The Economic Cost of Climate Change in Europe

Policy Summary

Europe

Funded by the European Union’s Horizon 2020 research and innovation programme
Key Messages - Europe

• The COACCH project has developed new sectoral analysis of the impacts of climate change in Europe. This work has been delivered using a co-design process, which has jointly developed and delivered research outputs that meet user interests.

• The project has run a series of sectoral assessments. These identify very large damage costs from climate change for Europe, for direct damages such as from coastal and river flooding, but also for non-market sectors, notably health.

• These sector results have been fed into macro-economic models to estimate the overall economic costs. This finds high economic costs of climate change in Europe, even for central scenarios at mid-century. These findings contrast with some of the earlier literature, which estimated more modest impacts for the continent.

• The analysis also finds a very strong distributional pattern of economic costs across Europe, with higher costs projected for south and south-eastern Europe. These economic costs rise significantly, especially for higher warming scenarios later in the century.

• Ambitious global mitigation policy has a major benefit in reducing these economic costs in Europe, however, these benefits mostly arise after mid-century.

• The project has found the use of economic models provides additional insight, for examples, economic impacts in Europe are influenced by what happens globally.

• The COACCH project has also looked at climate and socio-economic tipping points. It finds these large-scale events would have major economic consequences for Europe, and add weight to the need for ambitious mitigation.

• Even if the Paris Goals are achieved, there will still be high economic costs of climate change in Europe. The lags in the climate system means that the impacts in the next two decades are locked-in, and can only be reduced with adaptation.

• The COACCH project has also looked at the economics of adaptation. Adaptation can dramatically reduce the economic costs of climate change, reducing down impacts over the next twenty years, as well as later. However, adaptation, although very effective, does not negate the need for ambitious mitigation.

• Many early adaptation investments deliver high benefit to cost ratios, i.e. they are no or low-regret in nature, and a priority for early plans.

• Finally, national level macro-economic analysis finds that adaptation reduces the negative impacts of climate change, and leads to net positive outcomes for public budgets, due to the benefits of adaptation on government revenues.
Introduction

Climate change will lead to economic costs. These costs, which are often known as the 'costs of inaction', provide key inputs to the policy debate on climate risks, mitigation and adaptation.

The objective of the COACCH project (Codesigning the Assessment of Climate Change costs) is to produce an improved downscaled assessment of the risks and costs of climate change in Europe. The project is proactively involving stakeholders in co-design, co-production and co-dissemination, to produce research that is of direct use to end users. This brief summarises the various results from the COACCH project on the economic costs of climate change in Europe.

Co-Design

The COACCH project adopted a co-creation process as a core part of the research. This adopted a different way of working to a traditional research project, and involved stakeholders (from the policy, business and research domains) in a co-operative process of design, production and dissemination (see box).

There are different approaches to co-design and COACCH has focused on generating usable information for policy makers, and has used knowledge brokers, as shown in the figure.

To help the co-design process, COACCH undertook a detailed literature review on previous studies, to identify what makes a successful co-design process. Based on this, the project co-design was designed to be:

- Process orientated;
- Objective and outcome led, with clearly identified roles and responsibilities;
- Targeted, ensuring representative stakeholders;
- User and decision orientated, with the aim to meet produce information of relevance for decisions and decision makers;
- Joint product orientated, using outputs to help build the engagement process;
- Iterative, with an ongoing process of review, learning and update regularly throughout.

The most important benefits of co-design were found to be the improved relevance of research outputs for uptake and use (in decisions) and the improvement in the dissemination and communication of research outputs.

However, compared to a traditional research project, co-design was found to involve considerably more resources and time, particularly at the start of the project.

Co-design (cooperative design) is the participatory design of a research project with stakeholders (users of the research). The aim is to jointly develop and define research questions that meet collective interests and needs.

Co-production is the participatory development and implementation of a research project with stakeholders. This is also sometimes called joint knowledge production.

Co-delivery is the participatory design and implementation for the appropriate use of the research, including the joint delivery of research outputs and exploitation of results.

