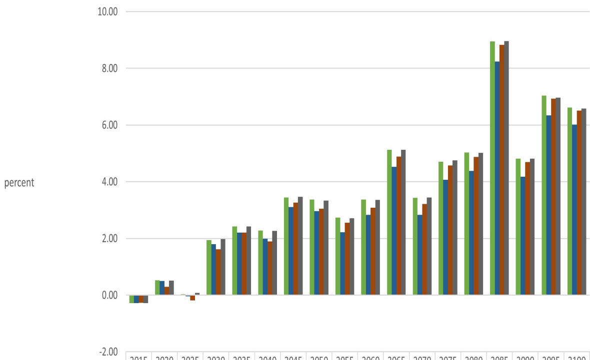


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	-0.52	-0.08	0.12	1.29	1.24	-0.51	0.03	2.81	-0.97	2.01	1.94	0.59	0.83	2.65	1.83	4.89	4.12	4.19
SSP 585 Adaptation Housing	-0.52	-0.10	0.05	1.13	1.01	-0.83	-0.39	2.32	-1.52	1.38	1.26	-0.15	0.02	1.70	0.78	3.73	2.98	3.11
SSP 585 Adaptation Transport	-0.52	-0.28	-0.09	0.94	0.99	-0.87	-0.35	2.49	-1.33	1.69	1.65	0.32	0.60	2.41	1.61	4.67	3.94	4.00
SSP 585 Adaptation Forestry	-0.52	-0.10	0.17	1.31	1.26	-0.48	0.03	2.75	-0.93	1.99	1.93	0.58	0.93	2.65	1.92	4.85	4.30	4.44

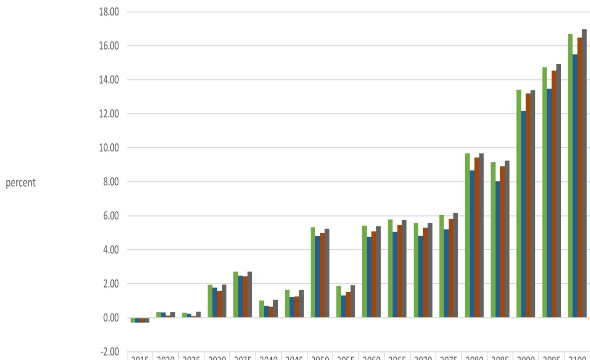
Source: own computation.

Value added agriculture excluding rice (continued)

Central Highlands

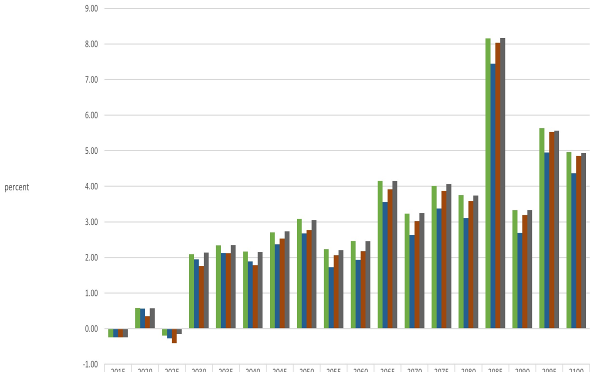


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	-0.28	0.52	0.03	1.94	2.42	2.28	3.45	3.37	2.73	3.37	5.12	3.43	4.71	5.03	8.95	4.82	7.04	6.61
SSP 126 Adaptation Housing	-0.28	0.50	-0.04	1.79	2.21	1.99	3.11	2.96	2.22	2.84	4.52	2.83	4.07	4.39	8.24	4.18	6.35	6.01
SSP 126 Adaptation Transport	-0.27	0.29	-0.18	1.61	2.20	1.90	3.27	3.05	2.56	3.08	4.89	3.21	4.57	4.87	8.82	4.69	6.93	6.51
SSP 126 Adaptation Forestry	-0.28	0.51	0.08	1.98	2.42	2.27	3.47	3.34	2.71	3.36	5.13	3.44	4.76	5.02	8.96	4.82	6.97	6.58

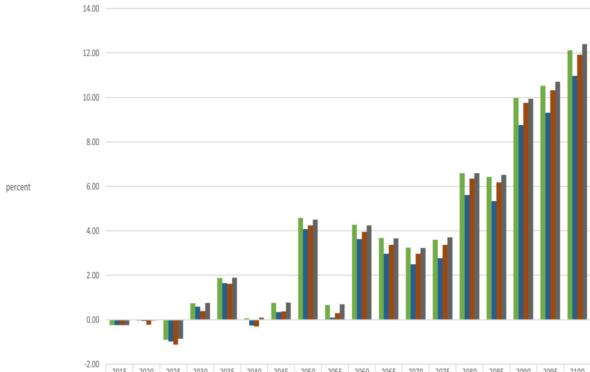


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	-0.28	0.34	0.30	1.93	2.71	1.02	1.64	5.31	1.88	5.41	5.77	5.59	6.06	9.68	9.15	13.42	14.74	16.70
SSP 585 Adaptation Housing	-0.28	0.32	0.23	1.78	2.47	0.69	1.21	4.81	1.31	4.76	5.06	4.81	5.20	8.67	8.03	12.17	13.48	15.50
SSP 585 Adaptation Transport	-0.28	0.14	0.09	1.58	2.44	0.65	1.25	4.98	1.51	5.08	5.46	5.31	5.81	9.42	8.91	13.19	14.54	16.49
SSP 585 Adaptation Forestry	-0.28	0.33	0.36	1.96	2.72	1.05	1.64	5.25	1.92	5.38	5.75	5.58	6.16	9.67	9.24	13.38	14.94	16.98

South East

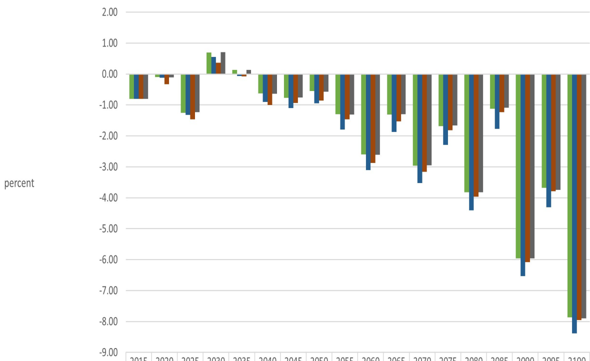


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	-0.24	0.58	-0.20	2.09	2.34	2.17	2.70	3.09	2.23	2.46	4.15	3.24	4.01	3.75	8.15	3.33	5.64	4.96
SSP 126 Adaptation Housing	-0.24	0.56	-0.27	1.94	2.13	1.88	2.37	2.67	1.72	1.93	3.55	2.64	3.38	3.11	7.45	2.70	4.95	4.37
SSP 126 Adaptation Transport	-0.24	0.35	-0.41	1.76	2.12	1.78	2.53	2.77	2.06	2.17	3.92	3.02	3.87	3.59	8.03	3.20	5.52	4.86
SSP 126 Adaptation Forestry	-0.24	0.57	-0.15	2.13	2.34	2.16	2.73	3.05	2.21	2.45	4.15	3.25	4.06	3.74	8.17	3.32	5.56	4.93

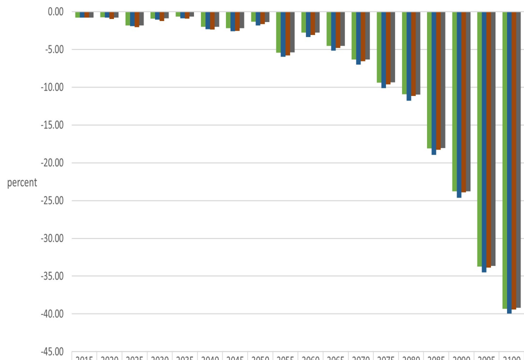


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	-0.25	-0.04	-0.91	0.73	1.87	0.06	0.76	4.57	0.66	4.27	3.67	3.24	3.60	6.59	6.41	9.98	10.52	12.12
SSP 585 Adaptation Housing	-0.25	-0.06	-0.98	0.58	1.64	-0.26	0.34	4.07	0.10	3.62	2.97	2.48	2.76	5.61	5.32	8.76	9.31	10.97
SSP 585 Adaptation Transport	-0.25	-0.24	-1.12	0.39	1.61	-0.30	0.37	4.24	0.29	3.94	3.36	2.96	3.36	6.35	6.18	9.75	10.32	11.92
SSP 585 Adaptation Forestry	-0.25	-0.05	-0.86	0.76	1.88	0.09	0.76	4.51	0.70	4.24	3.65	3.23	3.70	6.59	6.51	9.94	10.71	12.40

Mekong River Delta



	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	-0.81	-0.10	-1.26	0.69	0.14	-0.63	-0.77	-0.55	-1.30	-2.60	-1.31	-2.96	-1.69	-3.82	-1.12	-5.96	-3.68	-7.87
SSP 126 Adaptation Housing	-0.81	-0.12	-1.33	0.55	-0.07	-0.90	-1.10	-0.95	-1.79	-3.10	-1.87	-3.53	-2.29	-4.41	-1.77	-6.53	-4.31	-8.38
SSP 126 Adaptation Transport	-0.80	-0.33	-1.47	0.37	-0.07	-1.00	-0.94	-0.86	-1.47	-2.88	-1.53	-3.17	-1.81	-3.97	-1.24	-6.08	-3.78	-7.95
SSP 126 Adaptation Forestry	-0.81	-0.11	-1.23	0.70	0.13	-0.64	-0.76	-0.57	-1.31	-2.61	-1.30	-2.95	-1.66	-3.83	-1.09	-5.96	-3.75	-7.89

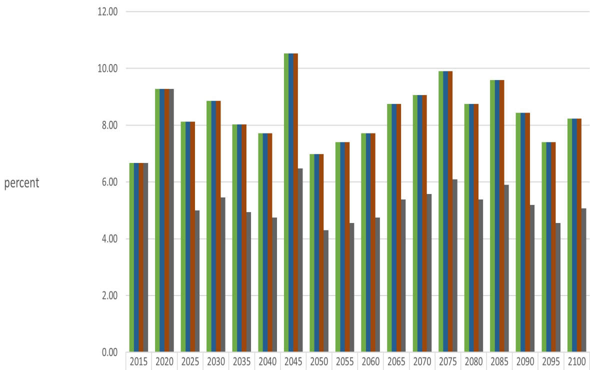


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	-0.78	-0.76	-1.84	-0.92	-0.66	-2.02	-2.19	-1.34	-5.43	-2.78	-4.52	-6.33	-9.41	-10.9	-18.1	-23.7	-33.7	-39.3
SSP 585 Adaptation Housing	-0.77	-0.78	-1.91	-1.07	-0.88	-2.34	-2.60	-1.81	-5.96	-3.38	-5.16	-7.02	-10.1	-11.7	-18.9	-24.6	-34.4	-39.9
SSP 585 Adaptation Transport	-0.77	-0.96	-2.05	-1.26	-0.91	-2.38	-2.56	-1.65	-5.78	-3.09	-4.80	-6.58	-9.62	-11.1	-18.3	-23.9	-33.8	-39.4
SSP 585 Adaptation Forestry	-0.78	-0.77	-1.82	-0.90	-0.64	-2.02	-2.19	-1.37	-5.40	-2.78	-4.52	-6.34	-9.34	-10.9	-18.0	-23.7	-33.6	-39.2

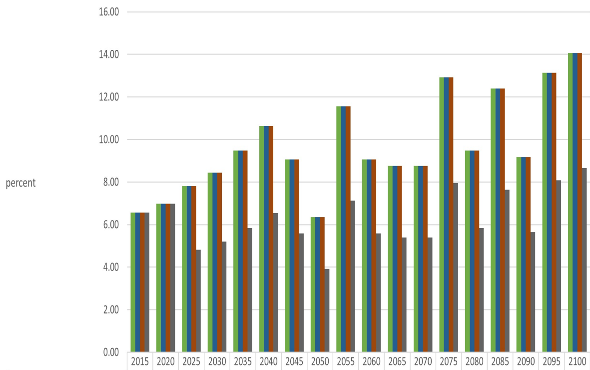
Source: own computation.

Figure 23: Damages forestry

Red River Delta

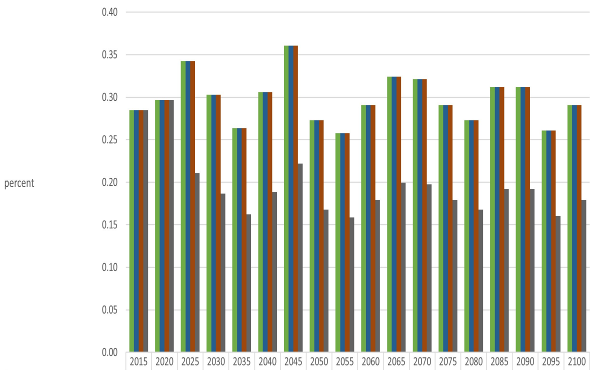


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	6.67	9.27	8.13	8.86	8.02	7.71	10.52	6.98	7.40	7.71	8.75	9.07	9.90	8.75	9.59	8.44	7.40	8.23
SSP 126 Adaptation Housing	6.67	9.27	8.13	8.86	8.02	7.71	10.52	6.98	7.40	7.71	8.75	9.07	9.90	8.75	9.59	8.44	7.40	8.23
SSP 126 Adaptation Transport	6.67	9.27	8.13	8.86	8.02	7.71	10.52	6.98	7.40	7.71	8.75	9.07	9.90	8.75	9.59	8.44	7.40	8.23
SSP 126 Adaptation Forestry	6.67	9.27	5.00	5.45	4.94	4.75	6.48	4.30	4.55	4.75	5.39	5.58	6.09	5.39	5.90	5.19	4.55	5.07

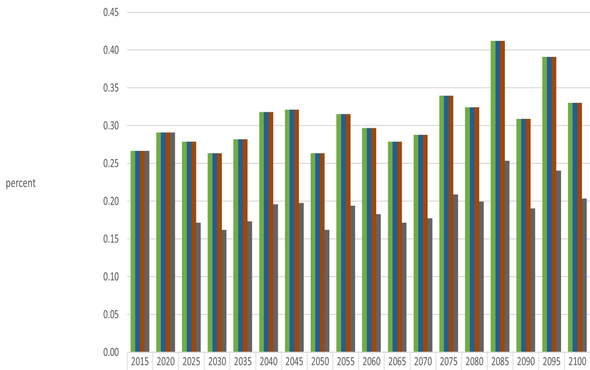


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	6.57	6.98	7.82	8.44	9.48	10.63	9.07	6.36	11.57	9.07	8.75	8.75	12.92	9.48	12.40	9.17	13.13	14.07
SSP 585 Adaptation Housing	6.57	6.98	7.82	8.44	9.48	10.63	9.07	6.36	11.57	9.07	8.75	8.75	12.92	9.48	12.40	9.17	13.13	14.07
SSP 585 Adaptation Transport	6.57	6.98	7.82	8.44	9.48	10.63	9.07	6.36	11.57	9.07	8.75	8.75	12.92	9.48	12.40	9.17	13.13	14.07
SSP 585 Adaptation Forestry	6.57	6.98	4.81	5.19	5.84	6.54	5.58	3.91	7.12	5.58	5.39	5.39	7.95	5.84	7.63	5.64	8.08	8.66

Northern midlands and mountain areas

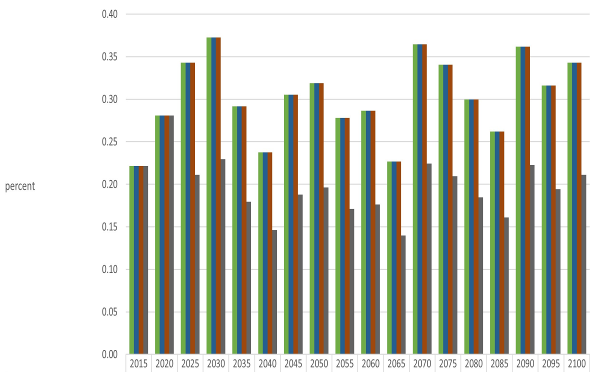


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	0.2849	0.2970	0.3424	0.3030	0.2636	0.3061	0.3606	0.2727	0.2576	0.2909	0.3243	0.3212	0.2909	0.2727	0.3121	0.3121	0.2606	0.2909
SSP 126 Adaptation Housing	0.2849	0.2970	0.3424	0.3030	0.2636	0.3061	0.3606	0.2727	0.2576	0.2909	0.3243	0.3212	0.2909	0.2727	0.3121	0.3121	0.2606	0.2909
SSP 126 Adaptation Transport	0.2849	0.2970	0.3424	0.3030	0.2636	0.3061	0.3606	0.2727	0.2576	0.2909	0.3243	0.3212	0.2909	0.2727	0.3121	0.3121	0.2606	0.2909
SSP 126 Adaptation Forestry	0.2849	0.2970	0.2107	0.1865	0.1622	0.1883	0.2219	0.1678	0.1585	0.1790	0.1995	0.1977	0.1790	0.1678	0.1921	0.1921	0.1604	0.1790

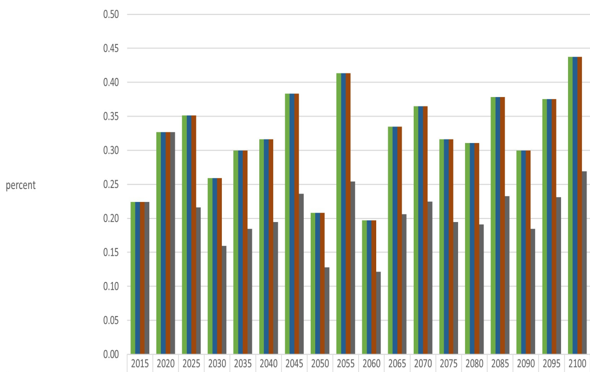


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	0.2667	0.2909	0.2788	0.2636	0.2818	0.3182	0.3212	0.2636	0.3152	0.2970	0.2788	0.2879	0.3394	0.3243	0.4121	0.3091	0.3909	0.3303
SSP 585 Adaptation Housing	0.2667	0.2909	0.2788	0.2636	0.2818	0.3182	0.3212	0.2636	0.3152	0.2970	0.2788	0.2879	0.3394	0.3243	0.4121	0.3091	0.3909	0.3303
SSP 585 Adaptation Transport	0.2667	0.2909	0.2788	0.2636	0.2818	0.3182	0.3212	0.2636	0.3152	0.2970	0.2788	0.2879	0.3394	0.3243	0.4121	0.3091	0.3909	0.3303
SSP 585 Adaptation Forestry	0.2667	0.2909	0.1716	0.1622	0.1734	0.1958	0.1977	0.1622	0.1939	0.1828	0.1716	0.1772	0.2089	0.1995	0.2536	0.1902	0.2406	0.2033

Northern Central area and Central coastal area



	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	0.221	0.281	0.343	0.373	0.292	0.238	0.305	0.319	0.278	0.286	0.227	0.365	0.340	0.300	0.262	0.362	0.316	0.343
SSP 126 Adaptation Housing	0.221	0.281	0.343	0.373	0.292	0.238	0.305	0.319	0.278	0.286	0.227	0.365	0.340	0.300	0.262	0.362	0.316	0.343
SSP 126 Adaptation Transport	0.221	0.281	0.343	0.373	0.292	0.238	0.305	0.319	0.278	0.286	0.227	0.365	0.340	0.300	0.262	0.362	0.316	0.343
SSP 126 Adaptation Forestry	0.221	0.281	0.211	0.229	0.180	0.146	0.188	0.196	0.171	0.176	0.140	0.224	0.209	0.185	0.161	0.223	0.194	0.211

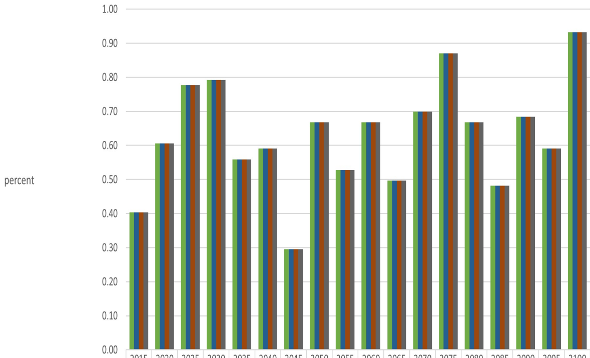


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	0.224	0.327	0.351	0.259	0.300	0.316	0.384	0.208	0.413	0.197	0.335	0.365	0.316	0.311	0.378	0.300	0.375	0.438
SSP 585 Adaptation Housing	0.224	0.327	0.351	0.259	0.300	0.316	0.384	0.208	0.413	0.197	0.335	0.365	0.316	0.311	0.378	0.300	0.375	0.438
SSP 585 Adaptation Transport	0.224	0.327	0.351	0.259	0.300	0.316	0.384	0.208	0.413	0.197	0.335	0.365	0.316	0.311	0.378	0.300	0.375	0.438
SSP 585 Adaptation Forestry	0.224	0.327	0.216	0.160	0.185	0.194	0.236	0.128	0.254	0.121	0.206	0.224	0.194	0.191	0.233	0.185	0.231	0.269

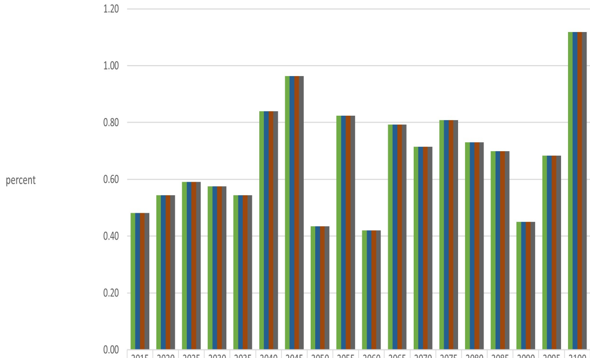
Source: own computation.

Damages forestry (continued)

Central Highlands

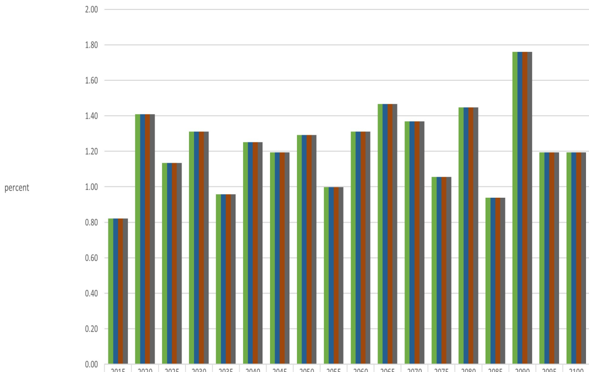


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	0.404	0.606	0.777	0.792	0.559	0.590	0.295	0.668	0.528	0.668	0.497	0.699	0.870	0.668	0.482	0.684	0.590	0.932
SSP 126 Adaptation Housing	0.404	0.606	0.777	0.792	0.559	0.590	0.295	0.668	0.528	0.668	0.497	0.699	0.870	0.668	0.482	0.684	0.590	0.932
SSP 126 Adaptation Transport	0.404	0.606	0.777	0.792	0.559	0.590	0.295	0.668	0.528	0.668	0.497	0.699	0.870	0.668	0.482	0.684	0.590	0.932
SSP 126 Adaptation Forestry	0.404	0.606	0.777	0.792	0.559	0.590	0.295	0.668	0.528	0.668	0.497	0.699	0.870	0.668	0.482	0.684	0.590	0.932

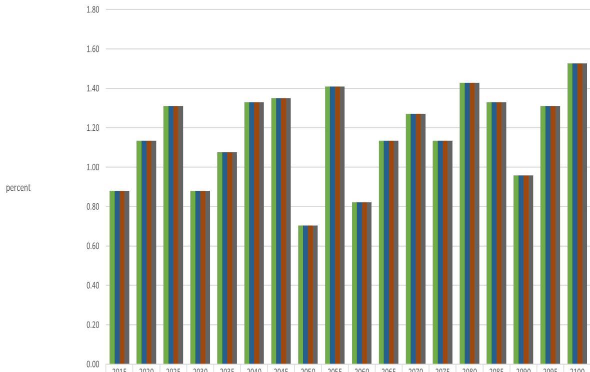


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	0.482	0.544	0.590	0.575	0.544	0.839	0.963	0.435	0.823	0.420	0.792	0.715	0.808	0.730	0.699	0.451	0.684	1.119
SSP 585 Adaptation Housing	0.482	0.544	0.590	0.575	0.544	0.839	0.963	0.435	0.823	0.420	0.792	0.715	0.808	0.730	0.699	0.451	0.684	1.119
SSP 585 Adaptation Transport	0.482	0.544	0.590	0.575	0.544	0.839	0.963	0.435	0.823	0.420	0.792	0.715	0.808	0.730	0.699	0.451	0.684	1.119
SSP 585 Adaptation Forestry	0.482	0.544	0.590	0.575	0.544	0.839	0.963	0.435	0.823	0.420	0.792	0.715	0.808	0.730	0.699	0.451	0.684	1.119

South East

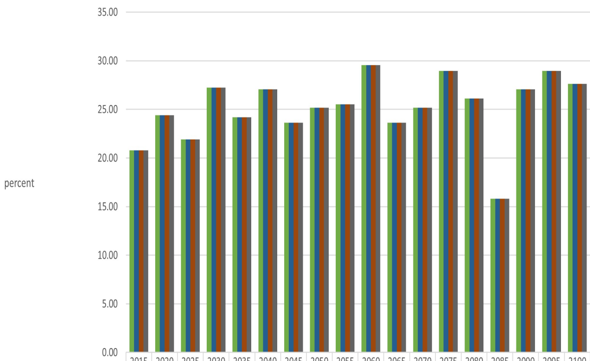


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	0.821	1.408	1.134	1.310	0.958	1.252	1.193	1.291	0.998	1.310	1.467	1.369	1.056	1.447	0.939	1.760	1.193	1.193
SSP 126 Adaptation Housing	0.821	1.408	1.134	1.310	0.958	1.252	1.193	1.291	0.998	1.310	1.467	1.369	1.056	1.447	0.939	1.760	1.193	1.193
SSP 126 Adaptation Transport	0.821	1.408	1.134	1.310	0.958	1.252	1.193	1.291	0.998	1.310	1.467	1.369	1.056	1.447	0.939	1.760	1.193	1.193
SSP 126 Adaptation Forestry	0.821	1.408	1.134	1.310	0.958	1.252	1.193	1.291	0.998	1.310	1.467	1.369	1.056	1.447	0.939	1.760	1.193	1.193

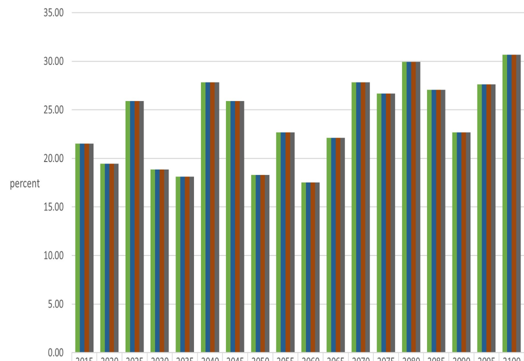


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	0.880	1.134	1.310	0.880	1.076	1.330	1.350	0.704	1.408	0.821	1.134	1.271	1.134	1.428	1.330	0.958	1.310	1.526
SSP 585 Adaptation Housing	0.880	1.134	1.310	0.880	1.076	1.330	1.350	0.704	1.408	0.821	1.134	1.271	1.134	1.428	1.330	0.958	1.310	1.526
SSP 585 Adaptation Transport	0.880	1.134	1.310	0.880	1.076	1.330	1.350	0.704	1.408	0.821	1.134	1.271	1.134	1.428	1.330	0.958	1.310	1.526
SSP 585 Adaptation Forestry	0.880	1.134	1.310	0.880	1.076	1.330	1.350	0.704	1.408	0.821	1.134	1.271	1.134	1.428	1.330	0.958	1.310	1.526

Mekong River Delta



	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	20.77	24.39	21.91	27.25	24.20	27.06	23.63	25.15	25.53	29.54	23.63	25.15	28.96	26.11	15.82	27.06	28.96	27.63
SSP 126 Adaptation Housing	20.77	24.39	21.91	27.25	24.20	27.06	23.63	25.15	25.53	29.54	23.63	25.15	28.96	26.11	15.82	27.06	28.96	27.63
SSP 126 Adaptation Transport	20.77	24.39	21.91	27.25	24.20	27.06	23.63	25.15	25.53	29.54	23.63	25.15	28.96	26.11	15.82	27.06	28.96	27.63
SSP 126 Adaptation Forestry	20.77	24.39	21.91	27.25	24.20	27.06	23.63	25.15	25.53	29.54	23.63	25.15	28.96	26.11	15.82	27.06	28.96	27.63

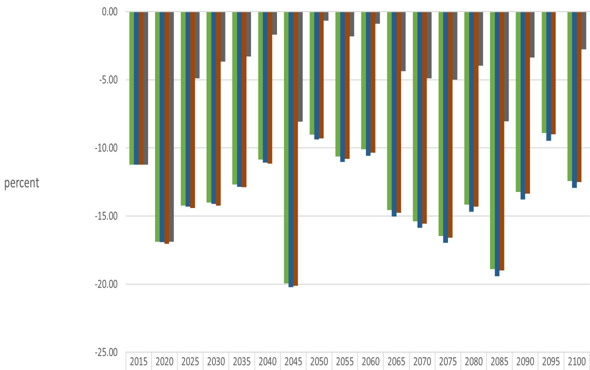


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	21.53	19.44	25.91	18.86	18.10	27.82	25.91	18.29	22.68	17.53	22.10	27.82	26.68	29.92	27.06	22.68	27.63	30.68
SSP 585 Adaptation Housing	21.53	19.44	25.91	18.86	18.10	27.82	25.91	18.29	22.68	17.53	22.10	27.82	26.68	29.92	27.06	22.68	27.63	30.68
SSP 585 Adaptation Transport	21.53	19.44	25.91	18.86	18.10	27.82	25.91	18.29	22.68	17.53	22.10	27.82	26.68	29.92	27.06	22.68	27.63	30.68
SSP 585 Adaptation Forestry	21.53	19.44	25.91	18.86	18.10	27.82	25.91	18.29	22.68	17.53	22.10	27.82	26.68	29.92	27.06	22.68	27.63	30.68

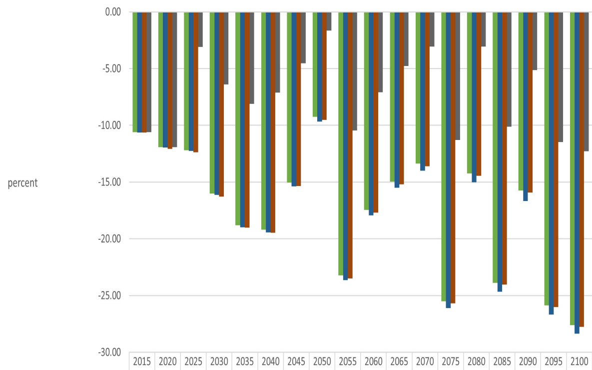
Source: own computation.

