Financing climate resilience: Macroeconomic implications of physical and transition climate risks

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Abstract

Flood damages, biodiversity loss, and climate-related financial risks represent distinct but interconnected sources of macroeconomic stress under climate change. Existing studies typically analyse these channels in isolation, limiting understanding of their combined economic impacts and the mechanisms through which risks propagate through the real economy. This paper provides an integrated macroeconomic assessment of climate resilience by jointly analysing flood risk adaptation, biodiversity conservation, and climate-related financial risk within a consistent modelling framework. We evaluate nine policy scenarios spanning two mitigation pathways and alternative adaptation regimes, with financial risk incorporated in the final scenario using outputs from the CLIMACRED model. Using two structurally distinct macroeconomic models, GEM-E3 and E3ME, we assess GDP impacts from coastal and riverine flood damages, biodiversity conservation expenditures, and changes in capital costs associated with climate risk. Results show that proactive adaptation reduces flood-related GDP losses across both models and mitigation pathways, despite requiring concentrated upfront investment before 2030. Biodiversity conservation costs remain modest in macroeconomic terms while supporting long-term resilience. The inclusion of financial risk amplifies macroeconomic effects through adjustments in capital costs, with climate-related risk premia influencing investment decisions and production costs across sectors. Overall, the findings highlight the importance of jointly considering physical and transition climate risks, as well as the role of financial transmission channels in shaping macroeconomic outcomes. Coordinated investment in adaptation, ecosystem conservation, and financial risk management emerges as a complementary strategy for strengthening climate resilience.

Keywords: Physical and transition climate risks; Flood risk and adaptation; Biodiversity conservation; Financial risk; Macroeconomic modelling

JEL Classification: Q54, Q57, E17

1. Introduction

Climate change is increasingly recognised as a systemic economic risk, with physical hazards such as flooding already generating substantial and uneven impacts across regions, sectors, and communities. Flood risk, in particular, has emerged as one of the most economically consequential

climate hazards, with evidence pointing to rapidly rising damages under continued warming, especially in coastal and riverine systems (IPCC, 2022; EEA, 2024). Recent projections suggest that, in the absence of adaptation, annual flood-related losses in Europe could increase dramatically over the course of the century, reflecting both intensifying hazards and growing exposure of economic assets. At the same time, these risks are not confined to direct damages alone, but propagate through supply chains, capital accumulation, and macroeconomic performance.

Alongside these physical risks, biodiversity loss is increasingly recognised as a parallel and interacting source of economic vulnerability. Ecosystem degradation reduces the capacity of natural systems to buffer climate impacts, including flood regulation, thereby amplifying exposure to physical damages. Emerging evidence highlights that biodiversity loss is not only an environmental concern but also a material economic and financial risk, particularly through its effects on ecosystem services and natural capital (Ceglar et al., 2024). Despite this, biodiversity remains only partially integrated into macroeconomic modelling frameworks, and its interaction with climate risks is often treated in a fragmented manner.

Macroeconomic assessments of climate change have traditionally relied on modelling frameworks that link emissions to temperature changes and subsequently to economic damages. Computable general equilibrium models and macro-econometric models have been widely used to evaluate these impacts, offering complementary perspectives on how economies respond to shocks and policy interventions (Tol, 2018). However, most existing studies focus on individual dimensions of climate policy, such as mitigation or adaptation, while treating biodiversity and financial risk either exogenously or not at all. Even where flood damages are incorporated, the interaction between adaptation, ecosystem degradation, and financial conditions is rarely examined within a unified analytical framework.

Recent advances in integrated modelling highlight the importance of jointly analysing mitigation, adaptation, and biodiversity (IPCC 2022; Tol, 2018). Complementary modelling applications in the literature suggest that such integration allows for a systematic assessment of policy portfolios, rather than isolated interventions, thereby improving the robustness of policy insights (IPCC, 2022). In parallel, policy-oriented analyses point to the potential role of adaptation and biodiversity investments in reducing macroeconomic risks, but their combined effects and interactions remain insufficiently explored within integrated macroeconomic modelling frameworks (EEA, 2024; UNEP, 2023).

Against this background, this paper provides an integrated macroeconomic assessment of climate policy by jointly analysing mitigation, flood risk adaptation, biodiversity conservation, and climate-related financial risk. The analysis is based on a consistent scenario framework combining two mitigation pathways and alternative adaptation strategies, and employs two structurally distinct macroeconomic models, GEM-E3 and E3ME, to capture differences in economic representation and transmission mechanisms. Flood damages are incorporated as capital losses derived from coastal and riverine risk models, biodiversity impacts are represented through conservation cost functions linked to species loss, and financial risk is introduced via capital cost adjustments derived from the CLIMACRED framework.

The contribution of this paper is threefold. First, it advances the integration of environmental and economic modelling by jointly incorporating flood damages and biodiversity conservation costs within a macroeconomic framework, allowing for a more comprehensive representation of climate-related risks. Second, it evaluates how different modelling structures influence the

transmission of climate impacts and policy responses, providing insights into the robustness of macroeconomic outcomes. Third, it explicitly incorporates financial risk as an additional transmission channel, highlighting how climate-related risks can affect investment dynamics and economic performance.

By bringing together these dimensions within a unified framework, the analysis aims to provide a more comprehensive understanding of economic resilience to climate change and to inform the design of policy strategies that account for interactions across mitigation, adaptation, biodiversity, and financial systems.

Rest of the paper is organised as follows. Section 2 describes the integrated modelling framework, including the macroeconomic models, scenario design, and the linkage between climate, environmental, and financial modules. Section 3 presents the results, focusing on macroeconomic impacts across mitigation pathways and the role of adaptation, biodiversity conservation, and financial risk. Section 4 discusses the implications of the findings in relation to existing literature, highlighting key mechanisms, policy trade-offs, and model-specific dynamics. Section 5 concludes with a summary of the main insights, limitations, and directions for future research.

2. Methodology

This paper develops an integrated modelling framework to assess the macroeconomic implications of climate resilience across three interrelated channels: flood damages and adaptation, biodiversity conservation, and climate-related financial risk. The framework combines outputs from environmental and financial models with two large-scale macroeconomic models, enabling a consistent evaluation of policy scenarios under alternative mitigation and adaptation pathways.

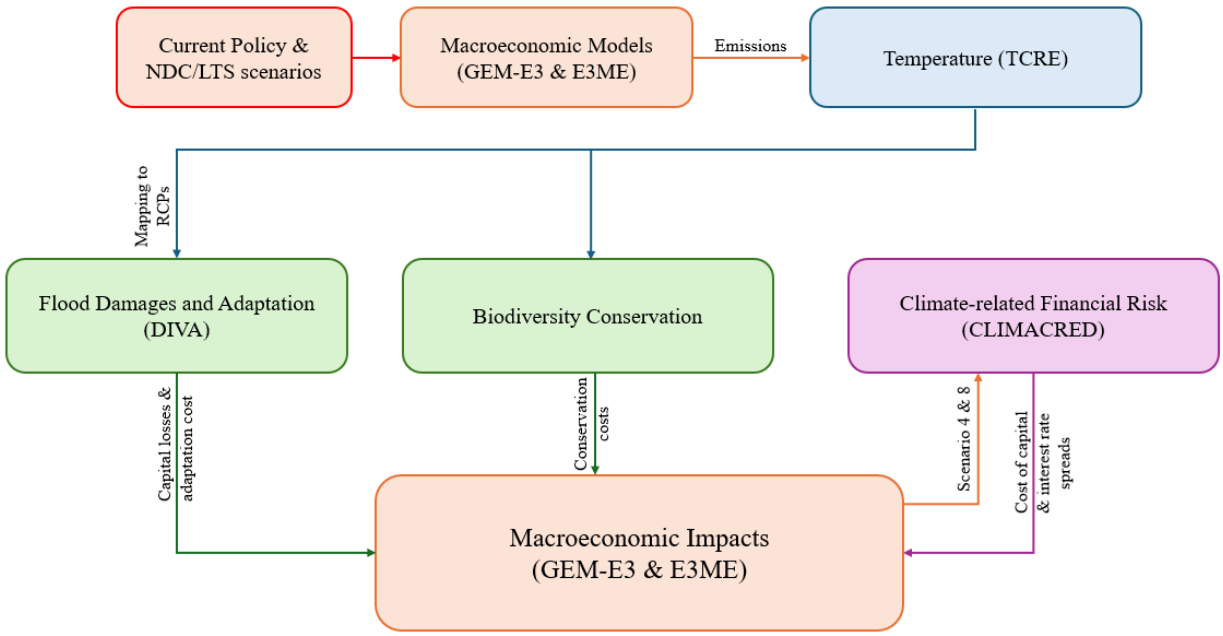


Figure 1. Integrated climate–economy modelling framework. Mitigation pathways are implemented in macroeconomic models (GEM-E3 and E3ME), generating emissions trajectories that are translated into temperature outcomes using the TCRE framework. Temperature drives biodiversity impacts directly and flood damages through mapping to RCP-based DIVA outputs. Climate-related financial risk is incorporated via CLIMACRED in a two-stage procedure, using Scenario 4 as a baseline and Scenario 8 as a counterfactual to estimate adjustments to the cost of capital and interest rate spreads, which are then fed back

into the macroeconomic models (Scenario 9). The framework enables a consistent assessment of macroeconomic impacts across physical and financial risk channels.

The approach captures both direct physical impacts and indirect macroeconomic effects transmitted through investment, production, and financial channels. A schematic overview of the modelling framework is provided in Figure 1, which illustrates the linkages between policy scenarios, emissions, climate outcomes, impact modules, and macroeconomic response.

Macroeconomic Models

The analysis is conducted using two structurally distinct macroeconomic models, GEM-E3 and E3ME, which provide complementary representations of economic structure and adjustment dynamics. The use of two models is a deliberate feature of the methodological design. Where results converge, findings can be interpreted as robust across modelling approaches; where they diverge, the differences provide insight into the mechanisms through which economies respond to climate risks and investment.

GEM-E3 is a large-scale hybrid computable general equilibrium model that simulates interactions between the economy, energy system, and environment (Capros et al., 2017). It represents households, firms, governments, and foreign trade with detailed sectoral and regional disaggregation and integrates bottom-up technological detail for selected energy-related sectors within an otherwise top-down general equilibrium framework. The model adopts a recursive dynamic structure in which equilibrium is solved sequentially over time, with markets clearing through price adjustments.

In this framework, climate-related shocks affect the economy primarily through changes in production costs and the availability of productive capital. Flood damages are introduced as reductions in the capital stock and, in the absence of endogenous reconstruction, these losses persist over time. Adaptation and biodiversity conservation are treated as non-productive government expenditures, financed through indirect taxation. While these expenditures generate demand, they do not augment productive capacity, implying potential crowding-out effects.

E3ME is a global macroeconometric model based on post-Keynesian principles, combining national accounting identities with empirically estimated behavioural relationships (Cambridge Econometrics, 2022). It allows for demand-driven dynamics, spare capacity, and path dependence, and represents interactions through an input–output framework.

In contrast to GEM-E3, climate-related expenditures in E3ME are treated as productive investments. Adaptation and biodiversity conservation enter as public investment, while flood damages reduce capital but also induce reconstruction activity. This allows the model to capture both negative supply-side impacts and positive demand-side multiplier effects, which may partially offset initial losses, particularly in the presence of underutilised capacity.

Both models have been widely applied in European climate policy assessment. Their combined use enables the analysis to capture a range of plausible macroeconomic responses and strengthens the robustness of the results.

Scenario design and climate–economy linkage

The analysis considers nine scenarios combining alternative assumptions on mitigation pathways, flood damages, adaptation, biodiversity conservation, and financial risk. Two baseline mitigation pathways are defined: a Current Policies scenario and an NDC/LTS scenario. Starting from these baselines, additional scenarios are constructed incrementally by introducing physical impacts and response measures, allowing the marginal contribution of each channel to be identified through structured comparisons. Climate-related financial risk is incorporated in a final step through adjustments to financing conditions derived from the CLIMACRED framework. This approach is broadly consistent with short- to medium-term scenario analysis frameworks developed by the Network for Greening the Financial System (NGFS), which emphasise the role of climate-related financial risks in shaping capital costs and investment decisions over policy-relevant time horizons.

Across scenarios, emissions are generated endogenously within the macroeconomic models and translated into temperature outcomes using a reduced-form approximation based on the Transient Climate Response to Cumulative Emissions. These temperature pathways are then used to derive climate impacts, either directly, as in the case of biodiversity, or through mapping to impact models, as in the case of flood damages. Transmission to the macroeconomy occurs through capital losses, investment responses, production costs, and financial conditions. Full details on parameterisation, impact modelling, sectoral allocation, and scenario construction are provided in Appendices A to E.

Scope conditions and limitations

While the framework enables a consistent integration of physical and financial climate risks, several scope conditions should be noted. The climate–economy linkage relies on a reduced-form temperature representation, which supports tractability but does not capture regional climate heterogeneity or potential nonlinearities, including tipping points. Flood damages and adaptation are based on stylised mappings from impact models and may not fully reflect localised exposure or extreme tail risks. The biodiversity module focuses on temperature-driven impacts and does not incorporate land-use change or other ecological pressures, which represent an important extension for future research. Financial risk is introduced through adjustments to capital costs, providing a tractable transmission mechanism while abstracting from fully endogenous financial market dynamics. Finally, the time horizon to 2050 captures medium-term dynamics but does not reflect longer-term climate impacts. Additional methodological detail is provided in the appendices.

3. Results

This section presents the macroeconomic implications of climate resilience across alternative mitigation pathways and risk channels. Results are reported for both GEM-E3 and E3ME, allowing for a comparative assessment of model responses. The analysis traces how macroeconomic outcomes evolve as flood damages, adaptation, biodiversity conservation, and financial risk are progressively incorporated within a consistent scenario framework.