Practice orientated research aims to help inform decisions and/or decision makers. It uses participatory approaches and trans-disciplinary research.
The use of knowledge brokers was also found to be critical, and the co-production process was found to work best when there was deep and regulator engagement, and use of case studies.

Finally, based on the experience and lessons of the project, the COACCH project has produced a set of co-design guidance, available for future research.

Modelling Approach

Climate change will lead to wide ranging impacts on the natural and man-made environment across different sectors and regions. These impacts will, in turn, lead to economic costs in market and non-market sectors.

The COACCH project has undertaken detailed sector by sector analysis of the potential economic costs of climate change in Europe. This includes analysis of energy demand and supply, labour productivity, agriculture, forestry, fisheries, transport, sea level rise, and riverine floods.

These sector results have subsequently been fed into a macro-economic model, the ICES macroeconomic computable general equilibrium (CGE) model. This allows the analysis of the higher order economic implications of climate change impacts, within the economic system, and captures the linkages between sectors and trade flows of domestic and international goods and services.

This analysis was undertaken for a range of future warming scenarios to consider uncertainty, captured by the Representative Concentration Pathways (RCPs), as well as future socioeconomic development, using the Shared Socioeconomic Pathways (SSPs). The combination of RCPs and SSPs are shown below. Further, the analysis of RCPs took account of climate model uncertainty.

Complementing this, COACCH has also undertaken new work on climate and socio-economic tipping points, i.e. low-likelihood, high-impact events, and their potential impact on Europe.

The project has also looked at the economics of adaptation. This has involved a number of sectoral assessments on adaptation, and the consideration of the macro-economic effects of adaptation on the public finance.

These results are summarised in this policy brief. Further details are available from a series of longer technical policy briefs on the COACCH website, and the project deliverables.

| Table 1: Selected scenario combinations to be used in the COACCH project |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                  | SSP1            | SSP2            | SSP3            | SSP4            | SSP5            |
| (Green Growth)   | (Middle of the road) | (Regional rivalry) | (Inequality)  | (Fossil fuel development) |
| RCP8.5           |                  |                  |                  |                  |                 |
| RCP6.0           |                  |                  |                  |                  |                 |
| RCP4.5           |                  |                  |                  |                  |                 |
|                  |                  |                  |                  |                  |                 |
| RCP2.6           |                  |                  |                  |                  |                 |

*=“low signal” climate model; ○ = “average” climate model; □ = “high signal” climate model; ★ = fixed adaptation, “average” climate model

* The “low signal” and “high signal” climate model refers to, respectively, choosing a model which leads to relatively low/high temperature change and/or to low/high precipitation changes.
Results – economic costs of climate change by sector

The COACCH project produced new sector estimates of the economic costs of climate change, using a suite of sectoral models and econometric analysis (see framework below).

The analysis of future impacts was taken for the set of RCP-SSP scenarios (see previous page) to allow a harmonised approach for use in subsequent Integrated analysis. However, some of the models also generate direct damage costs that provide valuable policy insights.

The analysis assessed the impacts of climate change in terms of social welfare, to capture the costs and benefits to society, including both market and non-market impacts. These estimates are presented in terms of current prices (Euros) for future time periods, without adjustment or discounting, to facilitate direct comparison, over time and between sectors.

A first finding is that the economic costs of climate change in Europe are estimated to be very large in future years.

The largest impacts are projected from flooding, with the combined impact of coastal and river flooding estimated to lead to damages in excess of €100 billion/year by the 2050s, even under a moderate warming scenario (RCP4.5) [combined impact of climate and socio-economic change, with no adaptation, current prices, undiscounted].

There are also very large non-market impacts projected, for example the impacts of additional heat related mortality are of a similar level, in excess of €100 billion/year by the 2050s [RCP4.5, combined impact of climate and socio-economic change, with no adaptation, VSL valuation, current prices, undiscounted]. It is noted that these are not captured in the macro-economic analysis in the next section, and are important to consider alongside impacts on GDP.