Figure 24: Value added forestry

Red River Delta

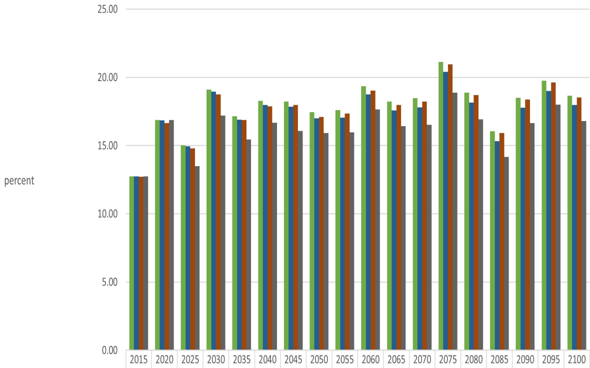


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	-11.22	-16.88	-14.24	-14.00	-12.69	-10.85	-19.95	-9.03	-10.62	-10.11	-14.57	-15.39	-16.45	-14.16	-18.89	-13.24	-8.90	-12.43
SSP 126 Adaptation Housing	-11.22	-16.90	-14.30	-14.10	-12.86	-11.08	-20.21	-9.38	-11.03	-10.58	-15.04	-15.87	-16.96	-14.69	-19.41	-13.77	-9.48	-12.92
SSP 126 Adaptation Transport	-11.22	-17.04	-14.41	-14.24	-12.89	-11.15	-20.12	-9.30	-10.80	-10.36	-14.76	-15.56	-16.58	-14.30	-18.99	-13.35	-9.00	-12.51
SSP 126 Adaptation Forestry	-11.22	-16.88	-4.89	-3.68	-3.29	-1.69	-8.08	-0.67	-1.82	-0.89	-4.36	-4.90	-4.99	-3.96	-8.04	-3.37	-0.02	-2.77

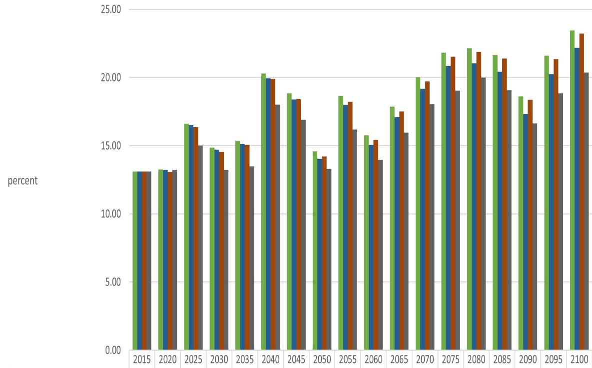


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	-10.62	-11.93	-12.20	-16.02	-18.80	-19.20	-15.05	-9.24	-23.23	-17.45	-14.95	-13.38	-25.51	-14.24	-23.88	-15.75	-25.87	-27.62
SSP 585 Adaptation Housing	-10.63	-11.95	-12.26	-16.13	-18.98	-19.44	-15.38	-9.67	-23.64	-17.94	-15.51	-14.00	-26.10	-15.02	-24.65	-16.67	-26.69	-28.37
SSP 585 Adaptation Transport	-10.63	-12.08	-12.38	-16.27	-19.01	-19.48	-15.36	-9.53	-23.50	-17.71	-15.20	-13.61	-25.68	-14.44	-24.05	-15.92	-26.01	-27.75
SSP 585 Adaptation Forestry	-10.62	-11.92	-3.08	-6.38	-8.11	-7.11	-4.52	-1.64	-10.44	-7.09	-4.78	-3.08	-11.30	-3.06	-10.13	-5.12	-11.46	-12.29

Northern midlands and mountain areas

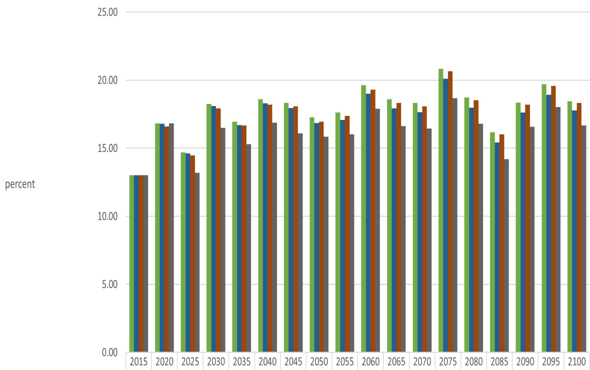


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	12.74	16.87	15.01	19.10	17.14	18.28	18.22	17.46	17.59	19.36	18.24	18.48	21.12	18.89	16.06	18.51	19.75	18.66
SSP 126 Adaptation Housing	12.74	16.85	14.94	18.95	16.91	17.98	17.85	17.01	17.04	18.75	17.58	17.80	20.40	18.16	15.31	17.78	18.99	17.98
SSP 126 Adaptation Transport	12.73	16.65	14.79	18.75	16.88	17.88	17.98	17.11	17.35	19.04	17.97	18.23	20.95	18.70	15.91	18.37	19.62	18.54
SSP 126 Adaptation Forestry	12.74	16.86	13.50	17.21	15.44	16.67	16.08	15.93	15.96	17.65	16.43	16.53	18.89	16.93	14.16	16.66	18.00	16.79

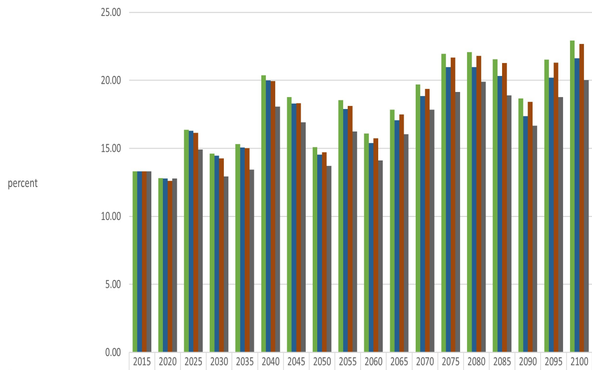


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	13.11	13.25	16.60	14.87	15.37	20.30	18.84	14.58	18.64	15.77	17.87	20.03	21.82	22.16	21.65	18.62	21.58	23.45
SSP 585 Adaptation Housing	13.10	13.22	16.52	14.72	15.12	19.95	18.38	14.04	18.00	15.07	17.10	19.17	20.85	21.05	20.42	17.32	20.25	22.17
SSP 585 Adaptation Transport	13.10	13.06	16.38	14.52	15.07	19.89	18.41	14.21	18.22	15.40	17.53	19.71	21.53	21.87	21.38	18.37	21.36	23.22
SSP 585 Adaptation Forestry	13.11	13.24	15.02	13.21	13.48	18.01	16.90	13.30	16.19	13.95	15.97	18.04	19.05	20.00	19.06	16.63	18.85	20.38

Northern Central area and Central coastal area



	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	13.03	16.83	14.70	18.26	16.94	18.61	18.33	17.29	17.62	19.62	18.60	18.33	20.83	18.72	16.18	18.36	19.70	18.45
SSP 126 Adaptation Housing	13.03	16.80	14.62	18.11	16.71	18.31	17.96	16.84	17.07	19.01	17.94	17.65	20.11	17.99	15.43	17.63	18.94	17.78
SSP 126 Adaptation Transport	13.02	16.60	14.47	17.92	16.68	18.21	18.09	16.94	17.38	19.30	18.33	18.09	20.65	18.53	16.04	18.21	19.57	18.33
SSP 126 Adaptation Forestry	13.03	16.82	13.19	16.50	15.29	16.88	16.10	15.84	16.03	17.90	16.63	16.46	18.69	16.80	14.20	16.59	18.04	16.67

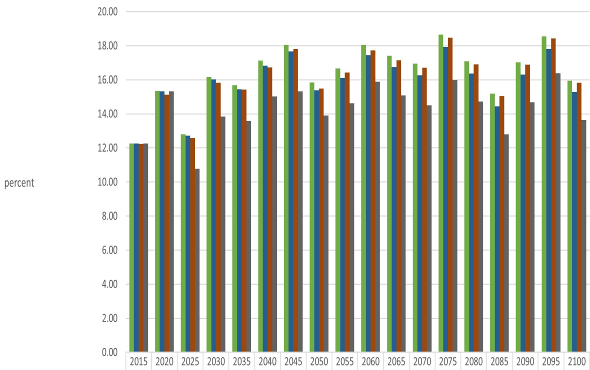


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	13.32	12.80	16.37	14.61	15.30	20.37	18.76	15.09	18.53	16.09	17.83	19.69	21.95	22.08	21.54	18.66	21.52	22.91
SSP 585 Adaptation Housing	13.31	12.77	16.29	14.46	15.05	20.01	18.29	14.54	17.89	15.39	17.06	18.83	20.98	20.98	20.32	17.36	20.18	21.63
SSP 585 Adaptation Transport	13.31	12.61	16.14	14.26	15.00	19.95	18.32	14.71	18.11	15.73	17.49	19.37	21.66	21.80	21.28	18.41	21.29	22.68
SSP 585 Adaptation Forestry	13.32	12.79	14.90	12.94	13.44	18.06	16.91	13.71	16.24	14.11	16.02	17.83	19.14	19.91	18.90	16.66	18.77	20.03

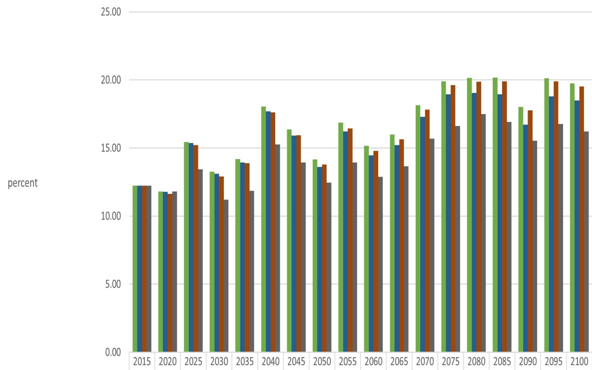
Source: own computation.

Value added forestry (continued)

Central Highlands

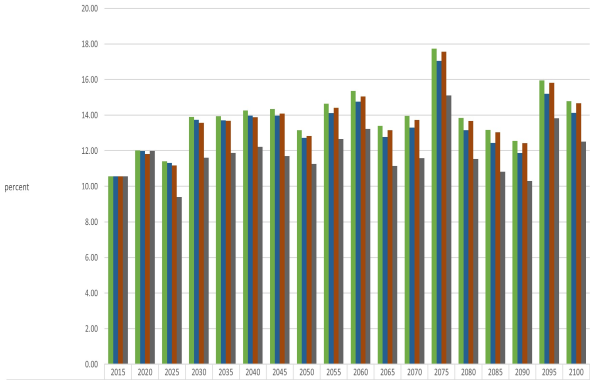


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	12.25	15.34	12.79	16.16	15.68	17.12	18.05	15.83	16.66	18.05	17.40	16.94	18.64	17.09	15.18	17.03	18.55	15.93
SSP 126 Adaptation Housing	12.25	15.31	12.72	16.02	15.44	16.82	17.67	15.39	16.11	17.44	16.75	16.27	17.93	16.37	14.44	16.31	17.80	15.28
SSP 126 Adaptation Transport	12.24	15.12	12.57	15.83	15.41	16.73	17.80	15.49	16.42	17.73	17.14	16.70	18.47	16.91	15.04	16.89	18.42	15.82
SSP 126 Adaptation Forestry	12.25	15.33	10.78	13.84	13.57	15.03	15.32	13.89	14.63	15.88	15.08	14.50	15.97	14.72	12.80	14.69	16.39	13.65

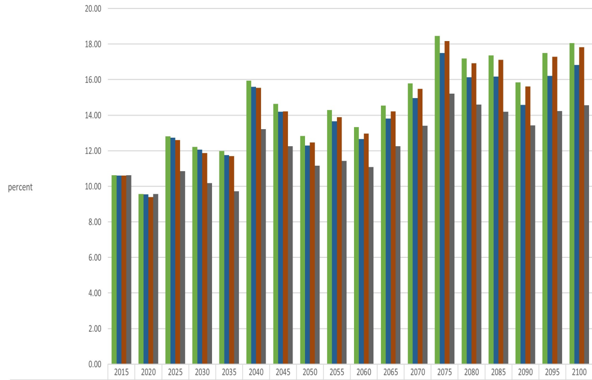


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	12.23	11.81	15.45	13.25	14.17	18.03	16.37	14.16	16.85	15.16	15.98	18.13	19.90	20.14	20.16	18.01	20.11	19.74
SSP 585 Adaptation Housing	12.22	11.78	15.37	13.10	13.92	17.68	15.92	13.61	16.22	14.47	15.22	17.28	18.94	19.05	18.95	16.72	18.79	18.49
SSP 585 Adaptation Transport	12.22	11.63	15.22	12.91	13.88	17.63	15.94	13.78	16.44	14.80	15.64	17.82	19.62	19.86	19.90	17.77	19.89	19.51
SSP 585 Adaptation Forestry	12.23	11.81	13.43	11.20	11.85	15.26	13.94	12.46	13.92	12.87	13.66	15.70	16.62	17.48	16.92	15.54	16.77	16.20

South East

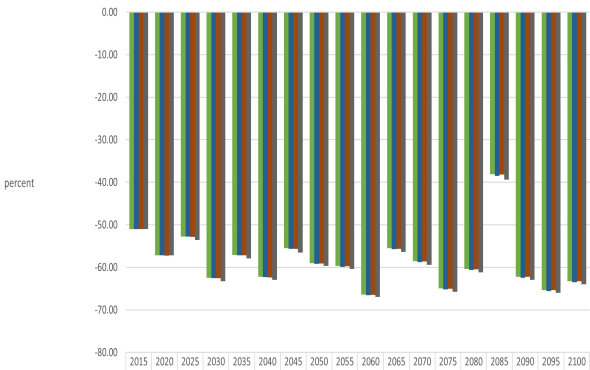


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	10.56	12.01	11.40	13.89	13.94	14.26	14.33	13.16	14.65	15.36	13.40	13.96	17.75	13.85	13.17	12.56	15.94	14.77
SSP 126 Adaptation Housing	10.56	11.98	11.33	13.75	13.71	13.97	13.97	12.72	14.11	14.76	12.76	13.30	17.04	13.15	12.44	11.86	15.21	14.12
SSP 126 Adaptation Transport	10.55	11.80	11.18	13.56	13.68	13.88	14.09	12.82	14.41	15.04	13.14	13.72	17.57	13.67	13.03	12.42	15.82	14.66
SSP 126 Adaptation Forestry	10.56	12.00	9.41	11.61	11.87	12.22	11.69	11.26	12.65	13.23	11.15	11.58	15.10	11.54	10.83	10.30	13.83	12.51

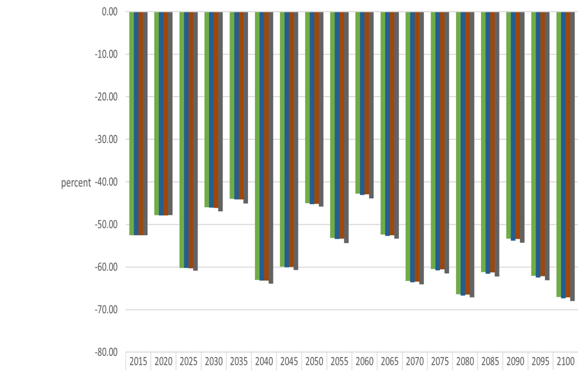


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	10.62	9.57	12.82	12.22	11.99	15.94	14.64	12.83	14.29	13.33	14.55	15.79	18.45	17.19	17.36	15.85	17.50	18.05
SSP 585 Adaptation Housing	10.61	9.54	12.74	12.07	11.75	15.59	14.19	12.30	13.66	12.65	13.80	14.96	17.51	16.13	16.18	14.58	16.21	16.82
SSP 585 Adaptation Transport	10.61	9.38	12.60	11.88	11.70	15.54	14.22	12.47	13.88	12.97	14.21	15.48	18.17	16.92	17.10	15.61	17.28	17.83
SSP 585 Adaptation Forestry	10.62	9.56	10.85	10.19	9.72	13.21	12.25	11.16	11.42	11.08	12.26	13.41	15.21	14.60	14.19	13.42	14.23	14.57

Mekong River Delta



	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	-51.00	-57.19	-52.73	-62.46	-57.10	-62.22	-55.52	-58.98	-59.66	-66.35	-55.51	-58.56	-64.96	-60.36	-38.11	-62.19	-65.33	-63.25
SSP 126 Adaptation Housing	-51.00	-57.20	-52.76	-62.51	-57.19	-62.32	-55.66	-59.14	-59.85	-66.52	-55.75	-58.80	-65.17	-60.60	-38.51	-62.42	-65.55	-63.46
SSP 126 Adaptation Transport	-51.00	-57.27	-52.82	-62.57	-57.20	-62.35	-55.61	-59.10	-59.75	-66.44	-55.61	-58.65	-65.01	-60.42	-38.19	-62.24	-65.37	-63.29
SSP 126 Adaptation Forestry	-51.00	-57.19	-53.58	-63.22	-57.88	-62.90	-56.55	-59.66	-60.36	-66.97	-56.39	-59.43	-65.76	-61.17	-39.38	-62.95	-65.97	-63.98

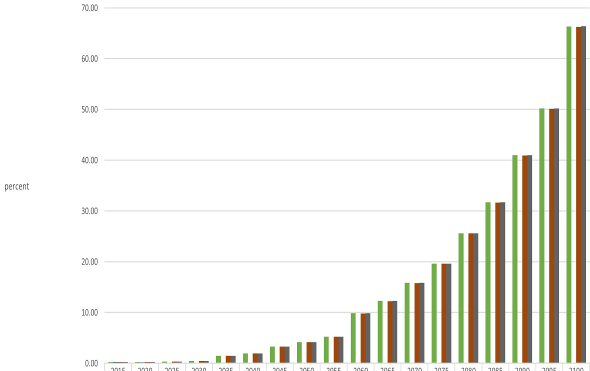


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	-52.5	-47.8	-60.2	-45.9	-43.9	-63.0	-59.8	-44.9	-53.1	-42.7	-52.3	-63.2	-60.4	-66.4	-61.2	-53.3	-62.0	-67.0
SSP 585 Adaptation Housing	-52.5	-47.8	-60.2	-46.0	-44.0	-63.1	-60.0	-45.2	-53.4	-43.0	-52.6	-63.5	-60.7	-66.7	-61.6	-53.8	-62.4	-67.3
SSP 585 Adaptation Transport	-52.5	-47.9	-60.2	-46.1	-44.1	-63.1	-60.0	-45.1	-53.3	-42.9	-52.5	-63.3	-60.5	-66.4	-61.3	-53.4	-62.1	-67.0
SSP 585 Adaptation Forestry	-52.5	-47.8	-60.9	-46.9	-45.1	-63.9	-60.7	-45.7	-54.3	-43.8	-53.3	-64.0	-61.5	-67.1	-62.2	-54.2	-63.1	-68.0

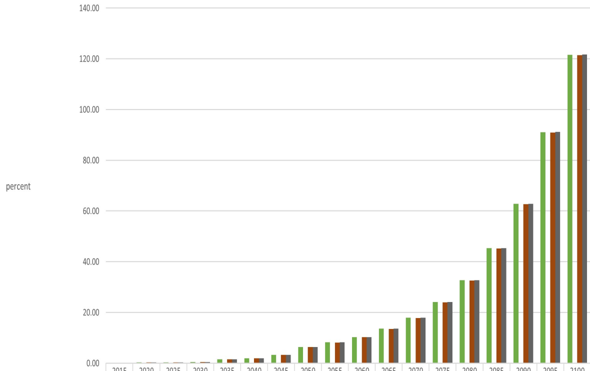
Source: own computation.

Figure 25: Housing

Damages to the housing stock

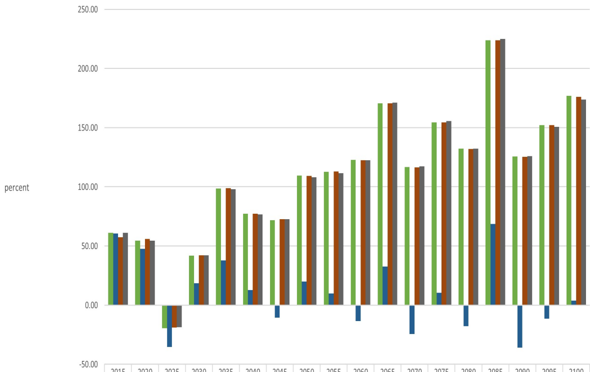


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	0.22	0.26	0.33	0.42	1.47	1.91	3.31	4.17	5.23	9.83	12.26	15.81	19.61	25.60	31.70	40.99	50.18	66.34
SSP 126 Adaptation Housing	0.22	0.17	0.06	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.01
SSP 126 Adaptation Transport	0.22	0.26	0.33	0.42	1.47	1.90	3.30	4.16	5.22	9.81	12.23	15.78	19.58	25.56	31.66	40.94	50.12	66.27
SSP 126 Adaptation Forestry	0.22	0.26	0.33	0.42	1.47	1.91	3.31	4.17	5.24	9.84	12.26	15.82	19.62	25.61	31.71	41.01	50.19	66.36

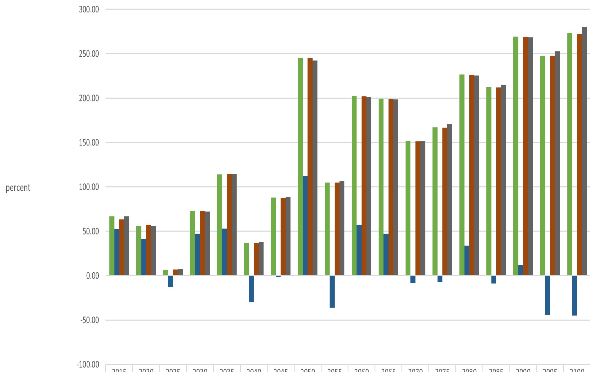


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	0.22	0.26	0.33	0.42	1.47	1.91	3.31	6.32	8.18	10.27	13.55	17.85	24.05	32.65	45.36	62.75	91.09	121.58
SSP 585 Adaptation Housing	0.07	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SSP 585 Adaptation Transport	0.22	0.26	0.33	0.42	1.47	1.90	3.30	6.30	8.16	10.24	13.51	17.81	23.99	32.58	45.26	62.62	90.92	121.35
SSP 585 Adaptation Forestry	0.22	0.26	0.33	0.42	1.47	1.91	3.31	6.32	8.19	10.27	13.55	17.86	24.06	32.66	45.38	62.77	91.16	121.68

Investment into the housing stock



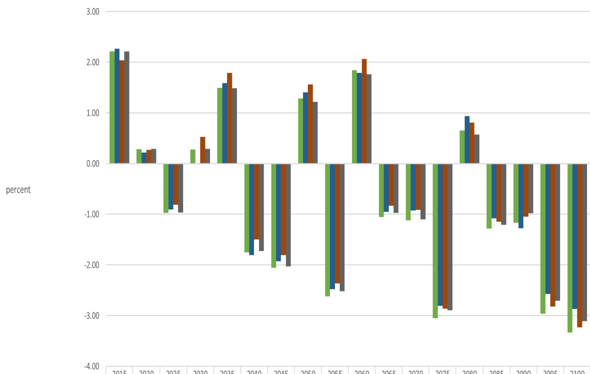
	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	61.09	54.53	-19.49	41.77	98.48	77.32	71.63	109.59	112.72	122.83	170.52	116.73	154.44	132.35	223.83	125.56	152.21	176.91
SSP 126 Adaptation Housing	60.41	47.69	-35.51	18.39	37.74	12.61	-10.63	19.94	9.73	-13.44	32.58	-24.41	10.29	-17.89	68.62	-35.95	-11.41	3.79
SSP 126 Adaptation Transport	57.47	55.87	-18.89	42.03	98.82	77.26	72.54	109.21	112.81	122.40	170.42	116.45	154.39	132.10	223.70	125.43	152.04	176.12
SSP 126 Adaptation Forestry	61.10	54.51	-18.79	42.06	98.07	76.68	72.55	107.98	111.45	122.45	171.07	117.22	155.49	132.28	225.01	126.04	150.66	173.85



	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	66.70	55.96	6.39	72.67	114.06	36.83	88.03	245.23	104.64	202.14	199.38	151.75	166.92	226.56	212.37	269.32	247.53	272.98
SSP 585 Adaptation Housing	52.55	41.51	-13.25	47.06	53.10	-30.01	-1.53	112.24	-36.01	57.00	47.34	-8.51	-7.39	33.57	-8.78	11.97	-44.27	-44.93
SSP 585 Adaptation Transport	63.20	57.26	6.95	72.86	114.22	36.80	87.49	244.78	104.86	201.82	198.84	151.30	166.42	225.91	211.83	268.80	247.52	271.74
SSP 585 Adaptation Forestry	66.71	55.94	7.28	72.20	114.42	37.69	88.13	242.32	106.20	201.08	198.55	151.50	170.54	225.48	215.17	268.48	252.70	280.14

Housing stock

	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	1.93	1.29	-0.78	0.46	1.63	0.15	-0.17	-0.44	1.37	-0.94	1.06	-3.16	0.57	-1.09	3.91	-3.60	-0.08	-2.13
SSP 126 Adaptation Housing	1.90	1.23	-0.72	0.13	1.70	0.22	-0.25	-0.32	0.47	-0.74	1.06	-3.00	0.51	-0.90	3.83	-3.38	0.09	-1.88
SSP 126 Adaptation Transport	1.75	1.28	-0.61	0.70	1.95	0.44	0.15	-0.20	1.56	-0.74	1.22	-2.99	0.71	-0.96	4.00	-3.50	-0.01	-2.06
SSP 126 Adaptation Forestry	1.93	1.29	-0.77	0.47	1.63	0.16	-0.13	-0.44	1.33	-0.93	1.14	-3.07	0.59	-1.04	3.93	-3.51	-0.13	-2.02

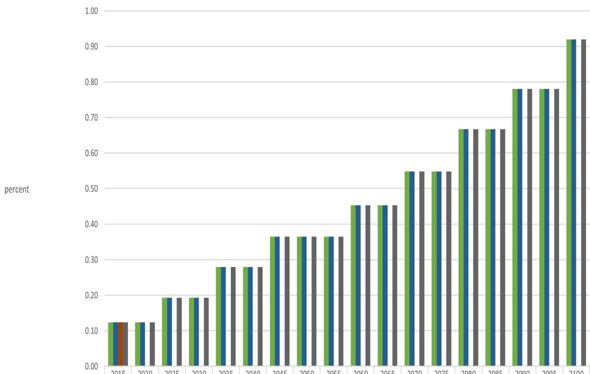


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	2.21	0.28	-0.98	0.28	1.49	-1.75	-2.06	1.28	-2.62	1.84	-1.06	-1.12	-3.05	0.65	-1.28	-1.17	-2.96	-3.33
SSP 585 Adaptation Housing	2.26	0.21	-0.91	-0.01	1.58	-1.81	-1.93	1.40	-2.48	1.79	-0.95	-0.93	-2.81	0.93	-1.08	-1.28	-2.57	-2.87
SSP 585 Adaptation Transport	2.03	0.27	-0.81	0.52	1.79	-1.50	-1.81	1.56	-2.36	2.06	-0.83	-0.92	-2.87	0.81	-1.15	-1.05	-2.82	-3.24
SSP 585 Adaptation Forestry	2.21	0.29	-0.97	0.29	1.48	-1.73	-2.03	1.22	-2.52	1.76	-0.97	-1.10	-2.90	0.57	-1.21	-0.98	-2.70	-3.11

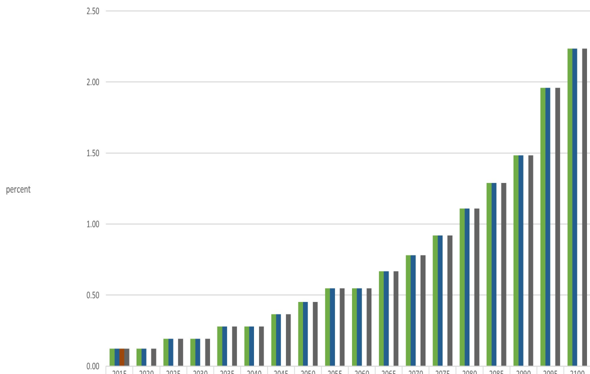
Source: own computation.

Figure 26: Damages capital stock transport

Red River Delta

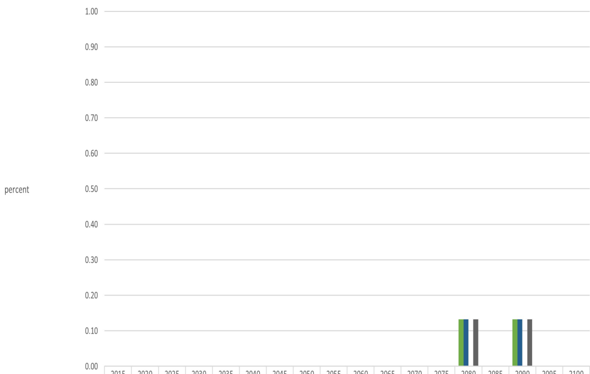


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	0.12	0.12	0.19	0.19	0.28	0.28	0.36	0.36	0.36	0.45	0.45	0.55	0.55	0.67	0.67	0.78	0.78	0.92
SSP 126 Adaptation Housing	0.12	0.12	0.19	0.19	0.28	0.28	0.36	0.36	0.36	0.45	0.45	0.55	0.55	0.67	0.67	0.78	0.78	0.92
SSP 126 Adaptation Transport	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SSP 126 Adaptation Forestry	0.12	0.12	0.19	0.19	0.28	0.28	0.36	0.36	0.36	0.45	0.45	0.55	0.55	0.67	0.67	0.78	0.78	0.92



	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	0.12	0.12	0.19	0.19	0.28	0.28	0.36	0.45	0.55	0.55	0.67	0.78	0.92	1.11	1.29	1.48	1.96	2.24
SSP 585 Adaptation Housing	0.12	0.12	0.19	0.19	0.28	0.28	0.36	0.45	0.55	0.55	0.67	0.78	0.92	1.11	1.29	1.48	1.96	2.24
SSP 585 Adaptation Transport	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SSP 585 Adaptation Forestry	0.12	0.12	0.19	0.19	0.28	0.28	0.36	0.45	0.55	0.55	0.67	0.78	0.92	1.11	1.29	1.48	1.96	2.24

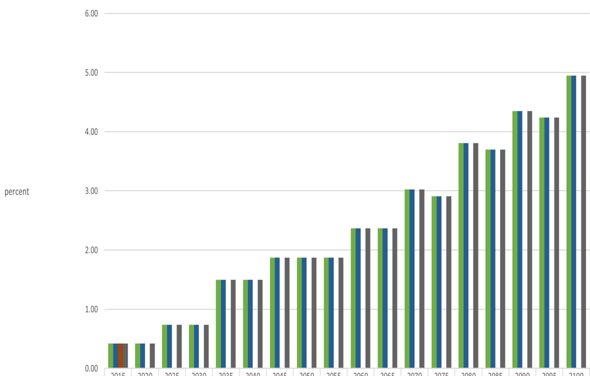
Northern midlands and mountain areas



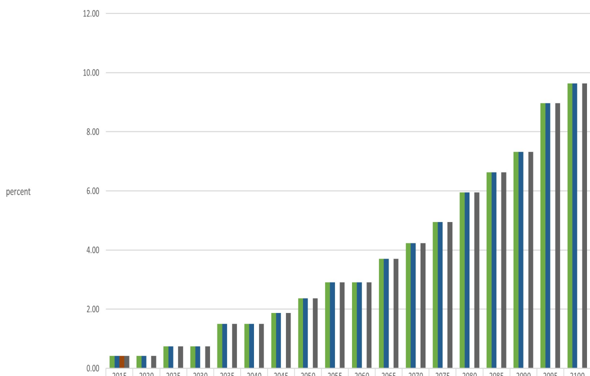
	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.13	0.00	0.00
SSP 126 Adaptation Housing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.13	0.00	0.00
SSP 126 Adaptation Transport	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SSP 126 Adaptation Forestry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.13	0.00	0.00

	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SSP 585 Adaptation Housing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SSP 585 Adaptation Transport	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SSP 585 Adaptation Forestry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Northern Central area and Central coastal area



	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	0.42	0.42	0.74	0.74	1.50	1.50	1.87	1.87	1.87	2.36	2.36	3.02	2.91	3.81	3.70	4.35	4.24	4.95
SSP 126 Adaptation Housing	0.42	0.42	0.74	0.74	1.50	1.50	1.87	1.87	1.87	2.36	2.36	3.02	2.91	3.81	3.70	4.35	4.24	4.95
SSP 126 Adaptation Transport	0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SSP 126 Adaptation Forestry	0.42	0.42	0.74	0.74	1.50	1.50	1.87	1.87	1.87	2.36	2.36	3.02	2.91	3.81	3.70	4.35	4.24	4.95



	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	0.42	0.42	0.74	0.74	1.50	1.50	1.87	2.36	2.91	2.91	3.70	4.24	4.95	5.94	6.63	7.32	8.96	9.63
SSP 585 Adaptation Housing	0.42	0.42	0.74	0.74	1.50	1.50	1.87	2.36	2.91	2.91	3.70	4.24	4.95	5.94	6.63	7.32	8.96	9.63
SSP 585 Adaptation Transport	0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SSP 585 Adaptation Forestry	0.42	0.42	0.74	0.74	1.50	1.50	1.87	2.36	2.91	2.91	3.70	4.24	4.95	5.94	6.63	7.32	8.96	9.63

Source: own computation.

