Policy Brief:

The Macroeconomic and Fiscal Effects of Climate Change and Adaptation in Europe and Globally



ACCREU
Assessing Climate Change Risk in EUrope

Funded by the European Union

Key messages

ACCREU is a Horizon Europe research project that is assessing the economic costs of climate change, using an integrated framework that considers impacts, mitigation and adaptation.

The project has developed new analysis of the impacts of climate change in **Europe** using a set of sector models. These results have then been integrated into macroeconomic models, to assess the overall economy-wide costs of climate change.

The results find that climate change will lead to high economic costs across Europe, even for central scenarios and even by mid-century. These economic costs rise significantly for higher warming scenarios later in the century.

The analysis finds that these economic costs are distributed unequally, with higher costs projected for Southern and Central-Eastern Europe. They are also projected to widen inequality in Europe, affecting per capita GDP more in poorer regions.

A comparison of different warming scenarios finds that ambitious global mitigation policy has a major benefit in reducing European economic costs, however, the benefits mostly arise after mid-century.

The analysis also looks at the macroeconomic costs and benefits of adaptation in Europe. Adaptation is found to significantly reduce the economic costs of climate change, with benefits for GDP and welfare. Indeed, all European countries experience net gains - in terms of GDP - from high levels of adaptation (relative to baseline). However, while adaptation is effective, residual risks remain, and it does not negate the need for ambitious mitigation.

ACCREU has also assessed the fiscal effects of these climate change impacts on government budgets in Europe, and the potential benefits of adaptation. The results find that adaptation leads to net positive outcomes for the public finances, even though it involves additional public spending: this is due to the benefits of adaptation in reducing government expenditure and maintaining revenues.

More in-depth analysis also finds that the way public adaptation is paid for alters the results, with different levels of fiscal costs and benefits when comparing a balanced budget to borrowing.

The ACCREU project has also developed new analysis of the impacts of climate change at the global scale, using global integrated assessment models (IAMs). The project has developed new functions for IAMs, with disaggregated sector functions for key impacts. It has also produced a set of adaptation functions which assess the costs and benefits of adaptation at different levels.

These new functions allow the combined analysis of global mitigation and adaptation policy. The new functions have been applied in three IAMs. The analysis has first assessed the temperature levels that arise from a no-policy scenario. This finds that without action global temperatures will rise to around 3°C (in all three models).

The project has then assessed the effects of different combinations of mitigation and adaptation – and their costs and benefits - in reducing these levels, using optimisation analysis. With mitigation only, the models identify optimal levels of between 1.9°C and 2.2°C. When both mitigation and adaptation are included, the optimal level rises slightly and is around 0.2-0.25°C higher than with mitigation alone.

The analysis has also looked at economic damage costs (as a % of GDP) from the IAMs. In the baseline with no policies, these future damages are large, with the highest relative impacts in Africa and Asia. These damages are reduced significantly by mitigation, and by adaptation, if implemented individually. However, the lowest levels arise when mitigation and adaptation are combined.

Finally, the ACCREU study has undertaken additional analysis to examine the effects of lower effectiveness, or limits to adaptation, on these results. This finds that these factors have large impacts on the overall costs and effectiveness, highlighting these as a priority for future research.

Introduction

ACCREU (Assessing Climate Change Risk in EUrope) is a project funded by the Horizon Europe Research and Innovation Funding Programme. The objective of the project is to develop a fully integrated framework for climate change impacts, mitigation, adaptation and the prospects for social and economic sustainable development, working directly with stakeholders using a co-creation approach.

This technical policy brief summarizes the macro-economic and fiscal effects of climate change and adaptation in Europe, and the global integrated assessment analysis. Further details are available in the deliverables on the ACCREU website.

Method - Europe

Climate change will lead to wide-ranging impacts across different sectors and regions in Europe. These impacts will, in turn, lead to economic costs (sometimes called the 'costs of inaction').

The ACCREU project has undertaken detailed analysis of these potential economic costs of climate change in Europe for key risks. This includes the effects on energy demand and supply, labour productivity, agriculture, and the risks of sea-level rise and riverine floods, using sector impact models (see policy brief 2).

These models have been run for consistent future climate warming scenarios using the Representative Concentration Pathways (RCPs). These include a mitigation scenario that is broadly consistent with a 2°C pathway (RCP2.6), a scenario consistent with current policies (RCP4.5), and a high warming scenario (RCP7.0). The models have also been run with adaptation included for each of these RCP scenarios, considering different levels of adaptation ambition (low, medium and high) for each RCP.

The analysis has also considered future socio-economic development using data from the Shared Socio-economic Pathways (SSPs). These reflect future population, economic development, and technology.

In ACCREU, results were modelled for one socio-economic scenario only, SSP2, the middle-of-the-road scenario. A single scenario was used because of the large number of RCPs and adaptation scenarios, and because it allows the direct comparison of results between mitigation and adaptation policies.

These results have then been fed into two global, multi-sectoral computable General equilibrium models (CGEs): the ICES model and the COIN-INT model (see details over the page).

These macroeconomic models can assess the higher-order economic costs of climate change and how these affect the economic performance of countries, represented by analysis of sector performance and GDP. This captures interactions across impacts and sectors through various economic transmission channels, including trade flows of domestic and international production factors, goods and services. This allows analysis of how climate change affects economic output, in terms of capital, labour and productivity, and the impact on economic growth.

A particular innovation of the ACCREU project has been to extend these macroeconomic models to include the effects of adaptation, drawing on high-resolution results from sectoral models. These provide improved representation compared to previous assessments, and ACCREU has used these results to look at different levels of adaptation ambition at the macroeconomic scale.

Climate change can also affect the public finances of countries, with fiscal impacts from increasing government expenditure and thus public spending for recovery from extremes, as well as impacts on revenues from reductions of the tax base. These fiscal effects can be assessed and quantified separately by CGE models.

The project has also investigated alternative fiscal strategies for paying for public adaptation, including shifting government consumption to maintain a balanced budget or by borrowing for investment.

Additional details on the European models and transmission pathways

Macroeconomic climate impacts and adaptation

ICES and COIN-INT are global, multi-regional, multi-sectoral recursive-dynamic CGE models. They both include higher resolution for Europe, working at national to sub-national level, to allow improved analysis of effects across the EU.

These models analyse the macroeconomic analysis of climate change by assessing how impacts flow through transmission channels, affecting sectoral capital and labour productivity, and thus how they affect the key components of GDP.

As an example, coastal and river floods lead to tangible damages on infrastructure, destroying capital stocks that are used in production and thus slowing down capital stock accumulation via a reduction in economic performance. This has a negative effect on the productive capital available for production. Adaptation can avoid these flood damages, but at the expense of increased government spending or debt (on flood protection). This in turn may lead to reallocation effects and affect demand.

In contrast, increased heat has a different pathway, reducing labour supply (employment) and labour productivity, and thus affecting output, especially in labour intensive sectors. Where heat leads to health impacts, this will increase healthcare costs, which, to a large extent, are borne by the public sector.

The models multi-sector, multi-country structure allows these effects to spill over through trade linkages, affecting net exports and the trade balance in ways that vary across countries depending on their degree of openness and sectoral composition.

Adaptation Scenarios

While there is an agreed set of warming and socio-economic scenarios (RCPs and SSPs), there are no equivalent scenarios for adaptation.

Adaptation delivers economic benefits because it reduces the costs of climate change, but it involves additional costs. However, adaptation rarely reduces climate impacts completely, and there are residual impacts after adaptation. This leads to a trade-off between the costs and benefits of adaptation and these residual impacts.

Scenarios that include more ambitious adaptation have greater benefits and lower residual impacts, but higher costs.

The ACCREU project has developed three levels of adaptation to explore these trade-offs, with a central reference level (medium), as well as low and high levels of adaptation.

Fiscal climate impacts and adaptation

Planned adaptation is usually viewed from the perspective of public policy and often requires public investment. This raises questions about the net fiscal impacts of adaptation on the public finances including on budgets and spending.

On the impact side, climate change will have implications for public spending. Additional climate-related extreme events often require public support to households and firms, as well as the reconstruction of damaged public assets, spending on public emergency measures and increased healthcare costs.

Further, by impacting economic activity, and thus the tax base, climate change can decrease tax revenues. These two elements put pressure on government budgets.

Investing in adaptation can reduce these impacts, however, adaptation often involves upfront capital investments by government, and it often delivers benefits that are in the future. This means there may be trade-offs between short-term costs (including higher government spending) and the long-run benefits.

This leads to the question of whether the benefits of adaptation - in reducing climate change related spending and tax revenue impacts - outweigh the additional public spending costs, and whether it leads to a net positive fiscal outcome.

