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Consistent economic cross-sectoral climate change impact scenario analysis: Method and application to Austria

Karl W. Steininger [a,b,*], Birgit Bednar-Friedl [a,b], Herbert Formayer [c], Martin König [d]

[a] *Wegener Center for Climate and Global Change, University of Graz, Graz, Austria*
[b] *Department of Economics, University of Graz, Graz, Austria*
[c] *Institute of Meteorology, University of Natural Resources and Life Sciences, Vienna, Austria*
[d] *Environmental Impact Assessment and Climate Change, Environment Agency Austria, Vienna, Austria*

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ABSTRACT

Climate change triggers manifold impacts at the national to local level, which in turn have various economy-wide implications (e.g. on welfare, employment, or tax revenues). In its response, society needs to prioritize which of these impacts to address and what share of resources to spend on each respective adaptation. A prerequisite to achieving that end is an economic impact analysis that is consistent across sectors and acknowledges intersectoral and economy-wide feedback effects. Traditional Integrated Assessment Models (IAMs) are usually operating at a level too aggregated for this end, while bottom-up impact models most often are not fully comprehensive, focusing on only a subset of climate sensitive sectors and/or a subset of climate change impact chains. Thus, we develop here an approach which applies climate and socio-economic scenario analysis, harmonized economic costing, and sector explicit bandwidth analysis in a coupled framework of eleven (bio)physical impact assessment models and a uniform multi-sectoral computable general equilibrium model. In applying this approach to the alpine country of Austria, we find that macroeconomic feedbacks can magnify sectoral climate damages up to fourfold, or that by mid-century costs of climate change clearly outweigh benefits, with net costs rising two- to fourfold above current damage cost levels. The resulting specific impact information – differentiated by climate and economic drivers – can support sector-specific adaptation as well as adaptive capacity building.

Practical implications

The rise in greenhouse gas emissions has triggered manmade climate change, with past emissions already strongly determining its dimension up to mid-century and current and future emissions (respectively global emissions reductions) determining the severity of climate change beyond (IPCC, 2013). Climate change induces manifold impacts around the globe. Adaptation to climate change at the regional to local level is thus a crucial policy area to keep net ecological, economic and social damages within limits (IPCC, 2014). One core ingredient to frame adequate adaptation and respective policy is detailed knowledge on the impacts foreseen, across all fields, including system feedback, and in a consistent way. This information can then be used for relative comparison and prioritization of adaptation options both among impact fields and relative to other policy areas.

Sophisticated global and regional circulation models supply rich regional climate scenarios under future climate change (see e.g. for Europe Jacob et al., 2014). Impact studies build upon these scenarios to quantify the specific impacts within their very field and region, from agriculture to energy, tourism, or water supply, to name a few. Any such scenario analysis of future impacts requires the choice of not only a specific climate scenario but also of a socio-economic, land use and demographic scenario, making it difficult to compare results of any two of such studies, as these assumptions will usually differ. While quantifying climate impacts bottom-up is crucial, when it is done in such a scattered way, it is difficult to obtain consistent information for a cross-sectoral comparison.

The approach we present here closes this gap by first ensuring consistency across impact fields; i.e. covering all impact fields identified for a country, requiring their analysis to apply a common climate and socioeconomic scenario and – to identify ranges

* Corresponding author.
E-mail address: karl.steininger@uni-graz.at (K.W. Steininger).

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– respective consistent climate and socioeconomic scenario ensembles. Second, the approach also acknowledges the fact that any specific impact within one field (or economic sector) usually will trickle on to other sectors in the economy, causing impacts there as well, and also triggering macroeconomic feedback effects. An increase in heat waves, for example, triggers labour productivity loss in the manufacturing of machinery, which will raise the cost of intermediate inputs for many other sectors, affecting their output, price levels, and tax revenues in turn.

The analysis starts in each impact field by identifying all economically relevant impact chains potentially triggered by climate change, as well as a selection and application of models or appropriate estimates available to quantify the respective (bio)physical impacts such as harvest losses due to an increase in droughts (Fig. 1). As a second step, each physical impact is translated into an economic impact by means of a consistent costing approach. We distinguish five types of economic impacts: changes in productivity, in production cost, in investment requirement, in final demand or in public expenditures. Where market data are available, market evaluation approaches are applied; for health impacts and impacts on urban green, indirect approaches can be applied such as via Life Years Lost or preventive costs for expansion of parks to reduce heat island effects.

As a third step, the economy-wide and cross-sectoral effects are assessed within a multi-sectoral computable general equilibrium (CGE) model, with the inputs being the economic impacts originating in each field. This macroeconomic impact model analysis informs pertinent stakeholders about the economy-wide implications their impact fields trigger and might indicate a higher relevance of adaptation; it also informs stakeholders at the economy-wide scale, such as national ministries, about aggregate implications on e.g. tax revenues or unemployment rates, so they are able to react proactively. In comparison, Integrated Assessment Models (IAMs) are usually less suitable for both of these ends, as such models are both characterized by much less economic sector (interaction) detail and are based on much more aggregated impact functions.