Macroeconomic impacts across scenarios

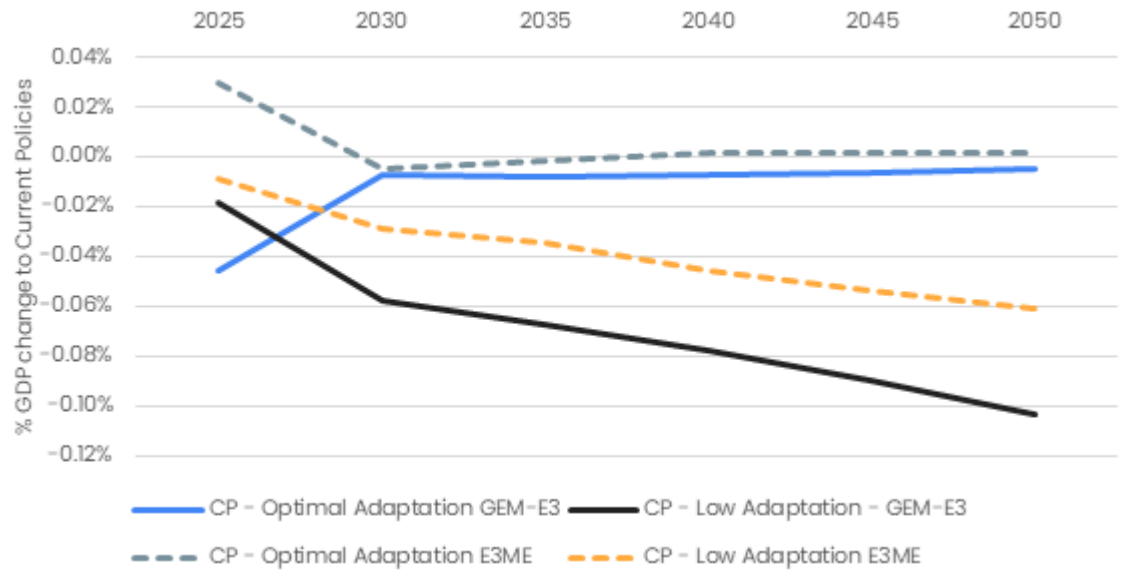


Figure 2 (a). EU GDP change under Current Policies with low vs optimal adaptation

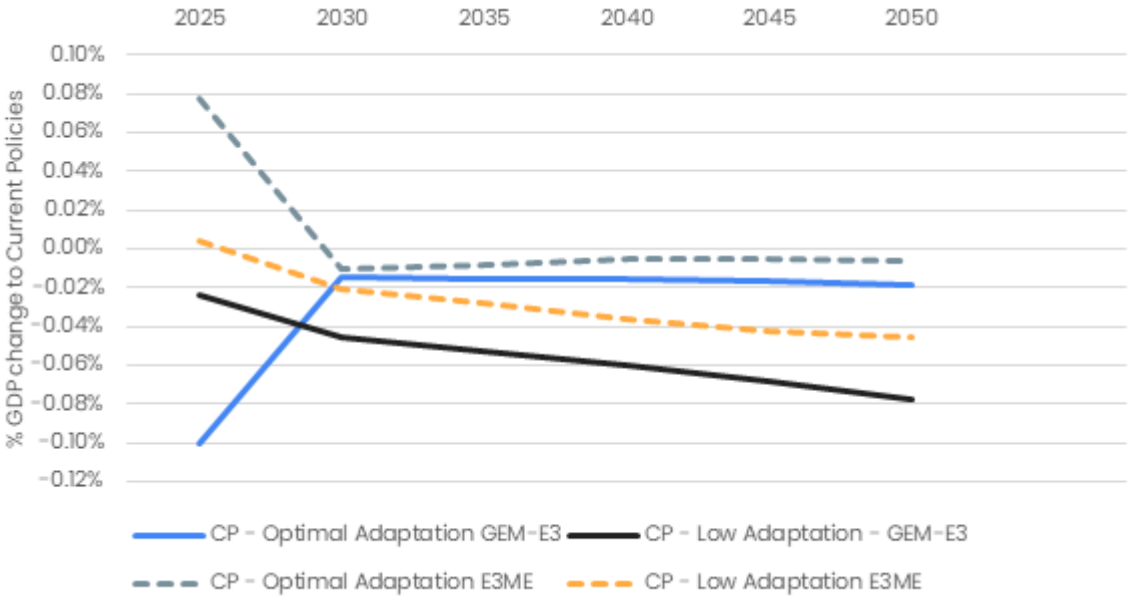


Figure 2 (b). World GDP change under Current Policies with low vs optimal adaptation

Macroeconomic outcomes differ across mitigation pathways, reflecting both policy stringency and model structure. Under the NDC/LTS pathway, emissions and temperature outcomes are lower than under Current Policies, although the resulting macroeconomic differences remain modest over the time horizon considered. This reflects the limited divergence in temperature trajectories across scenarios up to 2050, implying that near- to medium-term economic impacts are driven more by adaptation and damage dynamics than by mitigation alone. Differences across models arise from the treatment of investment and adjustment mechanisms, with GEM-E3 emphasising supply-side constraints and E3ME capturing demand-driven dynamics.

The introduction of flood damages leads to negative GDP impacts under both mitigation pathways, with stronger effects under Current Policies. At the EU level (Figure 2(a)), GDP losses in the low-adaptation scenario reach approximately 0.1% in GEM-E3 and 0.06% in E3ME by 2050. At the global level (Figure 2(b)), losses are of a similar magnitude, though slightly lower, reaching around 0.08% in GEM-E3 and 0.04% in E3ME. Across both models, the EU consistently exhibits somewhat larger GDP deviations than the global average. These impacts are driven by capital destruction and the resulting reduction in productive capacity, which is not offset when adaptation investment remains limited.

Optimal adaptation substantially moderates these effects. In the EU, GDP deviations are reduced to approximately -0.02% or less in GEM-E3 and remain close to baseline in E3ME by 2050. A similar pattern is observed globally, where losses are reduced to around -0.02% in GEM-E3 and largely offset in E3ME. This reflects the frontloaded nature of adaptation investment, which reduces exposure to flood damages over time and limits cumulative economic losses.

The divergence between models is evident in the short to medium term. In GEM-E3, adaptation generates demand but does not augment productive capacity, leading to potential crowding-out effects. In contrast, E3ME treats adaptation as investment, generating demand-side multiplier effects that partially offset damage-related losses. As a result, GDP losses are consistently smaller in E3ME, although the direction of effects remains aligned across models.

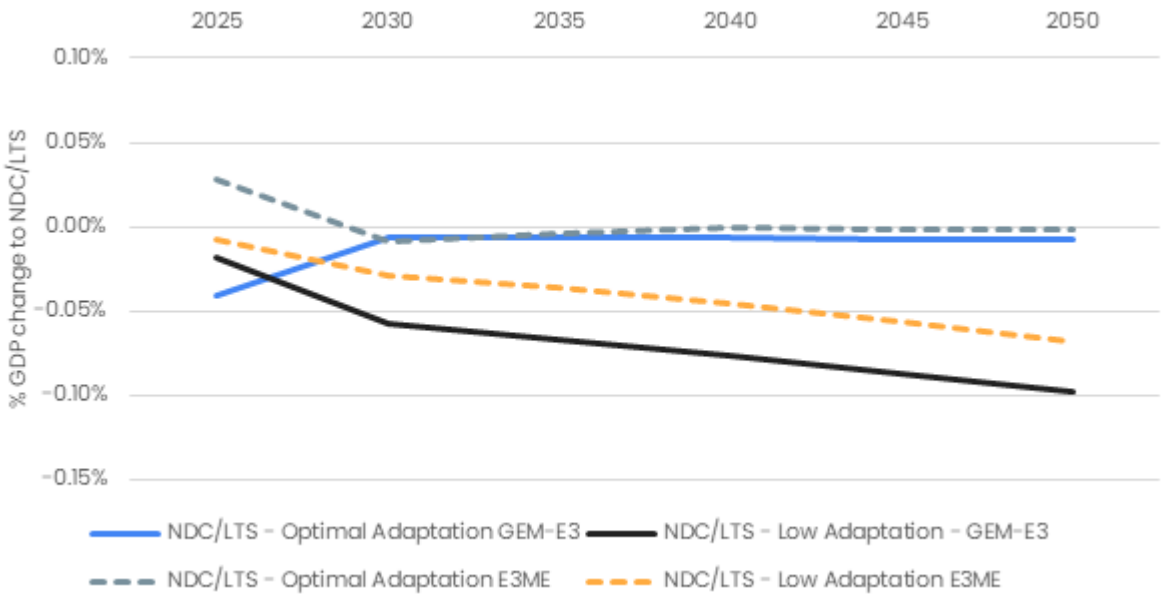


Figure 3 (a). EU GDP change under NDC/LTS with low vs optimal adaptation

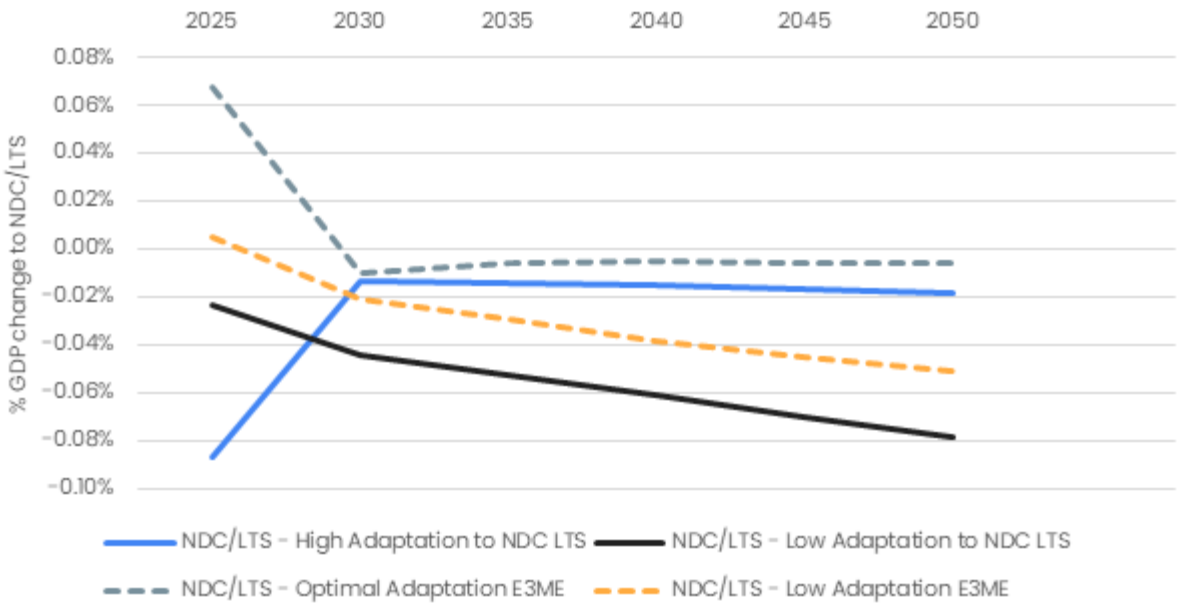
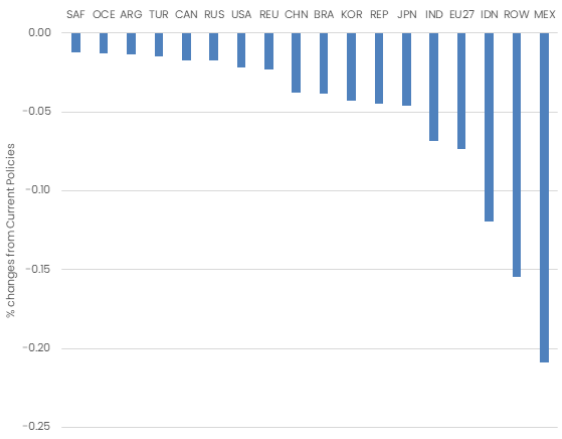


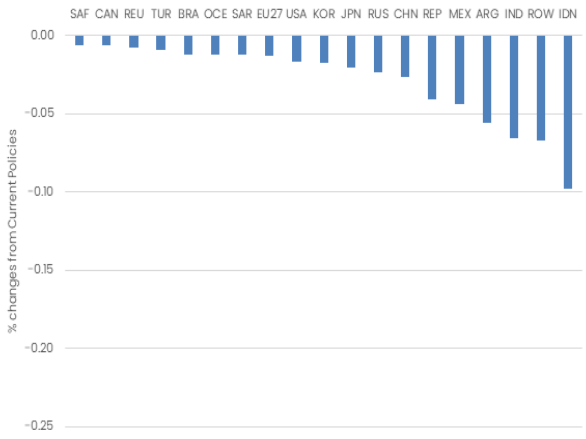
Figure 3 (b). World GDP change under NDC/LTS with low vs optimal adaptation

A similar pattern emerges under the NDC/LTS pathway (Figures 3(a) and 3(b)). Despite lower emissions and temperature outcomes, GDP impacts in the low-adaptation scenario remain comparable to those under Current Policies. This reflects the medium-run horizon of the analysis, over which temperature differences between pathways remain limited. As a result, flood damages and required adaptation investments are only marginally lower under NDC/LTS.

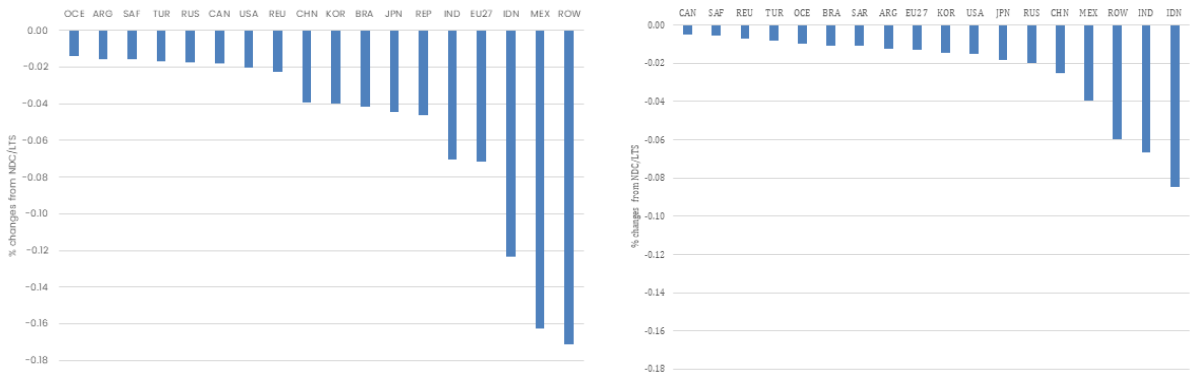
Optimal adaptation again reduces GDP losses substantially across both regions and models, reinforcing the robustness of the result across mitigation pathways. While overall impacts are slightly smaller under NDC/LTS, the relative effectiveness of adaptation in reducing losses remains consistent.



(a) Current Policies with low adaptation



(b) Current Policies with optimal adaptation



(c) NDC/LTS with low adaptation **(b)** NDC/LTS with optimal adaptation

Figure 4. Country-level cumulative GDP impacts under alternative mitigation pathways and adaptation scenarios

Country-level results reveal substantial heterogeneity in both scenarios (Figure 4). Under low adaptation, countries with higher exposure to flood risk, such as Mexico and Indonesia, experience larger GDP losses. Optimal adaptation reduces these losses significantly across all countries, although a residual cost remains. The cross-country distribution of impacts is broadly similar under Current Policies and NDC/LTS, indicating that vulnerability and exposure play a more important role than mitigation pathway differences over the time horizon considered.

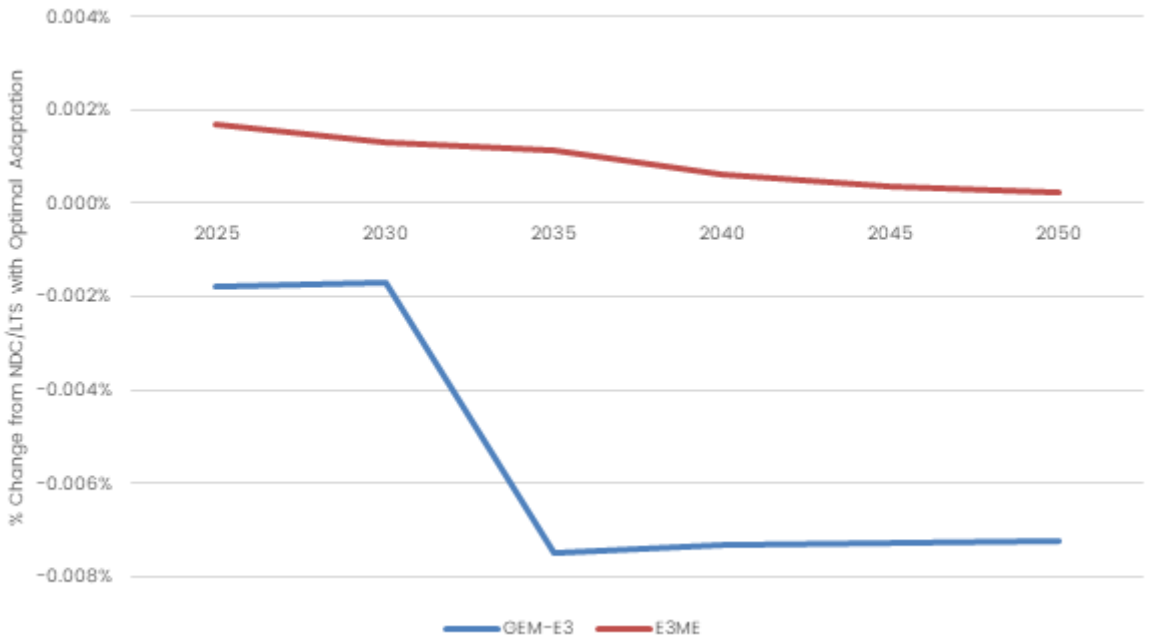


Figure 5. World GDP impacts of biodiversity conservation costs under the NDC/LTS

The introduction of biodiversity conservation costs adds an additional expenditure channel, although the associated macroeconomic effects remain very small. At the global level (Figure 5), GDP impacts range from approximately -0.007% in GEM-E3 to near zero or slightly positive values in E3ME. The divergence across models reflects differences in the treatment of these expenditures. In GEM-E3, biodiversity conservation costs are introduced as non-productive

expenditures, placing pressure on disposable income and output. In contrast, E3ME treats these expenditures as investment, generating demand-driven multiplier effects that can offset or slightly exceed the associated costs.