These damages increase strongly over time, and accelerate significantly for higher warming scenarios by the late century.
The results also show the large benefits of mitigation, as shown by the comparison of different RCP scenarios. There are very large benefits in moving from a RCP6.0 to RCP2.6 scenario, and even large benefits in moving from RCP4.5 to RCP2.6. However, these mitigation benefits mostly arise after 2050. Further, even with mitigation in place, there are high residual annual damages in Europe (i.e. tens of €billions/year under RCP2.6 scenarios).

There are also strong spatial patterns of these risks across Europe, with higher costs generally projected for most risks in south and south-eastern Europe as shown below, the exception being for coastal impacts.

More details are available in the sectoral results policy brief and project deliverables.
Results - macro-economic costs of climate change

The sector results from COACCH were fed into a macro-economic model, the ICES macroeconomic computable general equilibrium (CGE) model. This allows an analysis of the effect of climate change on the economic performance of a country or region (including on GDP).

This considers how climate change affects economic output, in terms of capital, labour and productivity, as well as the impact on economic growth from changes in capital investment, productivity and technological improvement. This allows an assessment of how climate change affects the drivers of growth, and thus might alter economic growth rates. Such impacts can lead to cumulative effects over time, which are much larger than from reductions in output alone.

The COACCH project undertook such an analysis, and developed the ICES model results to produce downscaled results at a sub-national level, looking at combinations of future scenarios (RCPs) socioeconomic development (SSPs).

To account for uncertainty, results from the sectoral studies for a “low”, “medium” and “high” cases were considered, to account for important sensitivities.

The central aggregated results at the country level for mid-century for the RCP4.5 – SSP 2 scenario are shown below. The overall results, when all sectoral effects are considered, show important losses in GDP across Europe. This contrasts with earlier modelling studies, which estimated more modest impacts for the continent.

Two different assumptions of investment mobility were considered. The first represents a highly integrated EU (shown left), where investments can rapidly move. In this case, economic shocks, especially those associated with capital stocks such as from floods, propagate more easily within the EU. The second case assumes lower inter-regional mobility of investment, (shown right) implying that negative impacts tend to “stay” within the region where they occur.

Climate change impacts on GDP by country in 2050, RCP4.5-SSP2, medium impact (left, high investment mobility upper panel, right, low investment mobility). Dots are total net effect. Values in percentage change from the baseline.
The results are also shown for different warming scenarios (RCP2.6, 4.5 and 6.0 scenarios) for the same socio-economic scenario (SSP2, a middle of the road socio-economic scenario) over time. The high investment mobility scenario is shown. Up to 2050, there is relatively little difference between RCP scenarios as the climate signal does not differ much, though there is a large difference across the low, medium and high sensitivity cases, reflecting uncertainty in climate projections and impact models. In the 2070s, there are very large differences across scenarios as well as across the sensitivity runs. In the higher warming scenario (RCP6.0, bottom), there are significant losses in the majority of countries.

Climate change impacts on GDP by region, medium impact case (high investment mobility) SSP2 for various RCP combinations. Values in percentage change from the baseline.
The main drivers of macroeconomic impacts and GDP losses are from sea-level rise (although SLR impacts drop dramatically under the adaptation scenario), river floods and crop yield changes.

There are also important impacts from labour productivity, energy supply and energy demand, but these tend to be more pronounced in southern Europe. The impacts on fishery and forestry are generally more modest, and in many regions could involve potential gains. The impacts of transport are low, but these only cover direct effects. As highlighted above, these results do not include impacts on health or biodiversity and ecosystem services.

There is a large difference according to the mobility assumptions. Lower inter-regional mobility of investment tends to decrease GDP losses, as impacts spread less across regions. However, this effect is important when impacts concern capital assets and, thus, for sea-level rise and river floods.

Diving down to the sources of uncertainty, there are large differences between sensitivity runs, shown below. The climate scenario (RCP) is more important than the social-economic path (SSP). However, even larger uncertainty arises from the differences in climate and impact models (and assumptions), and there are large differences between the low, medium and high sensitivity cases. There is also large uncertainty from the specific type of economic adjustment (investment mobility).

This uncertainty highlights a key message – it is still possible to experience high economic impacts in low warming climate change scenarios. This is a further incentive to implement aggressive mitigation policy, as even a fraction of a degree avoided can make a large difference.