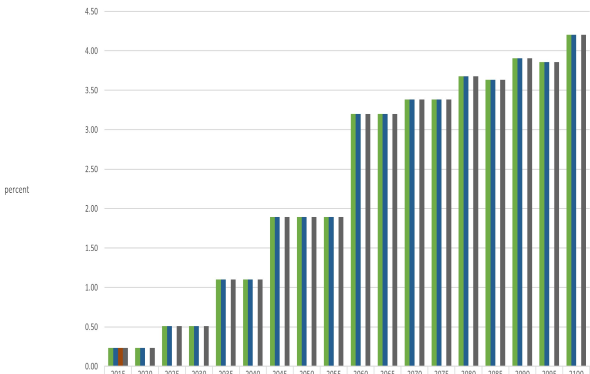
Damages capital stock transport (continued)

Central Highlands

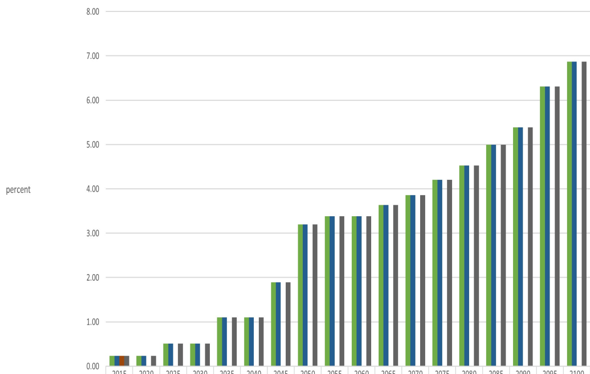
	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SSP 126 Adaptation Housing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SSP 126 Adaptation Transport	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SSP 126 Adaptation Forestry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SSP 585 Adaptation Housing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SSP 585 Adaptation Transport	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SSP 585 Adaptation Forestry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

South East

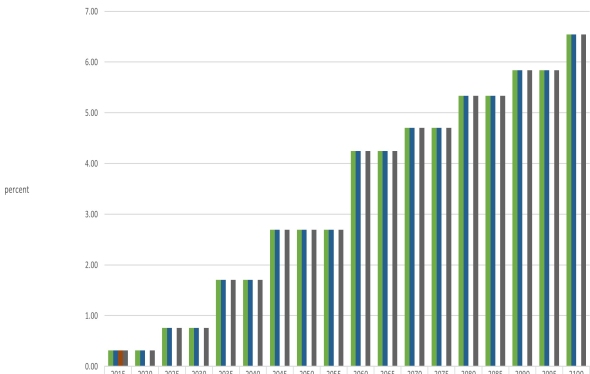


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	0.23	0.23	0.51	0.51	1.10	1.10	1.89	1.89	1.89	3.20	3.20	3.38	3.38	3.68	3.63	3.90	3.86	4.20
SSP 126 Adaptation Housing	0.23	0.23	0.51	0.51	1.10	1.10	1.89	1.89	1.89	3.20	3.20	3.38	3.38	3.68	3.63	3.90	3.86	4.20
SSP 126 Adaptation Transport	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SSP 126 Adaptation Forestry	0.23	0.23	0.51	0.51	1.10	1.10	1.89	1.89	1.89	3.20	3.20	3.38	3.38	3.68	3.63	3.90	3.86	4.20

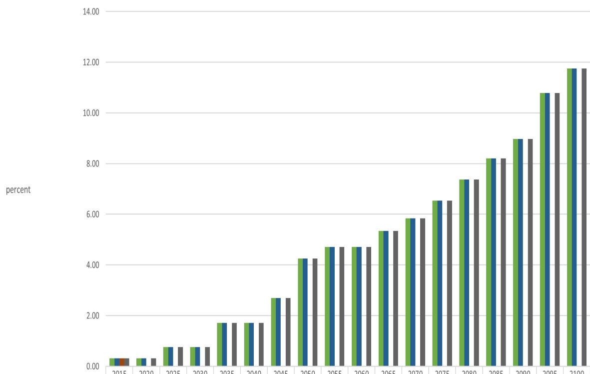


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	0.23	0.23	0.51	0.51	1.10	1.10	1.89	3.20	3.38	3.38	3.63	3.86	4.20	4.52	4.99	5.39	6.31	6.87
SSP 585 Adaptation Housing	0.23	0.23	0.51	0.51	1.10	1.10	1.89	3.20	3.38	3.38	3.63	3.86	4.20	4.52	4.99	5.39	6.31	6.87
SSP 585 Adaptation Transport	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SSP 585 Adaptation Forestry	0.23	0.23	0.51	0.51	1.10	1.10	1.89	3.20	3.38	3.38	3.63	3.86	4.20	4.52	4.99	5.39	6.31	6.87

Mekong River Delta



	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	0.32	0.32	0.76	0.76	1.71	1.71	2.69	2.69	2.69	4.25	4.25	4.70	4.70	5.33	5.33	5.84	5.84	6.54
SSP 126 Adaptation Housing	0.32	0.32	0.76	0.76	1.71	1.71	2.69	2.69	2.69	4.25	4.25	4.70	4.70	5.33	5.33	5.84	5.84	6.54
SSP 126 Adaptation Transport	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SSP 126 Adaptation Forestry	0.32	0.32	0.76	0.76	1.71	1.71	2.69	2.69	2.69	4.25	4.25	4.70	4.70	5.33	5.33	5.84	5.84	6.54

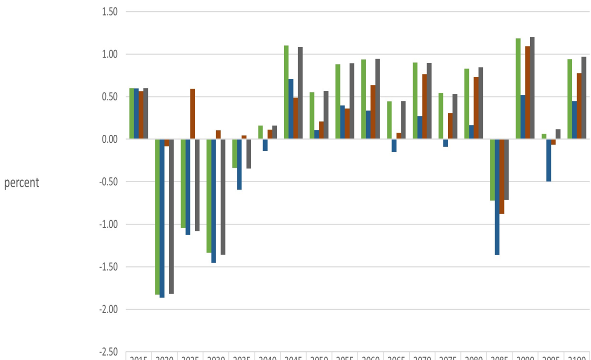


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	0.32	0.32	0.76	0.76	1.71	1.71	2.69	4.25	4.70	4.70	5.33	5.84	6.54	7.36	8.20	8.97	10.79	11.74
SSP 585 Adaptation Housing	0.32	0.32	0.76	0.76	1.71	1.71	2.69	4.25	4.70	4.70	5.33	5.84	6.54	7.36	8.20	8.97	10.79	11.74
SSP 585 Adaptation Transport	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SSP 585 Adaptation Forestry	0.32	0.32	0.76	0.76	1.71	1.71	2.69	4.25	4.70	4.70	5.33	5.84	6.54	7.36	8.20	8.97	10.79	11.74

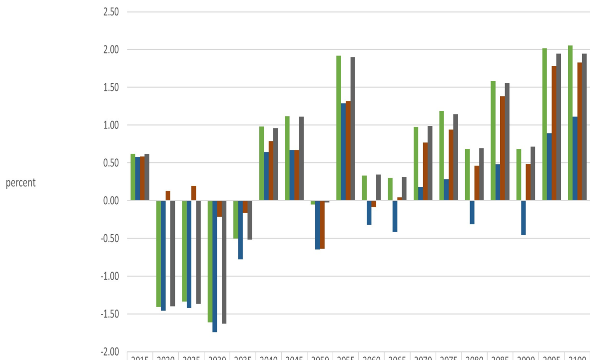
Source: own computation.

Figure 27: Capital stock transport

Red River Delta

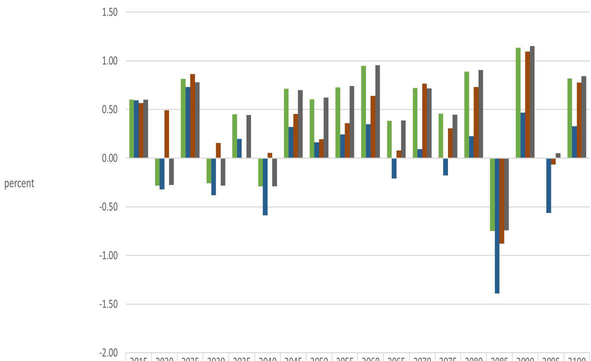


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	0.60	-1.83	-1.05	-1.33	-0.34	0.16	1.10	0.55	0.88	0.94	0.45	0.90	0.55	0.83	-0.72	1.19	0.07	0.94
SSP 126 Adaptation Housing	0.60	-1.86	-1.13	-1.45	-0.59	-0.14	0.71	0.11	0.40	0.34	-0.15	0.27	-0.09	0.16	-1.36	0.52	-0.50	0.45
SSP 126 Adaptation Transport	0.57	-0.09	0.59	0.11	0.04	0.11	0.49	0.21	0.36	0.64	0.08	0.77	0.31	0.73	-0.88	1.09	-0.07	0.78
SSP 126 Adaptation Forestry	0.60	-1.82	-1.08	-1.36	-0.34	0.16	1.09	0.57	0.89	0.95	0.45	0.90	0.53	0.85	-0.71	1.20	0.11	0.97

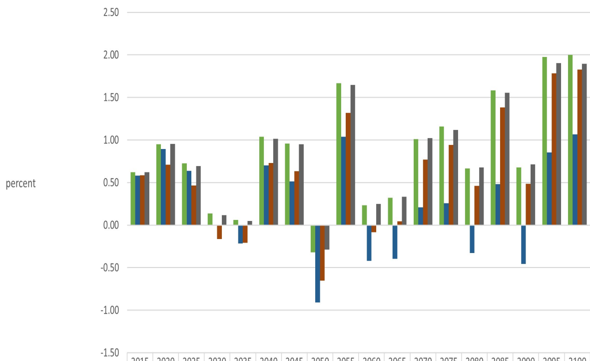


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	0.62	-1.41	-1.33	-1.61	-0.50	0.98	1.12	-0.05	1.92	0.33	0.30	0.98	1.19	0.68	1.59	0.68	2.02	2.05
SSP 585 Adaptation Housing	0.58	-1.46	-1.42	-1.74	-0.78	0.64	0.67	-0.64	1.29	-0.32	-0.42	0.18	0.28	-0.31	0.48	-0.46	0.89	1.11
SSP 585 Adaptation Transport	0.59	0.13	0.20	-0.21	-0.16	0.79	0.67	-0.64	1.32	-0.09	0.04	0.77	0.94	0.46	1.38	0.48	1.78	1.83
SSP 585 Adaptation Forestry	0.62	-1.40	-1.37	-1.63	-0.51	0.96	1.11	-0.02	1.90	0.35	0.31	0.99	1.15	0.69	1.56	0.72	1.95	1.95

Northern midlands and mountain areas

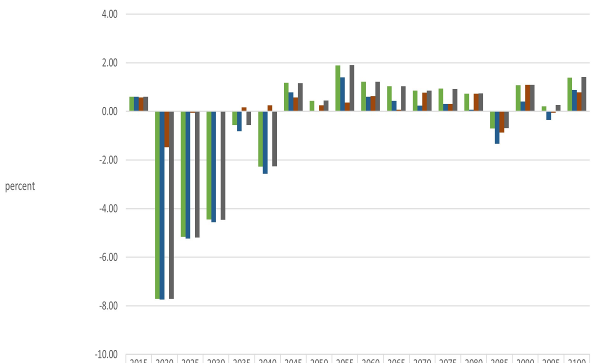


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	0.60	-0.28	0.81	-0.26	0.45	-0.29	0.71	0.60	0.73	0.95	0.38	0.72	0.46	0.89	-0.75	1.14	0.00	0.82
SSP 126 Adaptation Housing	0.60	-0.32	0.73	-0.38	0.20	-0.59	0.32	0.16	0.24	0.35	-0.21	0.09	-0.18	0.23	-1.39	0.47	-0.56	0.33
SSP 126 Adaptation Transport	0.57	0.49	0.86	0.16	0.00	0.05	0.45	0.20	0.36	0.64	0.08	0.77	0.31	0.73	-0.88	1.09	-0.07	0.78
SSP 126 Adaptation Forestry	0.60	-0.27	0.78	-0.28	0.44	-0.29	0.70	0.62	0.74	0.96	0.39	0.72	0.45	0.91	-0.74	1.15	0.05	0.84

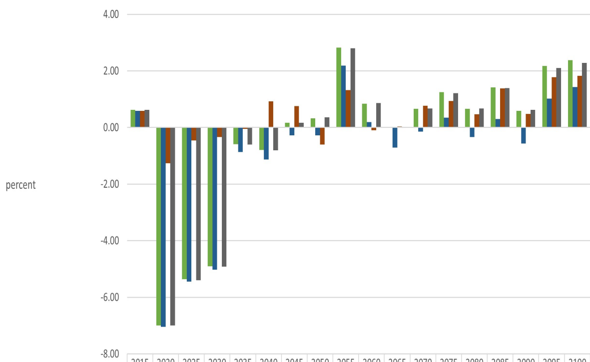


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	0.62	0.95	0.72	0.14	0.06	1.04	0.96	-0.32	1.67	0.23	0.32	1.01	1.16	0.66	1.58	0.68	1.98	2.00
SSP 585 Adaptation Housing	0.58	0.89	0.64	0.01	-0.21	0.70	0.51	-0.91	1.04	-0.42	-0.40	0.21	0.26	-0.33	0.48	-0.46	0.86	1.07
SSP 585 Adaptation Transport	0.59	0.71	0.47	-0.16	-0.21	0.73	0.63	-0.65	1.32	-0.09	0.04	0.77	0.94	0.46	1.38	0.48	1.78	1.83
SSP 585 Adaptation Forestry	0.62	0.95	0.69	0.12	0.05	1.01	0.95	-0.29	1.65	0.25	0.33	1.02	1.12	0.68	1.55	0.71	1.91	1.90

Northern Central area and Central coastal area



	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	0.60	-7.72	-5.16	-4.44	-0.56	-2.27	1.17	0.43	1.89	1.21	1.03	0.86	0.94	0.73	-0.70	1.07	0.21	1.38
SSP 126 Adaptation Housing	0.60	-7.75	-5.23	-4.56	-0.81	-2.56	0.78	-0.01	1.40	0.61	0.44	0.23	0.30	0.06	-1.34	0.40	-0.36	0.89
SSP 126 Adaptation Transport	0.57	-1.48	-0.06	-0.02	0.16	0.25	0.58	0.24	0.37	0.63	0.07	0.76	0.31	0.73	-0.88	1.09	-0.07	0.78
SSP 126 Adaptation Forestry	0.60	-7.71	-5.19	-4.47	-0.56	-2.26	1.16	0.45	1.91	1.22	1.03	0.86	0.92	0.75	-0.69	1.09	0.26	1.41

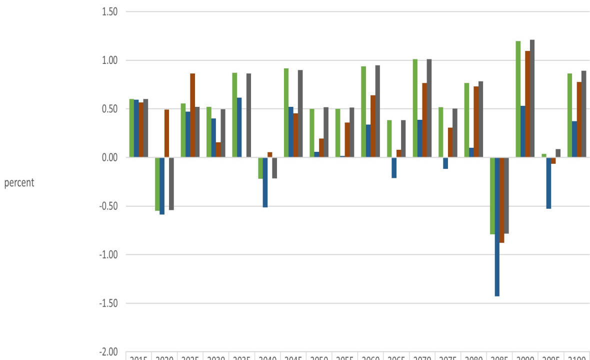


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	0.62	-7.00	-5.37	-4.90	-0.60	-0.79	0.17	0.32	2.82	0.84	0.00	0.66	1.25	0.66	1.42	0.59	2.17	2.38
SSP 585 Adaptation Housing	0.58	-7.05	-5.44	-5.03	-0.87	-1.13	-0.28	-0.28	2.19	0.19	-0.71	-0.14	0.35	-0.33	0.30	-0.57	1.02	1.43
SSP 585 Adaptation Transport	0.59	-1.27	-0.46	-0.34	-0.05	0.93	0.76	-0.60	1.33	-0.09	0.04	0.77	0.94	0.46	1.38	0.48	1.78	1.83
SSP 585 Adaptation Forestry	0.62	-7.00	-5.40	-4.92	-0.61	-0.81	0.16	0.35	2.80	0.86	0.02	0.67	1.21	0.68	1.39	0.62	2.10	2.28

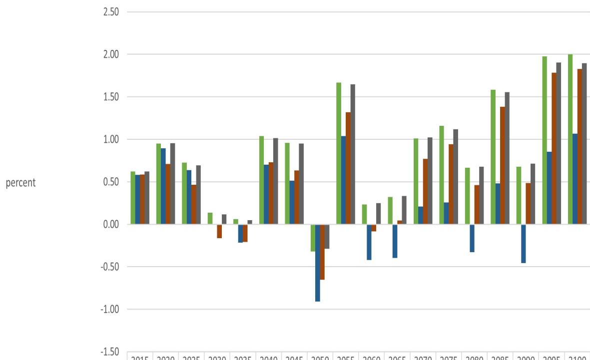
Source: own computation.

Capital stock transport (continued)

Central Highlands

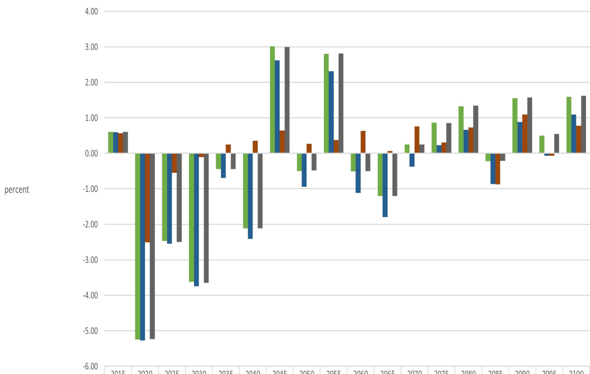


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	0.60	-0.55	0.55	0.52	0.87	-0.22	0.92	0.50	0.50	0.94	0.38	1.01	0.52	0.76	-0.79	1.20	0.04	0.86
SSP 126 Adaptation Housing	0.60	-0.59	0.47	0.40	0.61	-0.51	0.52	0.06	0.02	0.34	-0.21	0.39	-0.12	0.10	-1.43	0.53	-0.53	0.37
SSP 126 Adaptation Transport	0.57	0.49	0.86	0.16	0.00	0.05	0.45	0.20	0.36	0.64	0.08	0.77	0.31	0.73	-0.88	1.09	-0.07	0.78
SSP 126 Adaptation Forestry	0.60	-0.54	0.52	0.50	0.86	-0.22	0.90	0.52	0.51	0.95	0.38	1.01	0.50	0.78	-0.78	1.21	0.08	0.89

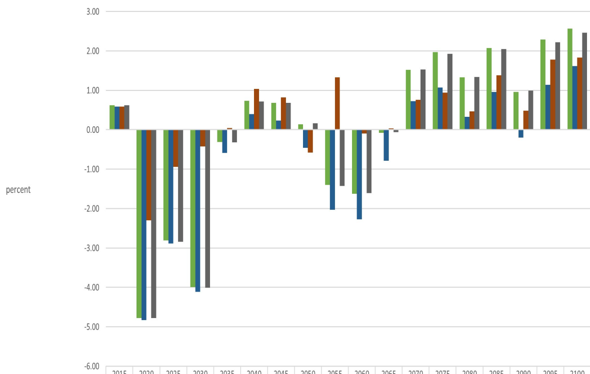


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	0.62	0.95	0.72	0.14	0.06	1.04	0.96	-0.32	1.67	0.23	0.32	1.01	1.16	0.66	1.58	0.68	1.98	2.00
SSP 585 Adaptation Housing	0.58	0.89	0.64	0.01	-0.21	0.70	0.51	-0.91	1.04	-0.42	-0.40	0.21	0.26	-0.33	0.48	-0.46	0.86	1.07
SSP 585 Adaptation Transport	0.59	0.71	0.47	-0.16	-0.21	0.73	0.63	-0.65	1.32	-0.09	0.04	0.77	0.94	0.46	1.38	0.48	1.78	1.83
SSP 585 Adaptation Forestry	0.62	0.95	0.69	0.12	0.05	1.01	0.95	-0.29	1.65	0.25	0.33	1.02	1.12	0.68	1.55	0.71	1.91	1.90

South East

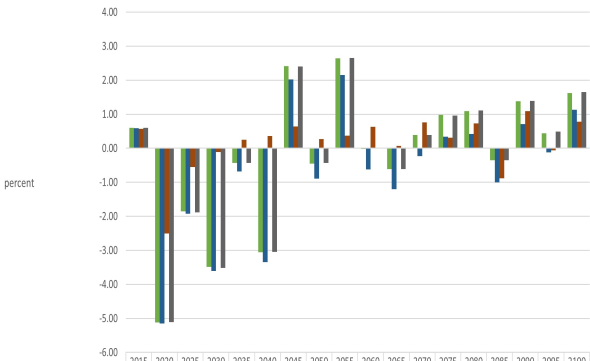


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	0.60	-5.24	-2.47	-3.62	-0.44	-2.11	3.01	-0.50	2.80	-0.51	-1.20	0.25	0.87	1.32	-0.22	1.55	0.50	1.59
SSP 126 Adaptation Housing	0.60	-5.27	-2.54	-3.74	-0.70	-2.41	2.62	-0.94	2.31	-1.12	-1.79	-0.37	0.23	0.66	-0.86	0.88	-0.07	1.10
SSP 126 Adaptation Transport	0.57	-2.51	-0.55	-0.11	0.24	0.36	0.64	0.27	0.37	0.63	0.07	0.76	0.30	0.73	-0.88	1.09	-0.07	0.78
SSP 126 Adaptation Forestry	0.60	-5.24	-2.50	-3.65	-0.45	-2.11	3.00	-0.48	2.82	-0.50	-1.20	0.25	0.85	1.34	-0.21	1.57	0.55	1.62

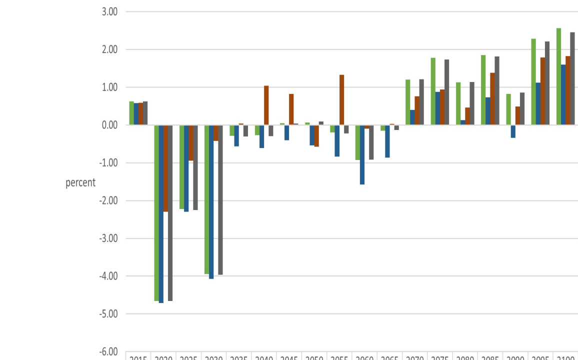


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	0.62	-4.78	-2.81	-3.99	-0.31	0.74	0.68	0.14	-1.40	-1.62	-0.07	1.52	1.97	1.33	2.07	0.96	2.29	2.57
SSP 585 Adaptation Housing	0.58	-4.83	-2.89	-4.12	-0.59	0.40	0.24	-0.46	-2.04	-2.27	-0.79	0.72	1.07	0.33	0.96	-0.20	1.14	1.61
SSP 585 Adaptation Transport	0.59	-2.30	-0.94	-0.43	0.04	1.03	0.82	-0.58	1.33	-0.10	0.03	0.76	0.94	0.46	1.38	0.48	1.78	1.83
SSP 585 Adaptation Forestry	0.62	-4.78	-2.84	-4.01	-0.32	0.72	0.68	0.17	-1.42	-1.61	-0.06	1.53	1.93	1.34	2.04	0.99	2.22	2.46

Mekong River Delta



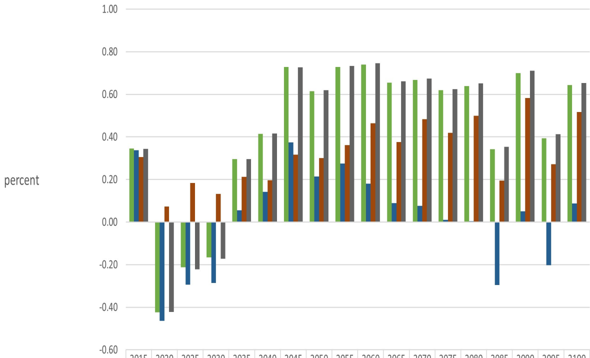
	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	0.60	-5.12	-1.85	-3.49	-0.43	-3.05	2.42	-0.45	2.64	-0.02	-0.61	0.39	0.98	1.09	-0.36	1.38	0.44	1.62
SSP 126 Adaptation Housing	0.60	-5.15	-1.92	-3.61	-0.69	-3.35	2.02	-0.89	2.15	-0.62	-1.20	-0.23	0.34	0.42	-1.00	0.71	-0.13	1.13
SSP 126 Adaptation Transport	0.57	-2.51	-0.55	-0.11	0.24	0.36	0.64	0.27	0.37	0.63	0.07	0.76	0.30	0.73	-0.88	1.09	-0.07	0.78
SSP 126 Adaptation Forestry	0.60	-5.11	-1.88	-3.51	-0.43	-3.05	2.40	-0.43	2.66	-0.01	-0.61	0.39	0.96	1.11	-0.35	1.40	0.49	1.65



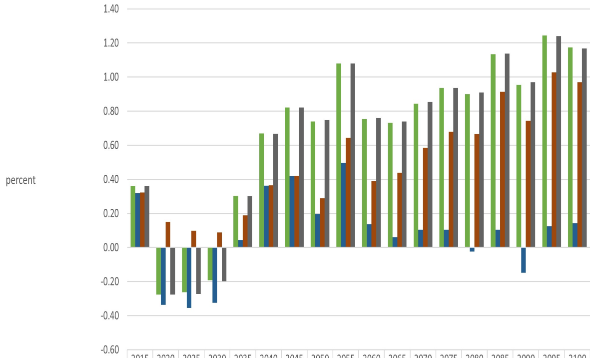
	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	0.62	-4.66	-2.22	-3.95	-0.29	-0.27	0.05	0.06	-0.20	-0.93	-0.15	1.20	1.78	1.13	1.85	0.82	2.28	2.56
SSP 585 Adaptation Housing	0.58	-4.71	-2.30	-4.07	-0.56	-0.61	-0.40	-0.54	-0.83	-1.58	-0.86	0.40	0.88	0.13	0.73	-0.34	1.12	1.60
SSP 585 Adaptation Transport	0.59	-2.30	-0.94	-0.43	0.04	1.03	0.82	-0.58	1.33	-0.10	0.03	0.76	0.94	0.46	1.38	0.48	1.78	1.83
SSP 585 Adaptation Forestry	0.62	-4.65	-2.25	-3.96	-0.30	-0.29	0.04	0.09	-0.22	-0.91	-0.14	1.21	1.74	1.14	1.82	0.86	2.21	2.45

Source: own computation.

Figure 28: Value added transport
Red River Delta

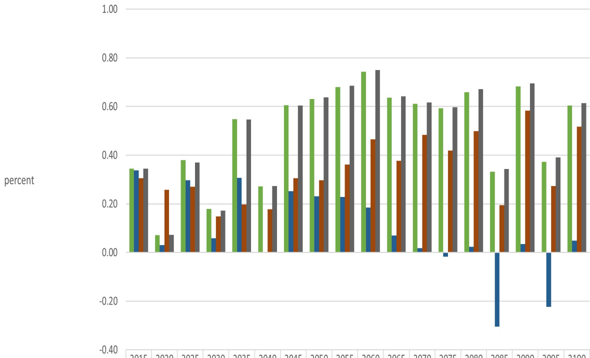


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	0.34	-0.42	-0.21	-0.17	0.30	0.41	0.73	0.61	0.73	0.74	0.66	0.67	0.62	0.64	0.34	0.70	0.39	0.64
SSP 126 Adaptation Housing	0.34	-0.46	-0.29	-0.29	0.05	0.14	0.37	0.21	0.28	0.18	0.09	0.08	0.01	0.00	-0.30	0.05	-0.20	0.09
SSP 126 Adaptation Transport	0.31	0.07	0.18	0.13	0.21	0.20	0.32	0.30	0.36	0.46	0.38	0.48	0.42	0.50	0.19	0.58	0.27	0.52
SSP 126 Adaptation Forestry	0.34	-0.42	-0.22	-0.17	0.30	0.42	0.73	0.62	0.73	0.75	0.66	0.67	0.62	0.65	0.35	0.71	0.41	0.65

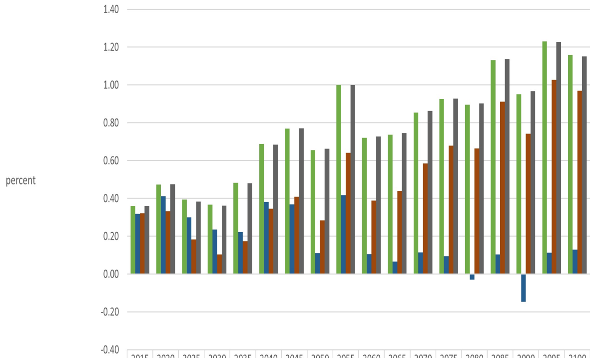


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	0.36	-0.28	-0.26	-0.19	0.30	0.67	0.82	0.74	1.08	0.75	0.73	0.84	0.94	0.90	1.13	0.95	1.24	1.17
SSP 585 Adaptation Housing	0.32	-0.34	-0.35	-0.32	0.04	0.36	0.42	0.20	0.50	0.14	0.06	0.10	0.10	-0.02	0.10	-0.15	0.12	0.14
SSP 585 Adaptation Transport	0.32	0.15	0.10	0.09	0.19	0.36	0.42	0.29	0.64	0.39	0.44	0.59	0.68	0.66	0.91	0.74	1.03	0.97
SSP 585 Adaptation Forestry	0.36	-0.28	-0.27	-0.20	0.30	0.67	0.82	0.75	1.08	0.76	0.74	0.85	0.94	0.91	1.14	0.97	1.24	1.17

Northern midlands and mountain areas

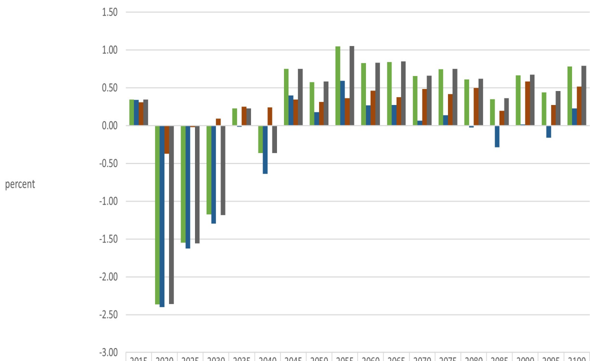


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	0.34	0.07	0.38	0.18	0.55	0.27	0.61	0.63	0.68	0.74	0.64	0.61	0.59	0.66	0.33	0.68	0.37	0.60
SSP 126 Adaptation Housing	0.34	0.03	0.30	0.06	0.31	0.00	0.25	0.23	0.23	0.18	0.07	0.02	-0.02	0.02	-0.30	0.03	-0.22	0.05
SSP 126 Adaptation Transport	0.31	0.26	0.27	0.15	0.20	0.18	0.30	0.30	0.36	0.47	0.38	0.48	0.42	0.50	0.19	0.58	0.27	0.52
SSP 126 Adaptation Forestry	0.34	0.07	0.37	0.17	0.55	0.27	0.60	0.64	0.69	0.75	0.64	0.62	0.60	0.67	0.34	0.69	0.39	0.61

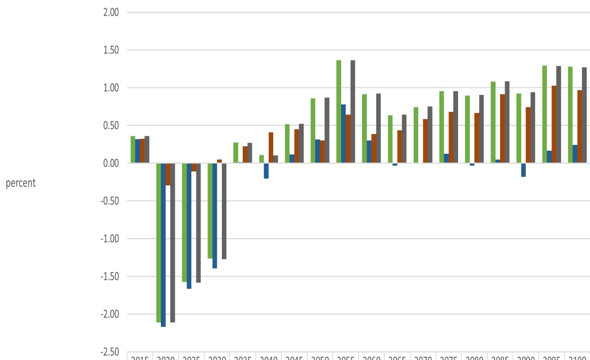


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	0.36	0.47	0.39	0.37	0.48	0.69	0.77	0.65	1.00	0.72	0.74	0.85	0.93	0.89	1.13	0.95	1.23	1.16
SSP 585 Adaptation Housing	0.32	0.41	0.30	0.24	0.22	0.38	0.37	0.11	0.42	0.11	0.07	0.11	0.10	-0.03	0.10	-0.15	0.11	0.13
SSP 585 Adaptation Transport	0.32	0.33	0.18	0.10	0.17	0.35	0.41	0.28	0.64	0.39	0.44	0.59	0.68	0.66	0.91	0.74	1.03	0.97
SSP 585 Adaptation Forestry	0.36	0.47	0.38	0.36	0.48	0.68	0.77	0.66	1.00	0.73	0.74	0.86	0.93	0.90	1.14	0.97	1.23	1.15

Northern Central area and Central coastal area



	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	0.345	-2.363	-1.547	-1.176	0.226	-0.363	0.751	0.576	1.047	0.826	0.840	0.655	0.744	0.608	0.349	0.662	0.439	0.782
SSP 126 Adaptation Housing	0.338	-2.400	-1.627	-1.295	-0.016	-0.637	0.397	0.176	0.594	0.266	0.274	0.063	0.135	-0.027	-0.289	0.013	-0.159	0.225
SSP 126 Adaptation Transport	0.306	-0.372	-0.023	0.094	0.250	0.241	0.344	0.312	0.364	0.463	0.375	0.482	0.418	0.499	0.195	0.583	0.272	0.516
SSP 126 Adaptation Forestry	0.344	-2.361	-1.558	-1.182	0.225	-0.361	0.750	0.582	1.053	0.833	0.847	0.661	0.748	0.620	0.360	0.675	0.458	0.792

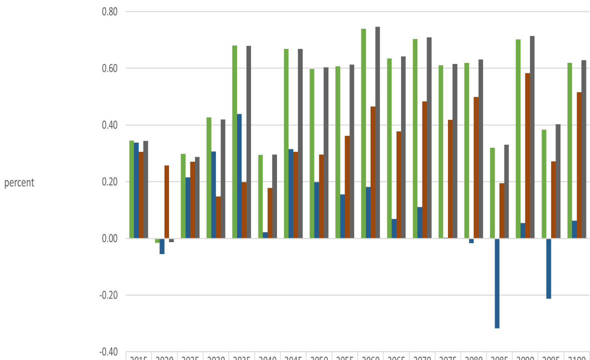


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	0.360	-2.111	-1.575	-1.264	0.273	0.106	0.519	0.860	1.363	0.915	0.636	0.742	0.956	0.894	1.079	0.923	1.291	1.278
SSP 585 Adaptation Housing	0.319	-2.167	-1.664	-1.394	0.014	-0.202	0.115	0.314	0.780	0.300	-0.034	0.003	0.125	-0.031	0.047	-0.182	0.165	0.241
SSP 585 Adaptation Transport	0.322	-0.296	-0.109	0.050	0.226	0.409	0.448	0.299	0.644	0.387	0.437	0.584	0.678	0.664	0.913	0.743	1.028	0.970
SSP 585 Adaptation Forestry	0.360	-2.109	-1.585	-1.270	0.271	0.103	0.520	0.868	1.364	0.922	0.644	0.751	0.957	0.903	1.084	0.940	1.288	1.270

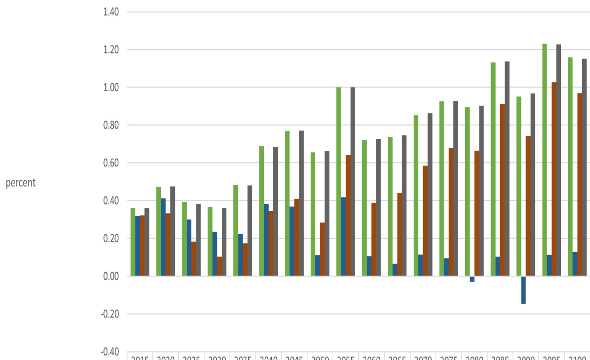
Source: own computation.

