Evaluating the Spatial Consequences of a Tipping Point*

José-Luis Cruz
FRB of New York

Klaus Desmet
SMU

Esteban Rossi-Hansberg
University of Chicago

February 18, 2026

Abstract

The Atlantic Meridional Overturning Circulation (AMOC) is a system of ocean currents that plays a key role in regulating global climate, including moderating temperatures in Europe and the North Atlantic. Its potential collapse due to global warming is widely considered one of the more likely climate tipping points. This paper examines the economic implications of such a collapse using a dynamic spatially integrated assessment model (S-IAM) of the world economy. Scandinavia and parts of Russia are predicted to experience significant losses in GDP and welfare, while southern Europe, northern Africa, and Brazil benefit from slightly colder temperatures. While S-IAMs generally predict that global warming is especially harmful to low-income regions, an AMOC collapse could mitigate some of these negative impacts in parts of the developing world, while instead harming some of the more advanced economies.

Keywords: climate tipping points, AMOC, spatially integrated assessment models, geography, development
JEL Codes: F18, F64, O11, Q54, Q56, R11

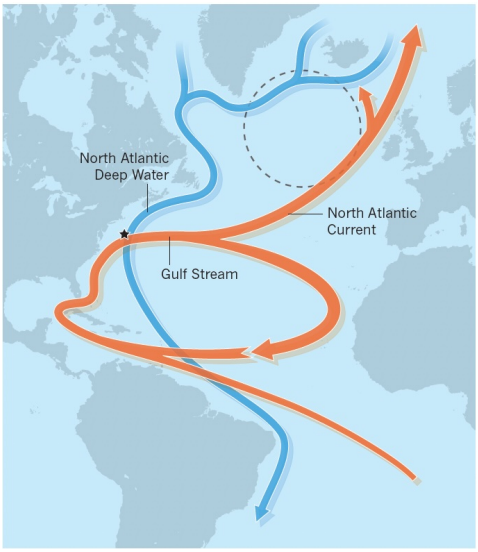
1 Introduction

The Atlantic Meridional Overturning Circulation (AMOC) is a system of ocean currents that transports warm, salty water northward near the surface and returns colder, denser water southward at depth. The AMOC has a profound impact on the global climate, including keeping northwest Europe warmer than other regions at comparable latitudes during the winter months. Global warming weakens these currents, and if temperatures reach a certain threshold, a climate tipping point may be crossed at which the AMOC starts to collapse. While climate science has extensively studied this potential collapse, its economic consequences remain poorly understood. This paper uses a global spatially integrated assessment model (S-IAM) to examine the economic impact of this climate tipping point across the globe.

The AMOC functions as a conveyor belt driven by thermohaline forces — that is, differences in temperature and salinity. In the subpolar North Atlantic, surface ocean waters lose heat to the cold atmosphere, increasing their density. In addition, waters from the subtropics, made saltier by evaporation, are transported northward. This raises the salinity of surface waters in the North Atlantic, further increasing their density. The resulting density differences between surface and deep waters in the North Atlantic lead to deep convection, the process of waters

*Cruz: Federal Reserve bank of New York, jose-luis.cruz@ny.frb.org, Desmet: Department of Economics and Cox School of Business, Southern Methodist University, kdesmet@smu.edu, Rossi-Hansberg: Department of Economics, University of Chicago, earossih@uchicago.edu.

Figure 1: The Atlantic Meridional Overturning Circulation (AMOC)



Source: Royal Meteorological Society. The Atlantic Meridional Overturning (AMOC) transports warm, salty surface water from the subtropics to the North Atlantic and returns cold water at depth.

moving vertically to depths of 1,000–4,000 m. To balance the mass of water in the ocean, deep waters must rise in other regions, most notably in the Southern Ocean. This vertical movement, whereby surface waters sink in the North Atlantic and rise back to the surface in the Southern Ocean, is referred to as overturning. It is what gives rise to the conveyor belt nature of the AMOC which transports warm surface water from the subtropics to the North Atlantic and returns cold water at depth (Figure 1).

With global warming, surface waters in the North Atlantic become less cold, and with the melting of the Greenland ice sheet, their salinity declines. Both mechanisms make the surface water less dense, weakening deep convection. As the AMOC slows down, less salty water from the subtropics is transported northward. This makes surface waters in the North Atlantic even lighter, further weakening the overturning. Once a certain threshold is reached, this salt advection feedback mechanism becomes self-reinforcing and a climate tipping point is crossed: the AMOC collapses, as it transitions from a state with strong, deep overturning to one with weak, shallow overturning.