More details on the results are presented in the macro-economic results policy brief and project deliverable.

The y-axis reports coefficients of the “Analysis of Variance” test. The higher the bar the higher the contribution to the economic impact. The RCPs are measured relative to RCP2.6, SSPs relative to SSP2, impact specifications relative to “low impact”, investment mobility role is measured against “high investment mobility”.

Decomposition of uncertainty sources.
In addition to the sectoral and macro-economic impacts above, there are a set of additional potential impacts from climate change, associated with low-likelihood, high-impact events, often termed tipping points.

Climate tipping points relate to critical thresholds at which a small change can alter the state of a system. A number of global (earth-system) climate tipping elements have been identified, which could pass tipping points as a result of climate change, leading to large-scale consequences. These may be triggered by self-amplifying processes and they can be potentially abrupt, non-linear and irreversible.

These ‘bio-physical’ climate tipping points provide a further justification for global mitigation policy, yet they are poorly represented in economic assessments of climate change.

The COACCH project has been analysing the potential climate tipping points of most concern for Europe. These are focusing on three tipping points that are relevant this century.

The COACCH project ran the DIVA model to estimate the potential economic costs for Europe for extreme sea-level rise scenarios. This considered a high-end scenario with global coastal average sea-level rise of 170cm by 2100, to illustrate the effects of high end sea-level rise.

Under this scenario, coastal SLR and floods were found to have severe effects with an expected 30 million people flooded each year, and EU expected annual damages of 13 trillion EUR. This is driven by the combination of higher climate change and the SSP5 scenario.

It is noted, however, that adaptation could reduce these costs down significantly, to €44 billion per year – but under such high SLR there could be technological and economic limits to adaptation that prevent adaptation at some locations.

COACCH also assessed projections of Arctic sea ice loss, and how these might evolve over this century, based on CMIP5 models.

These indicate that under RCP8.5, summer ice sheet loss is projected by mid-century, but that for some models, this might also occur within this time frame under RCP4.5. These would have potential impacts from changes in extreme cold conditions, and possible windstorms, with potentially important economic costs for Europe.

The project also considered the risks to Alpine glaciers, and glacier melting and retreat with warmer temperatures, exacerbated by ice-albedo feedback. The analysis found that under all RCPs, there is a projected reduction of about 50% of the glacier volume over the Alps by the 2050s, and much higher reductions later in the century, especially under high warming scenarios.

These will have economic costs from the decline in summer river flows, affecting water availability, hydropower, river transport and stability (landslide risk), as well as the loss of ecosystem services from Alpine species and habitats.
The COACCH project has also developed a new concept of socio-economic tipping points (SETP). This idea recognises that even gradual climate change may abruptly and significantly alter the functioning of socioeconomic systems, which can lead to major economic costs, especially at a more local level. These changes may arise directly in Europe, but may also involve global events that subsequently spill-over into Europe.

These may involve a case where climate change triggers a large-scale socio-economic event (a major shock). It might also involve a case where climate change pushes a socio-economic system above a threshold, affecting its functioning. Either of these socio-economic tipping points can trigger a rapid increase in costs, e.g. as measured by a large drop in the GDP of a local area or region.

A number of these SETPs were assessed in the project:
- Climate induced agriculture and food shocks, and potential land abandonment and price spikes;
- Migration induced tipping points, including from coastal areas due to extreme sea level rise, and from major climatic shocks;
- Energy and Transport tipping points, with analysis of wildfire related energy supply shocks, as well as multiple floods and transport disruption;
- Extreme sea-level rise, including transformational adaptation;
- Economic tipping points, including the potential for large macro-economic impacts;
- Financial tipping points, including the potential collapse of insurance markets from extreme weather risks, as well as major impacts on countries and financial markets.

The results indicate that smaller-scale SETP are likely to happen earlier and with greater certainty, but there are also potential major events that could occur in Europe. A further finding is that these SETPs often have strong distributional patterns, i.e. for specific regions of Europe or particular groups.

