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Testing Climate Damage Functions Against Realized Impacts: Evidence from Belgium[1]

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Motivation and research question

As climate impacts are becoming increasingly visible, policymakers face growing pressure to quantify the economic impacts of climate change. Climate economics has spent more than four decades developing methods to translate physical climate change into economic impacts, most commonly through damage functions embedded in integrated assessment models. Yet these damage functions remain heavily contested and can imply substantially different effects from the same amount of warming, including at the country level. Crucially, these country-level estimates have rarely been confronted with observed climate damages.

With global temperatures now close to 1.5°C above pre-industrial levels, climate change is no longer only a future counterfactual: a substantial amount of warming has already occurred. This creates an opportunity to ask the following research question:

- How can an observed bottom-up accounting of climate impacts be used to validate, refine, and ultimately improve the damage functions used to inform climate-policy analysis?

Why a new validation approach is needed

Existing country-level climate damage functions rely on two main methodological approaches, each with important limitations. For temperature damages, a large empirical literature beginning with Dell, Jones, and Olken (2012, 2014), Burke, Hsiang, and Miguel (2015), and Hsiang (2016) exploits panel variation in weather realizations to estimate causal relationships between temperature and economic outcomes. The literature has since expanded rapidly across countries, sectors, and outcomes and is now the empirical foundation for the headline climate-impact estimates used in policy analysis, including the damage functions that underpin social cost of greenhouse gas estimates. Recent work, however, highlights fundamental limits to this approach (Lemoine, Hausman, and Shrader, 2026; Curtin and Burgess, 2026).

Sea-level-rise damages are constructed very differently. Leading policy-facing integrated assessment models rely on the CIAM model developed by Diaz (2016). Rather than recovering damages from historical variation in economic outcomes, CIAM is an *ex ante* modelling framework that combines physical sea-level rise with assumptions about coastal exposure, adaptation, and residual damages under alternative policy responses. Its damage estimates therefore depend more heavily on the credibility of the physical, behavioral, and adaptation assumptions embedded in the model.

Despite these different methodological traditions, temperature and sea-level-rise damage functions share a common epistemological feature: they have largely been judged by scrutinizing how they are constructed. These questions remain essential, but they are not the only way to assess a model. In the spirit of Friedman's (1953) billiard-player analogy, we can also ask whether its predictions correspond to observed outcomes. Until recently, climate change offered little scope for such a test because most damages lay in the future. With substantial warming and measurable sea-level rise now realized, that is changing. Climate damage functions can increasingly be judged not only by how they are built, but also by whether they match observed reality.

[1] This work does not necessarily represent the views of the National Bank of Belgium or the Eurosystem.

A small recent literature has begun to quantify already-realized climate damages using bottom-up approaches. Frame et al. (2020) and Newman and Noy (2023) combine event attribution with observed economic losses, while Clausing, Knittel, and Wolfram (2025) broaden the accounting across impact channels and show that many current impacts arise through mechanisms not represented in IAMs. Most closely related is Emmerling, Waidelich, Bellon, and Massetti (2026), who ask whether augmenting IMF country-year GDP forecasts with commonly used temperature damage functions improves forecast quality. Our approach additionally covers sea-level-rise damages and allows us to assess which components of sectoral temperature damage functions are consistent with observed impacts.

Methodological approach

We will operationalize this idea by constructing a bottom-up accounting of realized climate damages in Belgium at today's level of warming and comparing those estimates with the damages implied by the key frontier IAMs: META (Dietz et al., 2021; Stoerk et al., 2025), GIVE (Rennert et al., 2022) and DSCIM (Rode et al., 2021; Carleton et al., 2022). These models span the main damage-function approaches currently used in policy analysis. All distinguish temperature from sea-level-rise damages, but their temperature components differ substantially: META uses an aggregate GDP damage function based on Burke, Hsiang, and Miguel (2015), while GIVE and DSCIM aggregate sector-specific empirical estimates for mortality, energy, agriculture, and other channels.

Contribution to SC-CO2 headline estimate in US EPA (2023), Table 3.1.4

	Energy	*Agriculture*
GIVE	$10	$103
DSCIM	-$4	$4

Despite producing social-cost-of-carbon estimates of similar overall magnitude, the US EPA's (2023) social cost of carbon estimates show that GIVE and DSCIM can differ sharply by channel - for example, even in the sign of energy damages, and by orders of magnitude for agriculture.