An AMOC shutdown redistributes heat across the globe, cooling large parts of the Northern Hemisphere while warming parts of the Southern Hemisphere. Because it is triggered by global warming, in some regions the cooling from an AMOC collapse may offset the temperature increases due to climate change. In high northern latitudes, such as Scandinavia and Russia, the net effect is expected to be substantial cooling, whereas in certain areas below the Equator, including Argentina, the effects of global warming may be amplified. An AMOC shutdown can therefore be interpreted as a spatial shock, affecting productivity and well-being heterogeneously across locations. Once a tipping point is reached, the associated temperature response is unlikely to be abrupt; instead, it is expected to materialize gradually over time (Drijfhout et al., 2025).

To evaluate the economic impact of an AMOC collapse across time and space, this paper uses the spatially integrated assessment model (S-IAM) of Cruz and Rossi-Hansberg (2024). This model features damage functions for productivity and amenities, and explicitly incorporates spatial linkages through trade and migration flows. Adaptation can occur through trade, migration, and endogenous innovation. It furthermore allows for substitution

between clean and carbon-based energy. The model is quantified at a $1° \times 1°$ spatial resolution for the entire globe, allowing for projections at a fine geographic scale rather than solely at the regional or country level. Starting in 2021, we simulate the model forward and assume that a tipping point is reached when global mean surface temperature rises to +3°C above preindustrial levels (van Westen et al., 2024). Once this threshold is crossed, we impose local temperature changes associated with an AMOC shutdown based on estimates from van Westen and Baatsen (2025), assuming that this temperature shock unfolds gradually over time.

Our analysis yields several key findings. First, Scandinavia and parts of Russia are projected to experience significant losses in GDP and welfare, while southern Europe, northern Africa, and Brazil benefit from slightly cooler temperatures. Second, although S-IAMs typically predict that global warming disproportionately harms low-income regions, an AMOC collapse may mitigate some of these adverse effects in parts of the developing world, while instead harming several advanced economies. Third, the overall global welfare impact is negative, though modest in magnitude. Fourth, while northern Europe loses and southern Europe gains, the geographic boundary between winners and losers shifts northward under higher emissions scenarios.

The potential collapse of the AMOC has been studied extensively by climate scientists, with some debate about whether a tipping point is likely to be reached in this century. The most recent report of the Intergovernmental Panel on Climate Change (IPCC) concludes that an AMOC decline is "very likely" over the 21st century, while expressing "medium confidence" that it will not undergo an abrupt collapse before 2100 (Fox-Kemper et al., 2021). In contrast, van Westen et al. (2024) estimate a critical threshold at a global mean surface temperature increase of +3°C above preindustrial levels, concluding an AMOC collapse before the end of the 21st century is more likely than not ($\geq 50\%$) under a middle-of-the-road emissions scenario and very likely ($\geq 90\%$) under a high emissions scenario. Using a statistical analysis of early warning signals, Ditlevsen and Ditlevsen (2023) estimate a collapse of the AMOC by the middle of this century. Part of the apparent disagreement between the IPCC and these studies may stem from the IPCC referring to an "abrupt" collapse. As shown by Drijfhout et al. (2025), once a tipping point is reached, the shutdown is likely to occur only gradually over the subsequent 100 years.

A few studies have evaluated the economic impact of tipping points, such as an AMOC collapse. Using an integrated assessment model with country-specific damage functions, Dietz et al. (2021) estimate that an AMOC slowdown reduces the social cost of carbon by 1.4% by reducing damages from warming, particularly in Europe. Anthoff et al. (2016) similarly finds modest positive effects, as the cooling largely amounts to reduced warming. However, the integrated assessment models used in these papers do not incorporate spatial linkages in the form of trade and migration. Instead, the geographic heterogeneity is limited to incorporating country-specific damage functions.

The rest of the paper is organized as follows. Section 2 summarizes the key elements of the S-IAM of Cruz and Rossi-Hansberg (2024) and describes the quantification of an AMOC shutdown. Section 3 discusses the global economic impact of a potential AMOC collapse. Section 4 zooms in on Europe, the continent expected to be most affected by this tipping point. Section 5 focuses on the spatial impact of an AMOC collapse. Section 6 concludes.

2 Framework and Quantification

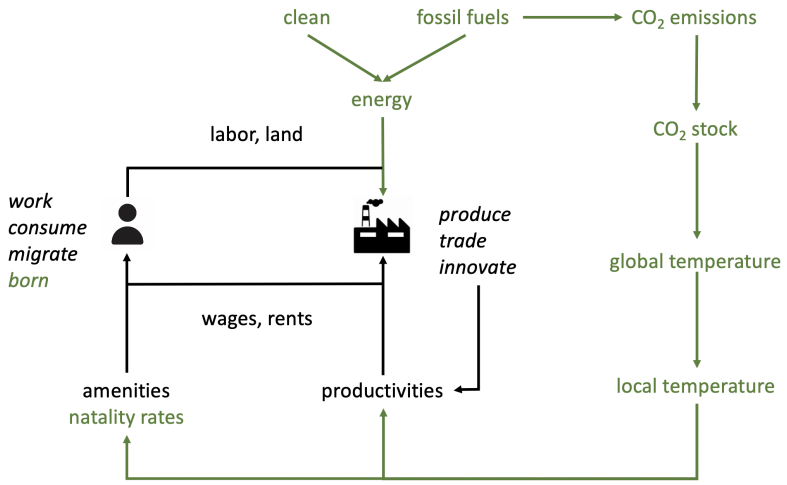
To analyze the spatial economic impact of a potential AMOC collapse, we use the S-IAM developed by Cruz and Rossi-Hansberg (2024) and combine it with high-resolution, time-varying estimates of the temperature effects of such a collapse. In this section, we briefly describe the key features of the model and its quantification, and refer