There is also a further issue of how governments should pay for this public adaptation. Faced with short-term spending pressures, governments can cut public spending in other areas (and run a balanced budget), raise taxes to pay for additional investment, or increase borrowing (increasing government debt). These different financing approaches will have different implications for the public finances.

Macroeconomic results for Europe

The results of the analysis are presented below. The results are expressed relative to a socio-economic baseline without climate change over the next fifty years. The results are first presented for the budget-neutral scenario, where governments and private households finance the additional adaptation expenditures budgets by shifting other expenditures. Note that mitigation costs are not included, but an analysis of mitigation costs and benefits is included later in this policy brief (in the global analysis).

The results for the EU from the COIN-INT model are shown in Figure 1. This shows different warming scenarios, as well as low, medium and high levels of adaptation, for the SSP2 scenario. The first key message is that climate change is projected to lead to large negative GDP impacts in Europe, with losses of up to 3 per cent of annual GDP by 2050 rising to almost 7 per cent by 2070, under the high warming RCP7.0 scenario (Figure 1, bottom).

The positive effects of global **mitigation** can be seen by comparing the low adaptation level in each of the three RCP scenarios (shown in orange at the bottom of each panel). This shows that economic costs under the RCP2.6 scenario (top), which is broadly consistent with the 2°C goal, are 2.5 per cent of annual GDP in 2050 and just over 3.5 per cent by 2070. This indicates mitigation could halve the long-term economic costs of climate change in Europe. However, this still leaves high residual damages especially over the next few decades.

The positive effects of European **adaptation** can be seen by looking at the three levels of ambition in each panel. These scenarios take account of the costs of adaptation, as well as its benefits, and thus provide insights into the net effects it has at the macroeconomic level.

The results show that adaptation is effective in reducing much of the macroeconomic disruptions caused by climate impacts. Under the RCP7.0 scenario, a high adaptation level could reduce impacts by around a third in 2050 (to 2 per cent of annual GDP) and by almost half by 2070 (to just over 4 per cent). Similar relative reductions are also seen with adaptation scenarios for RCP2.6 and RCP4.5.

The results also indicate that a combination of both mitigation and adaptation is needed to achieve low levels of residual impact (see RCP2.6 panel, top). The analysis also finds there are strong distributional patterns to these impacts across Europe. The results from the COIN-INT model are shown in Figure 2. This presents the results by European region, using the regional aggregation from EUCRA.

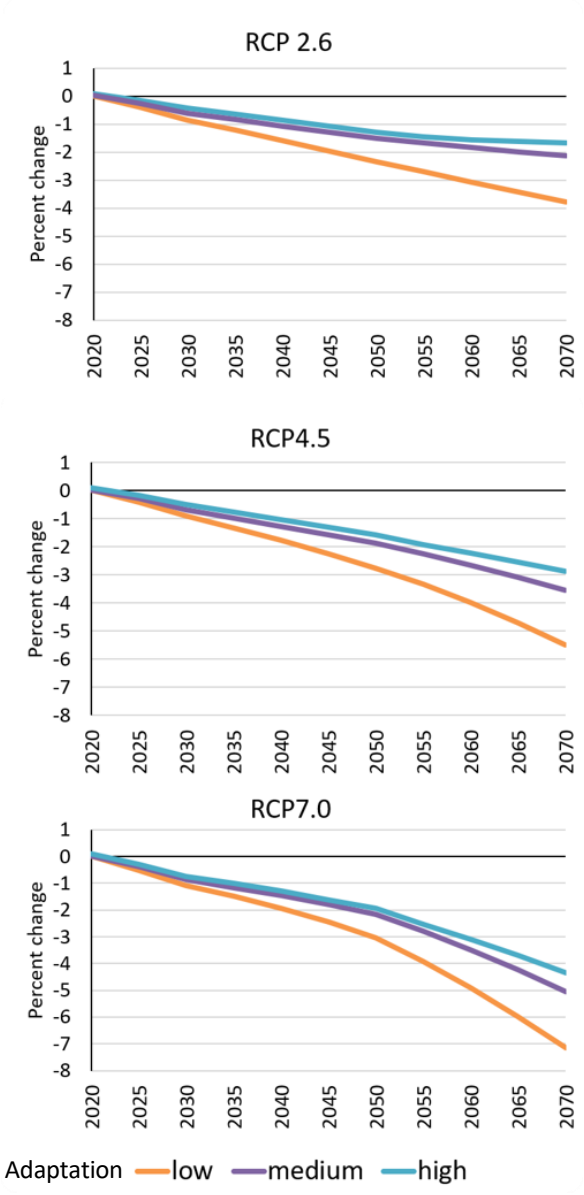


Figure 1. GDP climate change impact (%) for the EU and UK, Switzerland and Norway, for RCP scenarios and for low, medium and high adaptation. Values are relative to the SSP2 baseline without climate change.

Note: the results do not include adaptation for outdoor labour impacts.

Figure 2 shows that Central-Eastern Europe and Southern Europe experience disproportionately higher macroeconomic costs under all warming scenarios. For example, in a medium-warming scenario (RCP4.5) GDP losses for Central-Eastern Europe could reach over 5 per cent by 2050 and 9 per cent by 2070. Impacts are lower but still strongly negative for Western and Northern Europe.

These losses are significantly smaller with higher levels of adaptation ambition. Indeed, all countries experience net GDP gains with high adaptation (relative to the no adaptation baseline). There are broadly similar levels of relative reduction with adaptation across all regions, but residual damages in absolute terms for more significant for Central-Eastern and Southern Europe.

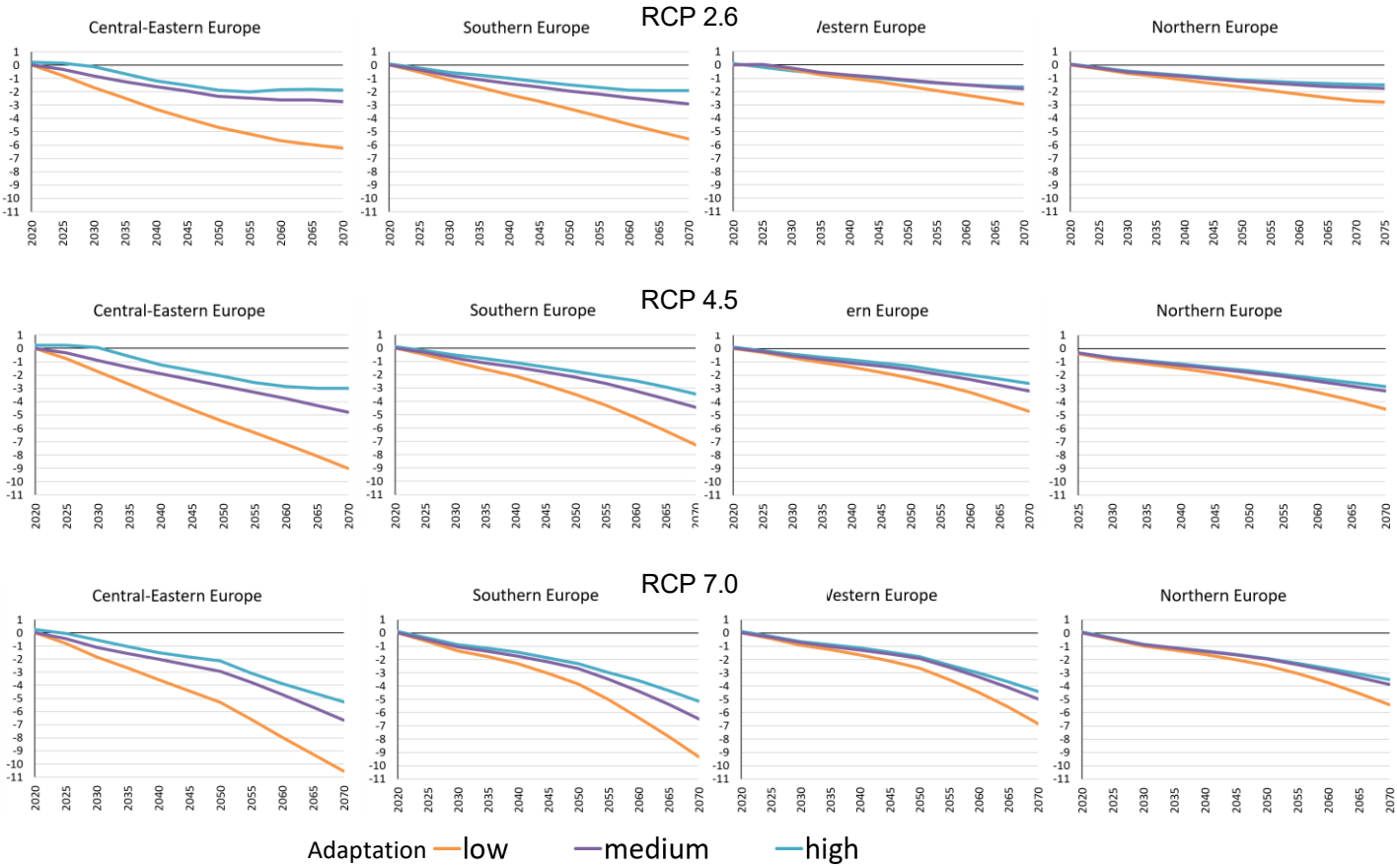
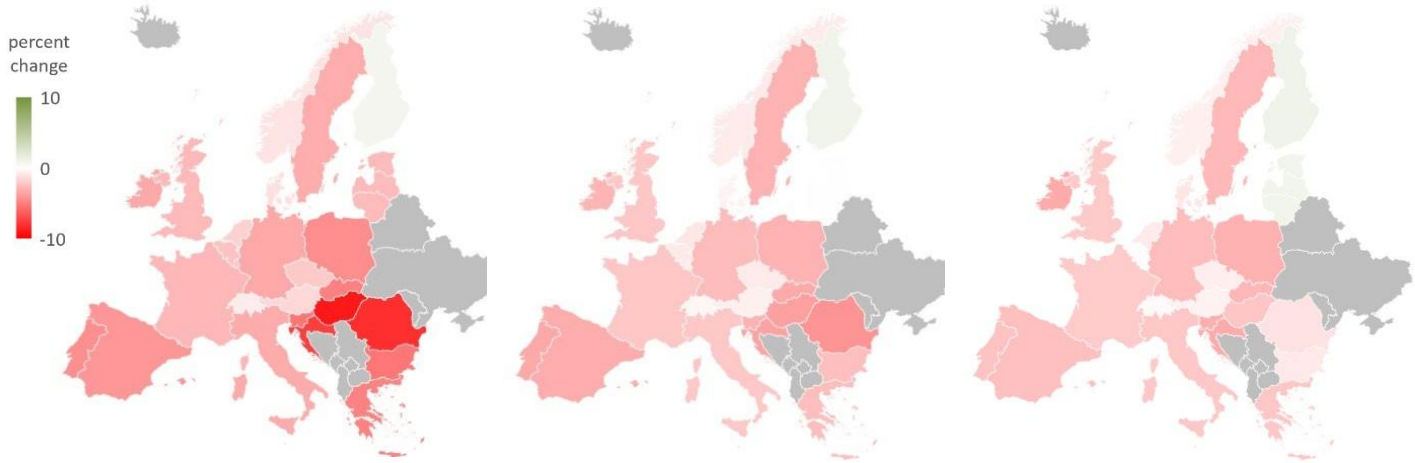