Value added transport (continued)

Central Highlands

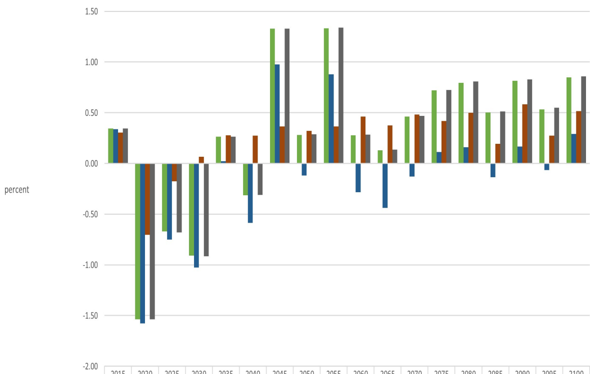


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	0.34	-0.02	0.30	0.43	0.68	0.29	0.67	0.60	0.61	0.74	0.63	0.70	0.61	0.62	0.32	0.70	0.38	0.62
SSP 126 Adaptation Housing	0.34	-0.06	0.22	0.31	0.44	0.02	0.32	0.20	0.16	0.18	0.07	0.11	0.00	-0.02	-0.32	0.05	-0.21	0.06
SSP 126 Adaptation Transport	0.31	0.26	0.27	0.15	0.20	0.18	0.30	0.30	0.36	0.47	0.38	0.48	0.42	0.50	0.19	0.58	0.27	0.52
SSP 126 Adaptation Forestry	0.34	-0.01	0.29	0.42	0.68	0.30	0.67	0.60	0.61	0.75	0.64	0.71	0.62	0.63	0.33	0.71	0.40	0.63

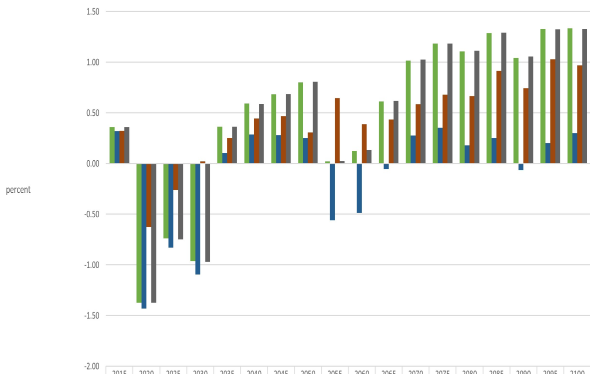


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	0.36	0.47	0.39	0.37	0.48	0.69	0.77	0.65	1.00	0.72	0.74	0.85	0.93	0.89	1.13	0.95	1.23	1.16
SSP 585 Adaptation Housing	0.32	0.41	0.30	0.24	0.22	0.38	0.37	0.11	0.42	0.11	0.07	0.11	0.10	-0.03	0.10	-0.15	0.11	0.13
SSP 585 Adaptation Transport	0.32	0.33	0.18	0.10	0.17	0.35	0.41	0.28	0.64	0.39	0.44	0.59	0.68	0.66	0.91	0.74	1.03	0.97
SSP 585 Adaptation Forestry	0.36	0.47	0.38	0.36	0.48	0.68	0.77	0.66	1.00	0.73	0.74	0.86	0.93	0.90	1.14	0.97	1.23	1.15

South East

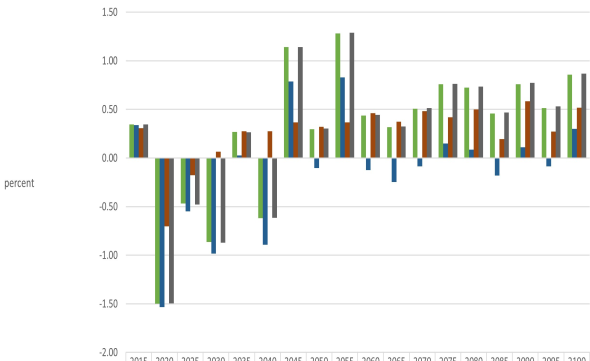


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	0.34	-1.54	-0.67	-0.91	0.26	-0.31	1.33	0.28	1.33	0.28	0.13	0.46	0.72	0.80	0.50	0.81	0.53	0.85
SSP 126 Adaptation Housing	0.34	-1.58	-0.75	-1.03	0.02	-0.59	0.98	-0.12	0.88	-0.28	-0.44	-0.13	0.11	0.16	-0.14	0.17	-0.07	0.29
SSP 126 Adaptation Transport	0.31	-0.70	-0.18	0.07	0.28	0.27	0.36	0.32	0.36	0.46	0.37	0.48	0.42	0.50	0.19	0.58	0.27	0.52
SSP 126 Adaptation Forestry	0.34	-1.54	-0.68	-0.91	0.26	-0.31	1.33	0.29	1.34	0.28	0.14	0.47	0.73	0.81	0.51	0.83	0.55	0.86

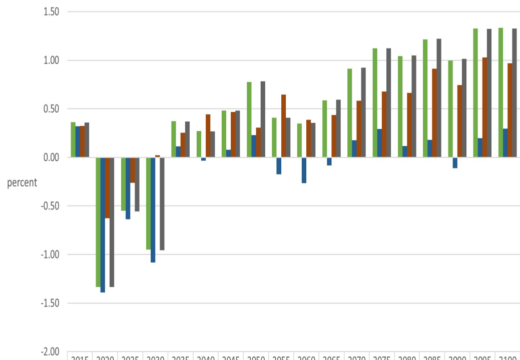


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	0.36	-1.37	-0.74	-0.96	0.36	0.59	0.68	0.80	0.02	0.13	0.61	1.02	1.18	1.10	1.29	1.04	1.33	1.34
SSP 585 Adaptation Housing	0.32	-1.43	-0.83	-1.10	0.11	0.29	0.28	0.25	-0.56	-0.49	-0.06	0.28	0.35	0.18	0.25	-0.07	0.20	0.30
SSP 585 Adaptation Transport	0.32	-0.63	-0.26	0.02	0.25	0.44	0.47	0.31	0.64	0.39	0.44	0.58	0.68	0.66	0.91	0.74	1.03	0.97
SSP 585 Adaptation Forestry	0.36	-1.37	-0.75	-0.97	0.36	0.59	0.69	0.81	0.02	0.13	0.62	1.02	1.18	1.11	1.29	1.06	1.33	1.33

Mekong River Delta



	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	0.34	-1.50	-0.47	-0.86	0.27	-0.62	1.14	0.30	1.28	0.44	0.32	0.51	0.76	0.72	0.46	0.76	0.51	0.86
SSP 126 Adaptation Housing	0.34	-1.54	-0.55	-0.98	0.03	-0.89	0.79	-0.10	0.83	-0.12	-0.25	-0.09	0.15	0.09	-0.18	0.11	-0.08	0.30
SSP 126 Adaptation Transport	0.31	-0.70	-0.18	0.07	0.28	0.27	0.36	0.32	0.36	0.46	0.37	0.48	0.42	0.50	0.19	0.58	0.27	0.52
SSP 126 Adaptation Forestry	0.34	-1.50	-0.48	-0.87	0.27	-0.62	1.14	0.30	1.29	0.44	0.33	0.51	0.76	0.73	0.47	0.77	0.53	0.87

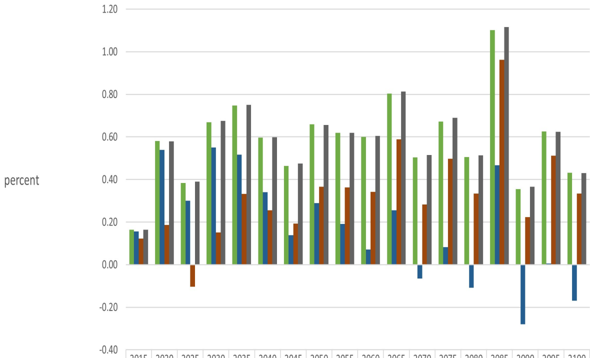


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	0.36	-1.33	-0.55	-0.95	0.37	0.27	0.48	0.78	0.41	0.35	0.59	0.91	1.12	1.04	1.21	1.00	1.32	1.33
SSP 585 Adaptation Housing	0.32	-1.39	-0.64	-1.08	0.11	-0.04	0.08	0.23	-0.18	-0.27	-0.08	0.17	0.29	0.12	0.18	-0.11	0.20	0.29
SSP 585 Adaptation Transport	0.32	-0.63	-0.26	0.02	0.25	0.44	0.47	0.31	0.64	0.39	0.44	0.58	0.68	0.66	0.91	0.74	1.03	0.97
SSP 585 Adaptation Forestry	0.36	-1.33	-0.56	-0.96	0.37	0.27	0.48	0.78	0.41	0.36	0.59	0.92	1.12	1.05	1.22	1.01	1.32	1.33

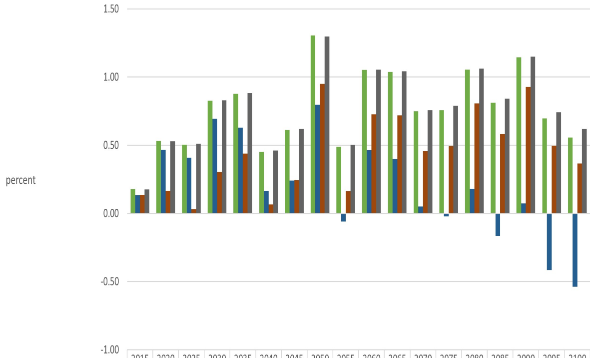
Source: own computation.

Figure 29: Employment transport

Red River Delta

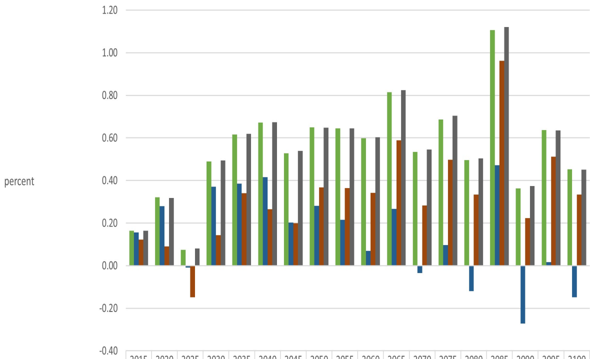


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	0.16	0.58	0.38	0.67	0.75	0.60	0.46	0.66	0.62	0.60	0.80	0.50	0.67	0.51	1.10	0.35	0.63	0.43
SSP 126 Adaptation Housing	0.16	0.54	0.30	0.55	0.52	0.34	0.14	0.29	0.19	0.07	0.26	-0.06	0.08	-0.11	0.47	-0.28	0.01	-0.17
SSP 126 Adaptation Transport	0.12	0.19	-0.10	0.15	0.33	0.26	0.19	0.37	0.36	0.34	0.59	0.28	0.50	0.33	0.96	0.22	0.51	0.33
SSP 126 Adaptation Forestry	0.16	0.58	0.39	0.68	0.75	0.60	0.47	0.66	0.62	0.60	0.81	0.52	0.69	0.51	1.12	0.37	0.62	0.43

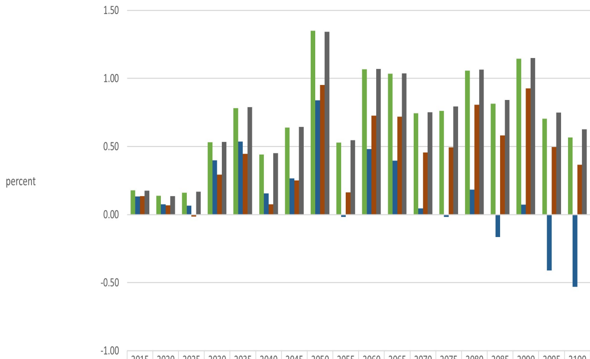


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	0.18	0.53	0.50	0.83	0.88	0.45	0.61	1.30	0.49	1.05	1.04	0.75	0.76	1.05	0.81	1.14	0.70	0.56
SSP 585 Adaptation Housing	0.13	0.47	0.41	0.69	0.63	0.17	0.24	0.80	-0.06	0.46	0.40	0.05	-0.02	0.18	-0.16	0.07	-0.42	-0.54
SSP 585 Adaptation Transport	0.14	0.16	0.03	0.30	0.44	0.07	0.24	0.95	0.16	0.73	0.72	0.46	0.49	0.81	0.58	0.93	0.50	0.37
SSP 585 Adaptation Forestry	0.18	0.53	0.51	0.83	0.88	0.46	0.62	1.30	0.50	1.05	1.04	0.76	0.79	1.06	0.84	1.15	0.74	0.62

Northern midlands and mountain areas

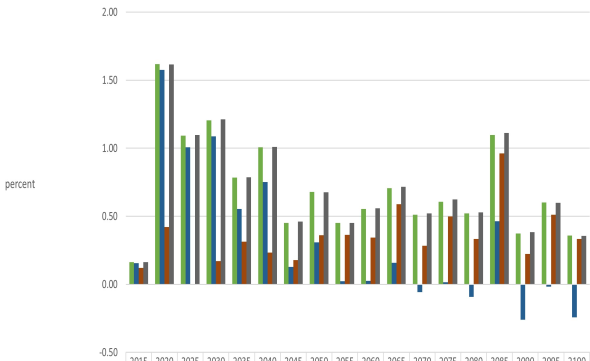


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	0.16	0.32	0.07	0.49	0.62	0.67	0.53	0.65	0.64	0.60	0.81	0.53	0.69	0.50	1.11	0.36	0.64	0.45
SSP 126 Adaptation Housing	0.16	0.28	-0.01	0.37	0.38	0.42	0.20	0.28	0.22	0.07	0.27	-0.03	0.10	-0.12	0.47	-0.27	0.02	-0.15
SSP 126 Adaptation Transport	0.12	0.09	-0.15	0.14	0.34	0.27	0.20	0.37	0.36	0.34	0.59	0.28	0.50	0.33	0.96	0.22	0.51	0.33
SSP 126 Adaptation Forestry	0.16	0.32	0.08	0.49	0.62	0.67	0.54	0.65	0.65	0.60	0.82	0.55	0.70	0.50	1.12	0.37	0.63	0.45

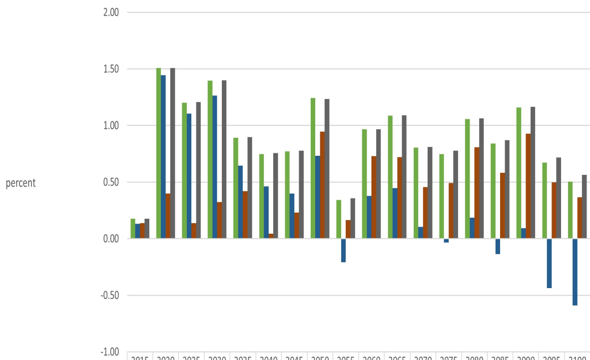


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	0.18	0.14	0.16	0.53	0.78	0.44	0.64	1.35	0.53	1.07	1.03	0.74	0.76	1.06	0.81	1.15	0.70	0.57
SSP 585 Adaptation Housing	0.13	0.07	0.06	0.40	0.54	0.16	0.27	0.84	-0.02	0.48	0.40	0.05	-0.02	0.18	-0.16	0.07	-0.41	-0.53
SSP 585 Adaptation Transport	0.14	0.07	-0.02	0.29	0.45	0.08	0.25	0.95	0.16	0.73	0.72	0.46	0.49	0.81	0.58	0.93	0.50	0.37
SSP 585 Adaptation Forestry	0.18	0.14	0.17	0.53	0.79	0.45	0.64	1.34	0.55	1.07	1.04	0.75	0.79	1.06	0.84	1.15	0.75	0.63

Northern Central area and Central coastal area



	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	0.16	1.62	1.09	1.21	0.78	1.01	0.45	0.68	0.45	0.55	0.71	0.51	0.61	0.52	1.10	0.37	0.60	0.36
SSP 126 Adaptation Housing	0.16	1.57	1.01	1.09	0.55	0.75	0.13	0.31	0.02	0.03	0.16	-0.06	0.02	-0.09	0.46	-0.26	-0.02	-0.24
SSP 126 Adaptation Transport	0.12	0.42	0.00	0.17	0.31	0.23	0.18	0.36	0.36	0.34	0.59	0.28	0.50	0.33	0.96	0.22	0.51	0.33
SSP 126 Adaptation Forestry	0.16	1.62	1.10	1.21	0.79	1.01	0.46	0.68	0.45	0.56	0.72	0.52	0.62	0.53	1.11	0.38	0.60	0.36

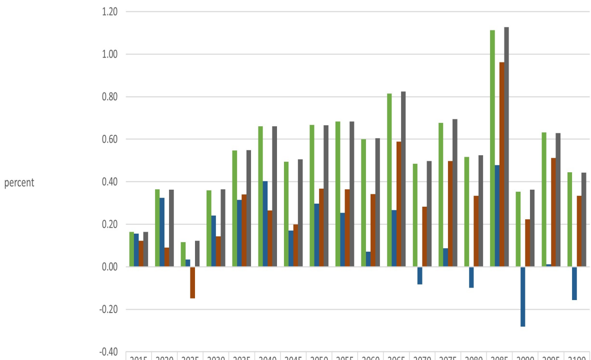


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	0.18	1.51	1.20	1.40	0.89	0.75	0.77	1.24	0.34	0.97	1.09	0.80	0.75	1.06	0.84	1.16	0.67	0.50
SSP 585 Adaptation Housing	0.13	1.44	1.10	1.26	0.65	0.46	0.40	0.73	-0.21	0.38	0.45	0.10	-0.03	0.18	-0.13	0.09	-0.44	-0.59
SSP 585 Adaptation Transport	0.14	0.40	0.14	0.32	0.42	0.04	0.23	0.94	0.16	0.73	0.72	0.46	0.49	0.81	0.58	0.93	0.50	0.37
SSP 585 Adaptation Forestry	0.18	1.51	1.21	1.40	0.90	0.76	0.78	1.23	0.36	0.97	1.09	0.81	0.78	1.06	0.87	1.16	0.72	0.56

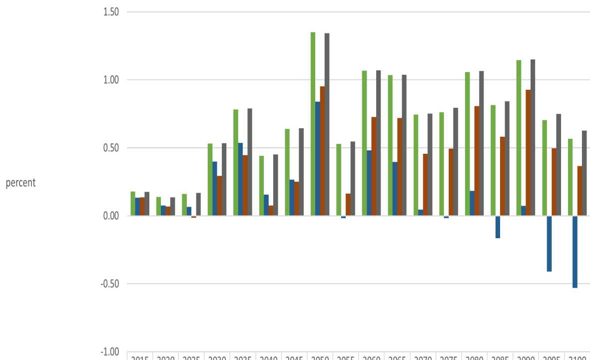
Source: own computation.

Employment transport (continued)

Central Highlands

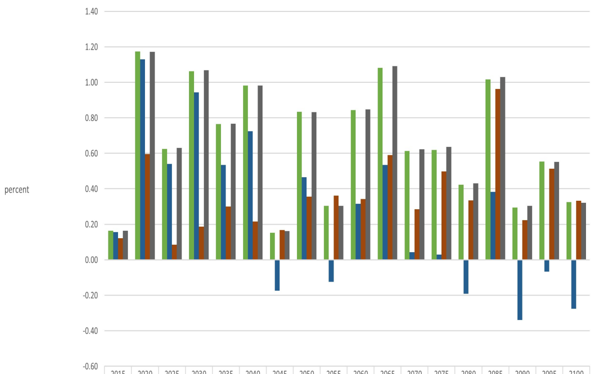


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	0.16	0.37	0.12	0.36	0.55	0.66	0.49	0.67	0.68	0.60	0.81	0.49	0.68	0.52	1.11	0.35	0.63	0.44
SSP 126 Adaptation Housing	0.16	0.32	0.03	0.24	0.32	0.40	0.17	0.30	0.25	0.07	0.27	-0.08	0.09	-0.10	0.48	-0.28	0.01	-0.16
SSP 126 Adaptation Transport	0.12	0.09	-0.15	0.14	0.34	0.27	0.20	0.37	0.36	0.34	0.59	0.28	0.50	0.33	0.96	0.22	0.51	0.33
SSP 126 Adaptation Forestry	0.16	0.36	0.12	0.37	0.55	0.66	0.51	0.67	0.68	0.60	0.82	0.50	0.69	0.52	1.13	0.36	0.63	0.44

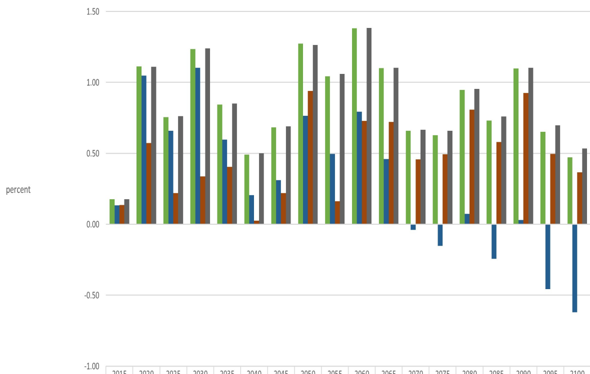


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	0.18	0.14	0.16	0.53	0.78	0.44	0.64	1.35	0.53	1.07	1.03	0.74	0.76	1.06	0.81	1.15	0.70	0.57
SSP 585 Adaptation Housing	0.13	0.07	0.06	0.40	0.54	0.16	0.27	0.84	-0.02	0.48	0.40	0.05	-0.02	0.18	-0.16	0.07	-0.41	-0.53
SSP 585 Adaptation Transport	0.14	0.07	-0.02	0.29	0.45	0.08	0.25	0.95	0.16	0.73	0.72	0.46	0.49	0.81	0.58	0.93	0.50	0.37
SSP 585 Adaptation Forestry	0.18	0.14	0.17	0.53	0.79	0.45	0.64	1.34	0.55	1.07	1.04	0.75	0.79	1.06	0.84	1.15	0.75	0.63

South East

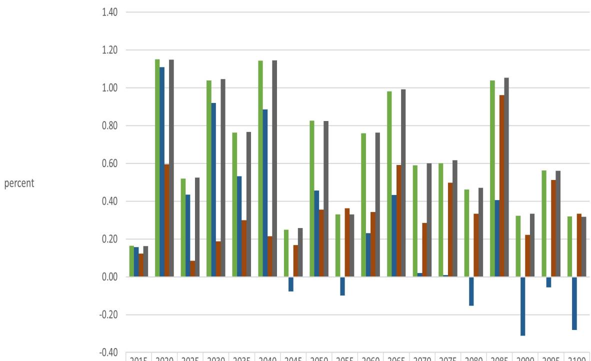


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	0.16	1.17	0.62	1.06	0.77	0.98	0.15	0.83	0.30	0.84	1.08	0.61	0.62	0.42	1.02	0.29	0.55	0.32
SSP 126 Adaptation Housing	0.16	1.13	0.54	0.94	0.53	0.72	-0.17	0.47	-0.12	0.31	0.53	0.04	0.03	-0.19	0.38	-0.34	-0.07	-0.28
SSP 126 Adaptation Transport	0.12	0.60	0.08	0.19	0.30	0.22	0.17	0.36	0.36	0.34	0.59	0.28	0.50	0.33	0.96	0.22	0.51	0.33
SSP 126 Adaptation Forestry	0.16	1.17	0.63	1.07	0.77	0.98	0.16	0.83	0.30	0.85	1.09	0.62	0.64	0.43	1.03	0.30	0.55	0.32

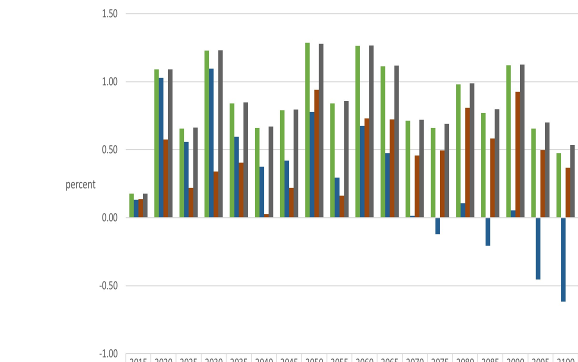


	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	0.18	1.11	0.76	1.24	0.84	0.49	0.68	1.27	1.04	1.38	1.10	0.66	0.63	0.95	0.73	1.10	0.65	0.47
SSP 585 Adaptation Housing	0.13	1.05	0.66	1.10	0.60	0.21	0.31	0.76	0.50	0.79	0.46	-0.04	-0.15	0.07	-0.24	0.03	-0.46	-0.62
SSP 585 Adaptation Transport	0.14	0.57	0.22	0.34	0.41	0.03	0.22	0.94	0.16	0.73	0.72	0.46	0.49	0.81	0.58	0.93	0.50	0.37
SSP 585 Adaptation Forestry	0.18	1.11	0.76	1.24	0.85	0.50	0.69	1.26	1.06	1.38	1.10	0.67	0.66	0.95	0.76	1.10	0.70	0.53

Mekong River Delta



	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 126	0.1636	1.1509	0.5191	1.0391	0.7634	1.1430	0.2484	0.8260	0.3300	0.7589	0.9812	0.5890	0.6004	0.4620	1.0390	0.3222	0.5630	0.3189
SSP 126 Adaptation Housing	0.1564	1.1081	0.4353	0.9202	0.5323	0.8861	-0.076	0.4571	-0.098	0.2314	0.4337	0.0202	0.0098	-0.152	0.4060	-0.311	-0.056	-0.280
SSP 126 Adaptation Transport	0.1220	0.5953	0.0850	0.1868	0.2992	0.2152	0.1683	0.3560	0.3619	0.3431	0.5908	0.2843	0.4979	0.3340	0.9620	0.2226	0.5125	0.3332
SSP 126 Adaptation Forestry	0.1633	1.1491	0.5256	1.0451	0.7656	1.1441	0.2589	0.8238	0.3303	0.7635	0.9910	0.6003	0.6174	0.4701	1.0537	0.3330	0.5602	0.3169



	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
SSP 585	0.177	1.091	0.654	1.228	0.840	0.658	0.790	1.285	0.840	1.264	1.112	0.713	0.659	0.980	0.769	1.120	0.654	0.474
SSP 585 Adaptation Housing	0.132	1.026	0.556	1.094	0.593	0.373	0.418	0.777	0.293	0.675	0.473	0.014	-0.12	0.106	-0.20	0.052	-0.45	-0.61
SSP 585 Adaptation Transport	0.136	0.573	0.218	0.338	0.405	0.025	0.218	0.940	0.162	0.728	0.721	0.456	0.493	0.807	0.580	0.926	0.496	0.366
SSP 585 Adaptation Forestry	0.176	1.089	0.661	1.231	0.846	0.668	0.796	1.277	0.856	1.266	1.116	0.720	0.690	0.986	0.798	1.125	0.699	0.534

Source: own computation.

B Tables

Table 17: Regional climate variable

Region	Red River Delta	Northern midlands and mountain areas	Northern Central area and Central coastal area	Central Highlands	South East	Mekong River Delta
initial surface temperature (Celsius) (tas)	20.85	18.55	22.86	22.26	25.64	26.27
initial surface windspeed (m/s) (SfcWind)	2.67	2.04958	3.39	1.96	2.276182	3.21
initial surface precipitation flux (mm) (pr)	1235.71	1322.53	2244.48	2638.4	2743.77	2701.13
initial sunshine (hour per day) (sunshine)	0	0	0	0	0	0
initial surface relative humidity (percent) (hurs)	83.84	85.10	88.02	89.54	84.48	85.74
initial heatwaves per year (heatwave)	0	0	0	0	0	0
initial maximal consecutive dry days (maxdrydays)	25.18	28.64	13.5	18.20	30.33	15.07
initial maximal consecutive wet days (maxwetdays)	12.09	16.35	25.86	67.20	56.16	39.77
initial number of storms (eq. to avg. historic storm) (storms)	0	0	0	0	0	0
initial number of floods (eq. to historic floods) (floods)	0	0	0	0	0	0
initial number of forest fire (fire) (fire)	0	0	0	0	0	0
initial landslide (landslide)	0	0	0	0	0	0

Source: National expert computation based on results from an NOAA.