the interested paper to the original paper for further details.

2.1 Framework

Figure 2 provides a graphical overview of the Cruz and Rossi-Hansberg (2024) model. Individuals reside in different locations across the globe, where they work and consume. They may also choose to migration, albeit at a cost. Firms use labor and a combination of clean and dirty energy inputs, invest in innovation, and engage in costly trade. Economic activity, through the use of fossil fuels, generates global warming, which in turn affects firms' productivity as well as local consumption amenities.

Figure 2: Graphical Overview of the S-IAM by Cruz and Rossi-Hansberg (2024)



Endowments and preferences. The world economy occupies a two-dimensional surface S, where each location is defined by a point $r \in S$ with land density $H(r)$. In each period t, the world economy is populated by L_t agents.

An agent derives utility from consuming a set of differentiated varieties, c_t^ω, from local amenities, $b_t(r)$, and from their idiosyncratic preference for the location where they reside, $\varepsilon_t^i(r)$. When agents move from r to s in period t, their utility is discounted by a permanent flow utility cost $m(r,s)$ incurred in t and all subsequent periods. More specifically, the period utility of an agent i residing in location r in period t, having previously resided in locations $\bar{r}_- = (r_0, \ldots, rt-1)$, is given by:

$$u_t^i(\bar{r}_-, r) = \underbrace{\left[\int_0^1 c_t^\omega(r)^\rho d\omega\right]^{1/\rho}}_{\text{consumption}} \underbrace{b_t(r)\varepsilon_t^i(r)}_{\text{amenities}} \underbrace{\prod_{\ell=1}^{t} m(r_{\ell-1}, r_\ell)^{-1}}_{\text{moving costs}}$$

Local amenities diminish with congestion, so

$$b_t(r) = \bar{b}_t(r) L_t(r)^{-\lambda},$$

where the fundamental component of amenities, $\bar{b}_t(r)$, evolves over time as a function of temperature,

$$\bar{b}_t(r) = \Big(1 + \Lambda^b(\Delta T_t(r), T_{t-1}(r))\Big)\bar{b}_{t-1}(r).$$

$\Lambda^b(\cdot)$ is the amenities damage function. Depending on a location's initial temperature and the magnitude of the temperature change it experiences, amenities may either deteriorate or improve over time. This constitutes the first channel through which climate change affects the economy.

The permanent flow utility cost incurred by moving from r to s is the product of an origin-specific cost, $m_1(r)$, and a destination-specific cost, $m_2(s)$. As in Desmet, Nagy, and Rossi-Hansberg (2018), remaining in the same location is costless, so $m_2(r) = m_1(r)^{-1}$. Hence, the permanent flow utility cost associated with moving into a location is compensated by a permanent flow utility benefit when moving out of that location. This implies that immigrants in location s only pay the cost associated with moving in while residing in s. As a result, the migration decision is fully reversible. This simplifies the forward-looking dynamic migration problem to a sequence of static decisions.

Technology. Output per unit of land of a firm in location r producing variety $\omega \in [0, 1]$ is given by

$$q_t^\omega(r) = \phi_t^\omega(r)^{\gamma_1} z_t^\omega(r) \left(L_t^{\omega(r)^\chi} e_t^{\omega(r)^{1-\chi}}\right)^\mu,$$

where $L_t^\omega(r)$ are labor inputs, $e_t^\omega(r)$ are energy inputs, $\phi_t^\omega(r)$ is productivity due to innovation, and $z_t^\omega(r)$ is an exogenous productivity shifter. Investing in innovation requires $\nu\phi_t^\omega(r)^\xi$ units of labor, and the productivity shifter is the realization of a random variable from a Fréchet distribution with c.d.f. $F(z, a) = e^{-a_t(r)z^{-\theta}}$. The scale parameter $a_t(r)$ determines the level of productivity, and it benefits from agglomeration economies,

$$a_t(r) = \bar{a}_t(r)L_t(r)^\alpha,$$

where the fundamental level of productivity follows a dynamic process,

$$\bar{a}_t(r) = (1 + \Lambda^a(\Delta T_t(r), T_{t-1}(r))\phi_{t-1}(r)^{\theta\gamma_1} \left(\int_S D(v, r)\bar{a}_{t-1}(v)dv\right)^{1-\gamma_2} \bar{a}_{t-1}^{\gamma_2}.$$