Financial risk and overall effects

The incorporation of climate-related financial risk introduces an additional transmission channel through changes in financing conditions. These effects are assessed under the NDC/LTS pathway, where adjustments in the cost of capital and sectoral risk premia derived from the CLIMACRED framework are fed back into the macroeconomic models.

The inclusion of financial risk leads to a clear divergence in outcomes across models. In GEM-E3, higher costs of capital increase production costs and reduce investment, resulting in additional GDP losses. By 2050, output declines by approximately 0.3% in the EU and around 0.5% at the global level relative to the baseline with optimal adaptation and biodiversity (Figures 6(a) and 6(b)). These effects reinforce the negative impacts observed under physical risk channels.

In contrast, E3ME produces consistently positive macroeconomic effects. This outcome is driven by reductions in electricity prices, as lower financing costs for renewable energy technologies reduce overall system costs. The resulting decline in energy prices supports household consumption and industrial activity, leading to GDP gains of approximately 0.2% in the EU and around 0.05% globally by 2050. These effects outweigh the adverse impacts associated with higher risk premia in other sectors.

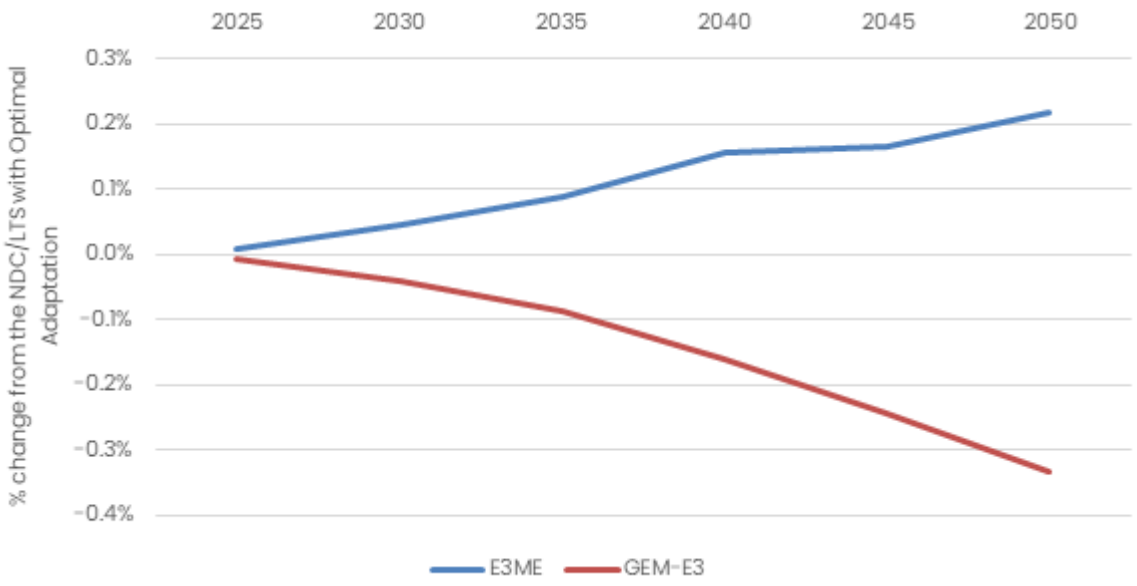


Figure 6 (a). EU GDP impacts of climate-related financial risk

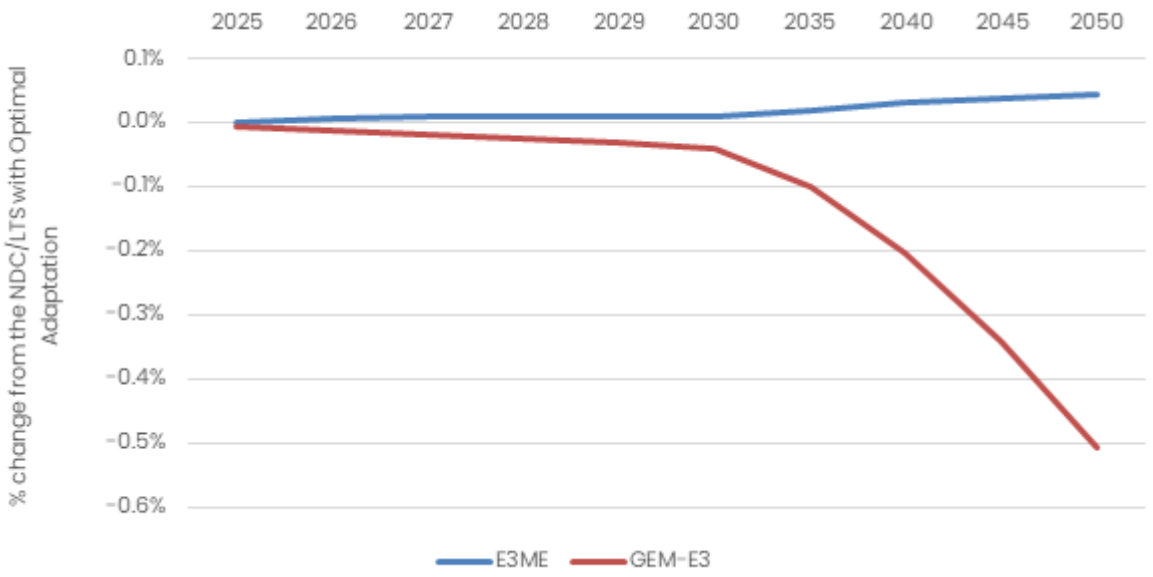


Figure 6 (b). World GDP impacts of climate-related financial risk

Overall, the results highlight systematic differences between the two modelling approaches. GEM-E3 transmits financial shocks primarily through cost increases and supply-side constraints, leading to negative output effects. E3ME captures demand-driven responses and sectoral cost reductions, particularly in the energy system, which can offset and exceed negative effects from increased financing costs. Despite these differences, both models confirm that financial conditions constitute an important channel through which climate policies and risks affect macroeconomic outcomes.

4. Discussion

This analysis provides an integrated macroeconomic assessment of mitigation, adaptation, and biodiversity conservation, offering insights into how these dimensions interact within economy-wide modelling frameworks. A central result is the consistent finding across both GEM-E3 and E3ME that higher levels of adaptation, despite their upfront costs, lead to improved macroeconomic outcomes relative to low adaptation scenarios. This aligns with a growing body of literature showing that early adaptation investments reduce long-term economic damages from climate-related hazards (IPCC, 2022; OECD, 2020). In particular, the results reinforce the understanding that flood-related damages, when insufficiently managed, translate into persistent capital losses and reduced economic output, as documented in previous CGE-based flood impact studies (Carrera et al., 2015; Gertz et al., 2019). At the same time, the results highlight pronounced heterogeneity across countries, with highly exposed economies, particularly coastal regions, accounting for a disproportionate share of aggregate losses, indicating that aggregate outcomes may mask significant national-level vulnerabilities.

A key insight emerging from this work concerns the temporal mismatch between costs and benefits. Adaptation investments are concentrated in the near term, while a substantial share of avoided damages materialises only in the longer term and particularly beyond 2050, when climate trajectories and associated impacts diverge more strongly across scenarios. This leads to a situation where adaptation costs may exceed avoided damages within the simulation period, even though the long-term net benefits are likely positive. Similar dynamics have been highlighted in the

literature on coastal adaptation and sea-level rise, where early investments appear costly in the short run but are justified when evaluated over longer time horizons (Schinko et al., 2020; Vousdoukas et al., 2020). This suggests that short- to medium-term macroeconomic assessments may systematically undervalue adaptation, particularly when future damages are non-linear and accelerating.

The comparison between modelling frameworks highlights the importance of structural assumptions in shaping macroeconomic outcomes. In GEM-E3, adaptation and biodiversity-related expenditures are treated as non-productive costs, leading to mild negative GDP impacts due to resource reallocation and potential crowding-out effects, whereas in E3ME they act as productive investments, generating demand-side stimulus and positive multiplier effects. These differences are further influenced by the assumed financing mechanisms, as adaptation investments funded through taxation, borrowing, or reallocation of resources can generate distinct macroeconomic responses, even when the direction of effects remains consistent across specifications. Despite these differences, both models converge on the same conclusion that underinvestment in adaptation leads to higher economic losses. This convergence is consistent with previous multi-model comparisons, which show that while the magnitude of impacts may vary, the direction of effects tends to be robust across modelling approaches (Schinko et al., 2020). The divergence, however, underscores the importance of policy design. The extent to which adaptation contributes to economic performance depends on whether it enhances productive capacity, supports domestic value chains, or induces technological spillovers. At the sectoral level, adaptation investments are associated with increased demand in construction and related activities, reflecting the infrastructure-intensive nature of flood protection measures.

Biodiversity conservation, as captured in this analysis through climate-induced species loss, emerges as a comparatively low-cost component of climate policy, with negligible macroeconomic impacts. This finding is consistent with recent assessments suggesting that investments in biodiversity protection are modest relative to the economic risks associated with ecosystem degradation (Ceglar et al., 2024; Dasgupta, 2021). At the same time, the analysis likely underestimates total biodiversity-related costs, as it excludes pressures arising from land-use change, which are widely recognised as a primary driver of biodiversity loss (IPBES, 2019). Beyond direct costs, biodiversity plays a critical role in supporting ecosystem services, including natural flood regulation, pointing to the potential of nature-based solutions to generate co-benefits across adaptation and conservation objectives (EEA, 2024). Given their relatively low macroeconomic cost, such measures can complement conventional adaptation strategies and strengthen overall system resilience.

The inclusion of financial risk through the CLIMACRED model introduces an additional transmission channel, illustrating how climate-related risks can propagate through the financial system and influence macroeconomic outcomes. Changes in the cost of capital and risk premia affect both investment decisions and production costs, with model results showing divergent outcomes depending on assumptions. In particular, increased capital costs in GEM-E3 dampen investment and economic activity, while reductions in financing costs for low-carbon technologies generate positive long-term effects in E3ME. These results highlight the importance of financial conditions as a key transmission channel in shaping macroeconomic outcomes, consistent with the emerging literature on climate-related financial risk, which emphasises the role of financial conditions in influencing the pace and cost of the transition (Ceglar et al., 2024; NGFS, 2023). The modelling framework applied here is consistent with recent approaches used in short-term climate

risk scenario analysis, including those developed in NGFS short-term climate risk scenarios, where financial variables are linked to macroeconomic models to capture transmission effects.

The results highlight the importance of designing climate policy as an integrated portfolio rather than a set of isolated interventions. Mitigation remains the most resource-intensive component, reflecting the scale of structural transformation required in energy and production systems. Adaptation plays a critical role in shaping near- to medium-term economic outcomes by reducing exposure to climate damages, while biodiversity conservation contributes to long-term resilience through ecosystem services. This reinforces the need for coordinated strategies that capture synergies across policy domains, in line with broader evidence from integrated assessment modelling (IPCC, 2022; Tol, 2018).

This analysis is subject to several limitations that should be considered when interpreting the results. The time horizon is limited to 2050, which restricts the ability to fully capture the long-term benefits of adaptation and the divergence across climate scenarios, particularly as climate impacts are expected to accelerate beyond mid-century. Biodiversity impacts are only partially represented and do not account for land-use dynamics or ecological feedback effects. In addition, while the analysis captures heterogeneity across countries through detailed country-level results, these results are not the primary focus of the present analysis and are therefore not explored in depth, and it does not explicitly account for distributional impacts within countries across households or income groups. This distinction is important, as the economic consequences of climate policies and climate damages are often unevenly distributed within economies, with implications for equity and policy acceptability (IPCC, 2022). Addressing these dimensions in future work would provide a more comprehensive understanding of the interactions between climate risks, economic systems, and policy responses.

Within these constraints, the findings have direct implications for the design of climate policy. The results suggest that prioritising early and well-targeted adaptation investments can reduce long-term economic risks, even when short-term costs appear significant. At the same time, the effectiveness of such investments depends on how they are financed and integrated into the broader economy, highlighting the importance of policy frameworks that support productive capacity, innovation, and domestic value creation. The relatively low macroeconomic cost of biodiversity conservation further indicates that integrating nature-based solutions into climate strategies can enhance resilience without imposing substantial economic burdens. Finally, the sensitivity of results to financial conditions underscores the need to align financial systems with climate objectives, ensuring that capital is directed efficiently towards low-risk, low-carbon investments.

5. Conclusions

This paper set out to assess economic resilience to climate change through an integrated macroeconomic framework that simultaneously considers flood risk adaptation, biodiversity conservation, and climate-related financial risk. Drawing on nine policy scenarios across two mitigation pathways and two adaptation levels, and employing two structurally distinct macroeconomic models, GEM-E3 and E3ME, the analysis quantified GDP impacts from coastal and riverine flood damages, species conservation expenditures, and capital cost adjustments derived from the CLIMACRED financial risk model. The modelling approach further aligns with recent developments in short-term climate risk scenario analysis, including NGFS applications,

where financial variables are explicitly linked to macroeconomic dynamics to capture transmission effects.

The results consistently demonstrate that proactive optimal adaptation generates superior macroeconomic outcomes relative to limited protection strategies, preserving economic resilience by substantially reducing flood-related GDP losses despite requiring concentrated upfront investment before 2030. Biodiversity conservation costs are affordable and macroeconomically negligible in the near term, yet their role in sustaining ecosystem-based flood protection makes them a strategically important complement to engineered adaptation measures. The incorporation of financial risk through CLIMACRED further demonstrates that capital cost adjustments driven by transition and physical risks can materially amplify macroeconomic outcomes, with the direction and magnitude of effects depending on structural assumptions about how economies transmit climate-related financial shocks. The divergence between GEM-E3 and E3ME in this respect reflects genuine uncertainty about these transmission mechanisms and underscores the value of employing multiple modelling frameworks in integrated climate assessments.

These findings should be interpreted in light of several constraints. The time horizon is limited to 2050, which restricts the ability to fully capture the long-term benefits of adaptation and the divergence across climate pathways. Biodiversity impacts are only partially represented, excluding land-use dynamics and ecological feedbacks, and distributional effects within countries are not explicitly modelled. These considerations point to important directions for future research rather than weakening the central conclusions.

Therefore, economic resilience to climate change cannot be achieved through any single policy instrument. Flood adaptation, biodiversity conservation, and financial risk management each address distinct dimensions of climate-related economic vulnerability, and the interactions between them are consequential enough that treating them in isolation risks both understating aggregate economic costs and overlooking potential synergies from coordinated action. An integrated policy approach that aligns investment, risk management, and ecosystem protection is therefore essential to sustain long-term economic resilience. The costs of this integrated strategy are affordable. The window for delivering it cost-effectively is not indefinite.

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Appendix A. Climate–Economy Linkage and Temperature Estimation

Temperature estimation framework

To translate emissions pathways generated by the macroeconomic models into temperature outcomes, this paper employs the Transient Climate Response to Cumulative Emissions (TCRE) framework. In principle, this transformation could be undertaken using a full climate model; however, the computational requirements of such models make them impractical within a multi-scenario macroeconomic setting.

Under the TCRE approach, global mean temperature increase is expressed as:

$$\Delta GMTI_t = \Delta GMTI_{t_0} + TCRE \times \sum_{t_0}^{t} CO_2 Emissions_t$$

where t denotes the projection year and t_0 the final historical year.