Table 18: Mapping of economic sectors

Aggregate sector	Sub-sector	Commodity group	Industry Group
Basics (1)	Rice (1)	1	1
Basics (1)	Agriculture excluding rice (2)	2-21	2-21
Basics (1)	Aquaculture (3)	26-27	26-27
Basics (1)	Forestry (4)	25	25
Basics (1)	Water (5)	101-102	101-102
Basics (1)	Energy (6)	28-30, 99-100	28-30, 99-100
Construction and Manufacturing (2)	Manufacturing (7)	31-97	31-97
Construction and Manufacturing (2)	Construction (8)	106-111	110-115
Transport Water (3)	Transport Water (9)	119-120	122-123
Transport Land (4)	Transport Land (10)	115-118, 121-122	118-121, 124-125
Services and Health (5)	Health (11)	154-155	157-158
Services and Health (5)	Services (12)	98, 103-105, 112-114, 123-164	98, 116-118, 127-168

Table 19: Mapping of provinces to statistical regions in Vietnam

Region	Province
Dak Nong	Central Highlands
Dak Lak	Central Highlands
Gia Lai	Central Highlands
Kon Tum	Central Highlands
Lam Dong	Central Highlands
Dong Thap	Mekong River Delta
An Giang	Mekong River Delta
Bac Lieu	Mekong River Delta
Ben Tre	Mekong River Delta
Ca Mau	Mekong River Delta
Can Tho	Mekong River Delta
Hau Giang	Mekong River Delta
Kien Giang	Mekong River Delta
Long An	Mekong River Delta

Table 19 – Continued

Region	Province
Soc Trang	Mekong River Delta
Tien Giang	Mekong River Delta
Tra Vinh	Mekong River Delta
Vinh Long	Mekong River Delta
Da Nang	Northern Central area and Central coastal area
Binh Dinh	Northern Central area and Central coastal area
Binh Thuan	Northern Central area and Central coastal area
Ha Tinh	Northern Central area and Central coastal area
Khanh Hoa	Northern Central area and Central coastal area
Nghe An	Northern Central area and Central coastal area
Ninh Thuan	Northern Central area and Central coastal area
Phu Yen	Northern Central area and Central coastal area
Quang Binh	Northern Central area and Central coastal area
Quang Nam	Northern Central area and Central coastal area
Quang Ngai	Northern Central area and Central coastal area
Quang Tri	Northern Central area and Central coastal area
Thua Thien-Hue	Northern Central area and Central coastal area
Thanh Hoa	Northern Central area and Central coastal area
Dien Bien	Northern midlands and mountain areas
Bac Giang	Northern midlands and mountain areas
Bac Kan	Northern midlands and mountain areas
Cao Bang	Northern midlands and mountain areas
Ha Giang	Northern midlands and mountain areas
Hoa Binh	Northern midlands and mountain areas
Lao Cai	Northern midlands and mountain areas
Lai Chau	Northern midlands and mountain areas
Lang Son	Northern midlands and mountain areas
Phu Tho	Northern midlands and mountain areas
Son La	Northern midlands and mountain areas
Thai Nguyen	Northern midlands and mountain areas
Tuyen Quang	Northern midlands and mountain areas
Yen Bai	Northern midlands and mountain areas
Bac Ninh	Red River Delta
Ha Noi	Red River Delta
Ha Nam	Red River Delta
Hung Yen	Red River Delta
Hai Duong	Red River Delta
Hai Phong	Red River Delta
Nam Dinh	Red River Delta
Ninh Binh	Red River Delta
Quang Ninh	Red River Delta
Thai Binh	Red River Delta
Vinh Phuc	Red River Delta
Dong Nai	South East
Ba Ria - Vung Tau	South East
Binh Duong	South East
Binh Phuoc	South East
Ho Chi Minh city	South East
Tay Ninh	South East

Table 20: Construction adaptation measures against sea-level rise

SLR in cm	Red River Delta	Northern midland and mountain area	Northern Central area and Central coastal area	Central Highlands	South East	Mekong River Delta	Vietnam
Benefit (avoided Damage)							
0	0.000298	0	0.000678	0	0	0.042223	0.0432
5	0.000772	0	0.001244	0	0.000179	0.077075	0.079269
10	0.002181	0	0.002706	0	0.000427	0.180979	0.186294
15	0.003752	0	0.0036	0	0.000819	0.28184	0.290011
20	0.005487	0	0.00459	0	0.001384	0.480361	0.491822
25	0.006701	0	0.005551	0	0.002214	0.502044	0.51651
30	0.007981	0	0.007021	0	0.003172	0.536664	0.554837
35	0.00934	0	0.008066	0	0.004192	0.574884	0.596483
40	0.010845	0	0.009317	0	0.005259	0.633413	0.658833
45	0.01258	0	0.010851	0	0.00628	0.704784	0.734494
50	0.014408	0	0.012154	0	0.007289	0.811796	0.845647
55	0.016436	0	0.013557	0	0.008281	0.927106	0.96538
60	0.018669	0	0.014995	0	0.009255	1.035385	1.078304
65	0.021082	0	0.0165	0	0.010276	1.127374	1.175232
70	0.02363	0	0.018013	0	0.011302	1.249021	1.301966
75	0.02633	0	0.019747	0	0.01245	1.359061	1.417588
80	0.029257	0	0.021546	0	0.013644	1.469071	1.533518
85	0.032306	0	0.023341	0	0.015039	1.558247	1.628933
90	0.035366	0	0.025083	0	0.01636	1.637068	1.713877
95	0.038634	0	0.035527	0	0.024139	1.696292	1.794592
Cost (to avoid Damage)							
0	0.003068	0	0.006946	0	0	0.435775	0.445789
5	0.004871	0	0.005788	0	0.001843	0.35969	0.372192
10	0.014506	0	0.014976	0	0.002556	1.072371	1.10441
15	0.016163	0	0.009152	0	0.004043	1.040948	1.070306
20	0.017852	0	0.010129	0	0.005826	2.048878	2.082685
25	0.012483	0	0.00984	0	0.008561	0.223789	0.254673
30	0.013177	0	0.015049	0	0.009869	0.357298	0.395392
35	0.013984	0	0.010708	0	0.010523	0.394463	0.429678
40	0.015477	0	0.012806	0	0.010999	0.604056	0.643338
45	0.017852	0	0.0157	0	0.010523	0.736607	0.780682
50	0.018814	0	0.013349	0	0.010404	1.104432	1.146999
55	0.020862	0	0.014361	0	0.010226	1.190088	1.235537
60	0.022975	0	0.014723	0	0.010047	1.117512	1.165258
65	0.024827	0	0.015411	0	0.010523	0.949391	1.000151
70	0.026223	0	0.015483	0	0.010582	1.255486	1.307774
75	0.027773	0	0.017762	0	0.011831	1.135696	1.193061
80	0.030122	0	0.018413	0	0.012306	1.135377	1.196219
85	0.031371	0	0.018377	0	0.014387	0.92036	0.984495
90	0.031485	0	0.017834	0	0.013614	0.81349	0.876424
95	0.033623	0	0.106933	0	0.0802	0.611234	0.83199

Source: Sectoral experts report and own computation.

Table 21: Construction adaptation measures against storms

Year after Start	Red River Delta	Northern midland and mountain area	Northern Central area and Central coastal area	Central Highlands	South East	Mekong River Delta	Vietnam
Benefit (avoided Damage)							
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.002	0.000	0.001	0.000	0.000	0.000	0.002
3	0.003	0.000	0.002	0.000	0.000	0.000	0.005
4	0.000	0.002	0.005	0.002	0.000	0.000	0.008
5	0.004	0.000	0.007	0.000	0.000	0.000	0.012
6	0.005	0.014	0.011	0.008	0.000	0.000	0.037
7	0.005	0.021	0.014	0.012	0.000	0.000	0.053
8	0.000	0.027	0.018	0.016	0.000	0.000	0.062
9	0.005	0.032	0.021	0.020	0.001	0.000	0.078
10	0.006	0.000	0.022	0.000	0.000	0.000	0.029
11	0.006	0.037	0.024	0.023	0.000	0.000	0.090
12	0.000	0.038	0.024	0.024	0.000	0.000	0.086
13	0.006	0.038	0.026	0.024	0.000	0.000	0.093
14	0.006	0.038	0.026	0.024	0.000	0.000	0.095

Table 21: Construction adaptation measures against storms

Year after Start	Red River Delta	Northern midland and mountain area	Northern Central area and Central coastal area	Central Highlands	South East	Mekong River Delta	Vietnam
Benefit (avoided Damage)							
15	0.006	0.000	0.026	0.000	0.000	0.000	0.033
16	0.000	0.041	0.027	0.025	0.000	0.000	0.093
17	0.006	0.043	0.027	0.025	0.000	0.001	0.102
18	0.006	0.044	0.028	0.026	0.000	0.000	0.104
19	0.006	0.044	0.029	0.026	0.000	0.001	0.106
20	0.000	0.000	0.030	0.000	0.000	0.001	0.030
21	0.006	0.045	0.030	0.027	0.000	0.000	0.108
22	0.006	0.046	0.030	0.027	0.000	0.001	0.109
23	0.006	0.046	0.030	0.027	0.000	0.001	0.109
24	0.000	0.046	0.030	0.027	0.000	0.000	0.103
25	0.006	0.000	0.030	0.000	0.000	0.001	0.037
26	0.006	0.046	0.030	0.027	0.000	0.001	0.110
27	0.006	0.046	0.030	0.027	0.000	0.000	0.109
28	0.000	0.046	0.030	0.027	0.000	0.001	0.103
29	0.006	0.046	0.030	0.027	0.000	0.001	0.110
30	0.006	0.000	0.030	0.000	0.000	0.000	0.037
31	0.006	0.046	0.030	0.027	0.000	0.001	0.110
32	0.000	0.046	0.030	0.027	0.000	0.001	0.103
33	0.006	0.046	0.030	0.027	0.000	0.000	0.109
34	0.006	0.046	0.030	0.027	0.000	0.001	0.110
35	0.006	0.000	0.030	0.000	0.000	0.001	0.037
36	0.000	0.046	0.030	0.027	0.000	0.000	0.103
37	0.006	0.046	0.030	0.027	0.000	0.001	0.110
38	0.006	0.046	0.030	0.027	0.000	0.001	0.110
39	0.006	0.046	0.030	0.027	0.000	0.000	0.109
40	0.000	0.000	0.030	0.000	0.000	0.001	0.031
Cost (to avoid Damage)							
1	0.003	0.000	0.001	0.000	0.000	0.000	0.004
2	0.013	0.000	0.007	0.000	0.000	0.000	0.020
3	0.013	0.002	0.015	0.000	0.000	0.000	0.030
4	0.010	0.016	0.023	0.019	0.000	0.000	0.067
5	0.004	0.051	0.029	0.027	0.000	0.000	0.111
6	0.005	0.066	0.034	0.033	0.000	0.000	0.137
7	0.002	0.078	0.034	0.044	0.000	0.005	0.163
8	0.002	0.059	0.040	0.038	0.000	0.000	0.139
9	0.001	0.044	0.026	0.037	0.000	0.000	0.108
10	0.004	0.023	0.018	0.025	0.000	0.000	0.069
11	0.001	0.031	0.016	0.003	0.000	0.000	0.050
12	0.002	0.008	0.005	0.010	0.000	0.000	0.024
13	0.002	0.003	0.011	0.001	0.000	0.000	0.016
14	0.001	0.004	0.004	0.006	0.000	0.000	0.016
15	0.000	0.014	0.005	0.003	0.000	0.000	0.022
16	0.000	0.016	0.005	0.004	0.000	0.000	0.025
17	0.000	0.016	0.007	0.005	0.000	0.001	0.029
18	0.000	0.012	0.006	0.005	0.000	0.000	0.024
19	0.000	0.008	0.005	0.004	0.000	0.000	0.017
20	0.000	0.005	0.011	0.002	0.000	0.000	0.019
21	0.000	0.006	0.004	0.001	0.000	0.000	0.011
22	0.000	0.002	0.001	0.001	0.000	0.000	0.004
23	0.000	0.001	0.002	0.001	0.000	0.000	0.004
24	0.000	0.000	0.000	0.000	0.000	0.000	0.001
25	0.000	0.002	0.000	0.000	0.000	0.000	0.003
26	0.000	0.000	0.000	0.000	0.000	0.000	0.001
27	0.000	0.000	0.000	0.000	0.000	0.000	0.001
28	0.000	0.000	0.000	0.000	0.000	0.000	0.001
29	0.000	0.000	0.000	0.000	0.000	0.000	0.001
30	0.000	0.000	0.001	0.000	0.000	0.000	0.001
31	0.000	0.000	0.000	0.000	0.000	0.000	0.001
32	0.000	0.000	0.000	0.000	0.000	0.000	0.001
33	0.000	0.000	0.000	0.000	0.000	0.000	0.001
34	0.000	0.000	0.000	0.000	0.000	0.000	0.001
35	0.000	0.000	0.000	0.000	0.000	0.000	0.001
36	0.000	0.000	0.000	0.000	0.000	0.000	0.001
37	0.000	0.000	0.000	0.000	0.000	0.000	0.001
38	0.000	0.000	0.000	0.000	0.000	0.000	0.001

Table 21: Construction adaptation measures against storms

Year after Start	Red River Delta	Northern midland and mountain area	Northern Central area and Central coastal area	Central Highlands	South East	Mekong River Delta	Vietnam
Benefit (avoided Damage)							
39	0.000	0.000	0.000	0.000	0.000	0.000	0.001
40	0.000	0.000	0.000	0.000	0.000	0.000	0.001

Source: Sectoral experts report and own computation.

Table 22: Damages caused by sea-level rise

SLR	Red River Delta	Northern midland and mountain area	Northern Central area and Central coastal area	Central Highlands	South East	Mekong River Delta
Damages						
0	0.001	0.000	0.002	0.000	0.001	0.002
5	0.001	0.000	0.004	0.000	0.003	0.004
10	0.001	0.000	0.008	0.000	0.006	0.009
15	0.002	0.000	0.010	0.000	0.010	0.014
20	0.002	0.000	0.013	0.000	0.017	0.023
25	0.003	0.000	0.016	0.000	0.018	0.025
30	0.004	0.000	0.020	0.000	0.020	0.029
35	0.004	0.000	0.023	0.000	0.021	0.031
40	0.005	0.000	0.027	0.000	0.023	0.035
45	0.006	0.000	0.032	0.000	0.024	0.040
50	0.007	0.000	0.036	0.000	0.027	0.044
55	0.008	0.000	0.039	0.000	0.029	0.048
60	0.009	0.000	0.044	0.000	0.032	0.053
65	0.011	0.000	0.048	0.000	0.034	0.058
70	0.012	0.000	0.052	0.000	0.037	0.063
75	0.014	0.000	0.056	0.000	0.040	0.068
80	0.015	0.000	0.062	0.000	0.043	0.074
85	0.017	0.000	0.067	0.000	0.045	0.080
90	0.019	0.000	0.071	0.000	0.048	0.086
95	0.021	0.000	0.083	0.000	0.052	0.095
Benefits						
0	0.001	0.000	0.004	0.000	0.002	0.003
5	0.001	0.000	0.003	0.000	0.003	0.004
10	0.001	0.000	0.008	0.000	0.006	0.008
15	0.001	0.000	0.004	0.000	0.008	0.011
20	0.001	0.000	0.005	0.000	0.014	0.019
25	0.001	0.000	0.006	0.000	0.002	0.003
30	0.001	0.000	0.008	0.000	0.003	0.004
35	0.001	0.000	0.006	0.000	0.002	0.003
40	0.001	0.000	0.007	0.000	0.004	0.005
45	0.002	0.000	0.010	0.000	0.003	0.005
50	0.002	0.000	0.007	0.000	0.005	0.007
55	0.002	0.000	0.007	0.000	0.004	0.006
60	0.003	0.000	0.008	0.000	0.005	0.007
65	0.003	0.000	0.009	0.000	0.004	0.006
70	0.003	0.000	0.007	0.000	0.006	0.008
75	0.003	0.000	0.008	0.000	0.005	0.007
80	0.004	0.000	0.012	0.000	0.006	0.008
85	0.004	0.000	0.009	0.000	0.005	0.007
90	0.004	0.000	0.009	0.000	0.006	0.008
95	0.004	0.000	0.021	0.000	0.008	0.011

Source: Sectoral experts report and own computation.

C Model equations for DGE-CRED

C.1 Expectations

C.2 Equations for the aggregate sector

aggregate sectoral production

$$P^A_{k\ t}\, Q^A_{k\ t} = \sum_s^S P^D_{s\ t}\, Q^D_{s\ t} \tag{61}$$

demand for

$$\frac{P^A_{k\ t}}{P^D{}_t} = \omega_k^{Q^A\,\frac{1}{\eta^Q}} \left(\frac{Q^A_{k\ t}}{Q^D{}_t}\right)^{\frac{(-1)}{\eta^Q}} \tag{62}$$

Households FOC for capital stock

$$\left(\mathbb{E}_t P_{t+1}\right) \left(\mathbb{E}_t r_{k,r,t+1}\right) \left(\mathbb{E}_t \lambda_{t+1}\right) \beta \left(1 - \left(\mathbb{E}_t \tau^{K^H}_{t+1}\right)\right) + (1-\delta)\, \beta \left(\mathbb{E}_t \lambda_{t+1}\right) \left(\mathbb{E}_t \omega^I_{k,r,t+1}\right) = \lambda_t\, \omega^I_{s,r,t} \tag{63}$$

Households FOC for investment into capital stock

$$\begin{aligned}
&P_t\, \lambda_t \\
&= \lambda_t\, \omega^I_{s,r,t} \left(1 - \left(\exp\left(\sqrt{\frac{\phi^K}{2}} \left(\frac{\frac{I_{k,r_t}}{I_{k,r_{t-1}}}\, PoP_{t-1}}{PoP_t} - 1\right)\right) + \exp\left(\left(\frac{\frac{I_{k,r_t}}{I_{k,r_{t-1}}}\, PoP_{t-1}}{PoP_t} - 1\right)\left(-\sqrt{\frac{\phi^K}{2}}\right)\right) - 2\right)\right. \\
&\qquad \left. - \sqrt{\frac{\phi^K}{2}}\, \frac{\frac{I_{k,r_t}}{I_{k,r_{t-1}}}\, PoP_{t-1}}{PoP_t} \left(\exp\left(\sqrt{\frac{\phi^K}{2}} \left(\frac{I_{k,r_t}}{I_{k,r_{t-1}}} - 1\right)\right) - \exp\left(\left(\frac{\frac{I_{k,r_t}}{I_{k,r_{t-1}}}\, PoP_{t-1}}{PoP_t} - 1\right)\left(-\sqrt{\frac{\phi^K}{2}}\right)\right)\right)\right) \\
&\quad + \sqrt{\frac{\phi^K}{2}}\, \frac{\left(\mathbb{E}_t \omega^I_{k,r,t+1}\right) \frac{\beta \left(\frac{\mathbb{E}_t C_{t+1}}{\mathbb{E}_t PoP_{t+1}}\right)^{\left(-\sigma^C\right)}}{\left(\mathbb{E}_t P_{t+1}\right)\left(1 + \mathbb{E}_t \tau^C_{t+1}\right)} \left(\mathbb{E}_t I_{k,r,t+1}\right)^2}{I_{k,r_t}^{\ 2}} \left(\frac{PoP_t}{\mathbb{E}_t PoP_{t+1}}\right)^2 \left(\exp\left(\sqrt{\frac{\phi^K}{2}} \left(\frac{PoP_t\, \frac{\mathbb{E}_t I_{k,r,t+1}}{I_{k,r_t}}}{\mathbb{E}_t PoP_{t+1}} - 1\right)\right)\right. \\
&\qquad \left. - \exp\left(\left(-\sqrt{\frac{\phi^K}{2}}\right)\left(\frac{PoP_t\, \frac{\mathbb{E}_t I_{k,r,t+1}}{I_{k,r_t}}}{\mathbb{E}_t PoP_{t+1}} - 1\right)\right)\right)
\end{aligned} \tag{64}$$

Law of motion for capital stock used in aggregate sector

$$\begin{aligned}
&\frac{K_{k,r_t}}{PoP_t} = \frac{(1-\delta)\, K_{k,r_{t-1}}}{PoP_{t-1}} \\
&\quad + \left(1 - \left(\exp\left(\sqrt{\frac{\phi^K}{2}} \left(\frac{\frac{I_{k,r_t}}{I_{k,r_{t-1}}}\, PoP_{t-1}}{PoP_t} - 1\right)\right) + \exp\left(\left(\frac{\frac{I_{k,r_t}}{I_{k,r_{t-1}}}\, PoP_{t-1}}{PoP_t} - 1\right)\left(-\sqrt{\frac{\phi^K}{2}}\right)\right) - 2\right)\right) \frac{I_{k,r_t}}{PoP_t} \\
&\quad - \frac{D_{s,r,t}}{PoP_t}
\end{aligned} \tag{65}$$

aggregate capital stock

$$P_t\, K_{k,r_{t-1}} = \sum_s^S P_{s,r,t}\, K_{s,r,t} \tag{66}$$

aggregate invesmtent into capital stock

$$I_{k\,t} = \sum_r^R I_{k,r_t} \tag{67}$$

C.3 Equations for the regional subsector

sector specific corporate tax rate paid by firms

$$\tau^K_{s,r,t} = \tau^{K,F}_{s,r} + \eta_{\tau^K,s,r_t} \tag{68}$$

sector specific labour tax rate paid by firms

$$\tau^N_{s,r,t} = \tau^{N,F}_{s,r} + \eta_{\tau^N,s,r_t} \tag{69}$$

sector and capital specific productivity shock

$$A_{s,r,t} = A_{s,r}\, {K^G_t}^{\phi^G} \exp\left(\eta_{A,s,r_t}\right) \tag{70}$$

sector and capital specific productivity shock

$$A^K_{s,r,t} = \exp\left(\eta_{A^K,s,r_t}\right) \tag{71}$$

sector and labour specific productivity shock

$$A^N_{s,r,t} = \exp\left(\eta_{A^N,s,r_t}\right) \tag{72}$$

sector specific damage function

$$D_{s,r,t} = \eta_{D,s,r_t} \tag{73}$$

sector specific damage function on labour productivity

$$D^N_{s,r,t} = \eta_{D^N,s,r_t} \tag{74}$$

sector specific damage function on capital formation

$$D_{s,r,t} = \eta_{D^K,s,r_t} Y_0 \tag{75}$$

sector specific adaptation expenditures by the government against climate change

$$K^A_{s,r,t} = Y_0\, \eta_{G^{A,landslide},s,r_t} \tag{76}$$

sector specific adaptation capital against climate change

$$K^A_{s,r,t} = \left(1 - \delta^{K^A_{s,r}}\right) K^A_{s,r_{t-1}} + G^A_{s,r,t} \tag{77}$$

demand for regional sector output

$$P_{s,r,t} = P^D_{s\ t}\, \omega^Q_{s,r}{}^{\frac{1}{\eta^C_k}} \left(\frac{Q_{s,r,t}}{Q_{s_t}}\right)^{\frac{(-1)}{\eta^C_k}} \tag{78}$$

demand for regional sector value added

$$P_{s,r,t} = P_{s,r,t} \left(1 - \omega^{Q^I}_{s,r}\right)^{\frac{1}{\eta^M_k}} \left(\frac{Y_{s,r,t}}{Q_{s,r,t}}\right)^{\frac{(-1)}{\eta^M_k}} \tag{79}$$

regional sector demand for intermediates

$$P_t = P_{s,r,t}\, \omega^{Q^I}_{s,r}{}^{\frac{1}{\eta^M_k}} \left(\frac{Q^I_{s,r,t}}{Q_{s,r,t}}\right)^{\frac{(-1)}{\eta^M_k}} \tag{80}$$

sector specific gross value added

$$Y_{s,r,t} = A_{s,r,t}\ (1 \tag{81}$$

$$-D_{s,r,t}) \begin{cases} \left(K_{s,r,t}\, A^K_{s,r,t}\right)^{\alpha^K_{s,r}} \left(A^N_{s,r,t}\, PoP_t\ (1 - D_{s,r,t})\ N_{s,r,t}\right)^{\alpha^N_{s,r}} & \eta^{N,K}_{s,r} = 1 \\ \left(\alpha^K_{s,r}{}^{\frac{1}{\eta^{N,K}_{s,r}}} \left(K_{s,r,t}\, A^K_{s,r,t}\right)^{\frac{\eta^{N,K}_{s,r}-1}{\eta^{N,K}_{s,r}}} + \alpha^N_{s,r}{}^{\frac{1}{\eta^{N,K}_{s,r}}} \left(A^N_{s,r,t}\, PoP_t\ (1 - D_{s,r,t})\ N_{s,r,t}\right)^{\frac{\eta^{N,K}_{s,r}-1}{\eta^{N,K}_{s,r}}}\right)^{\frac{\eta^{N,K}_{s,r}}{\eta^{N,K}_{s,r}-1}} & \eta^{N,K}_{s,r} \neq 1 \end{cases}$$

Firms FOC capital

$$r_{k,r_t} \left(1 + \tau^K_{s,r,t}\right) = \alpha^K_{s,r}{}^{\frac{1}{\eta^{N,K}_{s,r}}} \left(A^K_{s,r,t}\, A_{s,r,t}\ (1 - D_{s,r,t})\right)^{\frac{\eta^{N,K}_{s,r}-1}{\eta^{N,K}_{s,r}}} \left(\frac{K_{s,r,t}}{Y_{s,r,t}}\right)^{\frac{(-1)}{\eta^{N,K}_{s,r}}} \tag{82}$$

Firms FOC labour ($PoP_t\, N_{s,r,t}$)

$$\frac{W_{s,r,t}\left(1 + \tau^N_{s,r,t}\right)}{P_{s,r,t}} - \alpha^N_{s,r}{}^{\frac{1}{\eta^{N,K}_{s,r}}} \left(A_{s,r,t}\ (1 - D_{s,r,t})\ A^N_{s,r,t}\ (1 - D_{s,r,t})\right)^{\frac{\eta^{N,K}_{s,r}-1}{\eta^{N,K}_{s,r}}} \left(\frac{PoP_t\, N_{s,r,t}}{Y_{s,r,t}}\right)^{\frac{(-1)}{\eta^{N,K}_{s,r}}} = 0 \tag{83}$$

Households FOC labour ($N_{s,r,t}$)

$$\lambda_t\, W_{s,r,t} \left(1 - \tau^{N,H}{}_t\right) = A^N_{s,r,t}\, \phi^L_{s,r}\, N_{s,r,t}{}^{\sigma^L} \tag{84}$$

output production function

$$Q_{s,r,t} = \left(\omega^{Q^I}_{s,r}{}^{\frac{1}{\eta^M_k}}\ Q^I_{s,r,t}{}^{\frac{\eta^M_k-1}{\eta^M_k}} + \left(1 - \omega^{Q^I}_{s,r}\right)^{\frac{1}{\eta^M_k}}\ Y_{s,r,t}{}^{\frac{\eta^M_k-1}{\eta^M_k}}\right)^{\frac{\eta^M_k}{\eta^M_k-1}} \tag{85}$$

demand for subsectoral imports

$$\frac{P^M_{s\ t}}{P^M{}_t} = \omega^M_k{}^{\frac{1}{\eta^M}} \left(\frac{M_{s\,t}}{M_t}\right)^{\frac{(-1)}{\eta^M}} \tag{86}$$

use of total subsectoral production

$$Q_{s\,t} = Q^D_{s\ t} + X_{s\,t} \tag{87}$$

aggregate subsectoral production

$$P^D_{s\ t}\, Q_{s\,t} = \sum_r^R P_{s,r,t}\, Q_{s,r,t} \tag{88}$$

aggregate subsectoral demand for intermediate inputs

$$P_t\, Q^I_{s\,t} = P_t\, \sum_r^R Q^I_{s,r,t} \tag{89}$$

demand for subsectoral production

$$\frac{P^D_{s\ t}}{P^A_{k\ t}} = {\omega^Q_k}^{\frac{1}{\eta^{Q^A}_k}} \left(\frac{Q^D_{s\ t}}{Q^A_{k\ t}}\right)^{\frac{(-1)}{\eta^{Q^A}_k}} \tag{90}$$

aggregate subsectoral gross value added

$$Y_{s\,t} = \sum_r^R P_{s,r,t}\, Y_{s,r,t} \tag{91}$$

aggregate subsectoral labour

$$N_{s\,t} = \sum_r^R N_{s,r,t} \tag{92}$$

aggregate labour income in subsector

$$N_{s\,t}\, W_{s\,t} = \sum_r^R N_{s,r,t}\, W_{s,r,t} \tag{93}$$

subsectoral rented capital stock

$$P_t\, K_{s\,t} = \sum_r^R P_{s,r,t}\, K_{s,r,t} \tag{94}$$

subsectoral exports

$$X_{s,t} = D^X_s \left(\frac{P^D_{s,t}}{P^M_{s,t}}\right)^{-\eta^X} \tag{95}$$

share of products exported

$$D^X_{s\ t} = \frac{X_{s,t}}{Q_{s,t}} \tag{96}$$

total domestic output

$$P^D{}_t\, Q_t = \sum_s^S P^D_{s\ t}\, Q_{s\,t} \tag{97}$$

total domestic output used domestically

$$P^D{}_t\, Q^D{}_t = \sum_k^K P^A_{k\ t}\, Q^A_{k\ t} \tag{98}$$

total output used

$$P_t\, Q^U{}_t = P^D{}_t\, Q^D{}_t + P^M{}_t\, M_t \tag{99}$$

total gross value added

$$P_t\, Y_t = \sum_s^S \sum_r^R P_{s,r,t}\, Y_{s,r,t} \tag{100}$$

total intermediate output used

$$P_t\, Q^I{}_t = \sum_s^S P_t\, Q^I_{s\,t} \tag{101}$$

total investment

$$P_t\, I_t = \sum_k^K P_t\, I_{k\,t} \tag{102}$$

total exports

$$P^D{}_t\, X_t = \sum_s^S P^D_{s\ t}\, X_{s\,t} \tag{103}$$

aggregate imports

$$P^M{}_t\, M_t = \sum_s^S P^M_{s\ t}\, M_{s\,t} \tag{104}$$

aggregate capital stock

$$P_t\, K_t = \sum_s^S P_t\, K_{s\,t} \tag{105}$$

share of total hours worked on total time endowment

$$N_t = \sum_s^S N_{s\,t} \tag{106}$$

demand for imported goods

$$\frac{P^M{}_t}{P_t} = \omega^F{}^{\frac{1}{\eta^F}} \left(\frac{M_t}{Q^U{}_t}\right)^{\frac{(-1)}{\eta^F}} \tag{107}$$

demand for domestic goods used domestically

$$\frac{P^D{}_t}{P_t} = \left(1-\omega^F\right)^{\frac{1}{\eta^F}} \left(\frac{Q^D{}_t}{Q^U{}_t}\right)^{\frac{(-1)}{\eta^F}} \tag{108}$$

resource contraint

$$Q_t \, \frac{P^D{}_t}{P_t} = \sum_s^S \sum_r^R G^A_{s,r,t} + Q^I{}_t + NX_t + I_t + C_t + \frac{P^H{}_t}{P_t} \, I^H{}_t + G_t + G^{A,D^H}{}_t \tag{109}$$

aggregate price level

$$P_t = P_0 \, \exp\left(\eta_{P\,t}\right) \tag{110}$$

import price

$$P^M{}_t = P_0 + \eta_{M\,t} \tag{111}$$

net exports

$$P_t \, NX_t = P^D{}_t \, X_t - P^M{}_t \, M_t \tag{112}$$

exogenous world interest rate

$$r^f{}_t = r^f_0 + \eta_{r^f\,t} \tag{113}$$

FOC households consumption

$$P_t \, \lambda_t \, \left(1+\tau^C{}_t\right) = (1-\gamma) \, \left(\frac{C_t}{PoP_t}\right)^{(-\gamma)} \, \left(\frac{H_t}{PoP_t}\right)^{\gamma} \, \left(\left(\frac{H_t}{PoP_t}\right)^{\gamma} \, \left(\frac{C_t}{PoP_t}\right)^{1-\gamma}\right)^{\left(-\sigma^C\right)} \tag{114}$$

law of motion for houses

$$\frac{H_t}{PoP_t} = \left(1-\delta^H\right) \, \frac{H_{t-1}}{PoP_{t-1}} + \frac{I^H{}_t}{PoP_t} - \frac{D^H{}_t}{PoP_t} \tag{115}$$

price for houses

$$P^H{}_t = P^H_0 \, \exp\left(\eta_{H\,t}\right) \tag{116}$$

damages on housing induced by climate change

$$D^H{}_t = \frac{P_t \, Y_t \, \eta_{D^H\,t}}{P^H{}_t} \tag{117}$$

FOC households with respect to housing

$$\begin{aligned}\lambda_t \, \omega^H{}_t = \beta \, \Bigg(& \left(1-\delta^H\right) \, \left(\mathbb{E}_t \lambda_{t+1}\right) \, \left(\mathbb{E}_t \omega^H_{t+1}\right) \\ & + \gamma \, \left(\frac{\mathbb{E}_t C_{t+1}}{\mathbb{E}_t PoP_{t+1}}\right)^{1-\gamma} \, \left(\frac{H_t}{\mathbb{E}_t PoP_{t+1}}\right)^{\gamma-1} \, \left(\left(\frac{\mathbb{E}_t C_{t+1}}{\mathbb{E}_t PoP_{t+1}}\right)^{1-\gamma} \, \left(\frac{H_t}{\mathbb{E}_t PoP_{t+1}}\right)^{\gamma}\right)^{\left(-\sigma^C\right)} \Bigg)\end{aligned} \tag{118}$$