It depends on past innovation, $\phi_{t-1}(r)$, past technology in the own location, $\bar{a}_{t-1}$, technology diffusion from other locations, $\int_S D(v, r)\bar{a}_{t-1}(v)dv$, and the productivity damage function, $\Lambda^a(\cdot)$. This constitutes the second channel through which climate change affects the economy. As in Desmet et al. (2018), the model assumes that past innovations benefit all potential entrants, so that also the dynamic forward-looking innovation decision simplifies to a sequence of static decisions. Goods can be traded across locations, at a cost, and trade balance holds location by location.

Energy. Energy is a CES composite of fossil fuels, $e_t^{f,\omega}(r)$, and clean energy, $e_t^{c,\omega}(r)$,

$$e_t^\omega(r) = \left(\kappa e_t^{f,\omega}(r)^{\frac{\epsilon-1}{\epsilon}} + (1-\kappa)e_t^{c,\omega}(r)^{\frac{\epsilon-1}{\epsilon}}\right)^{\frac{\epsilon}{\epsilon-1}}.$$

Producing one unit of energy costs $\mathcal{Q}_t^j(r)$ units of labor,

$$\mathcal{Q}_t^f(r) = \frac{f(CumCO2_t)}{\zeta_t^f(r)} \quad \text{and} \quad \mathcal{Q}_t^c(r) = \frac{1}{\zeta_t^c(r)}$$

where $f(\cdot)$ denotes the extraction cost of fossil fuels, which is increasing and convex in cumulative CO_2, and $\zeta_t^j(r)$ is the productivity in energy generation, which increases in the growth of global GDP:

$$\zeta_t^j(r) = \left(\frac{y_t^w}{y_{t-1}^w}\right)^{\upsilon^j} \zeta_{t-1}^j(r)$$

Relationship between the economy and climate. As discussed above, climate affects the economy through the damage functions for amenities and productivity. Conversely, the economy affects climate through the use of fossil fuels, as CO_2 emissions raise global temperature. Following IPCC (2013), the stock of carbon in the atmosphere, S_t, evolves according to

$$S_{t+1} = S_{\text{pre-ind}} + \sum_{\ell=1}^{\infty}(1-\delta_\ell)\left(E_{t+1-\ell}^f + E_{t+1-\ell}^x\right). \tag{1}$$

where E_t^f denotes the endogenous global CO_2 emissions from fossil fuel combustion, E_t^x denotes exogenous CO_2 emissions from non-fuel sources, $S_{\text{pre-ind}}$ is the preindustrial atmospheric CO_2 stock, and $(1-\delta_\ell)$ is the fraction of CO_2 emissions remaining in the atmosphere ℓ periods later.

Higher atmospheric CO_2 concentrations increase radiative forcing, F_{t+1}, which is given by

$$F_{t+1} = \varphi \log_2(S_{t+1}/S_{\text{pre-ind}}) + F_{t+1}^x, \tag{2}$$

where φ denotes the forcing sensitivity to the atmospheric carbon stock and F_t^x represents radiative forcing from non-CO_2 greenhouse gases.

With positive radiative forcing, when the inflow of energy exceeds the outflow, global temperature increases:

$$T_{t+1} = T_{\text{pre-ind}} + \sum_{\ell=0}^{\infty}\zeta_\ell F_{t+1-\ell}, \tag{3}$$

where $T_{\text{pre-ind}}$ denotes preindustrial global mean surface temperature and ζ_ℓ is the current temperature response to an increase in the radiative force ℓ periods earlier.

Because our analysis focuses on local temperature changes, we downscale changes in global temperature to the local level by assuming

$$\Delta T_t(r) = g(r) \cdot \Delta T_t \tag{4}$$

where $g(r)$ determines the sensitivity of temperature in cell r to a one °C change in global temperature.

2.2 Quantification and Simulation

The model is quantified following Cruz and Rossi-Hansberg (2024), with the modification that 2021 is used as the base year. This requires updating several data inputs. In particular, high-resolution income data for 2021 come from the newly developed dataset of Rossi-Hansberg and Zhang (2025). We simulate the model forward until 2200 under two emissions scenarios: an intermediate-emissions scenario with emissions peaking by mid-century and subsequently declining (RCP 4.5), and a high-emissions scenario with emissions only starting to decline around 2100.

Within this framework, we assess the local and global economic consequences of a potential collapse of the AMOC. Based on an analysis of 24 CMIP6 models, van Westen et al. (2024) conclude that a tipping point is likely to be reached when the global mean surface temperature increases by approximately $+3°$C above preindustrial levels. van Westen and Baatsen (2025) provide high-resolution estimates of the long-run temperature impact. Importantly, once the tipping point is crossed, the transition to the new long-run climate state is expected to be slow and gradual.