Figure 2. GDP climate change impact (%) for European macro-regions, for RCPs and low, medium and high adaptation (relative to the SSP2 baseline without climate change). Below: distribution for RCP4.5 by country.



2050 RCP4.5 Low adaptation

2050 RCP4.5 Medium adaptation

2050 RCP4.5 High adaptation

Figure 3 presents the contribution of different impact channels to the macroeconomic impacts. Due to the optimizing nature of CGE models, the sum of separate model runs for each impact differs from the joint run, but the figure helps to contextualise the magnitude of different impact drivers.

The analysis finds that heat-related labour impacts dominate the overall results, followed by coastal and river floods. The figure also shows different levels of residual impacts, after adaptation.

The results show the effectiveness of adaptation varies with sector, with different residual impacts even with high adaptation (on the right). The highest residual impacts are for labour impacts, though it was only possible to model the effects of cooling (air conditioning) on indoor labour (adaptation to outdoor heat and labour were not modelled).

The analysis found that much higher effectiveness and lower levels of residual damage were projected with coastal adaptation and agricultural adaptation.

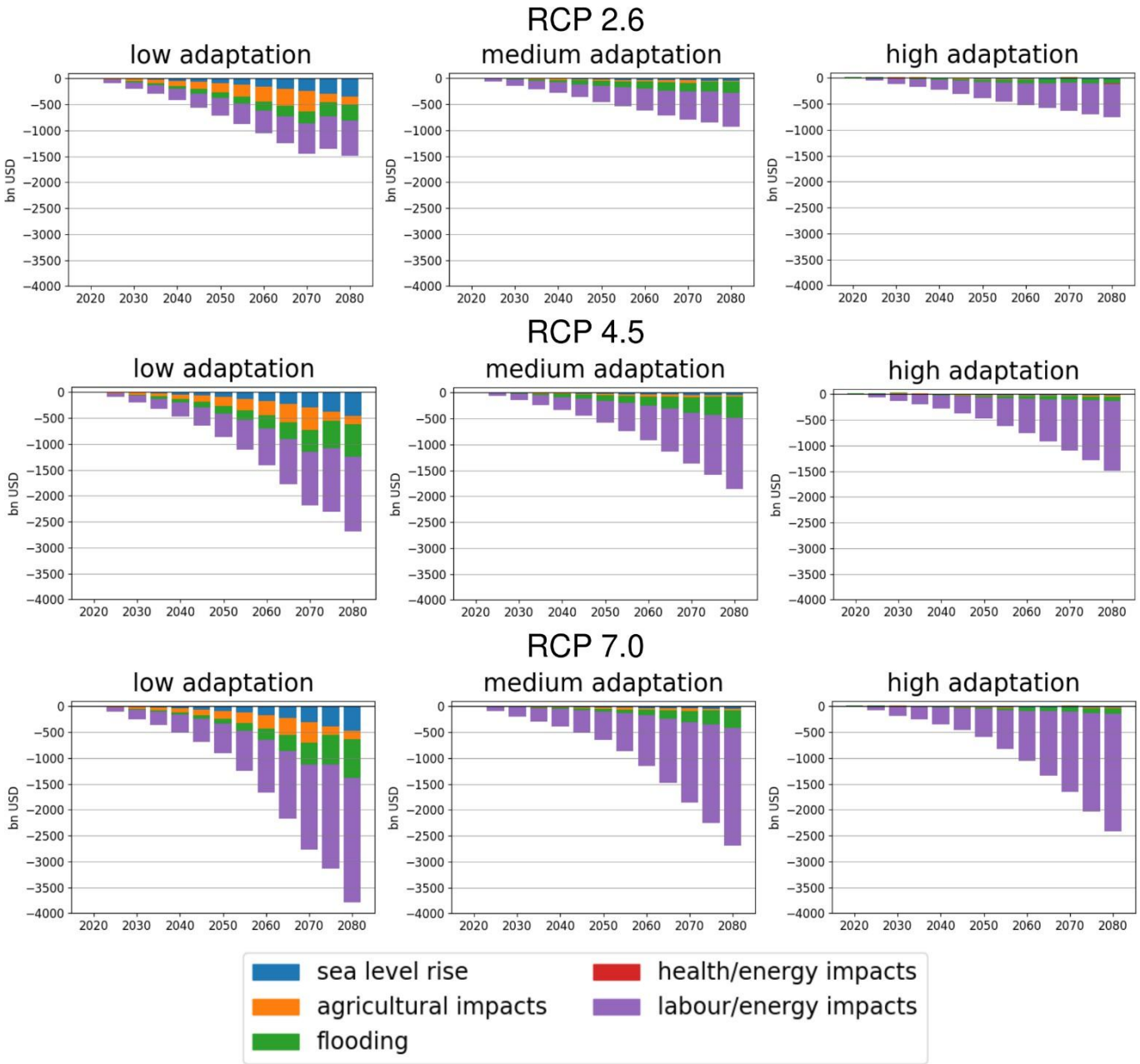
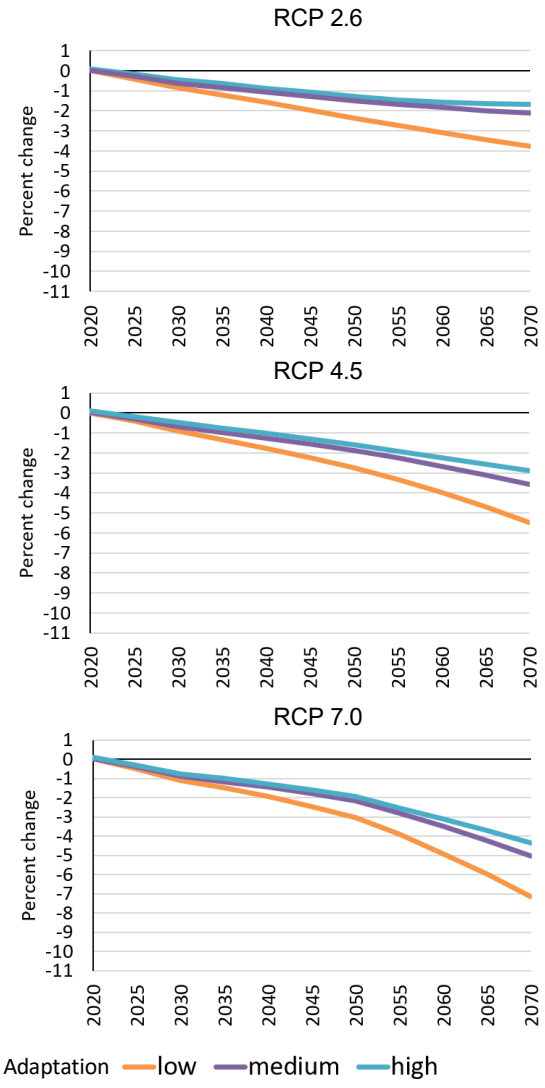


Figure 3. GDP effects across impact categories, for different RCPs and with low, medium and high adaptation.