FOC households with respect to invesmtnet into housing

$$\lambda_t \, \omega^H{}_t = \lambda_t \, P^H{}_t \, \left(1+\tau^C{}_t\right) \tag{119}$$

FOC households with respect to foreing assets

$$\left(\mathbb{E}_t \lambda_{t+1}\right) \, \beta \, \left(1+\mathbb{E}_t r^f_{t+1}\right) \, \exp\left(\left(-\phi^B\right) \, \left(\frac{\mathbb{E}_t NX_{t+1}}{\mathbb{E}_t Y_{t+1}} + \frac{\left(\mathbb{E}_t r^f_{t+1}\right) \, \left(\mathbb{E}_t B_{t+1} + BG_t\right)}{\mathbb{E}_t Y_{t+1}}\right)\right) = \lambda_t \tag{120}$$

C.4 Government

taxes on labour income

$$\tau^{N,H}{}_t = \tau^{N,H} + \eta_{\tau^{N,H}}{}_t \tag{121}$$

taxes on capital income

$$\tau^{K,H}{}_t = \tau^{K,H} + \eta_{\tau^{K,H}}{}_t \tag{122}$$

taxs on consumption

$$\tau^{C}{}_t = \tau^{C} + \eta_{\tau^{C}}{}_t \tag{123}$$

taxes on housing

$$\tau^{H}{}_t = \tau^{H} + \eta_{\tau^{C}}{}_t \tag{124}$$

adaptation expenditures in housing

$$G^{A,D^H}{}_t = Y_0\, \eta_{G^{A,H}}{}_t \tag{125}$$

government budget constraint

$$G^A_{s,r,t} + G^{A,D^H}{}_t + G_t + BG_t = K_{s,r,t}\, r_{k,r}{}_t\, \frac{P_{s,r,t}\, \left(\tau^{K,H}{}_t + \tau^K_{s,r,t}\right)}{P_t} + \frac{PoP_t\, N_{s,r,t}\, W_{s,r,t}\, \left(\tau^N_{s,r,t} + \tau^{N,H}{}_t\right)}{P_t} + I^H{}_t\, \frac{P^H{}_t\, \tau^C{}_t}{P_t}$$
$$+ \tau^C{}_t\, C_t + \left(1 + r^f{}_t\right)\, BG_{t-1}\, \exp\left(\left(-\phi^B\right)\, \left(\frac{NX_t}{Y_t} + \frac{r^f{}_t\, \left(B_{t-1} + BG_{t-1}\right)}{Y_t}\right)\right) \tag{126}$$

public capital stock

$$K^G{}_t = G_t + \left(1 - \delta^{K^G}\right)\, K^G{}_{t-1} \tag{127}$$

public foreing debt

$$BG_t = \eta_{BG\,t} \tag{128}$$

population

$$PoP_t = POP_0\, \exp\left(\eta_{PoP\,t}\right) \tag{129}$$

C.5 Climate variables

temperature

$$tas_{r\,t} = T_{0,n} + \eta_{tas,n}{}_t \tag{130}$$

surface wind speed

$$SfcWind_{r\,t} = T_{0,n} + \eta_{SfcWind,n}{}_t \tag{131}$$

percipitation

$$pr_{r\,t} = T_{0,n} + \eta_{pr,n}{}_t \tag{132}$$

sunshine influx

$$sunshine_{r\,t} = T_{0,n} + \eta_{sunshine,n}{}_t \tag{133}$$

relatuive surface humidity

$$hurs_{r\,t} = T_{0,n} + \eta_{hurs,n}{}_t \tag{134}$$

heatwave

$$heatwave_{r\,t} = T_{0,n} + \eta_{heatwave,n}{}_t \tag{135}$$

maximum consecutive dry days

$$maxdrydays_{r\,t} = T_{0,n} + \eta_{maxdrydays,n}{}_t \tag{136}$$

maximum consecutive wet days

$$maxwetdays_{r\,t} = T_{0,n} + \eta_{maxwetdays,n}{}_t \tag{137}$$

number of storms per year

$$storms_{r\,t} = T_{0,n} + \eta_{storms,n}{}_t \tag{138}$$

number of floods per year

$$floods_{r\,t} = T_{0,n} + \eta_{floods,n}{}_t \tag{139}$$

number of fires per year

$$fire_{r\,t} = T_{0,n} + \eta_{fire,n}{}_t \tag{140}$$

number of land slides per year

$$landslide_{r\,t} = T_{0,n} + \eta_{landslide,n}{}_t \tag{141}$$

sea level

$$SL_t = SL_0 + \eta_{SL,n}{}_t \tag{142}$$

D Calibration of DGE-CRED model

```
function [fval_vec,strpar,strys] = Calibration(x,strys,strexo,strpar)
    % function [ys,check] = Calibration(strys,strexo,strpar)
    % calibrates the parameters of the DGE_CRED_Model.mod
    % Inputs:
    %     strys      [structure]   endogeonous variables of the model
    %     strexo     [structure]   exogeonous variables of the model
    %     strpar     [structure]   parameters of the model
    %
    % Output:
    %     fval_vec   [numeric]     difference between demand and supply
    %                              for imports for a given national
    %                              price level
    %     strys      [structure]   see inputs
    %     strpar     [structure]   see inputs


    %% calculate exogenous variables
    [strys,strpar, strexo] = AssignPredeterminedVariables(strys,strpar,strexo);

    % assign initial value for national price level
    strys.P = x;

    % update parameter value for initila price level
    strpar.P0_p = strys.P;

    % assign value for initial gross vlaue added
    strys.Y = strpar.Y0_p./strys.P;

    % compute foreign interest rate
    strys.rf = 1/strpar.beta_p 1;

    % compute foreeing interest rate
    strpar.rf0_p = 1/strpar.beta_p 1;

    % assign value for effective exchange rate
    strys.Sf = 0;

    % population
    strys.PoP = strpar.PoP0_p * exp(strexo.exo_PoP);

    % housing area
    strys.H = strpar.H0_p * strys.PoP;

    % hours worked as share of total available hours
    strys.N = strpar.N0_p;

    % adaptation measures in the housing sector
    strys.G_A_DH = strexo.exo_G_A_DH * strpar.Y0_p;

    %% calculate sectoral and regional production factors and output

    for icosec = 1:strpar.inbsectors_p
        ssec = num2str(icosec);

        % sectoral interat rate
        strys.(['r_' ssec]) = (1/strpar.beta_p    1 ...
                                + strpar.delta_p)/(1    strys.tauKH);
        for icoreg = 1:strpar.inbregions_p
            sreg = num2str(icoreg);

            % subsectoral interat rate
            strys.(['r_' ssec '_' sreg]) = (1/strpar.beta_p    1 + strpar.delta_p)/(1    strys.
                tauKH);

            for icosubsec = strpar.(['substart_' ssec '_p']):strpar.(['subend_' ssec '_p'])
                ssubsec = num2str(icosubsec);

                % labour productivity
                strys.(['A_N_' ssubsec '_' sreg]) = strpar.(['A_N_' ssubsec '_' sreg '_p']);

                % sectoral productivity
                strys.(['A_' ssubsec '_' sreg]) = strpar.(['A_' ssubsec '_' sreg '_p']);

                % initial allocation of hours wotked
                strys.(['N_' ssubsec '_' sreg]) = strpar.(['phiN0_' ssubsec '_' sreg '_p']) *
                    strys.N;
            end
        end
    end

```

```
    for icosec = 1:strpar.inbsectors_p
        ssec = num2str(icosec);
        % intitialize sectoral capital stock
        strys.(['KH_' ssec]) = 0;
            for icoreg = 1:strpar.inbregions_p
                sreg = num2str(icoreg);
                % intitialize sectoral and regional capital stock
                strys.(['KH_' ssec '_' sreg]) = 0;

                for icosubsec = strpar.(['substart_' ssec '_p']):strpar.(['subend_' ssec '_p'])
                    ssubsec = num2str(icosubsec);
                    stemp = [ssubsec '_' sreg];

                    % degree of substitutability beween capital and labour
                    rhotemp = ((strpar.(['etaNK_' ssubsec '_' sreg '_p']) 1)/strpar.(['etaNK_' stemp '_p']));

                    % interest rate including taxes
                    rkgross = strys.(['r_' ssec '_' sreg]) * (1 + strys.(['tauKF_' stemp]));

                    %Differentiate between Cobb Douglas or CES
                    if strpar.(['etaNK_' stemp '_p']) == 1
                        % subsectoral and regional real labour costs
                        wtemp = (((1   strys.(['D_' stemp])) * strys.(['A_' stemp])) / ...
                        (rkgross / ((1   strpar.(['phiW_' stemp '_p']))...
                        * strys.(['A_K_' stemp])))^(1 strpar.(['phiW_' stemp '_p'])))^(1/strpar.(['phiW_' stemp '_p'])) * ...
                        strys.(['A_N_' stemp]) * (1   strys.(['D_N_' stemp]));

                    else
                        % subsectoral and regional real labour costs
                        wtemp = ((((1   strys.(['D_' stemp])) * strys.(['A_' stemp]))^(1/strpar.(['etaNK_' stemp '_p']))...
                          (1   strpar.(['phiW_' stemp '_p'])) * (rkgross/strys.(['A_K_' stemp]))^(strpar.(['etaNK_' stemp '_p']) 1))...
                        / strpar.(['phiW_' stemp '_p']))^(1/(strpar.(['etaNK_' stemp '_p']) 1))...
                        * strys.(['A_N_' stemp]) * (1   strys.(['D_N_' stemp]));

                    end
                    % price level for gross value added
                    strys.(['P_' stemp]) = strpar.(['phiW_' stemp '_p'])/wtemp * strpar.(['phiY_' stemp '_p']) * strys.Y *strys.P /(strys.PoP * strys.(['N_' stemp]));

                    % distribtuion parameter for capital in production function
                    strpar.(['alphaK_' stemp '_p']) = (1   strpar.(['phiW_' stemp '_p'])) * (rkgross/ ((1   strys.(['D_' stemp])) * strys.(['A_' stemp]) * strys.(['A_K_' stemp]) * (1   strys.(['D_K_' stemp]))))^(strpar.(['etaNK_' stemp '_p']) 1);

                    % distribtuion parameter for labour in production function
                    strpar.(['alphaN_' stemp '_p']) = strpar.(['phiW_' stemp '_p']) *  (wtemp /(((1   strys.(['D_N_' stemp])) * strys.(['A_N_' stemp]) * (1   strys.(['D_' stemp])) * strys.(['A_' stemp]))))^(strpar.(['etaNK_' stemp '_p']) 1);

                    % real gross value adde in the subsector and region
                    strys.(['Y_' stemp]) = strpar.(['phiY_' stemp '_p']) * strys.Y *strys.P / strys.(['P_' stemp]);

                    % capital stock used in the subsector and region
                    strys.(['K_' stemp]) = (1   strpar.(['phiW_' stemp '_p'])) * strys.(['Y_' stemp]) / rkgross;

                    % compute TFP
                    if strpar.(['etaNK_' stemp '_p']) == 1
                        strys.(['A_' stemp]) = strys.(['Y_' stemp]) / ((1   strys.(['D_' stemp])) *  (strys.(['A_K_' stemp]) * strys.(['K_' stemp]))^strpar.(['alphaK_' stemp '_p']) * (strys.PoP * strys.(['A_N_' stemp]) * (1  strys.(['D_N_' stemp])) * strys.(['N_' stemp]))^strpar.(['alphaN_' stemp '_p']));
                    else
                        strys.(['A_' stemp]) = strys.(['Y_' stemp]) /((1   strys.(['D_' stemp])) * (strpar.(['alphaK_' stemp '_p'])^(1/strpar.(['etaNK_' stemp '_p'])) * (strys.(['A_K_' stemp]) * strys.(['K_' stemp]))^rhotemp + strpar.(['alphaN_' stemp '_p'])^(1/strpar.(['etaNK_' stemp '_p'])) * (strys.PoP * strys.(['A_N_' stemp]) * (1   strys.(['D_N_' stemp])) * strys.(['N_' stemp]))^rhotemp)^(1/rhotemp));
                    end

                    % compute capital stock in the sector and region
```

```
                    strys.(['KH_' ssec '_' sreg]) = strys.(['KH_' ssec '_' sreg]) + strys.(['K_' stemp]) * strys.(['P_' stemp]) / strys.P;

                    % wages in the subsector and region
                    strys.(['W_' stemp]) = strpar.(['phiW_' stemp '_p']) * strys.(['Y_' stemp]) * strys.(['P_' stemp]) / (strys.PoP * strys.(['N_' stemp]) * (1 + strys.(['tauNF_' stemp])));

                    % demand for intermediate propducts in the subsector and region
                    strys.(['Q_I_' stemp]) = strys.(['Y_' stemp]) * strys.(['P_' stemp])  / strys.P * strpar.(['phiQI_' ssubsec '_p']) / (1   strpar.(['phiQI_' ssubsec '_p']));

                    % auxiliary variable to compute distribution parameter
                    tempQI = strys.P^strpar.(['etaI_' ssubsec '_p']) * strys.(['Q_I_' stemp]);

                    % auxiliary variable to compute distribution parameter
                    tempY = strys.(['P_' stemp])^strpar.(['etaI_' ssubsec '_p']) * strys.(['Y_' stemp]);

                    % compute distribution parameter for production function for intermedate products
                    strpar.(['omegaQI_' stemp '_p']) = tempQI / (tempY + tempQI);

                    % compute price of products produced in the region and subsector
                    strys.(['P_D_' stemp]) = (strpar.(['omegaQI_' stemp '_p']) * strys.P^(1   strpar.(['etaI_' ssubsec '_p'])) + (1   strpar.(['omegaQI_' stemp '_p']))...
                        * strys.(['P_' stemp])^(1   strpar.(['etaI_' ssubsec '_p'])))^(1/(1   strpar.(['etaI_' ssubsec '_p'])));

                    % compute output in the region and subsector
                    strys.(['Q_' stemp]) = (strys.(['P_' stemp]) * strys.(['Y_' stemp]) + strys.P * strys.(['Q_I_' stemp]))/strys.(['P_D_' stemp]);

                end

                % Lagrange multiplier for investment
                strys.(['omegaI_' ssec '_' sreg]) = strys.P;


                % compute sectoral and regional investment
                strys.(['I_' ssec '_' sreg]) = (strpar.delta_p) * strys.(['KH_' ssec '_' sreg]) + strys.(['D_K_' ssec '_' sreg]);

                % compute sectoral capital stock
                strys.(['KH_' ssec]) = strys.(['KH_' ssec]) + strys.(['KH_' ssec '_' sreg]);
            end
    end

    %% calculate sectoral and regional price indices and sectoral aggregates
    for icosec = 1:strpar.inbsectors_p
        ssec = num2str(icosec);
        iasubsec = strpar.(['substart_' ssec '_p']):strpar.(['subend_' ssec '_p']);
        for icosubsec = iasubsec
            ssubsec = num2str(icosubsec);

            % initialize subsectoral aggregate of employment
            strys.(['N_' ssubsec]) = 0;

            % intitalize subsectoral price index
            strys.(['P_D_' ssubsec]) = 0;

            for icoreg = 1:strpar.inbregions_p
                sreg = num2str(icoreg);

                % compute distribution parameters across regions in one subsector sectors
                temp = 0;
                tempdenom = (strys.(['P_D_' ssubsec '_' sreg]) /((strys.(['Q_' ssubsec '_' sreg]))^(1/strpar.(['etaQ_' ssubsec '_p']))))^(strpar.(['etaQ_' ssubsec '_p']));
                for icoregm = 1:strpar.inbregions_p
                    sregm = num2str(icoregm);
                    % compute numerator for distribution parameters across regions in one subsector
                    tempnum = (strys.(['P_D_' ssubsec '_' sregm]) / ((strys.(['Q_' ssubsec '_' sregm]))^(1/strpar.(['etaQ_' ssubsec '_p']))))^(strpar.(['etaQ_' ssubsec '_p']));


                    temp = temp + tempnum / tempdenom;
                end
                % distribution parameters across regions in one subsector sectors
```

```
                strpar.(['omegaQ_' ssubsec '_' sreg '_p']) = 1/temp;

                % aggregate labour across region in one sbsector
                strys.(['N_' ssubsec]) = strys.(['N_' ssubsec]) + strys.(['N_' ssubsec '_' sreg]);

                % aggregate price index across region in one sbsector
                strys.(['P_D_' ssubsec]) = strys.(['P_D_' ssubsec]) + strpar.(['omegaQ_' ssubsec '_' sreg '_p']) * strys.(['P_D_' ssubsec '_' sreg])^(1   strpar.(['etaQ_' ssubsec '_p']));
            end

            % aggregate price index across region in one sbsector
            strys.(['P_D_' ssubsec]) = strys.(['P_D_' ssubsec])^(1/(1   strpar.(['etaQ_' ssubsec '_p'])));

            % update intital aggregate price index across region in one sbsector
            strpar.(['P_D_' ssubsec '_p']) = strys.(['P_D_' ssubsec]);

            % inititlalize gross value added
            strys.(['Y_' ssubsec]) = 0;

            % inititlalize output
            strys.(['Q_' ssubsec]) = 0;

            % inititlalize gross vlaue added
            strys.(['Q_I_' ssubsec]) = 0;

            for icoreg = 1:strpar.inbregions_p
                sreg = num2str(icoreg);
                % aggregate gross value added
                strys.(['Y_' ssubsec]) = strys.(['Y_' ssubsec]) + strys.(['P_' ssubsec '_' sreg]) * strys.(['Y_' ssubsec '_' sreg]);

                % aggregate output
                strys.(['Q_' ssubsec]) = strys.(['Q_' ssubsec]) + strys.(['P_D_' ssubsec '_' sreg]) / strys.(['P_D_' ssubsec]) * strys.(['Q_' ssubsec '_' sreg]);

                % aggregate inermediate input
                strys.(['Q_I_' ssubsec]) = strys.(['Q_I_' ssubsec]) + strys.(['Q_I_' ssubsec '_' sreg]);
            end

            % compute sub sectoral exports
            strys.(['X_' ssubsec]) = strys.(['Q_' ssubsec]) * strpar.(['phiX_' ssubsec '_p']);


            % compute sub sectoral output used domestically
            strys.(['Q_D_' ssubsec]) = strys.(['Q_' ssubsec])   strys.(['X_' ssubsec]);

            % compute sub sectoral exports share
            strys.(['D_X_' ssubsec]) = strys.(['X_' ssubsec]) / strys.(['Q_' ssubsec]);

            % update exports share parameter
            strpar.(['D_X_' ssubsec '_p']) = strys.(['X_' ssubsec]) * (strys.(['P_D_' ssubsec])/strys.(['P_M_' ssubsec]))^(strpar.etaX_p) ;


        end
    end
    for icosec = 1:strpar.inbsectors_p
        ssec = num2str(icosec);

        % initiliaze sectoral aggregate investment
        strys.(['I_' ssec]) = 0;

        for icoreg = 1:strpar.inbregions_p
            sreg = num2str(icoreg);

            % aggregate sectoral aggregate investment
            strys.(['I_' ssec]) = strys.(['I_' ssec]) + strys.(['I_' ssec '_' sreg]) ;
        end

        % initialize sectoral aggregate output
        strys.(['Q_A_' ssec]) = 0;

        % initialize sectoral aggregate price level
        strys.(['P_A_' ssec]) = 0;


        for icosubsec = strpar.(['substart_' ssec '_p']):strpar.(['subend_' ssec '_p'])
            ssubsec = num2str(icosubsec);
            temp= 0;
```

```
            % compute auxiliary expression to compute distribution
            % parameters across subsectors in one sector (denominator)
            tempdenom = (strys.(['P_D_' ssubsec]) /((strys.(['Q_D_' ssubsec]))^( 1/strpar.(['etaQA' '_' ssec '_p'])))))^(strpar.(['etaQA' '_' ssec '_p']));
            for icosubsecm = strpar.(['substart_' ssec '_p']):strpar.(['subend_' ssec '_p'])
                    ssubsecm = num2str(icosubsecm);
                    % compute auxiliary expression to compute distribution
                    % parameters across subsectors in one sector (numerator)
                    tempnum = (strys.(['P_D_' ssubsecm]) /((strys.(['Q_D_' ssubsecm]))^( 1/strpar.(['etaQA' '_' ssec '_p'])))))^(strpar.(['etaQA' '_' ssec '_p']))
                        ;
                    % compute inverse distribution parameters across subsectors in one sector
                    temp = temp + tempnum / tempdenom;
            end

            % compute distribution parameters across subsectors in one sector
            strpar.(['omegaQ_' ssubsec '_p']) = 1/temp;

            % initialize subsectoral capital stock
            strys.(['K_' ssubsec]) = 0;

            % initialize subsectoral wage level
            strys.(['W_' ssubsec]) = 0;

            for icoreg = 1:strpar.inbregions_p
                sreg = num2str(icoreg);
                % aggregate  subsectoral capital stock
                strys.(['K_' ssubsec]) = strys.(['K_' ssubsec]) + strys.(['P_' ssubsec '_' sreg]) / strys.P * strys.(['K_' ssubsec '_' sreg]) ;

                % aggregate  subsectoral wages
                strys.(['W_' ssubsec]) = strys.(['W_' ssubsec]) + strys.(['N_' ssubsec '_' sreg]) / strys.(['N_' ssubsec]) * strys.(['W_' ssubsec '_' sreg]) ;

            end
            % aggregate  sectoral output
            strys.(['Q_A_' ssec]) = strys.(['Q_A_' ssec]) + strpar.(['omegaQ_' ssubsec '_p'])^(1/strpar.(['etaQA' '_' ssec '_p'])) * strys.(['Q_D_' ssubsec])^((strpar.(['etaQA' '_' ssec '_p']) 1)/strpar.(['etaQA' '_' ssec '_p']));

            % aggregate  sectoral price level
            strys.(['P_A_' ssec]) = strys.(['P_A_' ssec]) + strpar.(['omegaQ_' ssubsec '_p']) * strys.(['P_D_' ssubsec])^(1   strpar.(['etaQA' '_' ssec '_p']));
        end

        % aggregate  sectoral price level
        strys.(['P_A_' ssec]) = strys.(['P_A_' ssec])^(1/(1   strpar.(['etaQA' '_' ssec '_p'])));

        % aggregate  sectoral price level
        strys.(['Q_A_' ssec]) = strys.(['Q_A_' ssec])^(strpar.(['etaQA_' ssec '_p'])/(strpar.(['etaQA' '_' ssec '_p'])   1));

        % initialize  subsectoral capital stock
        strys.(['K_' ssubsec]) = 0;

        % initialize  subsectoral wages
        strys.(['W_' ssubsec]) = 0;

        for icoreg = 1:strpar.inbregions_p
            sreg = num2str(icoreg);
            % aggregate  subsectoral capital stock
            strys.(['K_' ssubsec]) = strys.(['K_' ssubsec]) + strys.(['P_' ssubsec '_' sreg]) / strys.P * strys.(['K_' ssubsec '_' sreg]) ;

            % aggregate  subsectoral wages
            strys.(['W_' ssubsec]) = strys.(['W_' ssubsec]) + strys.(['N_' ssubsec '_' sreg]) / strys.(['N_' ssubsec]) * strys.(['W_' ssubsec '_' sreg]) ;

        end
    end
    for icosec = 1:strpar.inbsectors_p
        ssec = num2str(icosec);
        % compute sectoral distribution parameters
        tempdenom = (strys.(['P_A_' ssec]) /((strys.(['Q_A_' ssec]))^( 1/strpar.etaQ_p)))^(strpar.etaQ_p);

        temp= 0;

        for icosecm = 1:strpar.inbsectors_p
            ssecm = num2str(icosecm);
            % compute sectoral distribution parameters
```

```
            tempnum = (strys.(['P_A_' ssecm]) /((strys.(['Q_A_' ssecm]))^( 1/strpar.etaQ_p)))^(strpar.etaQ_p);

            % compute sectoral distribution parameters
            temp = temp + tempnum / tempdenom;

        end
        % compute sectoral distribution parameters
        strpar.(['omegaQA_' ssec '_p']) = 1/temp;
    end

    % compute domestic price level
    strys.P_D = 0;
    for icosec = 1:strpar.inbsectors_p
        ssec = num2str(icosec);
        strys.P_D = strys.P_D + strpar.(['omegaQA_' ssec '_p']) * strys.(['P_A_' ssec])^(1  strpar.etaQ_p) ;
    end
    strys.P_D = strys.P_D^(1/(1   strpar.etaQ_p));

    % compute aggregates
    [strys, strpar, strexo] = ComputeAggregates(strys, strpar, strexo);

    % compute import price level
    strys.P_M = strpar.P0_M_p;

    % compute imports
    strys.M = strpar.phiM_p * strys.Q * strys.P_D / strys.P_M;

    % compute used products
    strys.Q_U = (strys.M * strys.P_M + strys.Q_D * strys.P_D)/strys.P;

    % compute distribution parameter for imports
    strpar.omegaF_p = strys.M * strys.P_M^strpar.etaF_p / (strys.M * strys.P_M^strpar.etaF_p + strys.Q_D * strys.P_D^strpar.etaF_p);

    % compute subsector imports and import prices
    for icosec = 1:strpar.inbsectors_p
        ssec = num2str(icosec);

        for icosubsec = strpar.(['substart_' ssec '_p']):strpar.(['subend_' ssec '_p'])
            ssubsec = num2str(icosubsec);

            if icosec == strpar.inbsectors_p && icosubsec == strpar.(['subend_' ssec '_p'])

                temp = strys.P_M^(strpar.etaM_p   1);

                for icosecm = 1:strpar.inbsectors_p
                    ssecm = num2str(icosecm);

                    if icosecm < strpar.inbsectors_p
                        for icosubsecm = strpar.(['substart_' ssecm '_p']):strpar.(['subend_' ssecm '_p'])
                            ssubsecm = num2str(icosubsecm);

                            temp = temp   strpar.(['phiM_' ssubsecm '_p']) * strys.(['P_M_' ssubsecm])^(strpar.etaM_p 1);

                        end
                    else
                        for icosubsecm = strpar.(['substart_' ssecm '_p']):(strpar.(['subend_' ssecm '_p']) 1)
                            ssubsecm = num2str(icosubsecm);

                            temp = temp   strpar.(['phiM_' ssubsecm '_p']) * strys.(['P_M_' ssubsecm])^(strpar.etaM_p 1);

                        end
                    end
                end
                strys.(['P_M_'  ssubsec]) = (temp / strpar.(['phiM_' ssubsec '_p']))^(1/(strpar.etaM_p 1));

            else
                strys.(['P_M_'  ssubsec]) = 0.9.*strys.P_M;%strpar.(['P_M_' ssec '_p']);

            end
            strpar.(['P_M_'  ssubsec '_p']) = strys.(['P_M_'  ssubsec]);

            strys.(['M_' ssubsec]) = strpar.(['phiM_' ssubsec '_p']) * strys.M * strys.P_M / strys.(['P_M_' ssubsec]);
        end
    end
```

```

    % compute distribution parameter for subsector imports
    for icosec = 1:strpar.inbsectors_p
        ssec = num2str(icosec);
        for icosubsec = strpar.(['substart_' ssec '_p']):strpar.(['subend_' ssec '_p'])
            ssubsec = num2str(icosubsec);

            temp = 0;

            tempdenom = strys.(['P_M_' ssubsec])^(strpar.etaM_p)  * strys.(['M_' ssubsec]);

            for icosecm = 1:strpar.inbsectors_p
                ssecm = num2str(icosecm);
                for icosubsecm = strpar.(['substart_' ssecm '_p']):strpar.(['subend_' ssecm '_p'])
                    ssubsecm = num2str(icosubsecm);

                    tempnum = strys.(['P_M_' ssubsecm])^(strpar.etaM_p)  * strys.(['M_' ssubsecm]);

                    temp = temp + tempnum / tempdenom;
                end
            end

            strpar.(['omegaM_' ssubsec '_p']) = 1/temp;

        end
    end

    % net exports
    strys.NX = (strys.P_D * strys.X   strys.P_M * strys.M)/strys.P;

    strpar.NX0_p = strys.NX/strys.Y;

    % domesitcally used products
    strys.Q_U = (strys.M * strys.P_M + strys.Q_D * strys.P_D)/strys.P;

    % compute tax income
    [strys,strpar, strexo] = TaxIncome(strys,strpar, strexo);

    % foreign debt / (B > 0 debitor vs. B < 0 creditor)
    strys.B =  strys.NX/strys.rf   strys.BG;

    % lagrange multiplier for houses
    strys.omegaH = strys.PH * (1 + strys.tauH);

    % house prices
    strys.PH = strpar.sH_p * strys.P * strys.Y / (strpar.deltaH_p * strys.H * (1 + strys.tauH));

    % consumption
    strys.C = ((strys.P_D / strys.P * strys.Q   strys.NX   strys.Q_I   strys.I   strys.wagetax   strys.capitaltax   strys.PH / strys.P * strys.H * strpar.deltaH_p * (1 + strys.tauH) + strys.rf * strys.BG) / (1 + strys.tauC));

    % auxiliary variable to compute gamma
    tempgam = strys.H * strys.PH * (1 + strys.tauH) / (strys.C * strys.P * (1 + strys.tauC)) * (1   strpar.beta_p * (1   strpar.deltaH_p)) / (strpar.beta_p);

    % preference parameter for houses to ensure housing share
    strpar.gamma_p = tempgam / (1 + tempgam);

    % house price level
    strpar.PH0_p = strys.PH;

    % damages to houses induced by climate change
    strys.DH = strexo.exo_DH * strpar.Y0_p /strys.PH;

    % Lagrange multiplier of budget constraint HH
    strys.lambda = (1 strpar.gamma_p) * (strys.C/strys.PoP)^( strpar.gamma_p) * (strys.H/strys.PoP)^strpar.gamma_p * ((strys.C/strys.PoP)^(1 strpar.gamma_p) * (strys.H/strys.PoP)^strpar.gamma_p)^( strpar.sigmaC_p) / (strys.P * (1 + strys.tauC));

    % investment into housing
    strys.IH = strpar.deltaH_p * strys.H;

    % government expenditure
    strys.G = (strys.wagetax + strys.capitaltax + strys.tauC * strys.C + strys.tauH * strys.PH/strys.P * strys.IH)   strys.rf * strys.BG   strys.adaptationcost;

    % public capital stock
    strys.KG = strys.G / strpar.deltaKG_p;

```

```
    %% compute labour disutlity parameters
    for icosec = 1:strpar.inbsectors_p
        ssec = num2str(icosec);

        for icoreg = 1:strpar.inbregions_p
            sreg = num2str(icoreg);

            for icosubsec = strpar.(['substart_' ssec '_p']):strpar.(['subend_' ssec '_p'])
                ssubsec = num2str(icosubsec);

                strpar.(['phiL_' ssubsec '_' sreg '_p']) = (1   strys.tauNH) * strys.(['W_' ssubsec '_' sreg]) * strys.lambda / (strys.(['A_N_' ssubsec '_' sreg]) * strys.(['N_' ssubsec '_' sreg])^(strpar.sigmaL_p));

                strpar.(['A_' ssubsec '_' sreg '_p']) = strys.(['A_' ssubsec '_' sreg]) ./ (strys.KG^strpar.phiG_p * exp(strexo.(['exo_' ssubsec '_' sreg])));

            end
        end
    end
    % check initial guess for price levle and implied one
    fval_vec = 1   strys.P / ((1   strpar.omegaF_p) * strys.P_D^(1   strpar.etaF_p) + (strpar.omegaF_p) * strys.P_M^(1   strpar.etaF_p))^(1/(1   strpar.etaF_p));

end
```