Incorporating these insights, we modify the equation governing the evolution of local temperature (4) to account for temperature changes in post-tipping point periods:

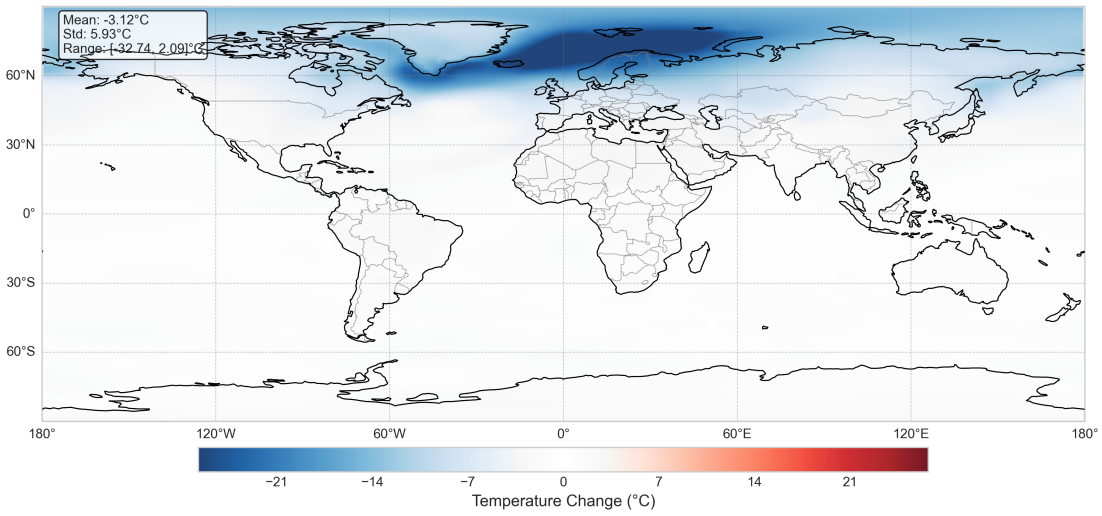
$$\Delta T_t(r) = \begin{cases} g(r) \cdot \Delta T_t, & \text{if } t < t_{\text{AMOC}}, \\ g(r) \cdot \Delta T_t + \left(1 - e^{-\phi(t - t_{\text{AMOC}})}\right) \cdot \Delta T_{\text{AMOC}}(r), & \text{if } t \geq t_{\text{AMOC}}. \end{cases} \tag{5}$$

Here, t_{AMOC} denotes the period in which the tipping point of $+3°$C is reached, $\Delta T_{\text{AMOC}}(r)$ is the total long-run local temperature change associated with an AMOC collapse, and ϕ is a parameter that governs the speed of temperature convergence to the new climate state. We set $\phi = 0.016$, implying that the AMOC loses approximately 80% of its strength within 100 years after the tipping point, consistent with estimates in van Westen and Baatsen (2025).

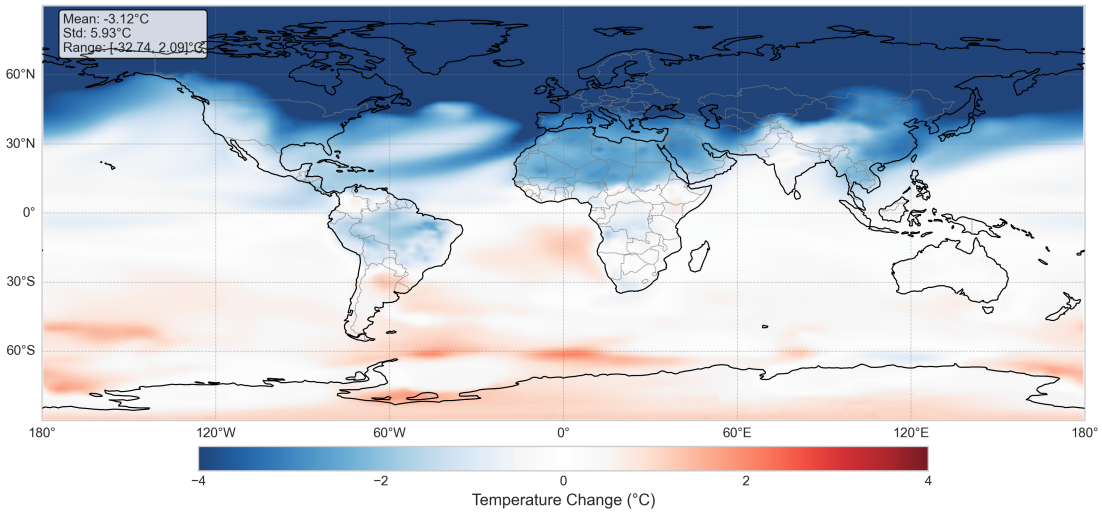
Figure 3 depicts the long-run winter temperature response to an AMOC collapse under emissions scenario RCP4.5, based on estimates from van Westen et al. (2024). Winter is defined as December–January–February in the Northern Hemisphere and June–July–August in the Southern Hemisphere. We focus on this season because the productivity and amenities damage functions in Cruz and Rossi-Hansberg (2024) are estimated for the winter months.