These macroeconomic models and GDP effects are based on market impacts only, and do not include non-market effects such as mortality. It is possible to consider these by looking at the effects on welfare within the models. When this is undertaken, the economic impacts increase significantly, as shown in Figure 4. Again, higher levels of adaptation reduce residual impacts across all warming scenarios.

Figure 4. Aggregated welfare effects for EU, UK, Switzerland and Norway for RCPs and adaptation.

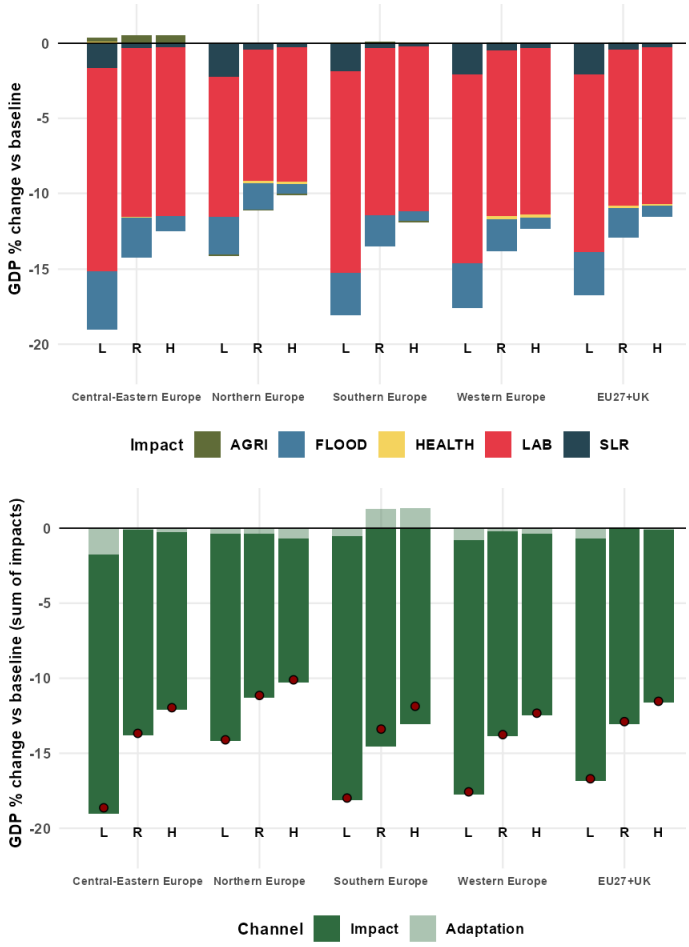


These results can be compared to the second CGE model, ICES. Figure 5 shows the SSP2-RCP7.0 scenario (high warming) and on disentangling the impacts from the adaption costs. It includes the contribution of each sector to the GDP loss under the three adaptation scenarios, expressed as percentage changes relative to the baseline.

This model projects higher impacts (than the COIN-INT model), with total GDP losses in EU27+UK at 16.7 per cent under low adaptation, 12.9 per cent under medium, and 11.5 per cent under high adaptation. This is due to the propagation of impact and adaption costs through this model. The impacts are dominated by labour impacts, followed by sea-level rise and river flooding. Again, Central-Eastern and Southern Europe experience the largest total GDP losses. These impacts are reduced with adaptation, but the reductions are lower in relative terms than with the COIN-INT model. The ICES analysis has also looked at the relative effects of impacts versus adaptation (Figure 5, bottom). This shows that the impact channel accounts for the majority of the total effect.

Figure 5. Top. Changes in GDP across channels (relative to baseline) for the RCP7.0 scenario in 2070, for different adaptation levels (L, M, H), by European macro-region.

Bottom. Changes in GDP attributable to adaptation and impact components.



Public expenditure (fiscal) results

Alongside the macroeconomic analysis, ACCREU has assessed the potential fiscal impacts of climate change on the public finances, and the benefits of adaptation in reducing these negative impacts.

The results are shown below for the COIN-INT model in Figure 6. This presents the impacts on public budgets from climate change in Europe. The results show how climate shocks raise government expenditure and at the same time reduce tax revenues, from the combination of damage to capital, labour, health impacts and other productivity losses. The analysis also considers government investment in adaptation. Adaptation reduces these climate fiscal impacts, but it adds pressure from increased spending. In this case, a balanced budget is assumed, and increased spending on adaptation is made possible by cuts elsewhere.

The results show the effects on revenues and expenditure, for RCP4.5 (left) and all RCPs right) for the three adaptation levels. The expenditures include spending on adaptation (shown above the zero line). The figure shows the net effects (red line), i.e., whether the reduction in climate impacts is offset by the investment in adaptation.

The analysis finds that higher adaptation spending leads to net fiscal benefits, as seen by the lower level of net impacts with greater adaptation investment in every case. Adaptation reduces fiscal impacts, but does not eliminate them, and there are residual fiscal impacts.

In these scenarios, adaptation is front-loaded, and thus adaptation costs are generally higher in 2050 than in 2070. This means the benefits of higher adaptation are greater in 2070 (not shown), reflecting higher climate impacts at this time, as well as the greater cumulative stock of adaptation that has been put in place. As a result, adaptation can expand the fiscal space, even though it involves higher public spending. This effect is present in 2050 but grows significantly towards 2070.

These results hold true for all European countries, with adaptation increasing fiscal space in every case. However, the level of fiscal benefit varies. Some countries, such as those in Western Europe, have the highest return on investment, while many countries in Central-Eastern Europe experience smaller fiscal gains, because they have much higher levels of investment costs needed for adaptation.

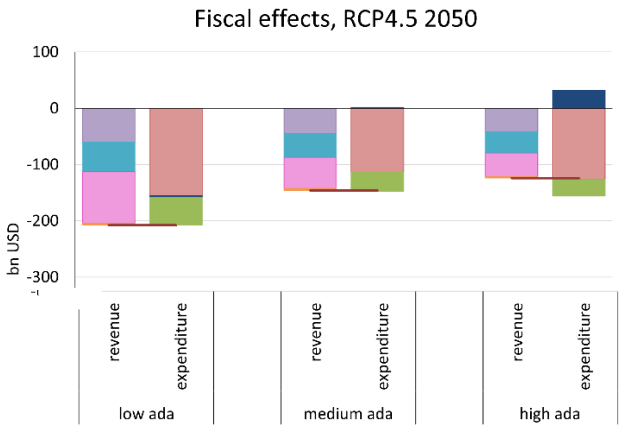
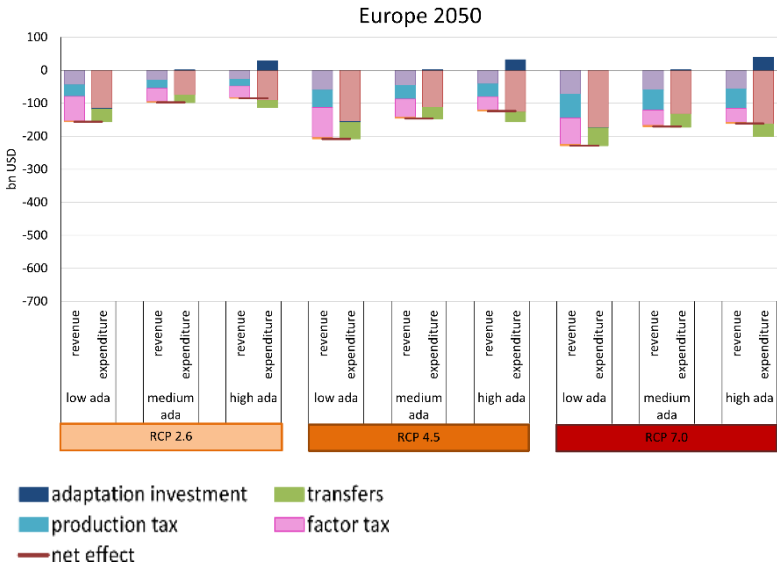


Figure 6. Left. Fiscal effects for Europe on revenue and expenditure, for different RCP4.5 with different adaptation levels in 2050.