E Steady state calculation of DGE-CRED model for the Baseline and Climate Change Scenarios

```
function [fval_vec,strys,strexo] = FindK(x,strys,strexo,strpar)
    % function [fval_vec,strys] = FindK(x,strys,strexo,strpar)
    % finds capital stock vector to fulfill the static equations of the
    % model
    % Inputs:
    %     x          [vector]      vector of initial values for the steady
    %                              state of the regional and sectoral capital
    %                              stock
    %     strys      [structure]   structure containing all endogeonous
    %                              variables of the model
    %     strexo     [structure]   structure containing all exogeonous
    %                              variables of the model
    %     strpar     [structure]   structure containing all parameters of the
    %                              model
    %
    % Output:
    %     fval_vec   [vector]      residuals of regional and sector specific
    %                              for FOC of Households with respect to
    %                              regional labour
    %     strys      [structure]   see inputs
    %     strexo     [structure]   see inputs

    % get maximum number of eectors
    strpar.sMaxsec = num2str(strpar.inbsectors_p);

    % get guesses for the capital stock
    istart = 1;

    iend = strpar.(['subend_' strpar.sMaxsec '_p'])*strpar.inbregions_p;

    x_start_vec_1 = x(istart:iend);

    % get guesses for intermediate production
    istart = (strpar.(['subend_' strpar.sMaxsec '_p'])*strpar.inbregions_p+1);

    iend   = (2*strpar.(['subend_' strpar.sMaxsec '_p'])*strpar.inbregions_p);

    x_start_vec_2 = x(istart:iend);

    % get guesses for exports
    istart = (2*strpar.(['subend_' strpar.sMaxsec '_p'])*strpar.inbregions_p)+1;

    iend   = (2*strpar.(['subend_' strpar.sMaxsec '_p'])*strpar.inbregions_p)+strpar.(['subend_' strpar.sMaxsec '_p']);

    x_start_vec_4 = x(istart:iend);

    % get guess for total imports
    strys.M = x((2*strpar.(['subend_' strpar.sMaxsec '_p'])*strpar.inbregions_p)+strpar.(['subend_' strpar.sMaxsec '_p'])+1);

    % compute foreing interest rate
    strys.rf = strpar.rf0_p + strexo.exo_rf;

    % assign regional climate variables
    for icoreg = 1:strpar.inbregions_p
        sreg = num2str(icoreg);
        for sClimateVar = strpar.casClimatevarsRegional
            strys.([char(sClimateVar) '_' sreg]) = strpar.([char(sClimateVar) '0_' sreg '_p']) + strexo.(['exo_' char(sClimateVar) '_' sreg]);

        end
    end
    for sClimateVar = strpar.casClimatevarsNational
        strys.(char(sClimateVar)) = strpar.([char(sClimateVar) '0_p']) + strexo.(['exo_' char(sClimateVar)]);

    end

    % define regional price level
    strys.P = strpar.P0_p .* exp(strexo.exo_P);

    % get import price
    if strpar.lEndogenousY_p == 0
        strys.P_M = x(end);

    else
        strys.P_M = strpar.P0_M_p + strexo.exo_M;
```

```
    end

    strys.P_M_1 = strys.P_M^(1    strpar.etaM_p);



    for icosec = 1:strpar.inbsectors_p
        ssec = num2str(icosec);
        for icosubsec = strpar.(['substart_' ssec '_p']):strpar.(['subend_' ssec '_p'])
            ssubsec = num2str(icosubsec);
            if strpar.lCalibration_p == 2
                % get initial guesses for export shares
                strys.(['D_X_' ssubsec]) = x_start_vec_4(icosubsec);

            else
                % get initial guesses for exports
                strys.(['X_' ssubsec]) = x_start_vec_4(icosubsec);

            end

            if icosubsec > 1
                % compute import prices
                strys.(['P_M_' ssubsec]) = (strpar.(['P_M_' ssubsec '_p'])./ strpar.P0_M_p + strexo.(['exo_M_' ssubsec])) * strys.P_M;

                % re compute the first import price
                strys.P_M_1 = strys.P_M_1    strpar.(['omegaM_' ssubsec '_p']) * strys.(['P_M_' ssubsec])^(1    strpar.etaM_p);
            end

        end
    end

    strys.P_M_1 = (strys.P_M_1/strpar.omegaM_1_p)^(1/(1    strpar.etaM_p));

    % compute domestic price level
    strys.P_D = ((strys.P^(1    strpar.etaF_p)    strpar.omegaF_p * strys.P_M^(1    strpar.etaF_p)) / (1    strpar.omegaF_p))^(1/(1    strpar.etaF_p));

    % assign predetermined variables
    [strys,strpar, strexo] = AssignPredeterminedVariables(strys,strpar, strexo);

    %
    if strpar.lCalibration_p == 2

        [strys, strpar, strexo] = Initialize_FindK_ExogenousY(strys, strpar, strexo, x, x_start_vec_1, x_start_vec_2);

    else
        for icosec = 1:strpar.inbsectors_p
            ssec = num2str(icosec);
            for icosubsec = strpar.(['substart_' ssec '_p']):strpar.(['subend_' ssec '_p'])
                ssubsec = num2str(icosubsec);
                for icoreg = 1:strpar.inbregions_p
                    sreg = num2str(icoreg);
                    icovec = icoreg + (icosubsec  1)*strpar.inbregions_p;

                    strys.(['Q_I_' ssubsec '_' sreg]) = sqrt(real(x_start_vec_2(icovec)).^2);

                    strys.(['K_' ssubsec '_' sreg]) = sqrt(real(x_start_vec_1(icovec)).^2);
                end
            end
        end
        if strpar.phiG_p > 0
            if strpar.lEndogenousY_p == 0

                strys.G = x(end 1);
            else

                strys.G = x(end);
            end
        end
    end

    % public capital stock
    strys.KG = strys.G / strpar.deltaKG_p;


    %% calculate exogenous variables

    % population stock
    strys.PoP = strpar.PoP0_p * exp(strexo.exo_PoP);
```

```
    if strpar.lEndogenousY_p == 0
        % housing area
        strys.H  = (strpar.H0_p + strexo.exo_H) * strys.PoP;

    else
        % price per housing area
        strys.PH  = strpar.PH0_p * exp(strexo.exo_H);

    end

    % government expenditure to the housing area
    strys.G_A_DH = strexo.exo_G_A_DH * strpar.Y0_p;


    %% calculate sectoral and regional production factors and output
    for icosec = 1:strpar.inbsectors_p
        ssec = num2str(icosec);
        % compute sectoral rental rate for capital
        strys.(['r_' ssec]) = (1/strpar.beta_p   1 + strpar.delta_p)/(1   strys.tauKH);

        for icoreg = 1:strpar.inbregions_p
            sreg = num2str(icoreg);

            % compute sectoral and regional rental rate for capital
            strys.(['r_' ssec '_' sreg]) = (1/strpar.beta_p   1 + strpar.delta_p)/(1   strys.tauKH);

            for icosubsec = strpar.(['substart_' ssec '_p']):strpar.(['subend_' ssec '_p'])
                ssubsec = num2str(icosubsec);

                % auxiliary variable to define the degree of substitutability
                % between capital and labour in the sector
                rhotemp = ((strpar.(['etaNK_' ssubsec '_' sreg '_p'])  1)/strpar.(['etaNK_' ssubsec '_' sreg '_p']));

                % compute sectoral and regional rental rate for capital
                strys.(['lambK_' ssubsec '_' sreg]) = 0;

                if strpar.lEndogenousY_p == 1
                    % compute regional and sub sectoral productivity
                    strys.(['A_' ssubsec '_' sreg]) = strpar.(['A_' ssubsec '_' sreg '_p']) * exp(strexo.(['exo_' ssubsec '_' sreg])) * strys.KG^strpar.phiG_p;

                end

                if strpar.lEndogenousY_p == 1
                    % compute regional and sub sectoral labour productivity
                    strys.(['A_N_' ssubsec '_' sreg]) = strpar.(['A_N_' ssubsec '_' sreg '_p']) * exp(strexo.(['exo_N_' ssubsec '_' sreg]));

                end

                rkgross = strys.(['r_' ssec '_' sreg]) * (1 + strys.(['tauKF_' ssubsec '_' sreg]));

                if strpar.lCalibration_p == 2 % Baseline / exogenous Y
                    if strpar.(['etaNK_' ssubsec '_' sreg '_p']) ~= 1
                        % compute regional and sub sectoral productivity
                        strys.(['A_' ssubsec '_' sreg]) = (rkgross / (strpar.(['alphaK_' ssubsec '_' sreg '_p'])^(1/ strpar.(['etaNK_' ssubsec '_' sreg '_p'])) *  (strys.(['A_K_' ssubsec '_' sreg]) * (1   strys.(['D_' ssubsec '_' sreg])))^rhotemp * (strys.(['K_' ssubsec '_' sreg])/strys.(['Y_' ssubsec '_' sreg]))^( 1/strpar.(['etaNK_' ssubsec '_' sreg '_p'])))))^(1/rhotemp);

                    else
                        % compute the capital stock
                        strys.(['K_' ssubsec '_' sreg]) = strpar.(['alphaK_' ssubsec '_' sreg '_p']) * strys.(['Y_' ssubsec '_' sreg]) / rkgross;

                        % compute the gross wage
                        wgross = strpar.(['alphaN_' ssubsec '_' sreg '_p']) / strpar.(['alphaK_' ssubsec '_' sreg '_p']) * strys.(['K_' ssubsec '_' sreg]) / (strys.PoP * strys.(['N_' ssubsec '_' sreg])) * rkgross * strys.(['P_' ssubsec '_' sreg]);

                        % compute auxiliary variable to compute
                        % productivity
                        temp = (rkgross/(strpar.(['alphaK_' ssubsec '_' sreg '_p']) * strys.(['A_K_' ssubsec '_' sreg])))^strpar.(['alphaK_' ssubsec '_' sreg '_p']) * ...
```

```
                        (wgross/(strpar.(['alphaN_' ssubsec '_' sreg '_p']) * strys.(['A_N_' ssubsec '_' sreg]) * (1   strys.(['D_N_' ssubsec '_' sreg]))))^strpar.(['alphaK_' ssubsec '_' sreg '_p']));

                    % compute subsectoral and regional productivity
                    strys.(['A_' ssubsec '_' sreg]) = strys.(['P_' ssubsec '_' sreg]) / temp;

                end

                % recompute the exogenous disturbances to productivity
                % should be unneccary if everything is correct
                if strpar.lEndogenousY_p == 1
                    strexo.(['exo_' ssubsec '_' sreg]) = log(strys.(['A_' ssubsec '_' sreg]) / (strys.KG^strpar.phiG_p * strpar.(['A_' ssubsec '_' sreg '_p'])));

                else
                    strexo.(['exo_' ssubsec '_' sreg]) = log((strys.(['Y_' ssubsec '_' sreg]) .* strys.(['P_' ssubsec '_' sreg])/strys.P) ./ (strpar.Y0_p ./strpar.P0_p .* strpar.(['phiY0_' ssubsec '_' sreg '_p'])));

                end
                % compute exogenous labour productivity
                if strpar.(['etaNK_' ssubsec '_' sreg '_p']) ~= 1 % CES
                    temp1 = (strys.(['K_' ssubsec '_' sreg]) * rkgross^strpar.(['etaNK_' ssubsec '_' sreg '_p']) / (strpar.(['alphaK_' ssubsec '_' sreg '_p']) * strys.(['A_K_' ssubsec '_' sreg])^(strpar.(['etaNK_' ssubsec '_' sreg '_p']) 1) * (strys.(['A_' ssubsec '_' sreg]) * (1 strys.(['D_' ssubsec '_' sreg])))^(strpar.(['etaNK_' ssubsec '_' sreg '_p'])))))^rhotemp;

                    temp2 = strpar.(['alphaK_' ssubsec '_' sreg '_p'])^(1/strpar.(['etaNK_' ssubsec '_' sreg '_p'])) * strys.(['A_K_' ssubsec '_' sreg])^rhotemp * strys.(['K_' ssubsec '_' sreg])^rhotemp;

                    temp = ((temp1   temp2) / (strpar.(['alphaN_' ssubsec '_' sreg '_p'])^(1/strpar.(['etaNK_' ssubsec '_' sreg '_p'])) * (strys.PoP .* strys.(['N_' ssubsec '_' sreg]))^rhotemp))^(1/rhotemp);

                    strys.(['A_N_' ssubsec '_' sreg]) = temp / (1   strys.(['D_N_' ssubsec '_' sreg]));

                    if strpar.lEndogenousY_p == 1
                        strexo.(['exo_N_' ssubsec '_' sreg]) = log(strys.(['A_N_' ssubsec '_' sreg])/strpar.(['A_N_' ssubsec '_' sreg '_p']));

                    else
                        strexo.(['exo_N_' ssubsec '_' sreg]) = log(strys.(['N_' ssubsec '_' sreg])/(strpar.(['phiN0_' ssubsec '_' sreg '_p'])*strpar.N0_p));

                    end
                else % Cobb Douglas
                    if strpar.lEndogenousY_p == 1
                        strexo.(['exo_N_' ssubsec '_' sreg]) = log(strys.(['A_N_' ssubsec '_' sreg])/strpar.(['A_N_' ssubsec '_' sreg '_p']));

                    end
                end
            else  % Climate Change Scenarios / endogenous Y
                if strpar.(['etaNK_' ssubsec '_' sreg '_p']) ~= 1
                    temp1 = (strys.(['K_' ssubsec '_' sreg]) * rkgross^strpar.(['etaNK_' ssubsec '_' sreg '_p']) / (strpar.(['alphaK_' ssubsec '_' sreg '_p']) * strys.(['A_K_' ssubsec '_' sreg])^(strpar.(['etaNK_' ssubsec '_' sreg '_p']) 1) * (strys.(['A_' ssubsec '_' sreg]) * (1 strys.(['D_' ssubsec '_' sreg])))^(strpar.(['etaNK_' ssubsec '_' sreg '_p'])))))^rhotemp;

                    temp2 = strpar.(['alphaK_' ssubsec '_' sreg '_p'])^(1/strpar.(['etaNK_' ssubsec '_' sreg '_p'])) * strys.(['A_K_' ssubsec '_' sreg])^rhotemp * strys.(['K_' ssubsec '_' sreg])^rhotemp;

                    temp = ((temp1   temp2) / (strpar.(['alphaN_' ssubsec '_' sreg '_p'])^(1/strpar.(['etaNK_' ssubsec '_' sreg '_p']))))^(1/rhotemp);

                    if strpar.lEndogenousY_p == 1
                        % compute labour
                        strys.(['N_' ssubsec '_' sreg]) = temp / (strys.PoP * (1   strys.(['D_N_' ssubsec '_' sreg])) * strys.(['A_N_' ssubsec '_' sreg]));

                    else
```

```
                    % compute labour productivity
                    strys.(['A_N_' ssubsec '_' sreg]) = temp / (strys.PoP * (1   strys.(['D_N_' ssubsec '_' sreg])) * strys.(['N_' ssubsec '_' sreg]));

                end
            else
                % compute labour demand
                strys.(['N_' ssubsec '_' sreg]) = (strys.(['K_' ssubsec '_' sreg]) * rkgross / (strpar.(['alphaK_' ssubsec '_' sreg '_p']) * strys.(['A_' ssubsec '_' sreg]) *  (1   strys.(['D_' ssubsec '_' sreg])) * (strys.(['A_K_' ssubsec '_' sreg]) * ...
                                                  strys.(['K_' ssubsec '_' sreg]))^strpar.(['alphaK_' ssubsec '_' sreg '_p'])))^(1/strpar.(['alphaN_' ssubsec '_' sreg '_p'])) / (strys.(['A_N_' ssubsec '_' sreg]) * (1   strys.(['D_N_' ssubsec '_' sreg])) * strys.PoP);


            end

        end
        if strpar.(['etaNK_' ssubsec '_' sreg '_p']) ~= 1 % CES
            if strpar.lEndogenousY_p == 1
                % compute gross vlaue added
                strys.(['Y_' ssubsec '_' sreg]) = strys.(['A_' ssubsec '_' sreg]) * (1   strys.(['D_' ssubsec '_' sreg])) * (strpar.(['alphaK_' ssubsec '_' sreg '_p'])^(1/strpar.(['etaNK_' ssubsec '_' sreg '_p'])) * (strys.(['A_K_' ssubsec '_' sreg]) * strys.(['K_' ssubsec '_' sreg]))^rhotemp + strpar.(['alphaN_' ssubsec '_' sreg '_p'])^(1/strpar.(['etaNK_' ssubsec '_' sreg '_p'])) * (strys.PoP * strys.(['A_N_' ssubsec '_' sreg]) * (1   strys.(['D_N_' ssubsec '_' sreg])) * strys.(['N_' ssubsec '_' sreg]))^rhotemp)^(1/rhotemp);

            else
                % compute productivity
                strys.(['A_' ssubsec '_' sreg]) = strys.(['Y_' ssubsec '_' sreg]) /((1   strys.(['D_' ssubsec '_' sreg])) * (strpar.(['alphaK_' ssubsec '_' sreg '_p'])^(1/strpar.(['etaNK_' ssubsec '_' sreg '_p'])) * (strys.(['A_K_' ssubsec '_' sreg]) * strys.(['K_' ssubsec '_' sreg]))^rhotemp + strpar.(['alphaN_' ssubsec '_' sreg '_p'])^(1/strpar.(['etaNK_' ssubsec '_' sreg '_p'])) * (strys.PoP * strys.(['A_N_' ssubsec '_' sreg]) * (1   strys.(['D_N_' ssubsec '_' sreg])) * strys.(['N_' ssubsec '_' sreg]))^rhotemp)^(1/rhotemp));

            end
        else
            if strpar.lEndogenousY_p == 1
                % compute gross vlaue added % Cobb Douglas
                strys.(['Y_' ssubsec '_' sreg]) = strys.(['A_' ssubsec '_' sreg]) * (1   strys.(['D_' ssubsec '_' sreg])) *  (strys.(['A_K_' ssubsec '_' sreg]) * strys.(['K_' ssubsec '_' sreg]))^strpar.(['alphaK_' ssubsec '_' sreg '_p']) * (strys.PoP * strys.(['A_N_' ssubsec '_' sreg]) * (1   strys.(['D_N_' ssubsec '_' sreg])) * strys.(['N_' ssubsec '_' sreg]))^strpar.(['alphaN_' ssubsec '_' sreg '_p']);

            else
                % compute productivity
                strys.(['A_' ssubsec '_' sreg]) = strys.(['Y_' ssubsec '_' sreg]) / ((1   strys.(['D_' ssubsec '_' sreg])) *  (strys.(['A_K_' ssubsec '_' sreg]) * strys.(['K_' ssubsec '_' sreg]))^strpar.(['alphaK_' ssubsec '_' sreg '_p']) * (strys.PoP * strys.(['A_N_' ssubsec '_' sreg]) * (1   strys.(['D_N_' ssubsec '_' sreg])) * strys.(['N_' ssubsec '_' sreg]))^strpar.(['alphaN_' ssubsec '_' sreg '_p']));

            end
        end
        % compute substitutability between intermediate goods and
        % gross value added
        rhotemp = (strpar.(['etaI_' ssubsec '_p'])   1)/strpar.(['etaI_' ssubsec '_p']);

        % compute outputs
        strys.(['Q_' ssubsec '_' sreg]) = (strpar.(['omegaQI_' ssubsec '_' sreg '_p'])^(1/strpar.(['etaI_' ssubsec '_p'])) * strys.(['Q_I_' ssubsec '_' sreg])^rhotemp + ...
                                  (1   strpar.(['omegaQI_' ssubsec '_' sreg '_p']))^(1/strpar.(['etaI_' ssubsec '_p'])) * strys.(['Y_' ssubsec '_' sreg])^rhotemp)^(1/rhotemp);
```

```
            end
        end
        % initiliaze aggregate sector production
        strys.(['Q_A_' ssec]) = 0;

        % compute subsitutability between different sbsectors in the sector
        rhotemp = (strpar.(['etaQA_' ssec '_p']) 1)/strpar.(['etaQA_' ssec '_p']);

        for icosubsec = strpar.(['substart_' ssec '_p']):strpar.(['subend_' ssec '_p'])
            ssubsec = num2str(icosubsec);
            % initiliaze aggregate subsector production
            strys.(['Q_' ssubsec]) = 0;

            for icoreg = 1:strpar.inbregions_p
                sreg = num2str(icoreg);
                % compute subsector production
                strys.(['Q_' ssubsec]) = strys.(['Q_' ssubsec]) + strpar.(['omegaQ_' ssubsec '_' sreg '_p'])^(1/strpar.(['etaQ_' ssubsec '_p'])) * (strys.(['Q_' ssubsec '_' sreg]))^((strpar.(['etaQ_' ssubsec '_p']) 1)/strpar.(['etaQ_' ssubsec '_p']));

            end
            % compute subsector production
            strys.(['Q_' ssubsec]) = strys.(['Q_' ssubsec])^(strpar.(['etaQ_' ssubsec '_p'])/(strpar.(['etaQ_' ssubsec '_p']) 1));

            if strpar.lCalibration_p == 2
                % compute exports
                strys.(['X_' ssubsec]) = strys.(['Q_' ssubsec]) * strys.(['D_X_' ssubsec]);

            else
                % compute export share
                strys.(['D_X_' ssubsec]) = strys.(['X_' ssubsec]) / strys.(['Q_' ssubsec]);

            end

            % compute domestically used products
            strys.(['Q_D_' ssubsec]) = strys.(['Q_' ssubsec])   strys.(['X_' ssubsec]);

            % aggregate sector production
            strys.(['Q_A_' ssec])  = strys.(['Q_A_' ssec]) + strpar.(['omegaQ_' ssubsec '_p'])^(1/strpar.(['etaQA_' ssec '_p'])) * strys.(['Q_D_' ssubsec])^rhotemp;
        end
        % aggregate sector production
        strys.(['Q_A_' ssec])  = strys.(['Q_A_' ssec])^(1/rhotemp);

    end

    % init domestically used products
    strys.Q_D = 0;

    % substituatibility between sectoral products
    rhotemp = (strpar.etaQ_p 1)/strpar.etaQ_p;

    for icosec = 1:strpar.inbsectors_p
        ssec = num2str(icosec);
        % aggregate domestically used products
        strys.Q_D  = strys.Q_D + strpar.(['omegaQA_' ssec '_p'])^(1/strpar.etaQ_p) * strys.(['Q_A_' ssec])^rhotemp;
    end

    % domestic output
    strys.Q_D = strys.Q_D^(1/rhotemp);

    % substituatibility between domestic and foreign products
    rhotemp = (strpar.etaF_p 1)/strpar.etaF_p;

    % domestically used output
    strys.Q_U = (strpar.omegaF_p^(1/strpar.etaF_p) * strys.M^rhotemp + (1   strpar.omegaF_p)^(1/strpar.etaF_p) * strys.Q_D^rhotemp)^(1/rhotemp);

    % domestic price level
    strys.P_D = (1   strpar.omegaF_p)^(1/strpar.etaF_p) * (strys.Q_D/strys.Q_U)^( 1/strpar.etaF_p) * strys.P;

    %% calculate sectoral and regional price indices and sectoral aggregates
    for icosec = 1:strpar.inbsectors_p
        ssec = num2str(icosec);
        % compute sectoral price level
        strys.(['P_A_' ssec]) = strpar.(['omegaQA_' ssec '_p'])^(1/strpar.etaQ_p) * (strys.(['Q_A_' ssec]) / strys.Q_D)^( 1/strpar.etaQ_p) * strys.P_D;

        % init sectoral capital stock
```

```
        strys.(['KH_' ssec]) = 0;

        for icosubsec = strpar.(['substart_' ssec '_p']):strpar.(['subend_' ssec '_p'])
            ssubsec = num2str(icosubsec);
            % compute sub sectoral imports
            strys.(['M_' ssubsec]) = strpar.(['omegaM_' ssubsec '_p']) * (strys.(['P_M_' ssubsec]) / strys.P_M)^( strpar.etaM_p) * strys.M;

            % init sub sectoral labour
            strys.(['N_' ssubsec]) = 0;

            % compute sub sectoral price level
            strys.(['P_D_' ssubsec]) = strpar.(['omegaQ_' ssubsec '_p'])^(1/strpar.(['etaQA_' ssec '_p'])) * (strys.(['Q_D_' ssubsec]) / strys.(['Q_A_' ssec]))^( 1/strpar.(['etaQA_' ssec '_p'])) * strys.(['P_A_' ssec]);strys.(['D_X_' ssubsec]);

            for icoreg = 1:strpar.inbregions_p
                sreg = num2str(icoreg);
                rhotemp = ((strpar.(['etaNK_' ssubsec '_' sreg '_p'])  1)/strpar.(['etaNK_' ssubsec '_' sreg '_p']));

                % compute sub sectoral and regional domestic price level
                strys.(['P_D_' ssubsec '_' sreg]) = strpar.(['omegaQ_' ssubsec '_' sreg '_p'])^(1/strpar.(['etaQ_' ssubsec '_p'])) * (strys.(['Q_' ssubsec '_' sreg]) / strys.(['Q_' ssubsec]))^( 1/strpar.(['etaQ_' ssubsec '_p'])) * strys.(['P_D_' ssubsec]);

                % compute sub sectoral and regional price level of primary
                % production factors
                strys.(['P_' ssubsec '_' sreg]) = (1   strpar.(['omegaQI_' ssubsec '_' sreg '_p']))^(1/strpar.(['etaI_' ssubsec '_p'])) * (strys.(['Y_' ssubsec '_' sreg]) / strys.(['Q_' ssubsec '_' sreg]))^( 1/strpar.(['etaI_' ssubsec '_p'])) * strys.(['P_D_' ssubsec '_' sreg]);

                % compute sub sectoral and regional wages
                strys.(['W_' ssubsec '_' sreg]) = strpar.(['alphaN_' ssubsec '_' sreg '_p'])^(1/strpar.(['etaNK_' ssubsec '_' sreg '_p'])) * (strys.(['A_' ssubsec '_' sreg]) * (1   strys.(['D_' ssubsec '_' sreg])) * strys.(['A_N_' ssubsec '_' sreg]) * (1   strys.(['D_N_' ssubsec '_' sreg])))^rhotemp * ((strys.(['N_' ssubsec '_' sreg]) * strys.PoP) / strys.(['Y_' ssubsec '_' sreg]))^( 1/strpar.(['etaNK_' ssubsec '_' sreg '_p']))*strys.(['P_' ssubsec '_' sreg]) / (1 + strys.(['tauNF_' ssubsec '_' sreg]));

                % aggregate sub sectoral labour
                strys.(['N_' ssubsec]) = strys.(['N_' ssubsec]) + strys.(['N_' ssubsec '_' sreg]);

            end

            % init sub sectoral capital stock
            strys.(['K_' ssubsec]) = 0;

            % init sub sectoral wages
            strys.(['W_' ssubsec]) = 0;

            % init intermediate subsectoral gross value added
            strys.(['Y_' ssubsec]) = 0;

            % init intermediate subsectoral products
            strys.(['Q_I_' ssubsec]) = 0;

            for icoreg = 1:strpar.inbregions_p
                sreg = num2str(icoreg);

                % aggregate sectoral and regional capital stock of households
                if icosubsec == strpar.(['substart_' ssec '_p'])
                    strys.(['KH_' ssec '_' sreg]) = 0;
                end

                % compute subsectoral capital sotck
                strys.(['K_' ssubsec]) = strys.(['K_' ssubsec]) + strys.(['P_' ssubsec '_' sreg]) / strys.P * strys.(['K_' ssubsec '_' sreg]) ;

                % compute subsectoral wages
                strys.(['W_' ssubsec]) = strys.(['W_' ssubsec]) + strys.(['N_' ssubsec '_' sreg]) / strys.(['N_' ssubsec]) * strys.(['W_' ssubsec '_' sreg]) ;

                % compute subsectoral gross value added
                strys.(['Y_' ssubsec]) = strys.(['Y_' ssubsec]) + strys.(['P_' ssubsec '_' sreg]) * strys.(['Y_' ssubsec '_' sreg]) ;

                % compute aggregate subsectoral intermediate products demand
```

```
                strys.(['Q_I_' ssubsec]) = strys.(['Q_I_' ssubsec]) + strys.(['Q_I_' ssubsec '
                    _' sreg]) ;

                % compute sectoral and regional capital demand
                strys.(['KH_' ssec '_' sreg]) = strys.(['KH_' ssec '_' sreg]) + strys.(['P_'
                    ssubsec '_' sreg]) * strys.(['K_' ssubsec '_' sreg]) ./ strys.P;

                % compute sectoral and regional investment
                strys.(['I_' ssec '_' sreg]) = (strpar.delta_p) * strys.(['KH_' ssec '_' sreg
                    ]) + strys.(['D_KHelp_' ssec '_' sreg]);

                % compute aggregate sectoral capital stock
                strys.(['KH_' ssec]) = strys.(['KH_' ssec]) + strys.(['P_' ssubsec '_' sreg])
                    * strys.(['K_' ssubsec '_' sreg]) ./ strys.P;

            end
        end

        % init aggregate sectoral invesment
        strys.(['I_' ssec]) = 0;

        % compute aggregate sectoral invesment
        for icoreg = 1:strpar.inbregions_p
            sreg = num2str(icoreg);
            strys.(['I_' ssec]) = strys.(['I_' ssec]) + strys.(['I_' ssec '_' sreg]) ;
        end
    end

    % compute aggregates
    [strys, strpar, strexo] = ComputeAggregates(strys, strpar, strexo);

    % net exports
    strys.NX = (strys.P_D * strys.X   strys.P_M * strys.M)/strys.P;

    % products used domestically
    strys.Q_U = (strys.M * strys.P_M + strys.Q_D * strys.P_D)/strys.P;

    % compute tax income of the government
    [strys,strpar, strexo] = TaxIncome(strys,strpar, strexo);

    % define private net foreign asset position
    strys.B =  strys.NX/strys.rf  strys.BG;


    %% Households consumption level, FOC w.r.t housing and consumption
    strys.C = ((strys.P_D / strys.P * strys.Q   strys.NX   strys.Q_I   strys.I   strys.
        wagetax   strys.capitaltax + strys.rf * strys.BG   strys.Y * strexo.exo_DH * (1 +
        strys.tauH)) / (1 + strys.tauC)) / (1 + strpar.gamma_p/(1  strpar.gamma_p) * strpar.
        deltaH_p * strpar.beta_p / (1 strpar.beta_p*(1 strpar.deltaH_p)));

    if strpar.lEndogenousY_p == 0
        % house prices
        strys.PH = (strpar.gamma_p/(1   strpar.gamma_p)  * strpar.beta_p / (1   strpar.beta_p
            * (1   strpar.deltaH_p)) * strys.C * strys.P * (1 + strys.tauC)) / (strys.H * (1 +
             strys.tauH));

    else
        % housing stock
        strys.H  = (strpar.gamma_p/(1   strpar.gamma_p)  * strpar.beta_p / (1   strpar.beta_p
            * (1   strpar.deltaH_p)) * strys.C * strys.P * (1 + strys.tauC)) / (strys.PH * (1
            + strys.tauH));

    end

    % Lagrange multiplier for the evolution of the household stock
    strys.omegaH = strys.PH * (1 + strys.tauH);

    % damages to the housing stock
    strys.DH = strexo.exo_DH * strys.Y .* strys.P  /strys.PH;

    % investments into the housing stock
    strys.IH = strpar.deltaH_p * strys.H + strys.DH;

    % Lagrange multiplier for the budget constraint
    strys.lambda = (1 strpar.gamma_p) * (strys.C/strys.PoP)^( strpar.gamma_p) * (strys.H/strys
        .PoP)^strpar.gamma_p * ((strys.C/strys.PoP)^(1 strpar.gamma_p) * (strys.H/strys.PoP)^
        strpar.gamma_p)^( strpar.sigmaC_p) / (strys.P * (1 + strys.tauC));


    %% government budget constraint
    if strpar.phiG_p > 0
        fval_vec_G = 1   strys.G / ((strys.wagetax + strys.capitaltax + strys.tauC * strys.C +
             strys.tauH * strys.PH/strys.P * strys.IH)   strys.rf * strys.BG   strys.
```

```
                adaptationcost);

    else
        strys.G = (strys.wagetax + strys.capitaltax + strys.tauC * strys.C + strys.tauH *
            strys.PH/strys.P * strys.IH)   strys.rf * strys.BG   strys.adaptationcost;

        strys.KG = strys.G/strpar.deltaKG_p;

    end
    %% evaluate resiudals for:
    %   HH FOC w.r.t. labour in each region and subsector
    %   Firms FOC w.r.t. intermediate goods in each region and subsector
    %   Export demand for each region and subsector

    strpar.sMaxsec = num2str(strpar.inbsectors_p);

    fval_vec_1 = nan(strpar.(['subend_' strpar.sMaxsec '_p'])*strpar.inbregions_p,1);

    fval_vec_2 = nan(strpar.(['subend_' strpar.sMaxsec '_p'])*strpar.inbregions_p,1);

    fval_vec_4 = nan(strpar.(['subend_' strpar.sMaxsec '_p']),1);

    for icosec = 1:strpar.inbsectors_p
        ssec = num2str(icosec);

        strys.(['omegaI_' ssec]) = strys.P;

        for icosubsec = strpar.(['substart_' ssec '_p']):strpar.(['subend_' ssec '_p'])
            ssubsec = num2str(icosubsec);

            lhs = strys.(['X_' ssubsec]);
            rhs = (strpar.(['D_X_' ssubsec '_p']) + strexo.(['exo_X_' ssubsec])) * (strys.(['
                P_D_' ssubsec])/strys.(['P_M_' ssubsec]))^( strpar.etaX_p);
            fval_vec_4(icosubsec) = 1   lhs/rhs;

            for icoreg = 1:strpar.inbregions_p
                sreg = num2str(icoreg);

                icovec = icoreg + strpar.inbregions_p * (icosubsec 1);

                lhs = (1   strys.tauNH) * strys.(['W_' ssubsec '_' sreg]) * strys.lambda;

                rhs = strpar.(['phiL_' ssubsec '_' sreg '_p']) * strys.(['A_N_' ssubsec '_'
                    sreg]) * (strys.(['N_' ssubsec '_' sreg]))^(strpar.sigmaL_p);

                fval_vec_1(icovec) = 1   lhs./rhs;

                lhs = strys.P / strys.(['P_D_' ssubsec '_' sreg]);

                rhs = (strpar.(['omegaQI_' ssubsec '_' sreg '_p']))^(1/strpar.(['etaI_'
                    ssubsec '_p'])) * (strys.(['Q_I_' ssubsec '_' sreg])/strys.(['Q_' ssubsec
                    '_' sreg]))^( 1/strpar.(['etaI_' ssubsec '_p']));

                fval_vec_2(icovec) = 1   lhs./rhs;
            end

        end
    end

    lhs = strys.P_M;

    rhs = strpar.omegaF_p^(1/strpar.etaF_p) * (strys.M/strys.Q_U)^( 1/strpar.etaF_p) * strys.P
        ;

    fval_vec_3 = 1   lhs./rhs;

    if strpar.phiG_p > 0
        fval_vec = [fval_vec_1(:); fval_vec_2(:); fval_vec_3(:); fval_vec_G; fval_vec_4(:)];

    else
        fval_vec = [fval_vec_1(:); fval_vec_2(:); fval_vec_3(:); fval_vec_4(:)];

    end
    if strpar.lEndogenousY_p == 0
        % evaluation of the net export to gross value added ratio
        fval_vec_NX = strys.NX./strys.Y   strpar.NX0_p;

        fval_vec = [fval_vec; fval_vec_NX];

    end
end
```

```
function [strys, strpar, strexo] = Initialize_FindK_ExogenousY(strys, strpar, strexo, x, x_start_vec_1, x_start_vec_2);
    % function [fval_vec,strys] =
    % Initialize_FindK_ExogenousY(strys, strpar, strexo, x, x_start_vec_1,
    %                             x_start_vec_2)
    % finds capital stock vector to fulfill the static equations of the
    % model
    % Inputs:
    %     x          [vector]      vector of initial values for the steady
    %                              state of the regional and sectoral capital
    %                              stock
    %     strys      [structure]   structure containing all endogeonous
    %                              variables of the model
    %     strexo     [structure]   structure containing all exogeonous
    %                              variables of the model
    %     strpar     [structure]   structure containing all parameters of the
    %                              model
    %
    % Output:
    %     fval_vec   [vector]      residuals of regional and sector specific
    %                              for FOC of Households with respect to
    %                              regional labour
    %     strys      [structure]   see inputs
    %     strexo     [structure]   see inputs

    % terminal labour supply
    strys.N = strpar.NT_p;

    % terminal GDP
    strys.Y = strpar.YT_p;

    % init output
    strys.Q = 0;

    % init domestically used output
    strys.Q_D = 0;

    % imports
    strys.M = x((2*strpar.(['subend_' strpar.sMaxsec '_p'])*strpar.inbregions_p)+strpar.(['subend_' strpar.sMaxsec '_p'])+1) *strys.Y;

    for icosec = 1:strpar.inbsectors_p
        ssec = num2str(icosec);
        % init sectoral expenditure
        strpar.(['phiQA_' ssec '_p']) = 0;

        for icosubsec = strpar.(['substart_' ssec '_p']):strpar.(['subend_' ssec '_p'])
            ssubsec = num2str(icosubsec);

            % init sub sectoral expenditure
            strpar.(['phiQ_' ssubsec '_p']) = 0;

            for icoreg = 1:strpar.inbregions_p
                sreg = num2str(icoreg);
                icovec = icoreg + (icosubsec 1)*strpar.inbregions_p;

                % labour
                strys.(['N_' ssubsec '_' sreg]) = strpar.(['phiN_' ssubsec '_' sreg '_p']) * strpar.NT_p;

                % intermediate goods
                strys.(['Q_I_' ssubsec '_' sreg]) = sqrt(real(x_start_vec_2(icovec)).^2) * strpar.(['phiY_' ssubsec '_' sreg '_p']) * strys.Y;

                % sub sectoral and regional expenditures
                strpar.(['phiQ_' ssubsec '_' sreg '_p']) = strys.P * strys.(['Q_I_' ssubsec '_' sreg]) + strpar.(['phiY_' ssubsec '_' sreg '_p']) * strys.Y * strys.P;

                % sub sectoral expenditures
                strpar.(['phiQ_' ssubsec '_p']) = strpar.(['phiQ_' ssubsec '_p']) + strpar.(['phiQ_' ssubsec '_' sreg '_p']);

            end
            % aggregate total production
            strys.Q = strys.Q + strpar.(['phiQ_' ssubsec '_p']) / strys.P_D;

            % aggregate domestic total production
            strys.Q_D = strys.Q_D + strpar.(['phiQ_' ssubsec '_p']) * (1   strys.(['D_X_' ssubsec])) / strys.P_D;

            % sectoral expenditure share
            strpar.(['phiQA_' ssec '_p']) = strpar.(['phiQA_' ssec '_p']) + strpar.(['phiQ_' ssubsec '_p']) * (1   strys.(['D_X_' ssubsec]));
```

```
        end
    end
    for icosec = 1:strpar.inbsectors_p
        ssec = num2str(icosec);

        % sectoral price level
        strys.(['P_A_' ssec]) = strpar.(['omegaQA_' ssec '_p'])^(1/(strpar.etaQ_p  1)) * (strpar.(['phiQA_' ssec '_p'])/(strys.P_D * strys.Q_D))^(1/(1  strpar.etaQ_p)) * strys.P_D;

        % sectoral output
        strys.(['Q_A_' ssec]) = strpar.(['phiQA_' ssec '_p']) / strys.(['P_A_' ssec]);

        for icosubsec = strpar.(['substart_' ssec '_p']):strpar.(['subend_' ssec '_p'])
            ssubsec = num2str(icosubsec);

            % subsectoral price level
            strys.(['P_D_' ssubsec]) = strpar.(['omegaQ_' ssubsec '_p'])^(1/(strpar.(['etaQA_' ssec '_p'])  1)) * (strpar.(['phiQ_' ssubsec '_p']) * (1  strys.(['D_X_' ssubsec]))/(strys.(['P_A_' ssec]) * strys.(['Q_A_' ssec])))^(1/(1  strpar.(['etaQA_' ssec '_p']))) * strys.(['P_A_' ssec]);

            % subsectoral output
            strys.(['Q_D_' ssubsec]) = strpar.(['phiQ_' ssubsec '_p']) * (1  strys.(['D_X_' ssubsec])) / strys.(['P_D_' ssubsec]);

            for icoreg = 1:strpar.inbregions_p
                sreg = num2str(icoreg);
                % subsectoral regional price level
                strys.(['P_D_' ssubsec '_' sreg]) = strpar.(['omegaQ_' ssubsec '_' sreg '_p'])^(1/(strpar.(['etaQ_' ssubsec '_p']) 1)) * (strpar.(['phiQ_' ssubsec '_' sreg '_p'])/strpar.(['phiQ_' ssubsec '_p']))^(1/(1 strpar.(['etaQ_' ssubsec '_p']))) * strys.(['P_D_' ssubsec]);

                % subsectoral output
                strys.(['Q_' ssubsec '_' sreg]) = strpar.(['phiQ_' ssubsec '_' sreg '_p']) / strys.(['P_D_' ssubsec '_' sreg]);

                % subsectoral price level of primary production factors
                strys.(['P_' ssubsec '_' sreg]) = ((strys.(['P_D_' ssubsec '_' sreg])^(1  strpar.(['etaI_' ssubsec '_p']))  strpar.(['omegaQI_' ssubsec '_' sreg '_p']) * strys.P^(1  strpar.(['etaI_' ssubsec '_p'])))/(1  strpar.(['omegaQI_' ssubsec '_' sreg '_p'])))^(1/(1  strpar.(['etaI_' ssubsec '_p'])));

                % subsectoral gross vlaue added
                strys.(['Y_' ssubsec '_' sreg]) = strpar.(['phiY_' ssubsec '_' sreg '_p']) * strys.Y * strys.P / strys.(['P_' ssubsec '_' sreg]);

                icovec = icoreg + (icosubsec 1)*strpar.inbregions_p;
                if strpar.(['etaNK_' ssubsec '_' sreg '_p']) ~= 1
                    % subsectoral regional capital stock
                    strys.(['K_' ssubsec '_' sreg]) = sqrt(real(x_start_vec_1(icovec)).^2) * strys.(['Y_' ssubsec '_' sreg]);

                else
                    % subsectoral regional labour productivity
                    strys.(['A_N_' ssubsec '_' sreg]) = sqrt(real(x_start_vec_1(icovec)).^2);

                end

            end
        end
    end
    if strpar.phiG_p > 0
        % init government expenditure
        strys.G = x(end 1) * strys.Y;

    end
end
```