The top panel shows pronounced temperature declines concentrated in the high northern latitudes. Around Svalbard, temperatures fall by more than $25°$C, while changes elsewhere appear comparatively muted. However, the wide range of temperature changes, from $-32.7°$C to $+2.1°$C, masks many other regional impacts. These become clearer in the bottom panel, where the range of temperature changes has been restricted. Most of the Northern Hemisphere, including northern Africa, the Sahara, Brazil, and Southeast Asia, experiences cooling, whereas parts of the Southern Hemisphere, notably Argentina and Antarctica, show slight warming. Although an AMOC shutdown is mostly about redistributing heat across the globe, there is a $3.1°$C decline in global mean temperature.

Figure 3: Temperature Impact of Full Collapse of AMOC



(a) Temperature impact range from -25° to +25°C



(b) Temperature impact range from -4° to +4°C

Source: Based on data in van Westen et al. (2024).

3 The Global Economic Impact of an AMOC Collapse

This section evaluates the economic impact of an AMOC collapse across the globe. As a benchmark, we first simulate our model for a world with global warming, but without an AMOC shutdown. We find the standard result of many S-IAMs: climate change tends to be particularly detrimental for less developed regions, while advanced economies are less impacted and the northernmost latitudes even gain.

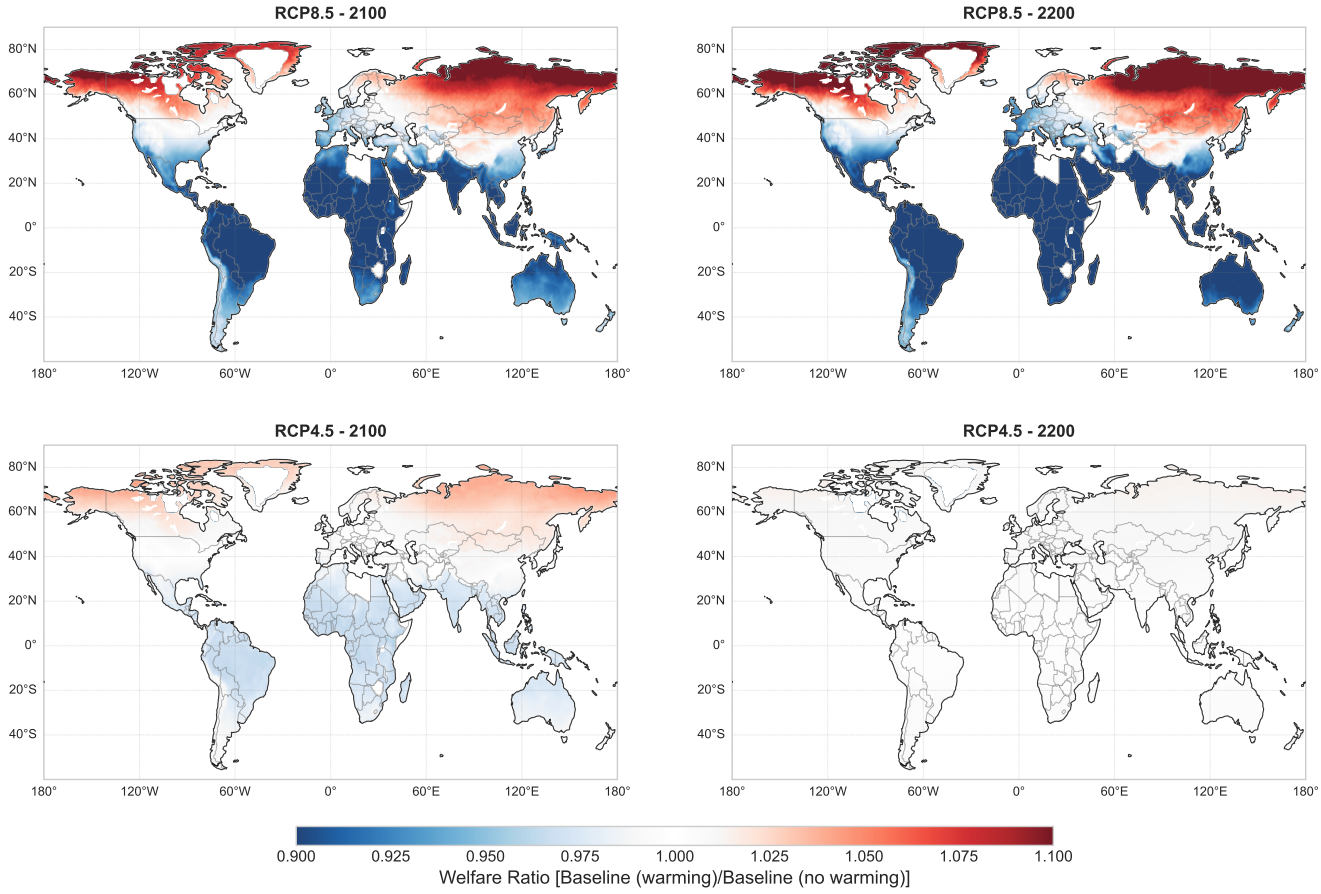
To examine the economic consequences of the AMOC shutting down, we then consider two comparisons. First, we compare an AMOC collapse to a baseline with global warming but no such collapse. We find that the shutdown