Below. Fiscal effects for Europe for all RCPs.



Case study: Fiscal effects under different financing mechanisms in the UK

The analysis on the previous page assumes that governments balance the budget to invest in adaptation. However, there are other choices: these include increasing borrowing for adaptation. A case study was undertaken to investigate this issue, looking at UK coastal and river flood adaptation.

This used detailed national-level data on the economic impacts of flooding, and the costs and benefits of public adaptation, for 2030 and 2050, for low and high climate change scenarios, and fed these into the COIN-INT model. The analysis included the direct flood damage to residential and non-residential properties, as well as to infrastructure. It also considered health impacts, and the increased demand for health services. It then looked at the reduction in these impacts from adaptation versus the additional investment costs.

These investments were compared using alternative financing strategies. The first was to assume a balanced budget, where public expenditure is shifted to adaptation. An alternative was for increased government borrowing (debt).

The analysis assessed both domestic and international green bonds. This takes account of the initial flows from the bond issuance, as well as the interest payments bond-holders receive over time.

The study found that adaptation reduces the GDP and welfare impacts of flooding, leading to net benefits and increasing the fiscal space. However, the choice of financing mechanism and time horizon matter. In the balanced budget scenario, cuts in other areas are required, which has negative impacts, as government spending is diverted from other important policy domains. These can be avoided by deficit financing (borrowing). This is less restrictive in the short term, but in the long run, it is counteracted by rising interest payments on accumulating public debt.

The results also found differences between the domestic and international bonds, because of the difference in domestic flows, and the interest rate significantly affected how these various outcomes played out. Nonetheless, all financing schemes led to improvements compared to the no-adaptation case.

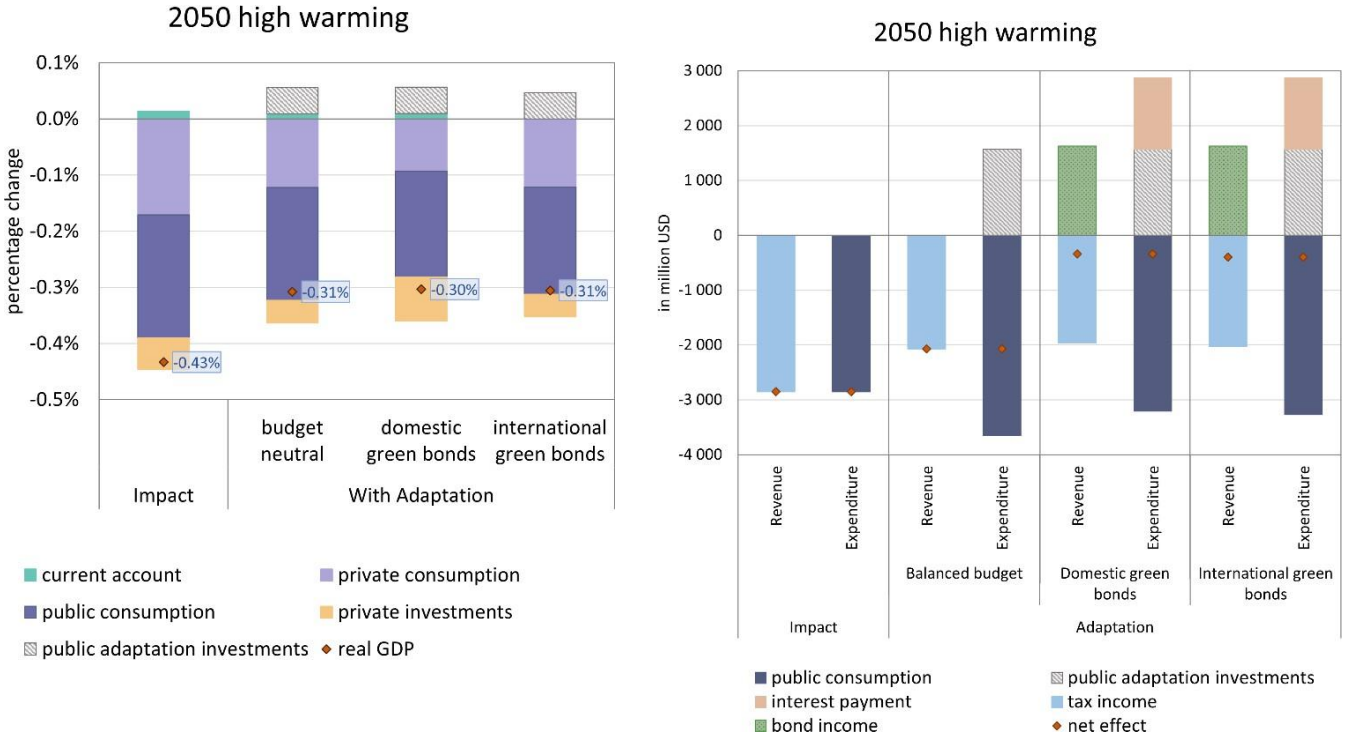


Figure 7. Comparison of fiscal effects of different government funding options for flood adaptation in the UK: budget neutral, domestic green bonds, international green bonds for the high warming scenario in 2050.

Case study: Distributional analysis

The ICES model, which has a high-level regional disaggregation (NUTS-2 level), was also used to investigate the inequality from climate change. This assessed the changes at the sub-national level across Europe, in terms of GDP per capita.

The results are shown in Figure 8 below. A clear pattern emerges when looking at climate change trends over time and across climate (RCP) scenarios, with the GDP per capita gap widening as climate change intensifies (left to right, and top to bottom).

Those in Southern and Central-Eastern regions lose the most in per capita terms, and poorer regions suffer disproportionally larger losses, with these differences increasing with warming scenario (RCP).

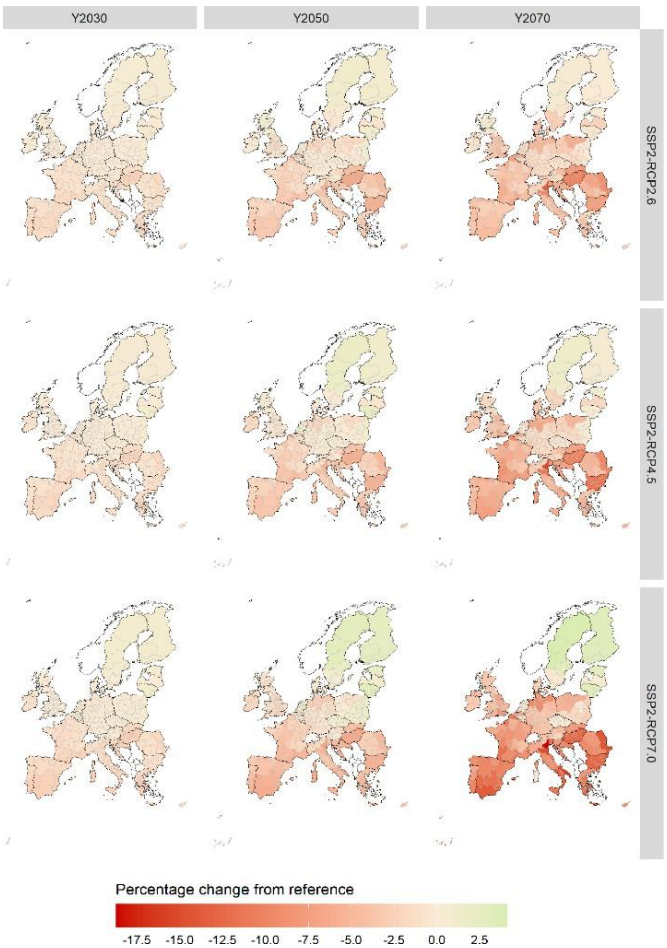


Figure 8. Climate change impacts on GDP per capita by EU NUTS-2 region, year, and reference scenario

Global results using IAMs

The sector results from ACCREU have also been used to look at the impacts of climate change, and mitigation and adaptation, at the global level. This was undertaken with a different set of tools, the **integrated assessment models (IAMs).** In ACCREU, three such models have been used: REMIND, WITCH and MIMOSA. More details are provided over the page.

These integrated models use a consistent framework that allows modelling of baseline and climate futures, socio-economic development, as well as economic impacts. They can be used to estimate the potential economic costs of climate change, expressed as aggregate values (equivalent % of GDP) or the social cost of carbon (the marginal cost of a tonne of additional carbon emitted, i.e. $/t$CO_2$).

These models also include mitigation components, which allow for the exploration of mitigation costs and benefits. Within ACCREU, new components were also added to these models. These drew on the project's sector level models, using their global runs. The project developed functions that include the costs and benefits for different RCPs and adaptation levels. These new damage functions were then used to explore two key issues. The first was to estimate global and regional GDP losses from climate change, taking climate-economy feedbacks into account . The second was to examine mitigation and adaptation policy costs and benefits.