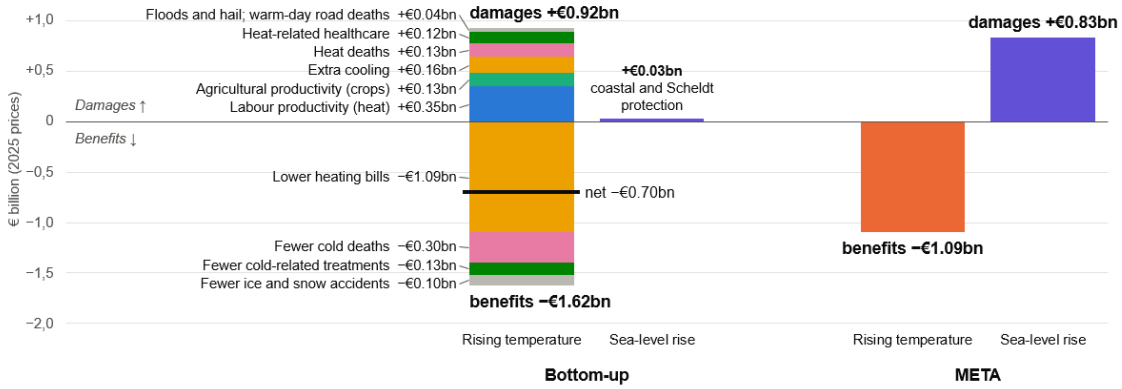
The bottom-up accounting will draw on both academic studies and the rapidly expanding body of policy and technical assessments of climate impacts in Belgium, which we will harmonize into a common economic framework. For temperature-related impacts, we will identify the main sectors and outcomes through which climate change could plausibly affect economic welfare in Belgium and assemble the best available evidence on realized effects to date. For sea-level rise, we will separately account for observed and avoided damages, including the role of existing coastal protection and adaptation.

Belgium is a particularly useful testing ground for both major damage channels. For temperature, leading damage functions disagree even about the sign of the effect at current warming levels, making realized outcomes especially informative for discriminating between competing estimates. For sea-level rise, Belgium has a substantial low-lying coastal area containing major economic activity, making it a useful test of modelled coastal damages and adaptation responses.

We will then map these bottom-up estimates onto the same broad damage categories represented in META, GIVE and DSCIM, allowing a direct comparison between observed outcomes and model-implied country-level damages. Where attribution is uncertain given the slow-moving nature of both temperature change and sea-level rise or evidence is incomplete, we will construct transparent ranges rather than forcing point estimates. The objective is not to claim a perfectly measured realized damage number, but to ask whether a frontier integrated assessment model delivers estimates broadly consistent with the order of magnitude, sign, and composition of damages observed in the real economy.

Bottom-up benchmark and expected results

Expected display item 1: Monetized climate impacts in Belgium for 2025, bottom-up vs. META, split by impacts channel (temperature vs sea-level rise) and impact category for bottom-up estimate. [Data displayed here are mock data to illustrate the approach.]



The figure uses mock data to illustrate the channels expected *a priori* to dominate current Belgian climate impacts. We will consider both extreme events and slow-moving changes and distinguish temperature from sea-level-rise damages, allowing direct comparison with IAM estimates whose component effects may differ even in sign at current warming levels.

Our hope is that realized damages can ultimately provide an empirical constraint on future damage projections, analogous to observational constraints in climate science (Portmann et al., 2026): damage functions that better reproduce impacts at current warming levels would receive greater weight in assessing the range of plausible future damages.

Both bottom-up and IAM estimates are uncertain; we will quantify this uncertainty explicitly in the comparison. META additionally allows climatic tipping points to be switched on and off separately. This matters because tipping-point damages are often treated as a distinct source of potentially large climate risk, yet their contribution at current warming levels is difficult to assess empirically. We will therefore ask whether including tipping-point channels moves total model-implied damages closer to or further from the bottom-up benchmark.

Policy relevance and broader contribution

The policy relevance of this exercise extends beyond model validation. Climate-policy targets are often set without explicitly tying their stringency to monetized estimates of avoided climate damages, in part because such estimates remain highly uncertain. This is particularly true in Europe, where climate targets have traditionally not been calibrated through explicit cost-benefit analysis. As climate policy becomes increasingly central to economic policy, credible estimates of climate damages are becoming correspondingly more important for governments and central banks..

Against this background, the paper makes two contributions. First, it evaluates climate damage functions by confronting model-implied country-level damages with realised economic outcomes, allowing us to assess not only whether aggregate estimates are plausible but also which components perform well and which may require revision. Second, it provides a transparent bottom-up accounting of current climate damages in Belgium across temperature, sea-level rise, and, where relevant, tipping-point channels. More broadly, the Belgian case illustrates how realised climate impacts can provide an additional empirical benchmark for assessing damage functions alongside their underlying assumptions and estimation methods. The approach is designed to be replicable across countries and warming levels.

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