To get informed on the spread of potential impacts, we identify as a fourth step which climatic and socioeconomic parameter constellations contribute to significantly higher (respectively lower) net damages, separately for each impact field. For a consistent evaluation, the starting point is the aggregate impact evaluation for one common mid-range climate and a reference socio-economic scenario across all impact fields. The bandwidth of results can be explored by appropriate combination of scenarios that enhance (or diminish) damages in specific sectors. For example, longer summer heat waves and increasing agricultural harvest losses can be consistent with higher winter temperatures that could raise winter tourism losses but will simultaneously induce higher benefits due to additional heating cost savings. Such impact field specific bandwidth analysis of impact ranges is crucial for well-designed explicit adaptation (e.g. height of dams to protect against riverine flooding), but also guides how socioeconomic development has to be steered to reduce vulnerability (e.g. social policy increasing equality will enhance adaptive capacity of the most vulnerable to respond to heat waves).

Finally, the communication strategy translates modelling results into fact sheets and narratives which inform stakeholders in a non-scientific language on the impacts for each impact field as well as in total, and point to limitations in coverage and modelling assumptions. For the application of this approach to Austria, these fact sheets are available in both German and English at http://coin.ccca.at.

Fig. 1 depicts the flow of analysis, integrating sectoral (bio)physical and economic impact assessments, the macroeconomic model, and range-of-impact analysis. Finally, a deliberate communication strategy of results acknowledges specific stakeholder information needs.

To see the type of results from such an approach, we provide exemplary results for climate change impacts in Austria by 2050 under the assumption that no additional public adaptation or mitigation measures are taken than those already agreed upon today ('inaction assumption'). Impact fields analysed are the fourteen identified for Austria by the Austrian Strategy for Adaptation to Climate Change (Federal Ministry of Agriculture, Forestry, Environment and Water Management, 2013): Agriculture, Forestry, Water Supply and Sanitation, Tourism, Energy, Construction and Housing, Human Health, Ecosystem Services/Biodiversity, Transportation and Mobility, Manufacturing and Trade, Cities as well as Spatial Planning (these two in our analysis considered as one field Cities and Urban Green), Protection from Natural Hazards, and Disaster Risk Management (with the last two here considered also as one field labeled Catastrophe Management).

We find significant cross-sectoral amplification of damages due to sectoral supply chain linkages: e.g. heat-induced productivity losses in manufacturing translate to damages across the whole economy at the three- to fourfold scale, or losses in overnight stays in winter tourism translate to 60% higher overall economic damages (as the former reduces intermediate supplies to the accommodation sector, e.g. of food). Economic gains due to climate change, such as reduced heating demand and higher crop yields in agriculture, turn out to be small relative to losses. Weather and climate-related economic damages are found to at least quadruple in a mid-range climate scenario by 2050 relative to today. Acknowledging different possible scenarios relevant to the impact fields indicates a range of damages from a quarter less to doubling these mid-range monetary damage values. However, for example, more than a third of these damages could be avoided by no further development in any flood-prone zones.

Such a consistent framework allows informed conclusions on adaptation in both spheres: explicit adaptation action but also the reduction of vulnerability, e.g. by steering socioeconomic development in such a way that construction in flood-prone zones is prohibited or poverty of the elderly is reduced which increases their heat adaptation capacity. The results, however, also point out the specific benefit of (global) greenhouse gas mitigation for the national and local scale.

Resource demands to carry out such an analysis – but also the feasibility of which impact fields can be included within a reasonable time frame – crucially depend on the availability of climate impact models and availability of base data sets in sufficient temporal and spatial resolution. Moreover, such a study necessitates inter- and transdisciplinary collaboration of (regional) climate scientists to supply an ensemble of (localized) climate scenarios, economists to advise impact field teams on consistent impact costing and transferring these impacts to the macroeconomic model, and a broad array of respective field scientists for each impact field analysed (from agronomists to different engineering disciplines).

Whether (bio)physical impact models are available or need to be set up has also important implications for resource demands. For the application to Austria, we evaluated only those impact chains where impact models had been available or for which impacts could be meaningfully transferred from other cases in the international literature based on the climate parameters. In our case, resources were used for running existing impact models for the new common climate and socioeconomic scenarios and respective climate dependent indicators, for translating physical impacts into economic ones in a consistent way, for setting up a macroeconomic model for the overall assessment and for devising the uncertainty (i.e. range-of-impacts) analysis and communication strategy. These tasks were accomplished by the collaboration of 18 research teams, involving a total of 42 researchers. The project was accomplished within 18 months, with results available in a book publication (Steininger et al., 2015a), one overall and ten impact field fact sheets, and a narrative document. The scale of total resource demand was close to half a million Euros for the breadth of impact fields analysed.