Notes on the IAM results

It is emphasized that all the IAM models used here, and the results presented are partial. They only include a subset of the economic impacts and costs of climate change. Furthermore, the results of IAM modelling are affected by the assumptions made. This includes aggregating assumptions, notably on whether and how to add up or adjust effects in different regions and time periods, including positive and negative values, and whether to account for equity/inequality.

Additional details on Integrated Assessment Models and the ACCREU functions

Estimating the global economic costs of climate change is difficult. This is because of the complexity of trying to assess and value the impacts of climate change for multiple hazards, for both market and non-market sectors, for all countries globally, over long time periods.

Integrated assessment models (IAMs) combine the scientific and economic aspects of climate change within a single, iterative analytical framework, to allow an exploration of these costs. The advantage of these models is that they link emissions, temperature and other climate change impacts with economic costs in a consistent and integrated framework. However, to make such analysis manageable, they often use simplified descriptions of climate projections and use simplified impact relationships in the form of damage functions.

In ACCREU, three different IAMs were used:

- MIMOSA - a relatively simple cost-benefit IAM
- WITCH - a dynamic optimisation IAM
- REMIND - an energy-economy general equilibrium model

These are similar models in that they all capture the interlinkages between impacts, mitigation and adaptation, but they differ in structure and levels of complexity.

The use of different models is particularly useful for an inter-comparison of the results and their robustness. The three IAMs were run with harmonised socio-economic scenarios (SSP2) and assumptions on GDP and population growth.

As part of the project, ACCREU produced a new set of damage functions for IAMs (see Figure 9 for examples). These are available for different macro-regions across the world. These functions build on the previous functions developed in the COACCH project, but they extend these in several ways.

First, the impact damage functions have been further disaggregated by sector, to allow more granularity in the analysis. This includes consideration of sea-level rise, river flooding, and labour productivity, as well as heat-related mortality. These functions are differentiated by region, based on the detailed impact results, providing greater resolution.

Second, functions for adaptation were developed. These consider the effectiveness, as well as relationships between cost and benefits, for these same regions. It is noted that the sectoral coverage used in ACCREU is slightly narrower than used in the previous COACCH project, but this is because it has focused on those sectors where adaptation functions were developed.

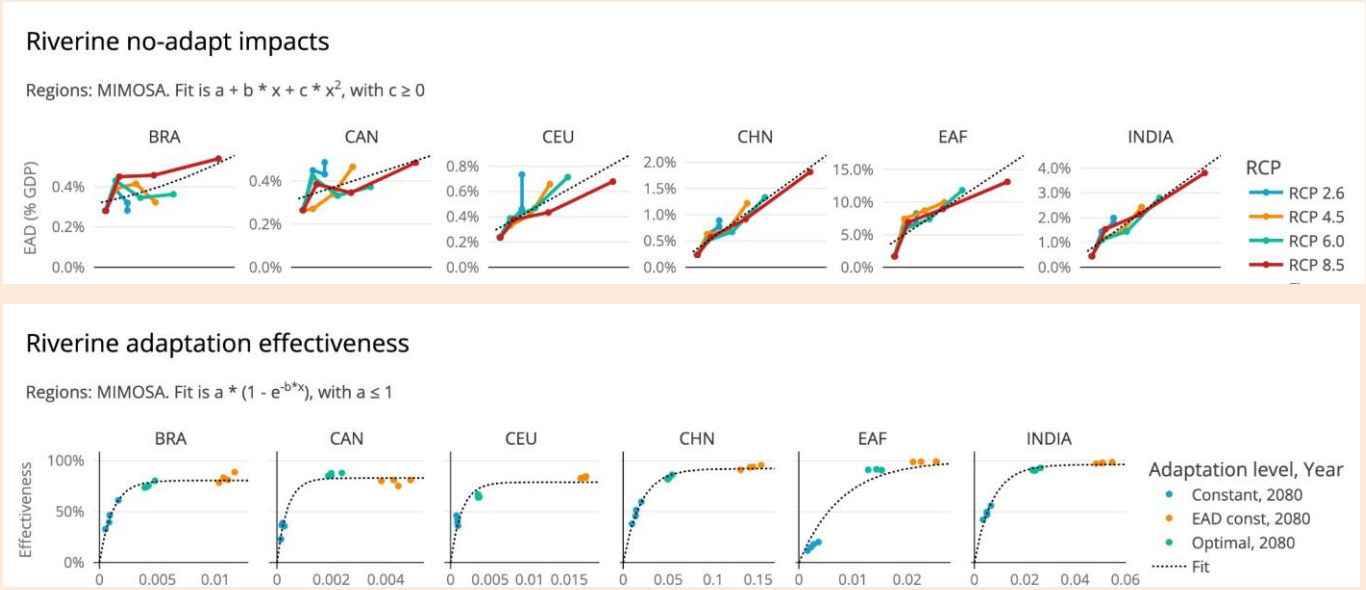


Figure 9. Examples of regional damage functions for impacts (top) and adaptation effectiveness vs costs (bottom)

Global Results

The IAMs were run first without additional mitigation or adaptation policy. This is shown in Figure 10 left (black bar). This is estimated to lead to a temperature rise of approximately 3°C in all models. The models were then run with a variety of mitigation (MIT) and adaptation (ADA) scenarios, both without (top) and with (bottom) the inclusion of mortality, to look at the optimal level of policy, and equivalent temperature stabilization level.

The lowest temperature arises when only mitigation (MIT) is included (see gold bar, centre). This results in optimal levels of between 1.9°C and 2.2°C across the IAMs. As adaptation is not undertaken in this run, this leads to more ambitious mitigation. Note that when mortality is included, slightly lower temperature levels are optimal (by 0.1-0.15°C) (see bottom).

The analysis also looked at the effects of adaptation (ADA), for the three key sectors assessed (labour, SLR and river floods). When mitigation and adaptation are both included (blue bar, right, MIT-ADA), the models assess the optimal level of both policies, including trade-offs. This leads to slightly higher levels of warming, around 0.2-0.25°C higher than with mitigation alone.

Two additional runs are also shown to look at the timing of policy. First, in MIT_then_ADA, adaptation is optimised in a separate second stage, while keeping the mitigation effort as in MIT. This leads to a similar temperature to MIT. Second, in MIT_late_ADA, there is a delayed start to mitigation: this later start cannot be compensated for, and this means higher temperatures are locked-in.