Parameterisation

The TCRE parameter represents the ratio between cumulative carbon emissions and global temperature change. The IPCC (2021) reports an assessed range of 1.0°C to 2.3°C per 1000 Pg of carbon, with a central estimate of 1.65°C per 1000 Pg of carbon. This corresponds to approximately 0.45°C per $GtCO_2$, which is the unit used in the present analysis.

Global mean temperature increase is measured relative to pre-industrial levels (1850–1900). Baseline warming is assumed to be approximately 1.3°C as of 2023, consistent with recent observational estimates (Hausfather, 2024).

Rationale for the TCRE approach

The use of the TCRE framework reflects a trade-off between model completeness and computational tractability. While full climate models capture complex feedback mechanisms and regional heterogeneity, they are not readily integrated into iterative macroeconomic simulations. The TCRE approach provides a consistent and transparent method for linking emissions to temperature across scenarios, while maintaining computational feasibility.

Validation

Temperature trajectories derived using the TCRE method are compared with standard Representative Concentration Pathway (RCP) projections to ensure consistency with established climate modelling frameworks. This validation step ensures that the estimated temperature pathways remain within plausible ranges implied by climate model ensembles.

Limitations

The TCRE framework simplifies the climate system by representing the relationship between emissions and temperature using a single parameter. As a result, it does not capture regional variation in climate responses, feedback mechanisms, or tipping points. In addition, uncertainty in the TCRE parameter is not explicitly propagated through the analysis. The results should therefore be interpreted as central estimates rather than probabilistic projections of climate outcomes.

Appendix B. Flood Damage and Adaptation Function Estimates

Functional specification

Flood damages are estimated at the country level using a quadratic log-linear specification:

$$\log\left(Damages_{c,t}\right) = \beta_0 + \beta_{1,c} GMTI_t + \beta_{2,c} GMTI_t^2 + \beta_{3,c} Adaptation_t + \varepsilon_{c,t}$$

where $Damages_{c,t}$ denotes expected annual damages from coastal and riverine flooding in country c at time t, $GMTI_t$ represents global mean temperature increase, $Adaptation_t$ captures the adaptation regime, and $\varepsilon_{c,t}$ is an error term.

The logarithmic transformation implies that the estimated coefficients can be interpreted as semi-elasticities, approximating percentage changes in damages associated with changes in temperature.

Interpretation of coefficients

The specification is designed to capture both first-order and higher-order responses of damages to climate change:

- The coefficient on the linear temperature term, $\beta_{1,c}$, reflects the initial sensitivity of flood damages to increases in global temperature. A positive value indicates that damages rise as temperature increases, while a negative or statistically insignificant coefficient may reflect limited exposure or buffering effects at lower temperature levels.
- The coefficient on the quadratic term, $\beta_{2,c}$, captures the extent to which damages accelerate as temperature increases. A positive value implies convexity, such that marginal damages increase at higher levels of warming. This is consistent with the physical processes underlying flood risk, including nonlinear sea-level rise, intensification of extreme precipitation events, and the increasing likelihood of infrastructure thresholds being exceeded.
- The coefficient associated with adaptation, $\beta_{3,c}$, measures the extent to which higher levels of protection reduce expected damages. This term allows the model to distinguish between policy regimes with different levels of flood defence.

Rationale for the quadratic specification

The inclusion of a quadratic temperature term reflects the expectation that flood damages respond nonlinearly to increases in global temperature. A purely linear specification would impose constant marginal damages from warming, which is unlikely to capture the dynamics of climate-related risks. Both empirical assessments and physical modelling suggest that damages tend to increase

gradually at lower levels of warming but accelerate as climate risks intensify, consistent with findings in the literature on climate impacts and coastal flood damages (Hinkel et al., 2014). The quadratic specification therefore provides a flexible functional form capable of capturing these nonlinearities in damage responses.

Adaptation regimes

Two alternative adaptation regimes are considered:

- **Low adaptation**, corresponding to constant flood protection standards. Under this regime, protection evolves mechanically with sea-level rise but is not optimised relative to changing risk. As a result, some regions may remain under-protected, while others may be over-protected.
- **Optimal adaptation**, in which protection levels are determined through cost-benefit optimisation. In this case, adaptation investments are chosen to minimise the sum of residual damages and adaptation costs. This regime typically involves higher upfront investment but results in significantly lower damages over time.

This distinction allows the analysis to capture the trade-off between early investment and future damage avoidance.

Estimation procedure

The damage functions are estimated using outputs from the Dynamic and Integrated Vulnerability Assessment (DIVA) model. DIVA provides estimates of expected annual damages under different Representative Concentration Pathways (RCPs) and socioeconomic scenarios. Because the macroeconomic scenarios used in this paper generate temperature trajectories rather than RCP-specific outputs, the estimated temperature paths are matched to the closest corresponding RCP scenario prior to estimation.

Separate regressions are estimated for each country, adaptation regime, and RCP scenario.

Adaptation cost functions

Adaptation costs are estimated using a similar functional approach, allowing investment requirements to vary systematically with temperature and policy assumptions. These functions capture the fact that higher levels of warming require more extensive and costly protection measures. In the optimal adaptation regime, costs are typically front-loaded, reflecting the need for early investment in infrastructure to prevent future damages.

Sectoral allocation of flood damages

Country-level flood damages are disaggregated across economic sectors using gross fixed capital formation (GFCF) shares as a proxy for sectoral exposure to physical capital losses. The allocation weight for sector s in country c is defined as:

$$w_{s,c} = \frac{GFCF_{s,c}}{\sum_s GFC\ F_{s,c}}, Damage_{s,c,t} = w_{s,c} \cdot Damage_{c,t}$$

where s indexes economic sectors, c indexes countries, and $t$denotes time. $GFCF_{s,c}$ represents sectoral investment, and $Damage_{c,t}$ denotes total country-level flood damages.

This approach assumes that sectors with larger capital stocks are more exposed to physical damage from flooding, as flood events primarily affect fixed assets such as infrastructure, buildings, and equipment. Allocating damages in proportion to capital formation therefore provides a tractable approximation of sectoral exposure in the absence of detailed asset-level vulnerability data.

Sectoral GFCF data are drawn from two sources. For European countries, data are obtained from the Annual Regional Database of the European Commission (ARDECO), which provides harmonised time series of socio-economic indicators, including sectoral investment, based on Eurostat regional accounts and national statistical sources. For non-European countries, comparable data are sourced from the United Nations statistical database (UNdata), which compiles internationally consistent national accounts statistics, including gross fixed capital formation by economic activity.

Model implementation

Flood damages and adaptation costs are incorporated differently across the two macroeconomic models, reflecting their underlying structural assumptions.

In GEM-E3, flood damages are modelled as exogenous reductions in capital stock. These losses are treated as persistent over the simulation horizon, as the model does not assume endogenous rebuilding of damaged assets. Adaptation costs enter separately as non-productive government expenditure, financed through higher indirect taxation. As a result, flood damages reduce productive capacity, while adaptation affects the economy through fiscal and resource-allocation channels.

In E3ME, flood damages affect the economy through two channels. First, they induce a temporary reduction in production, reflecting the disruption associated with asset losses. Second, they generate additional demand for reconstruction, which is introduced through sectoral cost and price effects associated with rebuilding activity. Adaptation costs are introduced as investment expenditure, allowing them to generate demand-driven multiplier effects. This treatment implies that the flood module affects the macroeconomy through both asset-loss and expenditure channels.

Regression results

Country-level regression coefficients for all specifications are reported in:

Table B1. Damage Function Coefficients – RCP 2.6, Constant Dike Height (No Adaptation)

Country	Intercept	Linear GMTI	Quadratic GMTI	RMSE
ABW	-9768.371	15308.53	-6010.075	23.8572

AGO	1973.151	-2708.703	927.6595	3.03859
AIA	234806.2	-341061.4	123814.4	48.7058
ALA	251.5099	-384.752	146.5348	2.67175
ALB	-16089.51	23519.67	-8591.709	4.48033
ARE	-9208.289	13373.17	-4850.254	2.23697
ARG	5531.092	-8093.527	2963.576	0.77681
ASM	107072	-154892.6	55984.42	47.7878
ATF	-103.6163	-5.69E-11	2.06E-11	1.8E-14
ATG	10953.07	-15823.63	5713.763	3.89896
AUS	-5500.368	7952.353	-2870.081	1.15867
BEL	4481.866	-6570.853	2412.425	2.99046
BEN	-44339.99	63440.68	-22732.52	34.3517
BGD	3039.915	-4517.389	1680.156	1.14048
BGR	-11190.74	16336.58	-5960.48	2.56219
BHR	-16299.64	23779.37	-8668.963	4.61265
BHS	-1534.658	2229.242	-809.5538	2.0111
BLZ	38028.34	-55240.51	20055.45	5.22971
BMU	-106826	155743.3	-56762.78	28.2597
BRA	-5298.375	7677.153	-2776.323	1.49959
BRB	83130.23	-119551.6	42957.24	47.098
BRN	-9087.677	13300.22	-4863.826	3.0507
BVT	-103.6163	-5.69E-11	2.06E-11	1.8E-14
CAN	-848.7938	1169.021	-397.5661	1.02091
CCK	6078.013	-9187.749	3413.345	12.926
CHL	170.5963	-320.8899	145.2946	1.12724
CHN	-4591.585	6615.532	-2376.957	1.97338
CIV	-39051.56	57303.79	-21034.96	32.1331
CMR	-1841.535	2659.168	-959.7872	2.33735
COD	-44502.51	64796.13	-23587.28	9.7693
COG	6482.305	-9203.46	3263.019	7.18092
COK	-103.6163	-5.69E-11	2.06E-11	1.8E-14
COL	-9948.278	14601.96	-5354.793	4.73119
COM	6308.595	-9165.334	3328.988	3.15985
CPV	185781.6	-269103.9	97411.51	47.0144
CRI	-13380.75	19572.41	-7155.336	2.04765
CUB	-5670.732	8265.511	-3010.766	1.70521
CUW	-196033.3	286379.9	-104608	39.8022
CYM	89217.29	-128803.3	46454.72	46.0318
CYP	26190.29	-37940.27	13738.19	8.34401
DEU	5366.433	-7848.121	2873.838	0.81802

DJI	-3891.855	5830.22	-2180.68	10.0816
DMA	46122.96	-68945.11	25703.02	44.8064
DNK	3942.009	-5797.437	2135.009	0.99738
DOM	1630.079	-2325.423	828.8989	3.15428
DZA	1081.392	-1546.184	554.7269	2.599
ECU	-7456.464	10913.26	-3989.73	3.8411
EGY	1046.124	-1397.144	467.0525	4.5497
ERI	6999.892	-10186.08	3705.23	3.06023
ESH	-23167.69	33897.32	-12397.48	12.3612
ESP	-5807.165	8431.943	-3056.569	2.08312
EST	3352.336	-4929.569	1812.742	0.8717
FIN	5913.739	-8651.715	3166.571	1.4806
FJI	491.2923	-632.8738	201.4543	1.86809
FLK	-86862	126506.7	-46060.46	25.8744
FRA	3585.589	-5280.483	1948.33	1.2265
FRO	-5591.151	8122.891	-2948.481	2.43287
GAB	4235.788	-6033.234	2148.048	3.13182
GBR	6399.496	-9379.966	3441.862	1.06259
GEO	-5329.836	7837.627	-2879.012	3.26801
GGY	-10710.1	15584.7	-5666.388	2.86508
GHA	3309.591	-4793.128	1735.013	2.13761
GIB	-39255.03	57203.96	-20838.52	16.1638
GIN	5059.958	-7361.486	2677.81	3.00536
GLP	-54219.84	78257.51	-28245.92	35.5853
GMB	2452.07	-3491.403	1240.095	4.76168
GNB	22735.94	-33271.26	12167.6	2.63852
GNQ	-3435.785	5149.709	-1926.5	3.03279
GRC	-6965.648	10152.15	-3695.83	1.98073
GRD	-34238.14	50194.7	-18398.64	28.457
GRL	-10011.46	14577.58	-5304.041	3.31322
GTM	2002.873	-2783.358	965.1082	2.2539
GUF	1725.744	-2386.728	823.1983	3.40869
GUM	108033	-157873	57619.23	33.9981
GUY	5360.477	-7715.955	2777.149	4.72693
HKG	-14672.63	21344.24	-7758.078	2.6786
HMD	-103.6163	-5.69E-11	2.06E-11	1.8E-14
HND	7743.639	-11282.57	4108.774	2.20697
HRV	-6214.956	9000.958	-3255.936	1.76553
HTI	-3562.461	5215.558	-1909.256	3.21913
IDN	-4701.401	6780.09	-2438.797	1.63683

IMN	4136.075	-6090.751	2242.893	1.24302
IND	-9992.83	14514.11	-5265.091	2.29136
IOT	-103.6163	-5.69E-11	2.06E-11	1.8E-14
IRL	-1159.096	1621.008	-562.4661	1.36556
IRN	-6097.867	8829.281	-3192.592	1.89974
IRQ	3637.009	-5370.361	1985.429	2.01903
ISL	-4338.127	6278.148	-2268.487	2.55874
ISR	7494.457	-10804.82	3894.937	3.92423
ITA	476.5743	-741.7454	291.6786	1.42746
JAM	17525.85	-25340.38	9157.496	10.3686
JEY	-8051.072	11684.93	-4236.89	2.18483
JOR	188816.2	-272402.1	98215.06	46.5008
JPN	-9380.63	13659.58	-4967.238	2.275
KEN	-7375.316	10737.78	-3906.195	3.39779
KHM	2332.392	-3434.736	1265.08	1.16146
KIR	-103.6163	-5.69E-11	2.06E-11	1.8E-14
KNA	118603.8	-172286.3	62539.67	46.3958
KOR	-8247.945	11987.13	-4351.047	2.11087
KWT	-7842.805	11349.1	-4101.873	1.90438
LBN	6665.692	-9634.576	3481.824	3.02117
LBR	2323.92	-3406.639	1247.868	1.98276
LBY	-12212.55	17826.34	-6502.192	3.05928
LCA	-13708.47	20077.64	-7353.858	19.261
LKA	3886.286	-5589.513	2009.084	1.76924
LTU	1037.352	-1578.698	601.0489	1.35187
LVA	3710.029	-5464.82	2014.398	1.26769
MAC	-10904.52	15827.23	-5740.37	2.58153
MAR	-5864.974	8515.749	-3088.028	2.3704
MDA	-8433.231	12292.11	-4476.89	2.48288
MDG	2238.497	-3301.022	1218.028	1.8946
MDV	-63613.39	93082.76	-34051.92	30.2415
MEX	-13968.23	20315.55	-7381.144	3.26831
MHL	98848.16	-141903.8	50882.45	38.9408
MLT	149534.7	-215813.2	77843.26	48.7367
MMR	-7362.459	10694.45	-3879.764	1.7704
MNE	-7079.038	10299.57	-3745.033	2.21544
MNP	81048.07	-118235.7	43064.22	24.4667
MOZ	7612.673	-11157.29	4087.693	1.23916
MRT	12622.33	-18225.02	6578.08	5.70805
MSR	-103.6163	-5.69E-11	2.06E-11	1.8E-14