While it is difficult to assign the likelihood of these events, the modelling shows these events are associated with high-end (RCP8.5) scenarios, though also sometimes at lower warming scenarios. They can include very large impacts, that would have major policy consequences at the European scale.

Importantly, these socio-economic tipping point events are currently omitted in policy discussions and further consideration of them is considered a priority, alongside climate tipping points. More details on the results are presented in the tipping points policy brief and project deliverables.

Results – economic benefits of adaptation

Even if the Paris Goals are achieved, there will still be high economic costs of climate change in Europe over the next two decades.

The COACCH project has explored the potential for adaptation in reducing these impacts. This has used a number of the sectoral models, extended the analysis look at the benefits of adaptation (i.e. the reduction in anticipated impacts) as compared to the costs.

The adaptation analysis was undertaken for the major impact categories, including coastal and river floods, as well as for non-market impacts with the analysis of health.

The first key finding is that adaptation has large economic benefits in reducing future impacts, often reducing damage costs by a factor of 2 to 5. Importantly, the level of reduction depends on the objectives set for adaptation, and whether this to the economically optimal level (considering the trade-off between benefits, costs and residual damage) or to pre-determined levels of acceptable risk or damage.

Nonetheless, some residual damage still remains even with adaptation, though in the medium to long term, this is much lower under ambitious mitigation scenarios, highlighting the complementary nature of mitigation and adaptation. The analysis finds that while adaptation has high benefits, it requires significant additional investment in Europe, with rising costs over the century.

As one of the applied policy assessments, further work was undertaken to support national adaptation planning, with a detailed review of the potential costs and benefits of early adaptation. This looked at the economic case for adaptation, based on analysis of the benefit to cost ratios (BCRs).

This analysis identified a larger number of no and low-regret options (with BCRs above 1), across market and non-market sectors (shown below).

The COACCH project also undertook new analysis to look at the macro-economic effects of climate change and adaptation at the national level.
This analysis built on the climate change impacts estimated for Europe, which are estimated to be several % of GDP in most countries. These climate change impacts will affect the public finances. This will have impacts from higher public expenditures for disaster relief and a lower tax base due to reduced economic activity.

These effects involve complex pathways and transmission mechanisms, e.g. the implications of climate change for government revenues and expenditures, the level of contingent liabilities, debt levels, etc. and feedbacks across the economy.

In order to look at these effects, therefore, there is a need to use economic models, which can consider the macroeconomic implications of impacts and adaptation in an integrated framework.

The COACCH project assessed these effects, using a multi-sectoral, multi-regional comparative static Computable General Equilibrium (CGE) model (COIN-INT) model.

The analysis looked at the macroeconomic effects of climate change and adaptation in three different countries in Europe – in Austria, Spain, and the Netherlands – with a deeper dive analysis in two risk areas, for flood risk management and adaptation in the agricultural & forestry sectors.

The analysis considered a baseline which assessed the economy-wide repercussions and budgetary consequences of climate change using results from COACCH. It then looked at the effectiveness of adaptation in reducing these risks, based on public adaptation expenditures through to 2050. However, while adaptation can reduce baseline impacts, it has an additional cost, increasing public sector expenditure.

The analysis then looked at the overall effects on government budgets, looking at both direct (expenditures) and indirect effects (e.g. changes to the tax base from changes in economic output, labour and capital income).

The first key finding is that for the adaptation strategies considered, national adaptation is effective in reducing the negative sectoral and economy-wide effects of a range of climate impacts, and was estimated to reduce these impacts by more than 50%.

The second key finding was that the benefits of adaptation on the government revenues, generated through taxes on consumption, factor income, output and trade, more than offset the direct costs of adaptation. In turn, this allows higher levels of government consumption and public transfers to private households in a scenario with adaptation.

This means that adaptation leads to net positive outcomes for public budgets, even though it requires public expenditure, due to the benefits of adaptation on government revenues.

More details on the results are presented in the policy results brief and project deliverable.
The COACCH project is co-ordinated by Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici (FONDAZIONE CMCC), Italy. To find out more about the COACCH project, please visit http://www.coacch.eu/

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