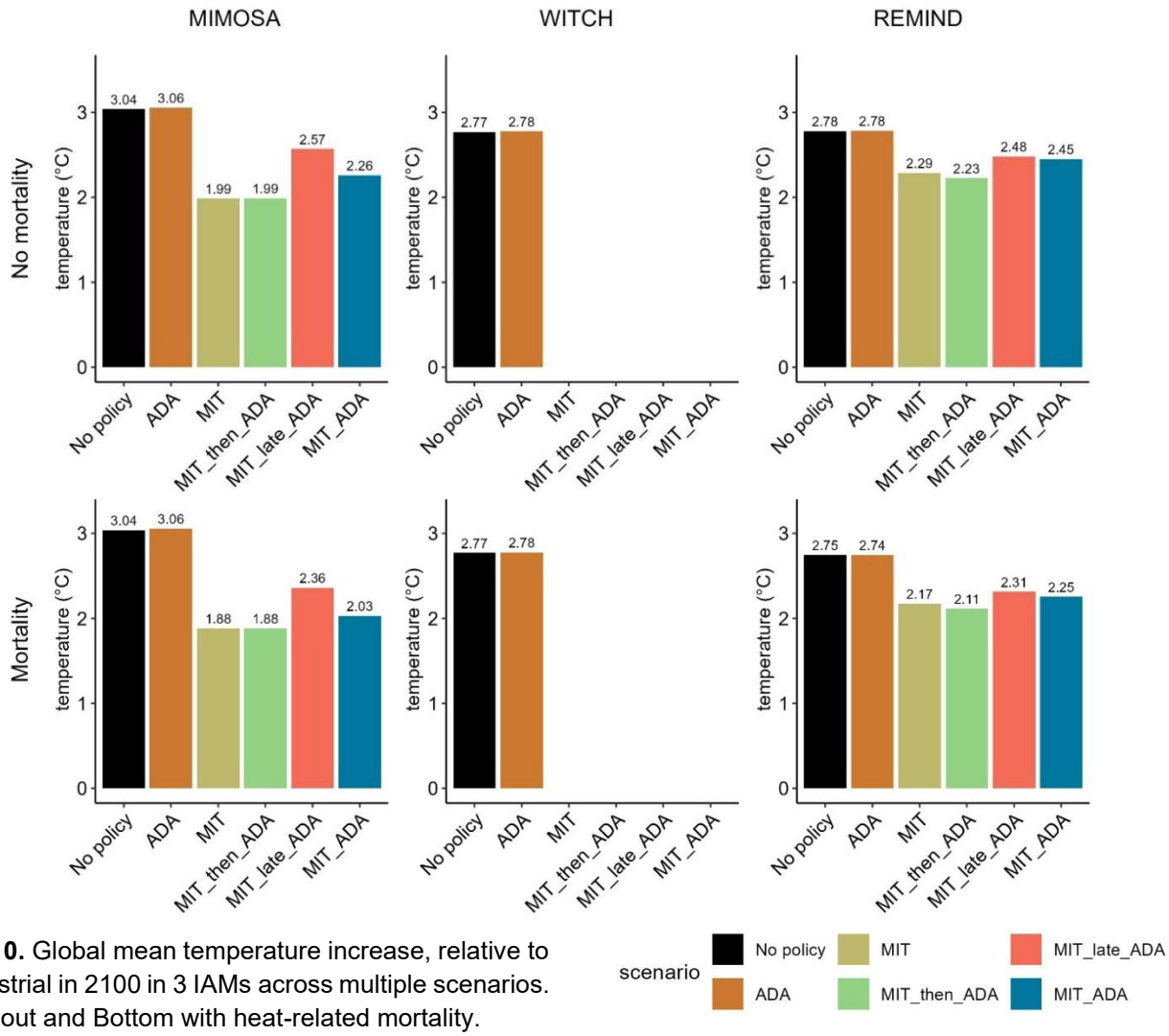
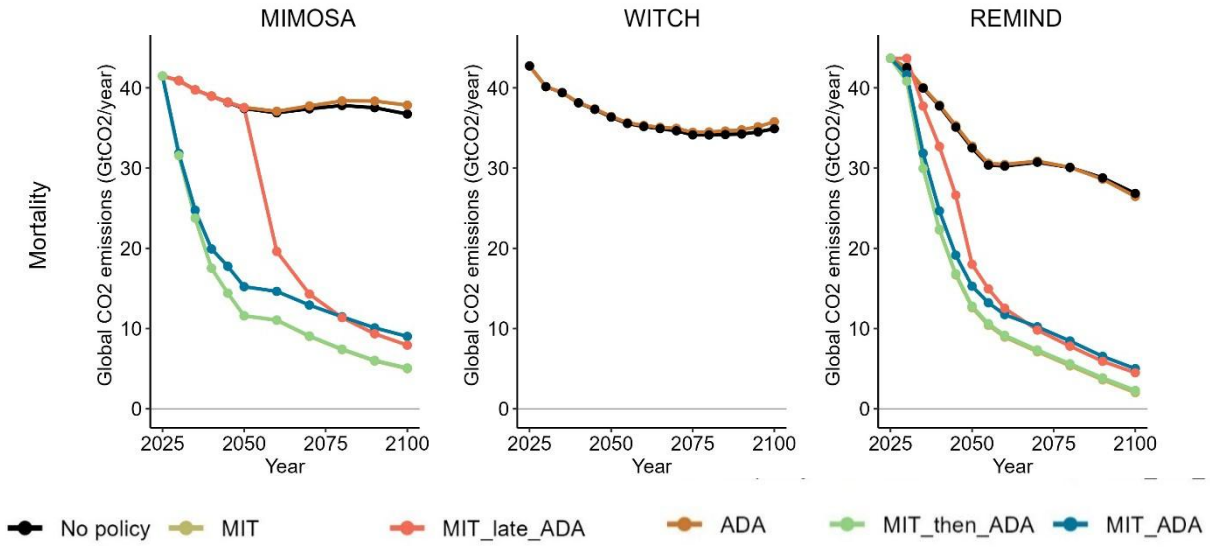


Figure 10. Global mean temperature increase, relative to pre-industrial in 2100 in 3 IAMs across multiple scenarios. Top without and Bottom with heat-related mortality.

Figure 11. Emission paths in the three IAMs across multiple scenarios (runs with mortality included).



These findings can be explained further by looking at the emission pathways from the various scenarios across the models, shown in Figure 11 above. All the models undertake large-scale mitigation before 2050 in all scenarios that permit this, even when adaptation is included. Indeed, between half and three-quarters of emissions are reduced in this early period.

Damage costs

It is also useful to look at the damage costs from the IAMs, which represent the economic costs of climate change, including the residual damage after adaptation.

The damages are highest in the no-policy scenario. Importantly, these impacts are not distributed evenly across the world. There are much higher relative impacts (% of GDP) projected in Sub-Saharan Africa and South Asia, as can be seen in Figure 12 below, though note the exact relative levels of damage differ between the different IAMs.

The global % damages can be seen in Figure 13. This also shows the damages across the three key impacts assessed. This shows that the relative damage costs from the three impacts considered are 20 per cent due to sea-level rise, 40 per cent to river floods and 40 per cent to due to labour productivity impact.

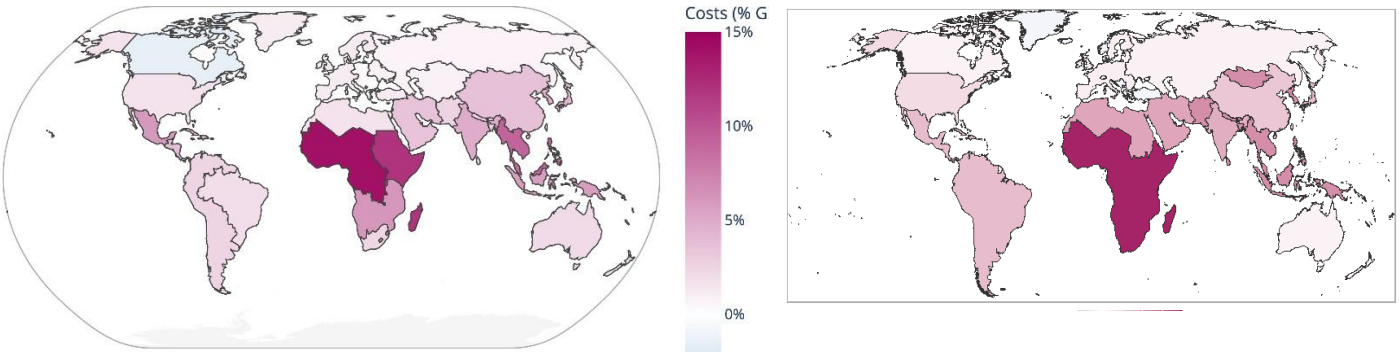


Figure 12. Regionally differentiated damage costs (% of GDP) in 2100 under no policy scenario. Left: MIMOSA. Right: REMIND. Note results exclude mortality.

The analysis has also looked at effects of different policy mixes on these damages, shown in Figure 13. Mitigation (MIT) reduces the total global damages by 35-50 per cent, but the lowest damage costs are projected for the mitigation then adaptation (MIT_then_ADA) scenario, as this sequential policy invests the most in overall damage reduction.

In the adaptation only scenario (ADA), there are large reductions in sea-level rise damages (due to the high effectiveness of adaptation) and to a lesser extent river flood damage. However, the reduction in labour productivity impacts with adaptation are smaller, reflecting lower adaptation effectiveness and higher residual damage after adaptation, but also because only indoor adaptation [cooling] was modelled (it was not possible to model outdoor adaptation).

In the scenarios where mortality impacts are monetised and included in the optimization, the damage reduction is, on average, 10 per cent greater than in the scenarios where this is not the case (though note no adaptation for this impactt was included in the modelling).

The results show that adaptation is highly cost-effective. However, some care is needed in interpreting these results, because the analysis of adaptation is still quite stylised. The analysis assumes high effectiveness (noting ex post evidence often indicates this is lower in practice) and very low costs. This highlights that better data on adaptation effectiveness and costs is still needed. Nonetheless, it does strongly indicate that adaptation can be an important part of the policy solution space.