MTQ	80748.78	-118011.4	43102.97	20.9971
MUS	629.481	-878.0188	305.5987	3.19882
MYS	-6509.335	9435.183	-3414.566	1.97281
MYT	-660.0817	998.0025	-378.0134	2.54064
NAM	-24482.9	36002.84	-13235.22	19.4276
NCL	-16080.49	23388.45	-8504.378	1.98943
NFK	-103.6163	-5.69E-11	2.06E-11	1.8E-14
NGA	7478.249	-10770.83	3881.208	3.48835
NIC	-3826.252	5665.08	-2095.7	2.22744
NLD	7243.865	-10594.54	3879.356	1.09381
NOR	3017.874	-4436.486	1634.024	2.11828
NRU	-2757.901	5854.211	-2829.869	38.329
NZL	-6908.573	10007.58	-3621.507	1.48821
OMN	-10016.22	14584.09	-5304.878	2.65901
PAK	-9541.256	13903.14	-5062.122	3.4446
PAN	-12072.17	17527.7	-6359.035	2.27359
PCN	-103.6163	-5.69E-11	2.06E-11	1.8E-14
PER	-10928.01	15968.07	-5831.064	2.99678
PHL	-6614.136	9612.507	-3487.52	1.85236
PLW	50153.5	-72290.63	26035.53	37.4443
PNG	1121.901	-1675.036	626.2721	1.03519
POL	822.3059	-1256.841	482.9908	0.90215
PRI	11675.67	-16905.36	6116.82	5.98031
PRK	-7231.947	10515.48	-3820.427	1.68032
PRT	-7386.71	10726.54	-3891.407	2.17143
PSE	55561.54	-78948.28	28010.97	47.2154
PYF	173623.5	-250300.3	90158.97	29.9113
QAT	-7144.631	10511.57	-3862.849	4.67593
REU	88502.48	-127700.1	46048.27	42.8729
ROU	-4956.581	7273.078	-2666.869	3.93124
RUS	3453.124	-5079.375	1871.351	0.97636
SAU	-8280.688	12080.85	-4401.939	3.20152
SDN	103780.4	-150557	54591.31	21.9967
SEN	9253.383	-13439.22	4879.73	2.65353
SGP	-9889.305	14430.05	-5261.36	2.72386
SGS	-103.6163	-5.69E-11	2.06E-11	1.8E-14
SJM	-2507.536	3634.314	-1317.109	3.23341
SLB	-5045.761	7307.616	-2645.479	1.88451
SLE	6332.881	-9208.154	3347.641	2.31063
SLV	-4030.553	5971.686	-2210.565	1.8882

SOM	7909.002	-11477.92	4165.651	3.29257
SPM	-100747.4	146716.8	-53411.86	26.4852
STP	-59198.21	86370.56	-31503.82	19.2943
SUR	-13773.8	20125.87	-7348.993	2.92035
SVN	-1940.86	2761.179	-979.8113	2.4857
SWE	4082.209	-6003.804	2210.162	1.28223
SYC	117033.2	-168256.5	60448.95	48.7814
SYR	7220.528	-10459.79	3786.937	3.09728
TCA	215322.8	-313117.1	113800.6	44.9158
TGO	-21307.85	29678.16	-10332.95	21.1898
THA	-8921.709	12935.89	-4684.667	2.64015
TKL	-103.6163	-5.69E-11	2.06E-11	1.8E-14
TLS	-6674.407	9706.585	-3529.089	3.05438
TON	-221233.8	322500.7	-117529.1	35.9338
TTO	15491.22	-22504.14	8172.049	2.94891
TUN	-4131.514	6031.85	-2197.822	2.26805
TUR	-4536.349	6630.14	-2419.488	2.45344
TUV	156408.7	-226519	81958.11	21.4262
TWN	-7045.026	10290.59	-3754.38	1.95298
TZA	-5212.359	7518.081	-2708.508	2.32256
UKR	-3317.476	4785.354	-1722.651	1.34172
UMI	-103.6163	-5.69E-11	2.06E-11	1.8E-14
URY	6315.753	-9268.563	3401.417	0.94422
USA	-1063.861	1485.514	-512.1411	0.81743
VCT	-141890.6	205376.6	-74331.18	45.3247
VEN	8127.598	-11708.52	4218.861	3.14296
VGB	162904.5	-236568.2	85853.7	48.9887
VNM	-4841.358	7033.538	-2550.033	1.79809
VUT	-4106.594	5924.972	-2138.302	1.3897
WLF	-93908.11	137291.8	-50202.42	44.045
WSM	206295.3	-299044.7	108334.5	47.9761
YEM	9225.143	-13408.78	4874.034	3.06995
ZAF	-9771.374	14217.66	-5169.647	2.17695

Source: Estimated from DIVA model output.

Note: RMSE is the root mean squared error of the regression fit. A lower RMSE indicates a closer fit between predicted and observed damage values from the DIVA model.

Table B2. Damage Function Coefficients – RCP 2.6, Constant Flood Protection Standards (BAU Adaptation)

Country	Intercept	Linear GMTI	Quadratic GMTI	RMSE
ABW	7450.9722	-10928.61	4005.77	0.44791

AGO	8402.3343	-12278.86	4487.16	0.48885
AIA	3623.3856	-5313.364	1947.15	0.37944
ALA	2204.7576	-3231.126	1183.46	0.23333
ALB	2155.8519	-3166.602	1165.22	0.15367
ARE	906.9325	-1346.311	503.159	0.13849
ARG	1178.6177	-1728.849	636.771	0.25832
ASM	3087.1903	-4544.425	1669.22	0.42353
ATF	-103.6163	-5.69E-11	2.1E-11	1.8E-14
ATG	3140.9179	-4604.228	1686.67	0.2633
AUS	3446.5419	-5048.938	1851.64	0.27014
BEL	2795.1919	-4086.249	1497.12	0.1974
BEN	9695.7287	-14208.58	5204.3	0.52803
BGD	6353.3533	-9318.981	3419.16	0.77534
BGR	955.4514	-1428.203	533.901	0.21287
BHR	2111.6992	-3114.712	1150.76	0.17703
BHS	2632.4479	-3868.488	1420.71	0.33165
BLZ	6111.7525	-8958.078	3282.06	0.51066
BMU	3307.4348	-4850.469	1777.02	0.26264
BRA	3126.996	-4586.915	1685.13	0.26276
BRB	1981.6982	-2918.296	1072.15	0.26689
BRN	1878.7956	-2761.757	1016.38	0.23467
BVT	-103.6163	-5.69E-11	2.1E-11	1.8E-14
CAN	3536.8565	-5170.782	1892.44	0.2997
CCK	6078.0134	-9187.749	3413.34	12.926
CHL	1815.7113	-2676.612	987.696	0.18208
CHN	-319.4864	428.63328	-137.785	0.30014
CIV	5818.6164	-8567.752	3154.01	0.40868
CMR	7740.5318	-11347.79	4158.77	0.53215
COD	9942.9925	-14614.5	5368.01	0.6106
COG	5794.5605	-8514.347	3126.88	0.39292
COK	-103.6163	-5.69E-11	2.1E-11	1.8E-14
COL	4109.665	-6024.645	2210.35	0.26851
COM	7784.2392	-11420.85	4188.56	0.41544
CPV	3788.8284	-5570.125	2047.15	0.27515
CRI	3554.7113	-5221.925	1918.18	0.293
CUB	2448.7898	-3611.758	1331.95	0.30467
CUW	2986.7582	-4377.103	1602.78	0.30077
CYM	4191.8358	-6144.041	2250.04	0.44366
CYP	3805.208	-5577.239	2042.83	0.36726
DEU	2013.6174	-2937.511	1075.62	0.12136

DJI	5179.7574	-7611.732	2797.23	0.29426
DMA	67442.693	-100018.1	37024.5	44.5113
DNK	2794.5056	-4083.781	1495.09	0.19761
DOM	2893.111	-4253.534	1563.97	0.22268
DZA	4165.7882	-6107.66	2239.72	0.3251
ECU	4733.9162	-6936.421	2543.28	0.31236
EGY	4164.8799	-6116.756	2250.01	0.31168
ERI	11579.119	-16950.34	6202.23	0.5859
ESH	3183.1494	-4692.847	1729.89	0.20555
ESP	3186.3033	-4655.818	1703.43	0.2408
EST	1141.4588	-1680.182	618.683	0.24423
FIN	2443.0357	-3571.898	1307.8	0.2957
FJI	6080.1593	-8905.63	3261.89	0.43258
FLK	3115.9206	-4582.574	1682.41	0.28236
FRA	3108.8553	-4544.245	1664.29	0.2011
FRO	3678.6883	-5381.495	1968.48	0.30602
FSM	5715.1285	-8376.073	3067.99	0.37373
GAB	4595.6986	-6746.917	2477.03	0.4514
GBR	2859.7002	-4179.654	1531.55	0.19677
GEO	2224.6585	-3283.282	1212.69	0.2998
GGY	3080.2526	-4507.323	1651.09	0.22728
GHA	7447.851	-10931.77	4010.9	0.46463
GIB	3488.09	-5111.054	1871.57	0.30808
GIN	5177.582	-7619.647	2803.48	0.85267
GLP	3378.2058	-4950.29	1812.8	0.28002
GMB	8540.0362	-12520.33	4586.8	0.68643
GNB	22735.939	-33271.26	12167.6	2.63852
GNQ	3693.928	-5423.383	1991.34	0.30812
GRC	2971.4569	-4353.963	1596.69	0.26667
GRD	3082.9666	-4525.27	1659.34	0.3048
GRL	2019.3315	-2954.41	1082.22	0.42772
GTM	6162.8584	-9040.706	3315.52	0.3656
GUF	2193.2055	-3192.266	1161.91	0.80451
GUM	108032.96	-157873	57619.2	33.9981
GUY	5429.06	-7961.038	2920.04	0.64272
HKG	357.89292	-536.1926	203.576	0.12889
HMD	-103.6163	-5.69E-11	2.1E-11	1.8E-14
HND	7847.1426	-11501.78	4214.29	0.58083
HRV	1249.8109	-1838.105	677.443	0.16088
HTI	7382.4778	-10837.52	3977.1	0.45969

IDN	3702.3001	-5448.136	2008.35	0.34825
IMN	3300.0553	-4834.125	1770.59	0.28656
IND	3980.3931	-5851.374	2154.4	0.33156
IOT	-103.6163	-5.69E-11	2.1E-11	1.8E-14
IRL	3177.7756	-4649.924	1703.32	0.2758
IRN	2982.7922	-4375.593	1606.65	0.26522
IRQ	5439.1651	-7966.343	2919.69	0.43341
ISL	2829.2422	-4146.688	1521.4	0.22278
ISR	4642.6932	-6805.443	2494.52	0.38782
ITA	2824.5137	-4126.196	1510.28	0.22081
JAM	4618.4413	-6765.325	2477.79	0.42635
JEY	2947.5126	-4314.344	1580.68	0.21666
JOR	5296.1566	-7790.276	2862.55	0.38808
JPN	1780.0847	-2599.804	953.352	0.23771
KEN	7995.2718	-11721.63	4297.03	0.45205
KHM	6188.8421	-9087.989	3336.29	0.66177
KIR	-103.6163	-5.69E-11	2.1E-11	1.8E-14
KNA	3815.6101	-5598.266	2050.23	0.41051
KOR	766.20268	-1134.606	423.161	0.19497
KWT	355.87587	-551.3882	215.256	0.14541
LBN	2373.677	-3498.012	1288.66	0.28099
LBR	9943.1667	-14600.23	5359.28	0.63726
LBY	2499.6813	-3676.182	1353.15	0.25387
LCA	5083.3392	-7459.946	2734.32	0.53852
LKA	3481.3335	-5126.136	1887.34	0.47549
LTU	3386.9344	-4961.237	1817.56	0.66973
LVA	1245.4551	-1840.13	681.379	0.21129
MAC	475.20643	-704.2332	262.365	0.25341
MAR	3420.4418	-5036.663	1855.87	0.25428
MDA	813.89918	-1231.312	466.639	0.21897
MDG	9829.0109	-14403.77	5277.18	0.53462
MDV	3797.9803	-5577.536	2048.45	0.2229
MEX	3091.4718	-4526.209	1660.9	0.16995
MHL	6085.4342	-8921.619	3269.12	0.45364
MLT	1464.1241	-2163.359	798.115	0.20389
MMR	3602.5203	-5295.333	1948.79	0.36692
MNE	2249.1505	-3310.092	1217.81	0.22026
MNP	81048.071	-118235.7	43064.2	24.4667
MOZ	11631.406	-17023.29	6227.54	0.92126
MRT	6961.8448	-10204.45	3739.71	0.66122

MSR	-103.6163	-5.69E-11	2.1E-11	1.8E-14
MTQ	4805.9067	-7041.657	2577.08	0.56921
MUS	3097.6792	-4563.979	1680.25	0.3711
MYS	3480.6494	-5109.19	1877.98	0.35992
MYT	3134.2944	-4595.513	1682.44	0.24697
NAM	3380.6004	-4974.535	1829.78	0.19729
NCL	2406.7004	-3544.421	1304.71	0.19035
NFK	-103.6163	-5.69E-11	2.1E-11	1.8E-14
NGA	8845.3653	-12955.84	4747.68	0.52336
NIC	6164.5992	-9048.697	3320.35	0.42816
NLD	2338.6564	-3411.946	1249.76	0.14728
NOR	2581.1405	-3772.398	1381.51	0.19651
NRU	5460.4506	-8005.111	2932.76	0.3398
NZL	5052.7277	-7392.547	2704.85	0.45444
OMN	1914.4043	-2822.29	1042.52	0.1848
PAK	6614.2824	-9694.626	3553.91	0.43596
PAN	2341.1047	-3451.143	1273.13	0.21643
PCN	-103.6163	-5.69E-11	2.1E-11	1.8E-14
PER	2616.0416	-3855.196	1421.09	0.22227
PHL	6080.2043	-8907.621	3265.93	0.36344
PLW	2894.9135	-4253.314	1559.45	0.30147
PNG	6698.8781	-9829.417	3606.21	0.43086
POL	1348.5614	-1983.91	732.403	0.17023
PRI	1009.7317	-1492.258	552.371	0.28154
PRK	1155.4154	-1709.733	633.589	0.33579
PRT	3450.681	-5051.678	1850.18	0.30874
PSE	4071.8302	-6011.736	2216.29	0.33354
PYF	3889.5576	-5706.078	2090.28	0.33893
QAT	352.45669	-528.8178	200.512	0.17006
REU	3420.0374	-5014.414	1836.73	0.25028
ROU	1738.2058	-2567.075	947.964	0.28297
RUS	1811.1149	-2663.606	982.27	0.37101
SAU	2271.2777	-3338.342	1229.62	0.22123
SDN	7804.5185	-11443.38	4194.41	0.41739
SEN	8777.632	-12860.63	4710.86	0.67014
SGP	-471.1864	672.49015	-238.237	0.15131
SGS	-103.6163	-5.69E-11	2.1E-11	1.8E-14
SJM	-571.1654	819.71987	-294.194	0.73275
SLB	6274.6194	-9213.778	3382.41	0.42013
SLE	8762.9545	-12851.85	4712.01	0.77584

SLV	4239.5744	-6220.504	2281.76	0.31455
SOM	11107.365	-16287.97	5972.37	0.55346
SPM	4220.924	-6188.434	2267.42	0.43071
STP	2877.6936	-4269.255	1582.37	0.27352
SUR	2791.367	-4121.936	1523	0.35893
SVN	2406.198	-3526.653	1293.02	0.1891
SWE	2610.726	-3820.592	1400.25	0.27537
SYC	3587.1988	-5269.492	1936.09	0.20113
SYR	5162.252	-7591.032	2789.21	0.43587
TCA	3671.7867	-5380.987	1970.71	0.38426
TGO	9950.217	-14580.4	5339.5	0.53831
THA	3601.0909	-5292.061	1947.39	0.62677
TKL	-103.6163	-5.69E-11	2.1E-11	1.8E-14
TLS	8169.0526	-11987.74	4397.02	0.52496
TON	5671.0266	-8319.346	3049.14	0.43683
TTO	807.92064	-1207.02	450.818	0.42756
TUN	1685.9375	-2498.507	928.293	0.1935
TUR	2904.7232	-4267.121	1569.01	0.33313
TUV	156408.72	-226519	81958.1	21.4262
TWN	573.4103	-849.1283	316.791	0.30834
TZA	8218.8089	-12054.44	4420.61	0.49989
UKR	2920.1025	-4294.318	1580.74	0.28699
UMI	-103.6163	-5.69E-11	2.1E-11	1.8E-14
URY	1923.2416	-2835.485	1045.85	0.22278
USA	2924.697	-4284.496	1573.39	0.23593
VCT	2547.6274	-3753.303	1380.01	0.28113
VEN	3513.759	-5149.627	1888.97	0.25474
VGB	3713.8391	-5446.969	1995.67	0.32083
VNM	4026.9844	-5920.075	2179.53	0.58826
VUT	7657.9781	-11232.05	4116.84	0.43477
WLF	-93908.11	137291.81	-50202.4	44.045
WSM	3463.2085	-5093.148	1869.87	0.20404
YEM	6431.4408	-9435.563	3461.88	0.48926
ZAF	2907.4997	-4276.409	1573.26	0.25173

Source: Estimated from DIVA model output.