tends to mitigate the adverse effects of climate change in regions that would otherwise be harmed, while it negatively affects some advanced northern economies that would not suffer losses from global warming in the absence of an AMOC tipping point. Second, we compare the overall impact of climate change, including an AMOC collapse, to a world without global warming. Depending on the emissions scenario, the geography of which regions lose or gain is very different.

3.1 Benchmark: Global Warming in a World without an AMOC Collapse

Figure 4 depicts the welfare impact of global warming in 2100 and 2200, assuming the AMOC does not collapse. Specifically, it shows the ratio of welfare under either a high- or an intermediate-emissions world to welfare in a counterfactual world without anthropogenic CO_2 emissions after 2021.

Figure 4: Benchmark: Welfare Impact of Global Warming without AMOC Collapse



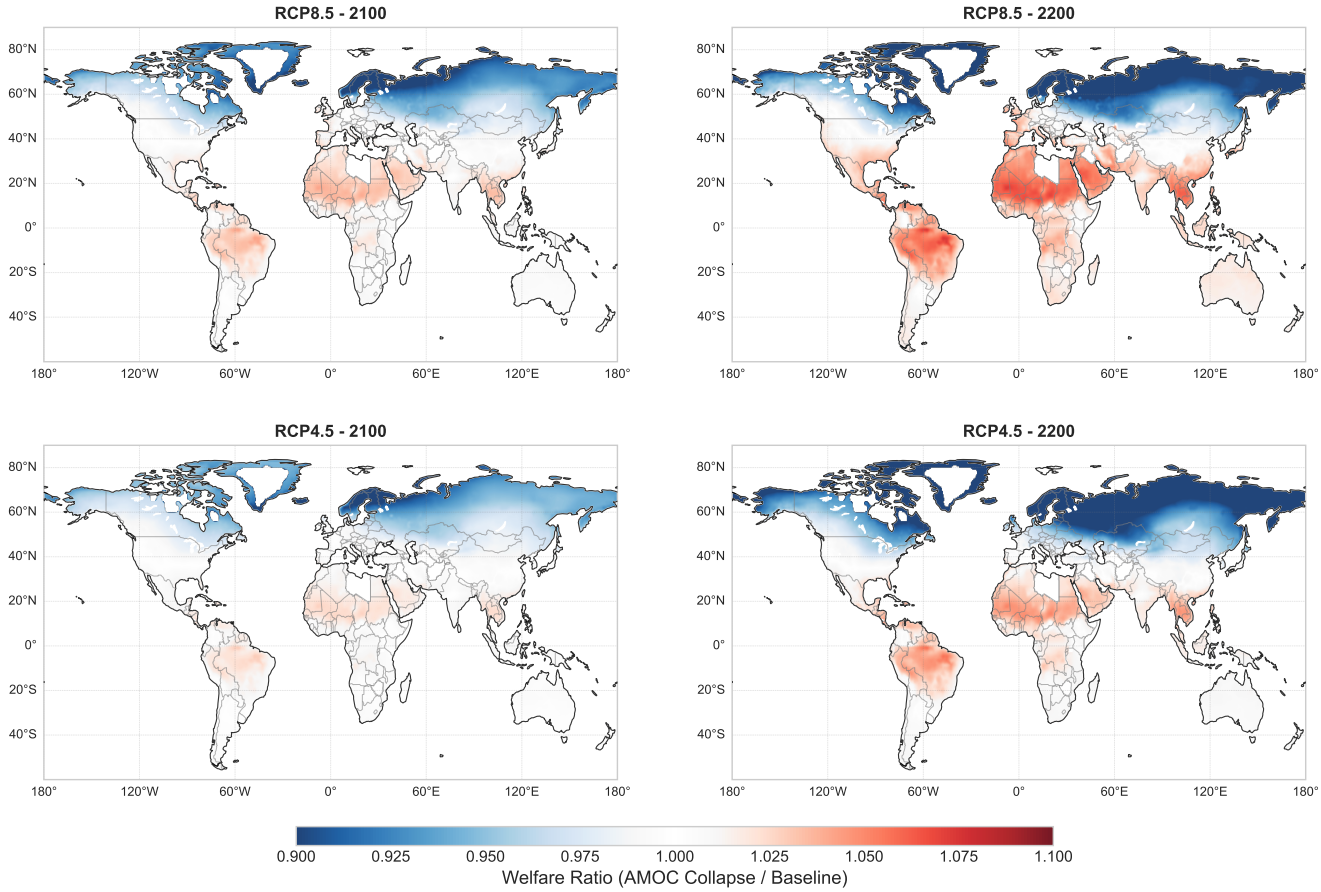
Global warming adversely affects most regions of the world, with the exception of those roughly north of the 50^{th} latitude, such as Scandinavia, Russia, and Canada. As expected, while qualitatively the results are similar, under the intermediate-emissions scenario (RCP 4.5), shown in the bottom panels, the effects are smaller than under the high-emissions scenario (RCP 8.5), shown in the top panels. Notably, under RCP 4.5, the welfare impact in 2200 is minimal. Because under this scenario emissions peak in the mid-21st century and then start to