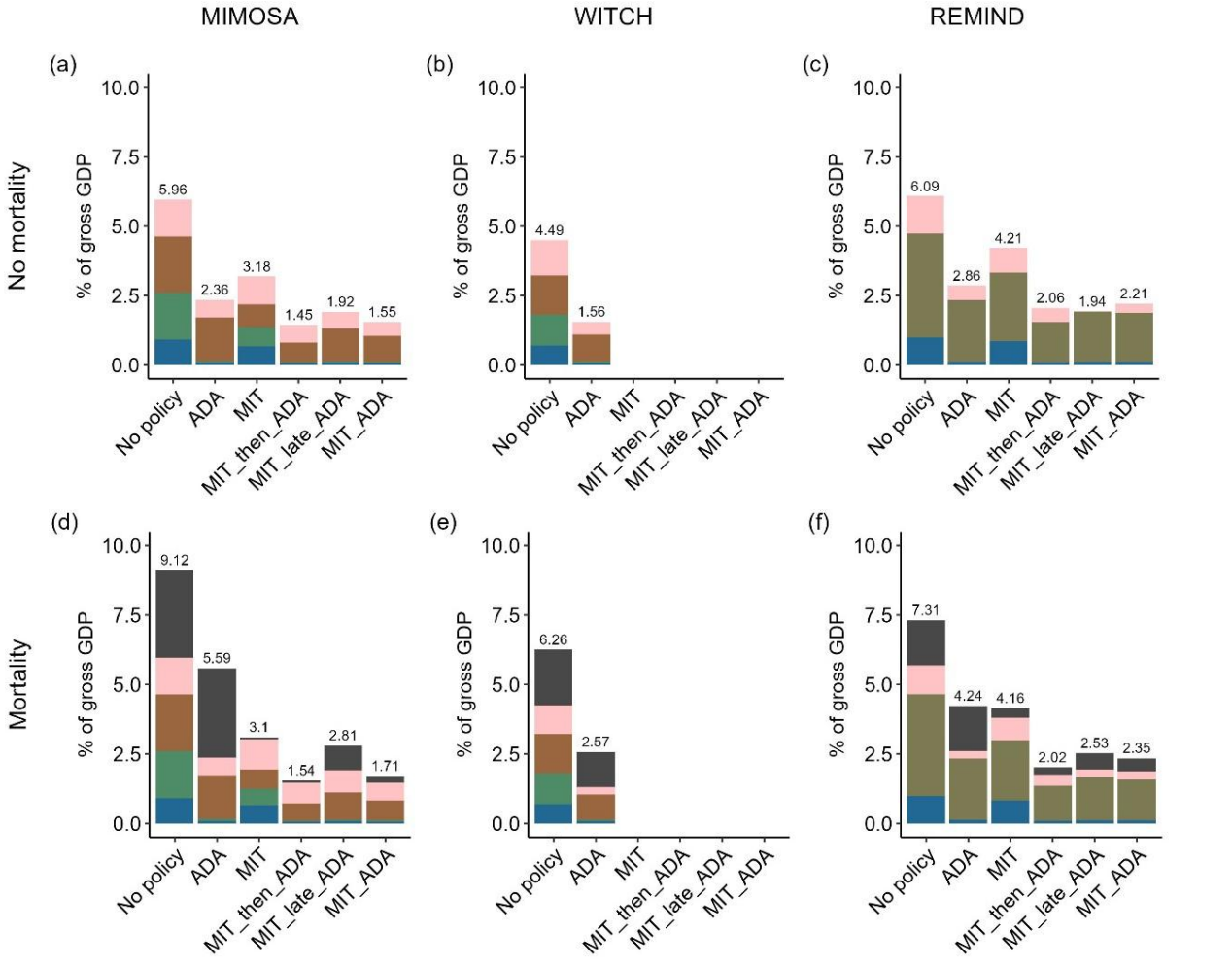


Figure 13. Damages in 2100 in the IAMs across multiple scenarios (variations regarding the goal of optimisation).

To investigate this, an additional set of runs was undertaken in which adaptation effectiveness was lower. The functions were adjusted based on a literature review of project-level studies. These results are shown in Figure 14 (see ADA_red_eff). In this case, damages are substantially lower than in the No Policy scenario but still, on average, 80% higher than in the optimal adaptation scenario.

A further analysis was included to look at implementation challenges and the limits of adaptation. This reflects the fact that even though adaptation can be highly effective, implementation can still be limited by available finance and other factors. This is shown in ADA_impl_gap. These results also show higher damage levels than ADA. These may reflect a more realistic assessment of an achievable best-case adaptation scenario.

This also highlights the need to consider real-world barriers and constraints when modelling adaptation.

These effectiveness issues can also be seen when looking at the costs of different runs. Adaptation investments – noting these are for three impacts only – are largest in the adaptation only scenario (ADA) and require around 0.3% of GDP. This relatively low level is due to the very high effectiveness, as well as the assumption that cost-effectiveness does not fall with rising levels of impacts (or limits of adaptation).

The findings indicate the need for further research on the effectiveness, costs and limits of adaptation (including soft and hard limits), across a range of sectors, and for incorporating these into modelling studies.

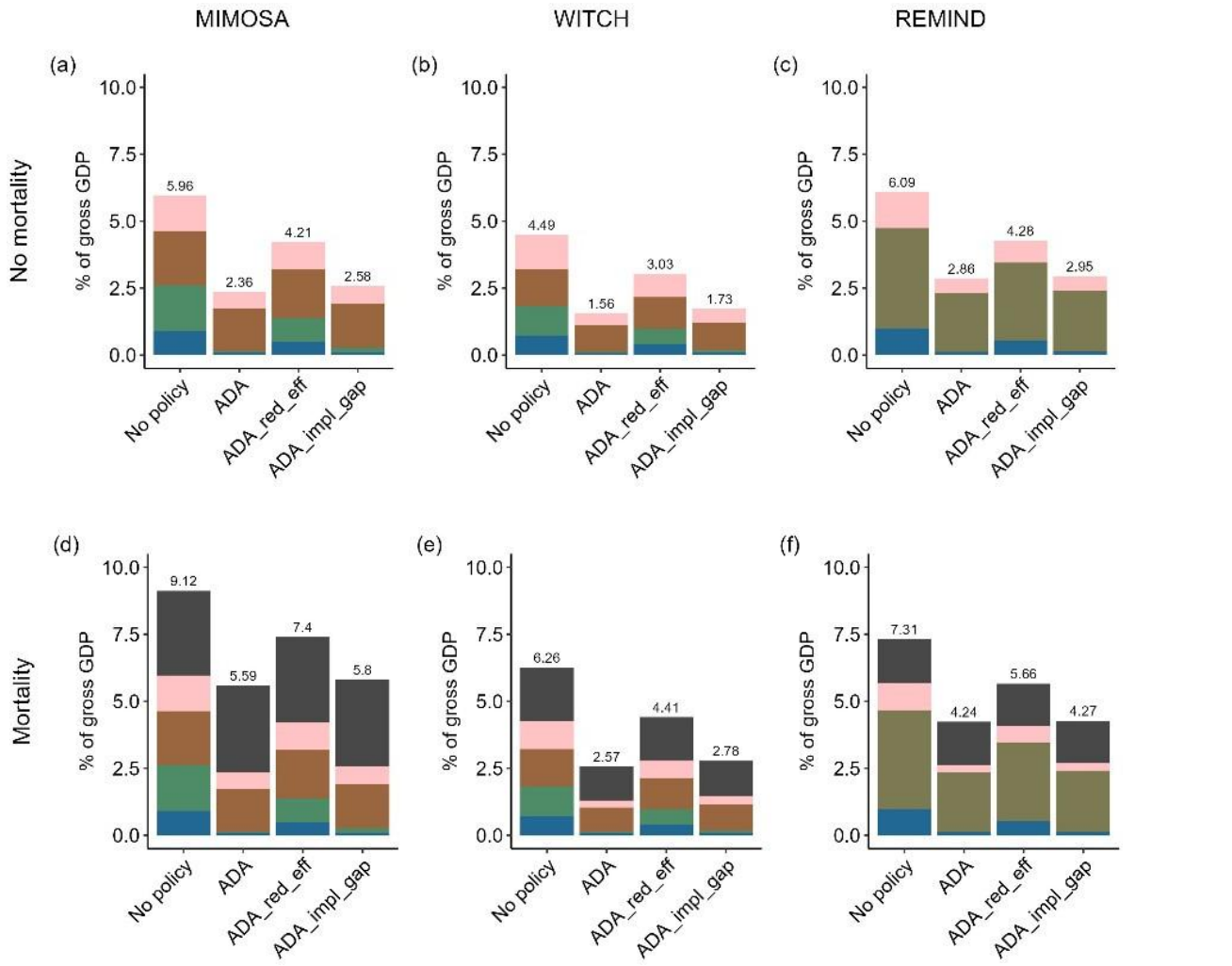


Figure 14. Damages in 2100 in three IAMs across multiple scenarios (variations of adaptation).

The ACCREU project is coordinated by Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici (FONDAZIONE CMCC), Italy. To find out more about the project, please visit https://www.accreu.eu/

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Citation. ACCREU (2026). Policy Brief. The Macroeconomic and Fiscal Effects of Climate Change and Adaptation in Europe and Globally. Published by the ACCREU Project, Copyright: ACCREU, 2026.

Funded by the European Union

The ACCREU Project is funded by the European Union through the HORIZON Europe RIA (Research and Innovation Action)

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