Note: RMSE is the root mean squared error of the regression fit. A lower RMSE indicates a closer fit between predicted and observed damage values from the DIVA model.

Table B3. Damage Function Coefficients – RCP 6, Constant Dike Height (No Adaptation)

Country	Intercept	Linear GMTI	Quadratic GMTI	RMSE
ABW	5758.72	-7935.97	2683.27	24.2858
AGO	1185.2	-1618	551.36	2.52937
AIA	3087.68	-4282.72	1454.16	49.5835
ALA	-171.43	229.872	-76.721	1.95873
ALB	557.302	-736.173	243.52	4.63677
ARE	-358.61	516.972	-181.22	2.5219
ARG	-19.451	16.5426	1.21107	0.55642
ASM	1018.93	-1441.81	481.101	48.034
ATF	-103.62	4E-12	-1E-12	9.7E-14
ATG	228.501	-293.861	92.4269	3.47186
AUS	-250.75	360.087	-125.28	1.03772
BEL	-1266.4	1777.79	-618.82	5.06395
BEN	-6520.5	8611.25	-2864.8	35.4385
BGD	-246.76	329.499	-106.58	0.98203
BGR	464.043	-624.656	210.124	3.13709
BHR	469.562	-615.944	202.951	4.93384
BHS	-127.07	187.567	-69.156	1.57111
BLZ	38.5618	-88.5503	40.2863	2.90487
BMU	547.093	-650.13	183.492	18.9876
BRA	-116.71	179.595	-64.463	1.17488
BRB	5647.09	-7642.98	2558.06	45.1895
BRN	477.886	-629.372	207.551	2.51138
BVT	-103.62	4E-12	-1E-12	9.7E-14
CAN	-349.06	483.808	-163.65	1.05126
CCK	-3857.7	5156.83	-1764	15.0845
CHL	-502.21	689.345	-233.65	1.00943
CHN	-467.65	654.378	-223.1	1.67829
CIV	-367.75	580.476	-247.81	34.6384
CMR	136.119	-188.875	65.4892	2.67784
COD	60.8788	-33.1034	-10.903	9.838
COG	1741.95	-2396.49	820.089	6.32485
COK	-103.62	4E-12	-1E-12	9.7E-14
COL	990.833	-1322.73	440.876	3.37155
COM	252.005	-337.848	112.491	2.81939
CPV	11525.1	-16142.8	5615.28	44.5265
CRI	594.703	-798.821	267.837	1.83031
CUB	193.095	-253.479	83.3519	1.40278
CUW	5615.57	-7606.48	2537.35	42.4683

CYM	6661.95	-9405.25	3288.5	46.5751
CYP	434.103	-599.382	205.196	7.40692
DEU	-77.083	102.763	-29.347	0.69234
DJI	69.1997	-33.1776	-11.351	9.56367
DMA	-5687.4	7479.37	-2473.2	44.0081
DNK	-256.24	349.204	-114.7	0.83604
DOM	213.643	-288.801	96.9949	2.78204
DZA	96.0856	-120.268	38.9533	2.31143
ECU	414.699	-531.493	170.512	2.53311
EGY	635.997	-849.987	286.143	3.80794
ERI	464.7	-636.12	216.53	2.44474
ESH	-595.1	924.779	-356.63	13.6917
ESP	-124.98	190.579	-68.445	2.14523
EST	-255.86	344.933	-114.75	0.83964
FIN	-120.89	155.938	-46.983	1.28467
FJI	724.528	-993.744	340.71	1.66422
FLK	-5462.2	7758	-2754.6	27.6814
FRA	-437.71	606.031	-204.72	1.24744
FRO	-53.775	78.3989	-26.938	2.37966
FSM	9358.04	-12920.3	4431.49	42.8153
GAB	952.342	-1304.93	446.101	2.52168
GBR	-242.72	329.18	-106.04	0.78328
GEO	382.971	-513.291	172.47	3.28595
GGY	-256.17	381.517	-139.04	2.78936
GHA	225.908	-308.486	104.59	1.73146
GIB	-1944.8	2800.49	-1007.1	19.7228
GIN	401.554	-554.356	191.184	2.61595
GLP	-34.188	-65.1003	54.0621	30.9769
GMB	942.882	-1303.2	447.252	3.57744
GNB	-841.05	1111.55	-367.26	2.41373
GNQ	803.152	-1084.97	365.566	2.37504
GRC	200.726	-264.643	89.2769	2.02396
GRD	2302.74	-3127.62	1052.88	25.5938
GRL	-153.59	230.121	-83.728	2.99887
GTM	568.038	-773.962	262.725	2.21783
GUF	844.129	-1141	383.834	2.66747
GUM	-3058.4	3882.65	-1260.9	34.8341
GUY	-793.26	1141.91	-409.83	4.82604
HKG	-104.77	161.58	-58.244	2.45311
HMD	-103.62	4E-12	-1E-12	9.7E-14

HND	48.6925	-72.7425	26.4198	1.98561
HRV	-265.01	373.708	-128.87	1.84373
HTI	683.247	-948.294	327.693	2.70689
IDN	-244.56	353.096	-122.13	1.6407
IMN	-396.36	537.588	-180.39	1.33507
IND	-115.6	172.856	-59.722	2.09314
IOT	-103.62	4E-12	-1E-12	9.7E-14
IRL	-387.37	536.887	-182.29	1.37206
IRN	-350.56	500.974	-175.63	2.00477
IRQ	-483.9	671.381	-228.82	2.56696
ISL	-324.14	450.962	-153.68	1.83818
ISR	157.128	-196.82	61.2376	3.45115
ITA	-343.94	480.906	-163.58	1.33992
JAM	1308.7	-1803.63	618.974	5.9605
JEY	-260.22	375.349	-132.79	2.3035
JOR	8432.02	-11404.7	3817.73	41.2308
JPN	-71.686	119.323	-43.757	2.25142
KEN	177.086	-219.414	67.8077	2.66167
KHM	101.719	-153.334	58.4395	1.08816
KIR	-103.62	4E-12	-1E-12	9.7E-14
KNA	1945.35	-2672.32	891.139	47.9346
KOR	-116.02	168.651	-57.232	1.80827
KWT	-341.32	483.707	-167.76	2.05882
LBN	-10.256	25.2089	-12.169	2.80958
LBR	51.941	-81.2408	30.9383	2.05402
LBY	265.126	-342.002	111.096	2.92696
LCA	-62.983	81.3173	-28.528	2.42206
LKA	-91.486	119.943	-39.035	2.57992
LTU	-442.46	607.15	-205.97	1.60765
LVA	-514.88	709.702	-241.49	1.54836
MAC	-396.53	560.768	-195.79	2.26273
MAR	-31.591	56.8699	-21.802	2.28282
MDA	127.043	-163.771	54.0071	2.86549
MDG	119.245	-165.04	58.1982	1.51745
MDV	1672.33	-2169.15	691.134	25.6669
MEX	-322.94	478.319	-171.82	2.99025
MHL	9995.27	-13857.2	4758.7	42.7362
MLT	3729.97	-4993.53	1646.2	49.1088
MMR	-31.839	55.4784	-19.962	1.85045
MNE	25.5963	-30.1433	9.43933	2.14934

MNP	-1427.4	1670.72	-514.39	32.2273
MOZ	133.885	-203.036	76.6713	1.16922
MRT	514.733	-697.5	235.083	4.4484
MSR	-103.62	4E-12	-1E-12	9.7E-14
MTQ	-2228.4	2934.83	-969.87	29.876
MUS	147.448	-181.501	54.2202	2.44361
MYS	-99.36	153.143	-54.527	1.74397
MYT	236.69	-308.267	97.8725	1.7697
NAM	689.663	-939.164	316.66	6.47872
NCL	586.129	-795.767	268.646	1.55078
NFK	-103.62	4E-12	-1E-12	9.7E-14
NGA	1056.69	-1436.85	489.899	2.89471
NIC	1019.81	-1400.41	479.593	1.73685
NLD	-234.93	321.335	-103.64	0.86227
NOR	-311.74	427.723	-142.47	1.54841
NRU	13048.6	-17920.1	6105.84	39.8372
NZL	-141.04	208.485	-74.602	1.19355
OMN	12.8235	7.34054	-8.4261	2.34245
PAK	332.598	-447.45	151.956	3.85917
PAN	-266.45	390.825	-140.44	1.71729
PCN	-103.62	4E-12	-1E-12	9.7E-14
PER	355.107	-463.319	150.912	2.40441
PHL	-60.298	109.647	-42.971	1.32555
PLW	4512.78	-6150.16	2081.04	33.187
PNG	56.224	-79.6124	29.5807	0.94185
POL	-335.82	467.264	-158.38	1.00312
PRI	40.3531	-66.1596	24.6057	5.762
PRK	-78.34	115.277	-40.584	1.61743
PRT	-51.133	84.7804	-32.096	2.24149
PSE	5764.32	-7709.01	2543.49	45.0185
PYF	10046.8	-13873.3	4739.16	32.3772
QAT	206.845	-254.827	78.6234	4.68464
REU	2669.38	-3445.95	1083.43	46.3504
ROU	308.39	-414.494	139.229	2.7205
RUS	-262.36	358.469	-118.25	0.82276
SAU	-59.405	107.491	-42.821	3.1927
SDN	3966.21	-5601.3	1963.72	23.594
SEN	496.948	-689.504	238.862	2.56137
SGP	186.483	-243.287	80.6866	2.97366
SGS	-103.62	4E-12	-1E-12	9.7E-14

SJM	-71.356	99.802	-35.113	2.71309
SLB	72.1322	-102.945	36.7598	1.36068
SLE	349.798	-476.506	162.19	1.72927
SLV	370.245	-492.048	162.607	1.8997
SOM	330.538	-448.315	152.536	2.69339
SPM	1573	-2121.15	711.563	19.2392
STP	-3657.9	5219	-1862.7	23.2548
SUR	-24.365	76.8882	-40.706	3.36055
SVN	-473.85	654.836	-223.95	2.71107
SWE	-271.49	365.987	-119.62	1.01144
SYC	9964.09	-13523.3	4553.05	46.8161
SYR	256.62	-356.226	122.458	2.52227
TCA	-1482.8	1981.23	-682.32	46.0022
TGO	-5864.6	7892.13	-2658.6	13.2183
THA	-281.45	402.142	-139.64	2.3641
TKL	3173.76	-4607.48	1617.6	13.9426
TLS	636.434	-871.572	296.951	2.91682
TON	6062.72	-8060.18	2651.26	37.1511
TTO	73.3926	-90.2229	26.6759	2.66577
TUN	-112.09	175.388	-64.671	2.01697
TUR	144.265	-186.976	62.6612	2.31047
TUV	-1407.6	1766.72	-595.63	15.102
TWN	5.98457	2.56306	-1.7418	2.00058
TZA	-21.337	36.3209	-13.142	2.11356
UKR	-188.17	264.795	-90.347	1.24814
UMI	-103.62	4E-12	-1E-12	9.7E-14
URY	-294.93	390.068	-126.46	0.71259
USA	-445.75	625.077	-213.46	0.90483
VCT	2847.49	-3946.57	1346.2	45.5343
VEN	641.13	-862.495	291.04	2.56488
VGB	8999.7	-12808.7	4524.69	43.1962
VNM	-49.613	79.9405	-27.443	1.89581
VUT	164.907	-234.622	81.9593	1.16474
WLF	3051.6	-4048.03	1303.96	41.0084
WSM	-3980.2	5543.81	-1955.6	48.0505
YEM	99.7565	-128.45	42.2342	2.86287
ZAF	-9.6054	33.8518	-17.735	1.6281

Source: Estimated from DIVA model output.

Note: RMSE is the root mean squared error of the regression fit. A lower RMSE indicates a closer fit between predicted and observed damage values from the DIVA model.

Table B4. Damage Function Coefficients – RCP 6, Constant Flood Protection Standards (BAU Adaptation)

Country	Intercept	Linear GMTI	Quadratic GMTI	RMSE
ABW	-152.1073	188.34	-57.794	0.21167
AGO	-6.750761	-3.40453	7.41714	0.17382
AIA	-53.83476	62.8775	-17.849	0.27043
ALA	11.569601	-23.8073	10.9194	0.29685
ALB	-73.37469	100.647	-31.889	0.13137
ARE	-101.7188	143.103	-46.581	0.13516
ARG	37.498365	-49.8886	19.251	0.21868
ASM	-84.94418	100.039	-30.769	0.2731
ATF	-103.6163	4E-12	-1E-12	9.7E-14
ATG	-43.86491	51.0954	-14.492	0.18154
AUS	-61.35851	82.6016	-24.959	0.17014
BEL	-49.49055	70.6864	-21.456	0.12138
BEN	-151.4382	185.196	-55.444	0.19658
BGD	-64.04305	75.212	-18.678	0.62779
BGR	-91.50193	120.399	-38.659	0.22899
BHR	-139.5941	188.924	-61.121	0.1446
BHS	-83.49004	105.538	-32.955	0.29728
BLZ	-71.95313	81.599	-21.503	0.36018
BMU	-61.03353	72.9624	-21.97	0.16016
BRA	-66.28349	90.543	-27.671	0.1834
BRB	-55.25077	64.0138	-19.42	0.22529
BRN	-76.12214	100.325	-31.115	0.1947
BVT	-103.6163	4E-12	-1E-12	9.7E-14
CAN	-34.43444	45.8533	-12.473	0.2059
CCK	-3857.718	5156.83	-1764	15.0845
CHL	-79.10254	104.622	-32.83	0.13203
CHN	-104.9851	150.615	-49.184	0.31971
CIV	-249.0051	325.24	-104.33	0.24819
CMR	-289.8842	381.378	-123.99	0.67093
COD	-332.3677	427.16	-136.49	0.277
COG	-174.3961	222.328	-69.93	0.22271
COK	-103.6163	4E-12	-1E-12	9.7E-14
COL	-86.56201	114.419	-34.924	0.16091
COM	-177.2445	223.983	-69.356	0.14511
CPV	-81.85532	101.003	-30.024	0.18362
CRI	-93.73805	118.99	-36.369	0.20377
CUB	-89.12927	114.603	-35.816	0.27139