F Estimation of Elasticity of Substitution

Here we estimate the elasticity of substitution between different sub-sectors and sectors in one region. Therefore we use the respective demand for each sector in each nest to estimate the following regression equation

$$ln\left(\frac{P^D_{s,t}}{P^D_{s,t-1}}\right) - log\left(\frac{P^D_{k,t}}{P^D_{k,t-1}}\right) = (1-\eta^{Q^A}_k)\left(log\left(\frac{P^D_{s,t}\,Q^D_{s,t}}{P^D_{s,t-1}\,Q^D_{s,t-1}}\right) - log\left(\frac{P^A_{k,t}\,Q^A_{k,t}}{P^A_{k,t-1}\,Q^A_{k,t-1}}\right)\right). \tag{143}$$

We approximate the domestic price levels with the price levels derived from the gross value added deflator for the respective sectors. We also need to approximate the change in nominal expenditures for domestic sectoral production with gross value added of the respective sector.

```
% ======================================================================
% === Estimation of elasticity of substitution between sectors ===
% ======================================================================

sFileName = [pwd() '\Data\Regression Data.xlsx'];
Real = readtable(sFileName, 'Sheet', 'Real');
Nom = readtable(sFileName, 'Sheet', 'Nominal');

% real GDP
BasicsReal = Real.A + Real.BDE;
ManConReal = Real.C + Real.F;
TransReal = Real.H;
ServReal   = Real.Services + Real.Health;
TotalReal = Real.Total;

% nominal GDP
BasicsNom = Nom.A + Nom.BDE;
ManConNom = Nom.C + Nom.F;
TransNom = Nom.H;
ServNom    = Nom.Services + Nom.Health;
TotalNom = Nom.Total;

% compute deflators
BasicsP = BasicsNom ./BasicsReal;
ManConP = ManConNom ./ManConReal;
ServP    = ServNom ./ ServReal;
AP = Nom.A./Real.A;
BDEP = Nom.BDE./Real.BDE;
CP = Nom.C./Real.C;
FP = Nom.F./Real.F;
SP = Nom.Services./Real.Services;
HealthP = Nom.Health./Real.Health;
TransP = Nom.H./Real.H;

P = TotalNom./TotalReal;
```

Health and Services

```
etaQ_p = 0.01;
X_vec = [diff(log(BasicsP./P)); diff(log(ManConP./P));...
diff(log(TransP./P)); diff(log(ServP./P))];
Y_vec = [diff(log(BasicsNom./TotalNom));diff(log(ManConNom./TotalNom));...
diff(log(TransNom./TotalNom)); diff(log(ServNom./TotalNom))];
fitlm(X_vec, Y_vec)
[pvaltest, Fvaltest, ~] = coefTest(fitlm(X_vec, Y_vec),[0 1], [1 etaQ_p]);

if pvaltest<0.05
disp('Reject H0')
else
disp('Do not reject H0')
end
```

Test whether the elasticity of substitution between Agriculture, Forestry, Aquaculture and Mining, Energy and Water supply is significantly different from 0.01. (maximum probability of type 1 error is 0.05)

```
etaQA_1_p = 0.01;
X_vec = [diff(log((AP./BasicsP))); diff(log(BDEP./BasicsP))];
Y_vec = [diff(log(Nom.A./BasicsNom));diff(log(Nom.BDE./BasicsNom))];
fitlm(X_vec, Y_vec)
[pvaltest, Fvaltest, ~] = coefTest(fitlm(X_vec, Y_vec),[0 1],...
[1 etaQA_1_p]);

if pvaltest<0.05
disp('Reject H0')
```

```
        else
        disp('Do not reject H0')
        end
```

Test whether the elasticity of substitution between Manufacturing and Construction is significantly different from 0.01. (maximum probability of type 1 error is 0.05)

```
        etaQA_2_p = 0.01;
        X_vec = [diff(log((CP./ManConP))); diff(log(FP./ManConP))];
        Y_vec = [diff(log(Nom.C./ManConNom));diff(log(Nom.F./ManConNom))];
        fitlm(X_vec, Y_vec)
        [pvaltest, Fvaltest, ~] = coefTest(fitlm(X_vec, Y_vec),[0 1],...
        [1 etaQA_2_p]);

        if pvaltest <0.05
        disp('Reject H0')
        else
        disp('Do not reject H0')
        end
```

Test whether the elasticity of substitution between Health and other Services is significantly different from 0.01. (maximum probability of type 1 error is 0.05)

```
        etaQA_3_p = 0.01;
        X_vec = [diff(log((SP./ServP))); diff(log((HealthP./ServP)));...
        diff(log((TransP./ServP)))];
        Y_vec = [diff(log(Nom.Services./ServNom));diff(log(Nom.Health./ServNom));...
        diff(log(Nom.H./ServNom))];
        fitlm(X_vec, Y_vec)
        [pvaltest, Fvaltest, ~] = coefTest(fitlm(X_vec, Y_vec),[0 1],...
        [1   etaQA_3_p]);

        if pvaltest <0.05
        disp('Reject H0')
        else
        disp('Do not reject H0')
        end
```

Table 23: Endogenous Variables

Variable	LaTeX	Description
K	K	capital stock
N	N	labour
SL	SL	SL
tas_1	tas_r	tas
SfcWind_1	$SfcWind_r$	SfcWind
pr_1	pr_r	pr
sunshine_1	$sunshine_r$	sunshine
hurs_1	$hurs_r$	hurs
heatwave_1	$heatwave_r$	heatwave
maxdrydays_1	$maxdrydays_r$	maxdrydays
maxwetdays_1	$maxwetdays_r$	maxwetdays
storms_1	$storms_r$	storms
floods_1	$floods_r$	floods
fire_1	$fire_r$	fire
landslide_1	$landslide_r$	landslide
I_1	I_k	sector private investment
Y_1	Y_s	sector GDP
Q_D_1	Q_s^D	domesitcally used sector output
Q_I_1	Q_s^I	sector intermediate inputs
M_1	M_s	sector imports
X_1	X_s	sector exports
D_X_1	D_s^X	world demand for sector exports
K_1	K_s	sector capital
N_1	N_s	sector employment
P_D_1	P_s^D	domestic sector price index
P_M_1	P_s^M	imports sector price index
W_1	W_s	sector wage index
Q_1_1	$Q_{s,r}$	regional sector Output
W_1_1	$W_{s,r}$	regional wage rate for sector labour
gA_1_1	$g_{s,r}^A$	regional growth rate of sector TFP
tauKF_1_1	$\tau_{s,r}^K$	regional sector corporate tax rate on capital
tauNF_1_1	$\tau_{s,r}^N$	regional sector labour tax rate on capital
P_D_1_1	$P_{s,r}$	regional sector price index
P	P	price level
lambda	λ	budget constraint lagrange multiplier
P_D	P^D	domestic price level
P_M	P^M	foreign price level
C	C	consumption
H	H	houses
IH	I^H	investment in houses
PH	P^H	prices for houses
DH	D^H	damages to the housing stock
omegaH	ω^H	lagrnage multiplier for the law of motion of houses
PoP	PoP	population
B	B	international traded bonds
BG	BG	government debt
NX	NX	net exports
rf	r^f	foreign interest rate
G	G	government expenditure
tauC	τ^C	consumption tax
tauH	τ^H	tax on housing
tauNH	τ^N	labour tax
tauKH	τ^K	capital tax
KG	K^G	public good capital stock
I	I	private investment
Y	Y	GDP
Q_U	Q^U	domestic used output
Q_D	Q^D	domestic produced and used products
Q_I	Q^I	demand for intermediate products
Q	Q	total production
M	M	Imports
X	X	Exports
G_A_DH	G^{A,D^H}	adaptation government expenditure for housing
Q_A_1	Q_k^A	sector aggregate output
P_A_1	P_k^A	sector aggregate price level
KH_1_1	$K_{k,r}$	regional sector capital

Table 23 – Continued

Variable	LaTeX	Description
r_1_1	$r_{k,r}$	regional rentqal rate for sector capital
I_1_1	$I_{k,r}$	regional sector investment
omegaI_1_1	$\omega^I_{s,r}$	shadow value of regional private sector investment
Q_1	Q_s	sector output
D_1_1	$D_{s,r}$	regional sector damages
D_N_1_1	$D_{s,r}$	regional sector damages to labour productivity
D_K_1_1	$D_{s,r}$	regional sector destuction of capital stock
K_1_1	$K_{s,r}$	regional sector capital
G_A_1_1	$G^A_{s,r}$	regional sector adaptation government expenditure
K_A_1_1	$K^A_{s,r}$	regional sector adaptation capital stock
P_1_1	$P_{s,r}$	regional sector price index
Y_1_1	$Y_{s,r}$	regional sector GDP
N_1_1	$N_{s,r}$	regional sector employment
Q_I_1_1	$Q^I_{s,r}$	regional sector intermediate inputs
A_1_1	$A_{s,r}$	regional sector TFP
A_N_1_1	$A^N_{s,r}$	regional sector labour specific TFP
A_K_1_1	$A^K_{s,r}$	regional sector capital specific TFP

Table 24: Exogenous Variables

Variable	LaTeX	Description
exo_tauC	η_{τ^C}	exogeneous consumption tax
exo_tauH	η_{τ^C}	exogeneous housing tax
exo_tauNH	η_{τ^N}	exogeneous labour income tax paid by households
exo_tauKH	η_{τ^K}	exogeneous capital income tax paid by households
exo_H	η_H	exogeneous housing area to population ratio
exo_DH	η_{D^H}	exogeneous damage to housing stock
exo_PoP	η_{PoP}	exogeneous population
exo_BG	η_{BG}	exogenous structural balance
exo_rf	η_{rf}	exogenous world interest rate
exo_P	η_P	exogenous price level
exo_M	η_M	exogenous import shock
exo_X_1	$\eta_{X,k}$	exogenus demand for sector exports
exo_1_1	$\eta_{A,s,r}$	exogenus TFP
exo_N_1_1	$\eta_{A^N,s,r}$	exogenous labour specific TFP
exo_K_1_1	$\eta_{A^K,s,r}$	exogenous capital specific TFP
exo_D_1_1	$\eta_{D,s,r}$	exogenus damage induced by climate change for the sector
exo_D_N_1_1	$\eta_{D^N,s,r}$	exogenus damage induced by climate change for labour productivity in the sector
exo_D_K_1_1	$\eta_{D^K,s,r}$	exogenus damage induced by climate change for capital productivity in the sector
exo_tauKF_1_1	$\eta_{\tau^K,s,r}$	exogenous sector and region corporate tax rate
exo_tauNF_1_1	$\eta_{\tau^N,s,r}$	exogenous sector and region labour tax rate
exo_GA_1_1	$\eta_{G^{A,landslide},s,r}$	exogenous sector adaptation expenditure against landslide
exo_G_A_DH	$\eta_{G^{A,H}}$	exogenous sector adaptation expenditure for housing
exo_SL	$\eta_{SL,n}$	exogenus SL
exo_tas_1	$\eta_{tas,n}$	exogenus regional tas
exo_SfcWind_1	$\eta_{SfcWind,n}$	exogenus regional SfcWind
exo_pr_1	$\eta_{pr,n}$	exogenus regional pr
exo_sunshine_1	$\eta_{sunshine,n}$	exogenus regional sunshine
exo_hurs_1	$\eta_{hurs,n}$	exogenus regional hurs
exo_heatwave_1	$\eta_{heatwave,n}$	exogenus regional heatwave
exo_maxdrydays_1	$\eta_{maxdrydays,n}$	exogenus regional maxdrydays
exo_maxwetdays_1	$\eta_{maxwetdays,n}$	exogenus regional maxwetdays
exo_storms_1	$\eta_{storms,n}$	exogenus regional storms
exo_floods_1	$\eta_{floods,n}$	exogenus regional floods
exo_fire_1	$\eta_{fire,n}$	exogenus regional fire
exo_landslide_1	$\eta_{landslide,n}$	exogenus regional landslide

Table 25: Parameters

Variable	LaTeX	Description
inbsectors_p	K	number of sectors
inbregions_p	R	number of regions
lEndogenousY_p	l^Y	logical indicator for endogenous or exogenous production
lCalibration_p	l^{Calib}	logical indiactor whether model is calibrated or not
lNationalK_p	l^K	logical indiactor whether national capital stock or not
substart_1_p	$substart\_1\_p$	substart_1_p
subend_1_p	$subend\_1\_p$	subend_1_p
omegaQA_1_p	$\omega_k^{Q^A}$	distribution parameter for aggregate output from one sector
etaQA_1_p	$\eta_k^{Q^A}$	elasticity of substitution between products from different subsectors in one sector
phiM_1_p	$\frac{M_{k,0}\,P^M_{k,0}}{P_0\,Q_0}$	share of sector imports on total output
phiX_1_p	$\frac{X_{k,0}\,P_{k,0}}{P_{k,0}\,Y_{k,0}}$	share of exports on gross value added
phiQI_1_p	$\frac{Q^I_{k,0}\,P_0}{P_{k,0}\,Q_{k,0}}$	share of intermediate inputs on total prodcution
D_X_1_p	D^X_k	long-run demand for exports
P_M_1_p	P^M_k	long-run price of sector imports
omegaM_1_p	ω^M_k	distribution parameter for imports from one sector
omegaQ_1_p	ω^Q_k	distribution parameter for output from one sector
etaQ_1_p	η^C_k	elasticity of substitution between regional production
etaI_1_p	η^M_k	elasticity of substitution between value added and intermediate products
rhoA_1_1_p	$\rho^A_{s,r}$	persistence productivity shock
tauKF_1_1_p	$\tau^{K,F}_{s,r}$	region and sector specific tax rate on capital paid by firms
tauNF_1_1_p	$\tau^{N,F}_{s,r}$	region and sector specific tax rate on labour paid by firms
rhoA_N_1_1_p	$\rho^{A,N}_{s,r}$	persistence labour specific productivity shock
rhoA_K_1_1_p	$\rho^{A,K}_{s,r}$	persistence capital specific productivity shock
phiY_1_1_p	$\frac{P_{s,r,0}\,Y_{s,r,0}}{P_0\,Y_0}$	share of regional and sectoral output
phiYT_1_1_p	$\frac{P_{s,r,T}\,Y_{s,r,T}}{P_T\,Y_T}$	terminal share of regional and sectoral output
phiY0_1_1_p	$\frac{P_{s,r,0}\,Y_{s,r,0}}{P_0\,Y_0}$	initial share of regional and sectoral output
phiN_1_1_p	$N_{s,r,0}$	long-run share of regional and sectoral employment
phiNT_1_1_p	$N_{s,r,T}$	terminal share of regional and sectoral employment
phiN0_1_1_p	$N_{s,r,0}$	initial share of regional and sectoral employment
phiW_1_1_p	$\frac{W_{s,r,0}\,N_{s,r,0}}{P_{s,r,0}\,Y_{s,r,0}}$	share of regional and sectoral employment
phiL_1_1_p	$\phi^L_{s,r}$	coefficient of disutility to work
omegaQ_1_1_p	$\omega^Q_{s,r}$	distribution parameter for regional production
omegaQI_1_1_p	$\omega^{Q^I}_{s,r}$	distribution parameter for intermeditate products
alphaK_1_1_p	$\alpha^K_{s,r}$	distribution parameter capital share
alphaN_1_1_p	$\alpha^N_{s,r}$	distribution parameter labour share
etaNK_1_1_p	$\eta^{N,K}_{s,r}$	elasticity of substitution between labour and capital
A_1_1_p	$A_{s,r}$	sector long-run TFP
phiGA_1_1_p	$\phi^{G^A}_{s,r}$	coefficient of effectiveness of government expenditure on adaptation measures in a specific region and se
deltaKA_1_1_p	$\delta^{K^A_{s,r}}$	depreciation rate of adaptation capital stock against landslide
gY0_1_1_p	$\frac{Y_{2,s,r}}{Y_{1,s,r}}$	initial sector growth
gN0_1_1_p	$\frac{\frac{N_{2,s,r}}{N_2}}{\frac{N_{1,s,r}}{N_1}}$	initial sector labour growth
omegaA_1_1_p	$\omega^A_{s,r}$	exponent for productivity growth
A_N_1_1_p	$A^N_{s,r}$	sector labour specific TFP
A_K_1_1_p	$A^K_{s,r}$	sector capital specific TFP
beta_p	β	discount factor
omegaP_p	ω^P	share of rational agents
gamma_p	γ	preferences for housing in utility function
delta_p	δ	capital depreciation rate
deltaH_p	δ^H	housing depreciation rate
deltaKG_p	δ^{K^G}	public capital depreciation rate
phiG_p	ϕ^G	elasticity of TFP to public capital
sigmaL_p	σ^L	inverse Frisch elasticity
sigmaC_p	σ^C	intertemporal elasticity of substitution
etaQ_p	η^Q	elasticity of substitution between sectoral production
etaM_p	η^M	elasticity of substitution between sectoral imports
etaF_p	η^F	elasticity of substitution between foreign and domestic products
omegaF_p	ω^F	distribution parameter between foreign and domestic products

Table 25 – Continued

Variable	LaTeX	Description
phiB_p	ϕ^B	coefficient of foreign adjustment cost
phiK_p	ϕ^K	coefficient of investment adjustment cost
tauC_p	τ^C	consumption tax
tauH_p	τ^H	tax on housing
tauNH_p	τ^N	labour tax
tauKH_p	τ^K	capital tax
omegaNX_p	ω^{NX}	share of net exports relative to domestic GDP
omegaNX0_p	$\omega^{NX,0}$	initial share of net exports relative to domestic GDP
omegaNXT_p	$\omega^{NX,T}$	terminal share of net exports relative to domestic GDP
tas0_1_p	$T_{0,n}$	initial regional tas
SfcWind0_1_p	$T_{0,n}$	initial regional SfcWind
pr0_1_p	$T_{0,n}$	initial regional pr
sunshine0_1_p	$T_{0,n}$	initial regional sunshine
hurs0_1_p	$T_{0,n}$	initial regional hurs
heatwave0_1_p	$T_{0,n}$	initial regional heatwave
maxdrydays0_1_p	$T_{0,n}$	initial regional maxdrydays
maxwetdays0_1_p	$T_{0,n}$	initial regional maxwetdays
storms0_1_p	$T_{0,n}$	initial regional storms
floods0_1_p	$T_{0,n}$	initial regional floods
fire0_1_p	$T_{0,n}$	initial regional fire
landslide0_1_p	$T_{0,n}$	initial regional landslide
phiQDD_p	$\frac{Q_0^I\,P_0}{P_0\,Q_0}$	share of domestically used and produced on total prodcution
phiM_p	$\frac{M_0\,P_0^M}{P_0\,Q_0}$	share of imports on total prodcution
SL0_p	SL_0	initial SL
PoP0_p	POP_0	initial population
H0_p	H_0	initial stocks of houses
PH0_p	P_0^H	initial price of houses
Y0_p	Y_0	initial output
NX0_p	NX_0	initial net export to value added ratio
P0_p	P_0	initial price level
P0_M_p	P_0^M	initial price level
N0_p	N_0	initial employment
rf0_p	r_0^f	initial world interest rate
PoPT_p	PoP_0	terminal population
YT_p	Y_T	terminal output
PT_p	P_T	terminal price level
NT_p	N_T	terminal employment
sH_p	s^H	share for housing investments

G How to use the model?

G.1 Usage

1. In order to use the model you need to install Dynare (at least version 4.6.1) and Matlab (at least 2020b) or Octave on your computing machine. For Octave, you need to have version 5.2.0 as reported by the Dynare team. Furthermore, MS Excel is used to specify the parameters and to save the results. Result tables are saved additionally in Latex format.
2. You need to download the repository from Github.
3. Open Octave or Matlab GUI and browse to the location of the folder in your computer. You have the right folder if the command `pwd()` returns `YourPath/DGE-CRED/DGE_CRED_Model`.
4. The script `RunSimulations.m` has to be executed in order to run simulations for different scenarios. Make sure that the scenarios and model parameters are defined in the file `ModelSimulationandCalibrationKSectorsandRRegions.xlsx`. You need to adopt the number of sectors and regions in the file `DGE_CRED_Model.mod`. All program files are described in the next section.
5. The simulation results are stored in the file `ResultsScenariosKSectorsandRRegions.xlsx`.

G.2 Folder structure

1. The main file containing all necessary mod-files is `DGE_CRED_Model.mod`. This file includes the following files stored in the `ModFiles` folder:
   (a) `DGE_CRED_Model_Declarations.mod` declares all endogenous and exogenous variables of the model and structural parameters.
   (b) `DGE_CRED_Model_Parameters.mod` assigns values to the structural parameters of the model.
   (c) `DGE_CRED_Model_Equations.mod` contains the equations of the model.
   (d) `DGE_CRED_Model_LatexOutput.mod` produces latex output for documentation of the declared variables and model equations.
2. Subroutines responsible for finding the initial and terminal conditions are located in the subfolder `Functions`:
   (a) `Simulation.m` simulates the model
   (b) `SteadyState.m` script responsible to calibrate the model
   (c) `Miscellaneous` folder containing different scripts and routines not necessary to run the model.
   (d) `Auxiliary` folder containing different scripts necessary to run the model.
3. To define scenarios and structural parameters you need to create an Excel file located in the subfolder `ExcelFiles`:
   (a) `ModelSimulationandCalibrationforKSectorsandRregions.xlsx` has multiple sheets:
      i. data for calibration `Data`
      ii. initial `Start`
      iii. structural parameters of the model `Structural Parameters`
      iv. coefficients for regional and sector-specific damage functions `Climate Damage Functions (Labour, Capital, TFP)`
      v. `Baseline` scenario and other optional scenario sheets `Adaptation and Extremes` defining paths for exogenous variables
      vi. `Data` to load external data sources
   (b) `ResultsScenariosKSectorsandRregions.xlsx` has as many sheets as scenarios defined in the previous Excel file.
4. The latex files produced by `DGE_CRED_Model_LatexOutput.mod` are stored in the sub-folder `LatexFiles`:
   (a) the system of dynamic equations as implemented in Matlab `DGE_CRED_Model_Dynamic`, `DGE_CRED_Model_Dynamic_content`
   (b) names of endogenous, exogenous variables and parameters `DGE_CRED_Model_latex_definitions`
   (c) the system of dynamic equations in original form without auxiliary variables for leads and lags `DGE_CRED_Model_original`, `DGE_CRED_Model_original_content`
5. The file to run different simulations is `RunSimulations.m`.
6. A Matlab function to find solutions to the static system of equations is `DGE_CRED_Model_steady_state.m`.