CUW	-44.18415	50.9082	-14.419	0.21349
CYM	-29.66538	26.6919	-4.8713	0.33382
CYP	-43.2968	47.2582	-12.109	0.32677
DEU	-20.20273	34.2768	-9.9333	0.06682
DJI	-188.9034	247.929	-79.262	0.14988
DMA	-4481.547	5677.09	-1800.8	38.8209
DNK	-18.13321	26.0977	-6.2158	0.10021
DOM	-89.52016	115.307	-35.788	0.158
DZA	-65.45074	81.8986	-23.751	0.21942
ECU	-84.97476	110.991	-33.25	0.18711
EGY	-150.8773	205.437	-65.242	0.23006
ERI	-117.935	138.33	-38.954	0.14558
ESH	-151.228	198.208	-63.636	0.13775
ESP	-18.65889	25.5334	-5.9692	0.16087
EST	-27.83207	34.925	-10.219	0.29443
FIN	-31.89313	42.6085	-11.861	0.3253
FJI	-76.18773	92.1729	-25.674	0.27082
FLK	-119.2466	149.535	-47.961	0.21724
FRA	-40.5296	58.5159	-17.353	0.1016
FRO	-36.89969	43.346	-11.547	0.21411
FSM	-81.69761	96.3623	-27.652	0.21187
GAB	-127.2181	164.102	-51.094	0.26677
GBR	-37.39572	55.893	-16.489	0.09549
GEO	-85.2735	111.833	-34.776	0.30143
GGY	-38.78041	51.7641	-14.858	0.13111
GHA	-184.7147	234.265	-72.776	0.24465
GIB	-45.74935	52.7871	-14.789	0.21832
GIN	-132.3844	169.308	-52.708	0.78035
GLP	-38.8666	43.9035	-11.939	0.18592
GMB	-170.6717	211.375	-65.24	0.30409
GNB	-841.053	1111.55	-367.26	2.41373
GNQ	-108.3337	140.078	-43.69	0.21182
GRC	-53.85329	70.6635	-21.055	0.2033
GRD	-66.12768	79.9862	-24.291	0.19647
GRL	-44.27479	59.6629	-18.314	0.17776
GTM	-130.214	163.388	-49.785	0.16598
GUF	124.14646	-170.78	58.8986	0.61052
GUM	-3058.404	3882.65	-1260.9	34.8341
GUY	-81.1564	100.859	-28.664	0.52271
HKG	-74.64523	105.674	-34.477	0.13152

HMD	-103.6163	4E-12	-1E-12	9.7E-14
HND	-124.678	151.685	-44.404	0.37842
HRV	-43.01531	58.2916	-17.966	0.15126
HTI	-180.6904	229.857	-71.555	0.29337
IDN	-147.336	201.794	-64.58	0.2783
IMN	-39.98122	47.5357	-13.059	0.21068
IND	-147.6985	201.482	-64.257	0.26441
IOT	-103.6163	4E-12	-1E-12	9.7E-14
IRL	-50.68757	67.4598	-19.848	0.19037
IRN	-79.92902	106.024	-32.733	0.23365
IRQ	-58.01835	73.3423	-19.699	0.26712
ISL	-73.71897	99.0179	-30.919	0.12451
ISR	-84.13654	105.306	-31.303	0.24627
ITA	-22.14589	32.7623	-8.721	0.16131
JAM	-26.98181	25.7618	-4.0689	0.36202
JEY	-35.29485	46.4439	-13.099	0.12528
JOR	-192.1697	243.686	-77.402	0.27029
JPN	-5.747302	14.3421	-3.2869	0.20715
KEN	-160.8042	205.522	-63.28	0.17363
KHM	-179.6336	232.11	-73.522	0.63883
KIR	-103.6163	4E-12	-1E-12	9.7E-14
KNA	-51.86386	53.6369	-14.618	0.29789
KOR	-67.11249	96.1595	-31.214	0.1821
KWT	-116.3119	159.957	-52.38	0.15578
LBN	-113.2479	147.334	-47.111	0.23237
LBR	-254.9025	324.74	-101.23	0.33087
LBY	-85.99852	113.251	-35.17	0.19614
LCA	-58.47222	60.3137	-15.32	0.3911
LKA	-118.2353	151.114	-46.783	0.4433
LTU	-134.2131	178.176	-57.724	0.66916
LVA	-52.11018	69.7374	-21.345	0.21891
MAC	-60.51075	83.2715	-27.022	0.22749
MAR	-147.9926	196.579	-62.721	0.19169
MDA	-102.7817	137.576	-44.167	0.22972
MDG	-181.8484	229.87	-70.405	0.26794
MDV	-114.3879	149.124	-47.04	0.13187
MEX	-69.22548	97.8371	-30.262	0.08809
MHL	-91.1744	108.459	-31.2	0.28816
MLT	-72.16109	90.4103	-28.423	0.18232
MMR	-67.90577	91.1891	-27.367	0.30173

MNE	-84.05275	107.983	-33.979	0.18778
MNP	-1427.386	1670.72	-514.39	32.2273
MOZ	-16.14701	-6.72586	12.6343	0.76194
MRT	-162.7836	208.933	-65.213	0.21252
MSR	-103.6163	4E-12	-1E-12	9.7E-14
MTQ	-61.96441	68.5627	-19.19	0.47198
MUS	-116.2694	147.291	-46.215	0.26286
MYS	-101.6479	136.644	-42.399	0.28393
MYT	-62.08328	74.8323	-23.499	0.09798
NAM	-132.158	171.587	-54.881	0.10182
NCL	-92.61597	118.921	-37.608	0.13244
NFK	-103.6163	4E-12	-1E-12	9.7E-14
NGA	-165.9813	217.349	-66.432	0.20496
NIC	-152.2492	192.768	-59.558	0.25719
NLD	-31.06585	50.8075	-15.178	0.05698
NOR	-20.34987	29.6465	-7.6092	0.11038
NRU	-83.97256	99.6786	-29.014	0.17604
NZL	-42.24229	48.2274	-11.713	0.34255
OMN	-83.63158	112.107	-34.811	0.14619
PAK	-125.8381	160.521	-48.401	0.28054
PAN	-110.3549	145.884	-46.265	0.17263
PCN	-103.6163	4E-12	-1E-12	9.7E-14
PER	-116.0708	152.777	-48.746	0.16812
PHL	-116.0242	153.948	-46.932	0.17281
PLW	-84.02762	102.707	-32.903	0.17247
PNG	-154.4316	197.18	-60.942	0.23562
POL	-53.99448	75.9027	-23.818	0.14875
PRI	-36.46642	46.505	-13.393	0.26254
PRK	-66.98649	89.3975	-28.338	0.31205
PRT	-54.58897	70.0691	-20.672	0.20374
PSE	-198.8809	252.635	-80.775	0.2341
PYF	-60.25711	65.8636	-18.312	0.24347
QAT	-56.79559	78.495	-24.697	0.19686
REU	-65.12716	78.7739	-23.986	0.13262
ROU	-62.21731	79.7465	-24.759	0.29951
RUS	-91.71419	126.559	-40.521	0.33419
SAU	-83.97248	114.738	-35.96	0.16854
SDN	-157.6493	198.74	-61.152	0.12184
SEN	-162.2007	204.926	-62.791	0.21108
SGP	-65.39957	91.2989	-30.215	0.14801

SGS	-103.6163	4E-12	-1E-12	9.7E-14
SJM	0.7543683	-3.1078	1.6824	0.67623
SLB	-157.9224	200.636	-62.104	0.23374
SLE	-192.8093	248.911	-78.81	0.54282
SLV	-93.88729	118	-35.966	0.23152
SOM	-201.5811	256.177	-78.201	0.13397
SPM	-81.6849	99.7373	-30.003	0.30027
STP	-191.7929	248.943	-80.151	0.1994
SUR	-161.0351	213.017	-68.147	0.2967
SVN	-50.27925	64.7647	-19.61	0.12045
SWE	-50.38182	68.4243	-20.581	0.21345
SYC	-110.1306	144.084	-45.444	0.12055
SYR	-166.5789	210.4	-65.993	0.31332
TCA	-63.04389	76.368	-22.799	0.28822
TGO	-152.2273	184.665	-55.258	0.25947
THA	-107.0145	142.685	-43.864	0.57668
TKL	3173.7637	-4607.48	1617.6	13.9426
TLS	-183.2323	230.917	-71.522	0.30994
TON	-72.15305	79.592	-21.445	0.30547
TTO	-64.89367	82.9544	-25.733	0.38002
TUN	-146.0344	199.563	-65.008	0.18433
TUR	-83.09004	109.025	-33.313	0.2984
TUV	-1407.555	1766.72	-595.63	15.102
TWN	-37.31057	52.1111	-15.646	0.2873
TZA	-165.3707	209.397	-63.894	0.22915
UKR	-107.9987	144.394	-45.816	0.27017
UMI	-103.6163	4E-12	-1E-12	9.7E-14
URY	-64.62095	82.7677	-25.117	0.17006
USA	-93.40161	132.563	-42.669	0.13604
VCT	-76.20058	90.2058	-27.489	0.23135
VEN	-85.4784	113.588	-35.063	0.16474
VGB	-66.47902	78.7493	-23.501	0.18951
VNM	-138.2731	186.648	-58.652	0.50162
VUT	-179.7523	226.064	-70.737	0.18346
WLF	3051.5998	-4048.03	1303.96	41.0084
WSM	-91.10948	109.437	-33.868	0.11836
YEM	-205.3823	269.929	-86.216	0.25557
ZAF	-93.00989	120.618	-37.553	0.1806

Source: Estimated from DIVA model output.

Note: RMSE is the root mean squared error of the regression fit. A lower RMSE indicates a closer fit between predicted and observed damage values from the DIVA model.

Limitations

The damage functions are estimated using model-generated data rather than observed historical events. As a result, they may not fully capture extreme tail risks or rare catastrophic outcomes, particularly those associated with low-probability, high-impact events.

In addition, the mapping between temperature trajectories and Representative Concentration Pathway (RCP) scenarios introduces approximation error, especially in cases where simulated temperature pathways diverge from standard RCP profiles. This may affect the precision of the linkage between emissions, temperature, and damages.

A further limitation arises from the functional form of the damage specification. While the quadratic formulation allows for nonlinear responses to warming, it remains a reduced-form approximation and may not fully capture complex dynamics such as threshold effects, regional heterogeneity in exposure, or interactions between climate hazards.

Appendix C. Country-Level Proportion-Affected Dataset for Biodiversity Cost Allocation

Biodiversity response to temperature

Biodiversity impacts are represented using the Potentially Disappeared Fraction (PDF) of species, defined as a function of global mean temperature increase (GMTI):

$$PDF_t = 0.0514 \times GMTI_t$$

This formulation implies that each additional degree of global warming increases the fraction of species at risk of disappearance by approximately 5.14 percentage points. The relationship is consistent with response functions reported in life cycle impact assessment frameworks such as LC-IMPACT, and is supported by meta-analyses of species extinction risks (Urban, 2015), providing a tractable global representation of biodiversity loss driven by temperature change.

Functional form and interpretation

The relationship between global mean temperature increase and biodiversity loss is represented using a linear specification. This choice reflects both empirical constraints and modelling considerations. At the global scale, the available evidence remains limited in supporting the consistent estimation of higher-order nonlinear relationships across species and ecosystems (Urban, 2015). The linear formulation therefore provides a transparent and tractable approximation that is suitable for integration within aggregate macroeconomic models.

While comprehensive life cycle impact assessment frameworks such as LC-IMPACT provide detailed characterisation of biodiversity impacts across multiple environmental pressures, their integration within large-scale macroeconomic models remains computationally challenging. The

present approach therefore adopts a reduced-form temperature–biodiversity relationship to ensure tractability and consistency within the modelling framework.

While this specification facilitates comparability across scenarios, it abstracts from potentially more complex ecological responses to climate change. In particular, biodiversity impacts may exhibit nonlinear dynamics at higher levels of warming, where ecological thresholds or tipping points could lead to accelerated species loss. These effects are not explicitly captured in the current framework, reflecting both limitations in the availability of robust global-scale estimates of such nonlinearities and the need to maintain a tractable representation within the macroeconomic modelling framework.

The response functions are specified as static relationships, so that the mapping between temperature change, biodiversity loss, and conservation costs remains constant over time. Changes in biodiversity impacts therefore arise solely through changes in global temperature, rather than through time-varying functional relationships.

Economic valuation of biodiversity impacts

Biodiversity impacts are monetised using a conservation cost approach, whereby the economic cost is interpreted as the expenditure required to prevent species loss:

$$Biodiversity\ Cost_{c,t} = 19.44 \times PDF_{c,t}$$

The parameter value is derived from global estimates of the financial resources required to conserve threatened species (McCarthy et al., 2012), scaled using the estimated PDF in 2015, resulting in a constant marginal cost of 19.44 billion USD per unit of PDF. These costs are interpreted as the investment required to offset biodiversity loss rather than direct economic damages, and therefore represent a lower-bound proxy for the economic costs associated with biodiversity loss. This approach does not attempt to quantify the broader economic value of ecosystem services or the contribution of biodiversity to production and welfare.

Country-level allocation

The global PDF is allocated across countries using a fixed distribution based on historical biodiversity exposure:

$$PDF_{c,t} = Share_c \times PDF_t$$

where $Share_c$ represents the proportion of global biodiversity impacts attributed to country c.

The allocation shares are derived from historical estimates of species impacts over the period 1970–2015 and are treated as constant over the projection horizon. This dataset reflects the relative contribution of each country to global biodiversity loss and serves as the allocation key for distributing projected conservation costs.

The shares sum to unity across all countries. Countries with zero values correspond either to negligible recorded biodiversity impacts over the reference period or to cases where data limitations prevent reliable estimation.

Table C1. Country-level biodiversity allocation shares

S.No.	Country	Proportion Affected (%)	S.No.	Country	Proportion Affected (%)
1	Afghanistan	0.423	98	Lesotho	0.068
2	Albania	0.005	99	Liberia	0.581
3	Algeria	0.242	100	Libya	0.122
4	American Samoa	0.000	101	Liechtenstein	0.000
5	Andorra	0.000	102	Lithuania	0.005
6	Angola	0.578	103	Luxembourg	0.000
7	Antigua and Barbuda	0.008	104	Macedonia	0.039
8	Argentina	2.263	105	Madagascar	0.299
9	Armenia	0.054	106	Malawi	0.094
10	Aruba	0.000	107	Malaysia	1.949
11	Australia	3.563	108	Mali	0.502
12	Austria	0.055	109	Malta	0.000
13	Azerbaijan	0.121	110	Martinique	0.007
14	Bahamas	0.021	111	Mauritania	0.027
15	Bahrain	0.000	112	Mauritius	0.009
16	Bangladesh	0.025	113	Mayotte	0.003
17	Barbados	0.001	114	Mexico	2.944
18	Belarus	0.016	115	Moldova	0.003
19	Belgium	0.004	116	Monaco	0.000
20	Belize	0.003	117	Mongolia	0.276
21	Benin	0.116	118	Montenegro	0.014
22	Bhutan	0.068	119	Morocco	0.017
23	Bolivia	0.711	120	Mozambique	0.391
24	Bosnia and Herzegovina	0.049	121	Myanmar	1.129
25	Botswana	0.277	122	Namibia	0.292
26	Brazil	13.159	123	Nepal	0.708
27	Brunei	0.039	124	Netherlands	0
28	Bulgaria	0.034	125	New Caledonia	0.016

29	Burkina Faso	0.452	126	New Zealand	0.011
30	Burundi	0.083	127	Nicaragua	0.217
31	Cambodia	0.348	128	Niger	0.132
32	Cameroon	1.199	129	Nigeria	0.849
33	Canada	0.816	130	North Korea	0.015
34	Cape Verde	0.000	131	Norway	0.013
35	Central African Republic	0.692	132	Oman	0.057
36	Chad	0.078	133	Pakistan	0.747
37	Chile	1.36	134	Panama	0.265
38	China	10.582	135	Papua New Guinea	2.416
39	Colombia	1.567	136	Paraguay	0.524
40	Comoros	0.019	137	Peru	1.668
41	Congo	0.321	138	Philippines	3.486
42	Costa Rica	0.245	139	Poland	0.016
43	Croatia	0.018	140	Portugal	0.1
44	Cuba	0.094	141	Puerto Rico	0.073
45	Cyprus	0.036	142	Qatar	0.001
46	Czech Republic	0.007	143	Reunion	0.006
47	Denmark	0.000	144	Romania	0.025
48	Djibouti	0.001	145	Russia	1.15
49	Dominica	0.003	146	Rwanda	0.172
50	Dominican Republic	0.116	147	Saudi Arabia	0.098
51	Ecuador	0.724	148	Senegal	0.12
52	Egypt	0.153	149	Seychelles	0.02
53	El Salvador	0.114	150	Sierra Leone	0.419
54	Equatorial Guinea	0.024	151	Singapore	0.002
55	Eritrea	0.036	152	Slovakia	0.019
56	Estonia	0.01	153	Slovenia	0.007
57	Ethiopia	1.106	154	Solomon Islands	0.591
58	Federated States of Micronesia	0.000	155	Somalia	0.687

59	Fiji	0.035	156	South Africa	1.231
60	Finland	0.038	157	South Korea	0.132
61	France	0.133	158	Spain	0.449
62	French Guiana	0.058	159	Sri Lanka	0.874
63	Gabon	0.071	160	St. Kitts and Nevis	0.001
64	Gambia	0.019	161	St. Lucia	0.002
65	Gaza Strip	0.002	162	St. Vincent and the Grenadines	0.001
66	Georgia	0.089	163	Sudan	0.345
67	Germany	0.038	164	Suriname	0.027
68	Ghana	0.5	165	Swaziland	0.042
69	Gibraltar	0.000	166	Sweden	0.038
70	Greece	0.223	167	Switzerland	0.04
71	Grenada	0.001	168	Syria	0
72	Guadeloupe	0.003	169	Taiwan	0.364
73	Guatemala	0.271	170	Tajikistan	0.052
74	Guinea	0.101	171	Tanzania	1.435
75	Guinea-Bissau	0.035	172	Thailand	1.07
76	Guyana	0.076	173	Togo	0.068
77	Haiti	0.034	174	Tonga	0.000
78	Honduras	0.224	175	Trinidad and Tobago	0.015
79	Hungary	0.008	176	Tunisia	0.066
80	Iceland	0.000	177	Turkey	0.636
81	India	1.942	178	Turkmenistan	0.369
82	Indonesia	8.105	179	Uganda	0.559
83	Iran	0.762	180	Ukraine	0.318
84	Iraq	0.063	181	United Arab Emirates	0.002
85	Ireland	0.001	182	United Kingdom	0.002
86	Israel	0.044	183	United States	5.006
87	Italy	0.387	184	Uruguay	0.326
88	Ivory Coast	0.676	185	Uzbekistan	0.367
89	Jamaica	0.025	186	Vanuatu	0.022
90	Japan	0.64	187	Venezuela	0.389

91	Jordan	0.016	188	Vietnam	0.979
92	Kazakhstan	0.849	189	Western Sahara	0.036
93	Kenya	0.912	190	Western Samoa	0.001
94	Kyrgyzstan	0.218	191	Yemen	0.099
95	Laos	0.58	192	Zaire	1.704
96	Latvia	0.015	193	Zambia	0.55
97	Lebanon	0.000	194	Zimbabwe	0.495

Source: Hilbers et al. (2024), DECIPHER Deliverable D3.1.
Note: Proportions reflect species affected between 1970 and 2015 and are used as a fixed allocation key throughout the projection period.

Sectoral allocation of Biodiversity Conservation Costs

Country-level biodiversity conservation costs are allocated across economic sectors using data from the ENCORE (Exploring Natural Capital Opportunities, Risks, and Exposure) framework. ENCORE links economic activities, classified according to the International Standard Industrial Classification (ISIC), to the ecosystem services on which they depend and the pressures they exert on biodiversity. It provides sector-specific materiality ratings, ranging from Very Low to Very High, for both dependency and impact dimensions.

To construct sectoral allocation weights, the maximum of the dependency and impact scores is used for each sector:

$$Score_s = \max\left(Dependency_s, Impact_s\right)$$

This pairwise maximum approach ensures that the most relevant dimension of biodiversity exposure is captured, whether through sectoral dependence on ecosystem services or contribution to biodiversity degradation.

The scores are then normalised across sectors to obtain allocation weights:

$$w_s^{bio} = \frac{Score_s}{\sum_s Score_s}$$

Country-level biodiversity conservation costs are distributed across sectors according to these weights:

$$Cost_{s,c,t} = w_s^{bio} \times Cost_{c,t}$$

This approach implies that sectors with either high ecological dependence or significant environmental impact bear a proportionally larger share of conservation costs.

Public and private financing

Total biodiversity conservation costs are divided between the public and private sectors, with 80 percent assigned to the public sector and 20 percent to the private sector. This allocation is based on estimates of historical biodiversity financing patterns reported by BloombergNEF (2021). The public component is treated as compulsory expenditure, while the private component is introduced as an additional cost borne by firms.

Model implementation

The treatment of biodiversity conservation costs differs across the two macroeconomic models, reflecting their underlying structural assumptions.

In **GEM-E3**, conservation costs are introduced as additional exogenous expenditures allocated across sectors. The public component is financed through government expenditure, while the private component enters as an additional cost of production. These expenditures do not increase the productive capital stock and may therefore generate crowding-out effects.

In **E3ME**, biodiversity conservation expenditure is introduced as a shock to sectoral investment. These expenditures are treated as productive investments and can generate multiplier effects through increased demand and capacity utilisation.

Conceptual distinction from flood damages

Biodiversity conservation costs differ fundamentally from flood damages in their economic interpretation. Flood damages represent realised losses to physical capital resulting from climate impacts, whereas biodiversity costs correspond to preventive expenditures aimed at avoiding future losses. As a result, the two channels affect the economy through different mechanisms and time horizons, with biodiversity costs operating primarily through investment and cost channels rather than capital destruction.

Limitations

The biodiversity framework captures only impacts driven by temperature change and excludes those arising from land-use change and other anthropogenic pressures, which may represent a substantial share of total biodiversity loss. As a result, the estimates presented here should be interpreted as partial measures of biodiversity-related impacts.

In addition, the functional form used to represent biodiversity loss assumes a linear relationship between global temperature increase and the potentially disappeared fraction of species. While this provides a tractable approximation, it does not capture potential nonlinear ecological responses, such as threshold effects or tipping points, which may lead to accelerated species loss at higher levels of warming.

The use of a fixed country-level allocation further implies that the spatial distribution of biodiversity impacts remains constant over time. This abstracts from potential shifts in ecological vulnerability and species distribution under changing climate conditions.

Finally, the conservation cost approach reflects the expenditure required to prevent species loss rather than the full economic value of biodiversity. It does not account for the broader contribution of ecosystem services to production, welfare, and resilience, and therefore provides a conservative estimate of total biodiversity-related economic costs.

Appendix D. Financial Risk Integration

Modelling approach

Climate-related financial risk is incorporated through a two-stage modelling procedure involving the CLIMACRED framework. In the first stage, the macroeconomic models (GEM-E3 and E3ME) are run under two scenarios: Scenario 4 (Current Policies with optimal adaptation and biodiversity), which serves as the reference baseline, and Scenario 8 (NDC/LTS with optimal adaptation and biodiversity), which serves as the counterfactual. The resulting outputs, including sectoral production, capital costs, and interest rates, are then used as inputs to the CLIMACRED model.

CLIMACRED produces adjustments to the cost of capital and sector-specific interest rate spreads, reflecting both transition and physical climate risks. These adjustments are subsequently introduced into the macroeconomic models in a second round of simulations, generating Scenario 9, which represents the integrated financial-risk case. This approach is consistent with the methodology used to link CLIMACRED with macroeconomic models in the NGFS short-term climate scenarios.

Transmission mechanisms

The transmission of financial risk differs across the two macroeconomic models, reflecting their structural characteristics.

In **GEM-E3**, increases in the cost of capital affect the economy through two channels. First, higher investment premia reduce investment demand. Second, higher capital costs increase the unit cost of production, affecting sectoral competitiveness and household consumption. The combined effect is generally negative for output.

In **E3ME**, financial risk operates through a broader set of demand-driven mechanisms. In particular, changes in risk premia for low-carbon technologies affect the cost of capital in the energy sector, contributing to lower electricity prices. These effects can generate positive spillovers to households and firms, partially offsetting negative impacts in other sectors.

Interpretation

The inclusion of financial risk introduces second-round macroeconomic effects that amplify the impact of climate-related shocks. The direction and magnitude of these effects depend on the interaction between financial conditions, investment behaviour, and sectoral structure.

Differences in model outcomes therefore reflect not only the magnitude of financial risk adjustments, but also the underlying representation of economic dynamics.

Scope and limitations

Financial risk is assessed only under the NDC/LTS scenario. This reflects the structure of the CLIMACRED modelling framework, in which the Current Policies scenario serves as a baseline and the NDC/LTS scenario as a counterfactual for estimating relative changes in capital costs and interest rate spreads. As a result, financial risk adjustments are defined with respect to a transition-consistent pathway and are not independently evaluated under the Current Policies scenario.

This design implies that the analysis does not capture the potential amplification of financial stress under lower-mitigation pathways, where higher physical damages and weaker adaptation could further affect financing conditions.

More broadly, the two-stage integration of financial risk abstracts from dynamic feedbacks between financial markets and macroeconomic conditions. The estimated effects should therefore be interpreted as conditional on the imposed adjustments to the cost of capital and interest rate spreads, rather than as a fully endogenous representation of financial system dynamics.

Appendix E. Scenario Design and Identification Strategy

Scenario framework

The analysis is based on a structured set of nine scenarios combining alternative assumptions on mitigation, flood damages, adaptation, biodiversity conservation, and climate-related financial risk. The scenario design follows a sequential structure, allowing the incremental introduction of adaptation and biodiversity components, while financial risk is incorporated separately through an additional modelling step.

Two baseline mitigation pathways are considered:

- Current Policies (CP) scenario, aligned with an RCP 6 temperature pathway, and
- Nationally Determined Contributions and Long-Term Strategies (NDC/LTS) scenario, aligned with an RCP 2.6 pathway.

The Current Policies scenario assumes that European Union climate and energy policies are fixed at their 2025 levels, while the rest of the world follows existing legislated policies (Frozen). The NDC/LTS scenario represents a transition-consistent pathway in which the European Union

achieves Net Zero emissions by 2050 and other regions implement their stated NDCs and long-term strategies (Net Zero).

All other scenarios are defined relative to these baselines by progressively incorporating climate damages, adaptation measures, biodiversity conservation, and financial risk.

Scenario specification

Table E1. Full Scenario Specifications

S.No.	Name	Flood Damages	Adaptation	Biodiversity	Financial Risk
1	CP	None	None	No	No
2	CP – Low Adaptation	Yes (RCP6)	Low	No	No
3	CP – Optimal Adaptation	Yes (RCP6)	Optimal	No	No
4	CP – Optimal Adaptation + Biodiversity	Yes (RCP6)	Optimal	Yes	No
5	NDC/LTS	None	None	No	No
6	NDC/LTS – Low Adaptation	Yes (RCP2.6)	Low	No	No
7	NDC/LTS – Optimal Adaptation	Yes (RCP2.6)	Optimal	No	No
8	NDC/LTS – Optimal Adaptation + Biodiversity	Yes (RCP2.6)	Optimal	Yes	No
9	NDC/LTS – Financial Risk	Yes (RCP2.6)	Optimal	Yes	Yes

Scenario narratives

The scenarios are constructed to reflect distinct combinations of policy ambition and resilience measures:

1. **Current Policies (CP)**: Baseline scenario with no climate damages, adaptation, biodiversity costs, or financial risk. Serves as the reference case under limited policy ambition.
2. **CP – Low Adaptation**: Introduces flood damages under RCP 6 with low adaptation, reflecting constant protection standards and relatively high residual damages.
3. **CP – Optimal Adaptation**: Incorporates flood damages with cost–benefit optimised adaptation, resulting in lower damages but higher upfront investment.
4. **CP – Optimal Adaptation + Biodiversity**: Extends optimal adaptation to include biodiversity conservation costs.
5. **NDC/LTS**: Baseline Net Zero pathway with no damages, adaptation, biodiversity, or financial risk. Serves as the reference case under high climate ambition.
6. **NDC/LTS – Low Adaptation**: Combines ambitious mitigation with flood damages under low adaptation, resulting in higher residual risks despite reduced emissions.

7. **NDC/LTS – Optimal Adaptation**: Represents a coordinated strategy combining mitigation and optimal adaptation to minimise flood damages.
8. **NDC/LTS – Optimal Adaptation + Biodiversity**: Extends the previous scenario to include biodiversity conservation measures.
9. **NDC/LTS – Financial Risk**: Builds on Scenario 8 by incorporating financial risk through the CLIMACRED framework. This follows a two-stage procedure in which Scenario 4 (Current Policies with optimal adaptation and biodiversity) serves as the reference baseline and Scenario 8 as the counterfactual. Outputs from these scenarios are used to estimate adjustments to the cost of capital and interest rate spreads, which are then fed back into the macroeconomic models to generate Scenario 9.

Identification strategy

The scenario structure is designed to isolate the marginal contribution of each component through pairwise comparisons. Specifically:

- The effect of adaptation is identified by comparing low and optimal adaptation scenarios relative to the same mitigation baseline.
- The effect of biodiversity conservation is identified by comparing scenarios with and without conservation costs, holding adaptation constant.
- The effect of financial risk is identified by comparing Scenario 9 with Scenario 8, isolating the impact of CLIMACRED-based adjustments to the cost of capital and interest rate spreads.

This incremental approach allows the economic impact of each channel to be evaluated independently, while maintaining internal consistency across scenarios.

Scenario comparison design

To quantify the marginal effects of individual policy components, the analysis relies on a set of pairwise scenario comparisons. Each comparison isolates the contribution of a specific dimension, including mitigation, adaptation, biodiversity conservation, and financial risk, by evaluating differences relative to an appropriate reference scenario.

Table E2. Summarises the scenario pairings used in the analysis.

S.No.	Scenario	Reference Scenario	Purpose
1	CP – Low Adaptation (2)	CP (1)	Isolates the impact of flood damages under low adaptation
2	CP – Optimal Adaptation (3)	CP (1)	Isolates the impact of optimal adaptation relative to no adaptation
3	CP – Optimal Adaptation + Biodiversity (4)	CP – Optimal Adaptation (3)	Isolates the marginal impact of biodiversity conservation costs

4	NDC/LTS (5)	CP (1)	Isolates the effect of increased mitigation ambition
5	NDC/LTS – Low Adaptation (6)	NDC/LTS (5)	Isolates the impact of flood damages under low adaptation (high mitigation context)
6	NDC/LTS – Optimal Adaptation (7)	NDC/LTS (5)	Isolates the impact of optimal adaptation under high mitigation
7	NDC/LTS – Optimal Adaptation + Biodiversity (8)	NDC/LTS – Optimal Adaptation (7)	Isolates the marginal impact of biodiversity conservation under high mitigation
8	NDC/LTS – Financial Risk (9)	NDC/LTS – Optimal Adaptation + Biodiversity (8)	Isolates the impact of financial risk via CLIMACRED adjustments

Interpretation of scenario comparisons

The scenario comparisons are structured as follows:

- Comparison 1 and 5 isolate the effects of flood damages under low adaptation relative to their respective mitigation baselines (Current Policies and NDC/LTS).
- Comparison 2 and 6 isolate the effects of optimal adaptation relative to the same baselines, capturing the net benefits of increased protection and reduced damages.
- Comparison 3 and 7 isolate the marginal impact of biodiversity conservation costs by comparing scenarios with and without biodiversity, holding mitigation and adaptation constant.
- Comparison **8** isolates the impact of financial risk by comparing Scenario 9 with Scenario 8, capturing the effects of CLIMACRED-based adjustments to the cost of capital and interest rate spreads under the NDC/LTS pathway.

In addition, the comparison between the NDC/LTS baseline (Scenario 5) and the Current Policies baseline (Scenario 1) captures the effect of increased mitigation ambition. This comparison is not emphasised in the main analysis, as the macroeconomic impacts of mitigation pathways have been extensively examined in the literature.

The analysis is conducted over the period to 2050. Within this time horizon, differences in temperature outcomes between mitigation pathways remain limited, as RCP 2.6 and RCP 6 trajectories diverge more substantially after mid-century. As a result, the full benefits of mitigation are only partially captured, and the relative importance of near-term adaptation costs is amplified. These factors should be considered when interpreting the results.