decline, the average global temperature increase above preindustrial levels in 2200 is comparable to that observed in 2021.

3.2 First Comparison: Global Warming with and without an AMOC Collapse

As a first comparison, we examine the welfare impact of an AMOC collapse relative to a world with global warming but no AMOC shutdown. As previously shown in Figure 3, an AMOC collapse leads to a dramatic cooling in the northernmost latitudes of Europe. More broadly, most of the Northern Hemisphere experiences lower temperatures, including northern Africa, Brazil, and Southeast Asia. In contrast, temperatures increase modestly in the Southern Hemisphere, most notably in parts of Argentina.

Figure 5: First Comparison: Welfare AMOC Collapse vs Welfare No AMOC Collapse

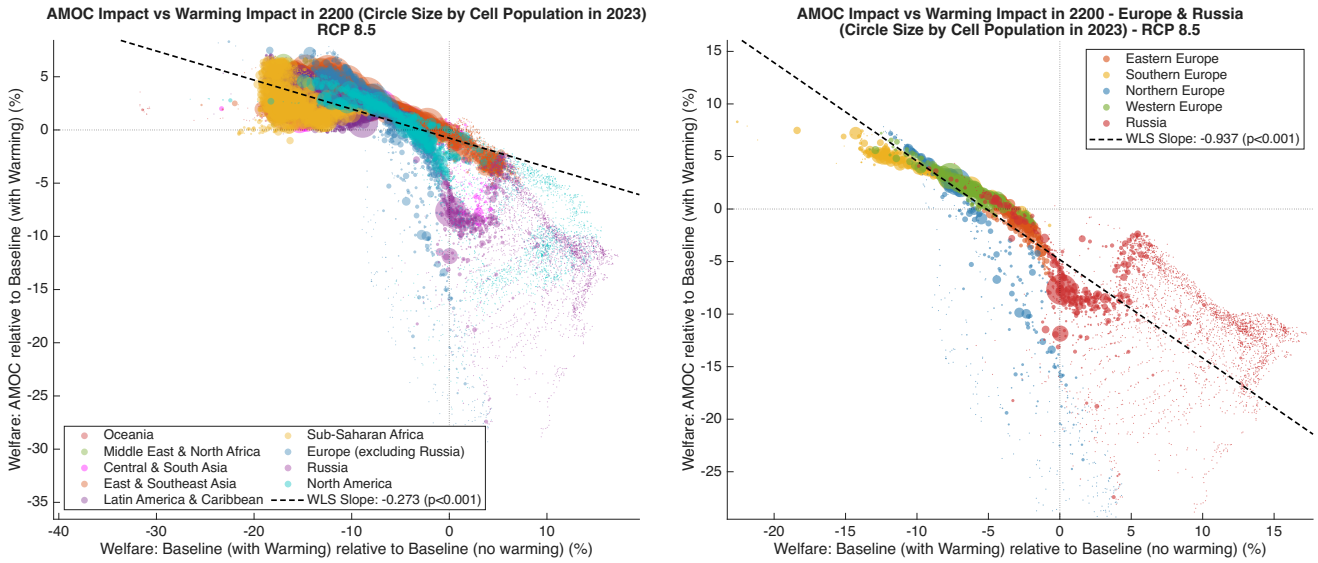


These temperature changes suggest that an AMOC collapse may reverse some of the spatial effects of global warming. In the Northern Hemisphere, we would expect the highest latitudes, where global warming is beneficial, to experience substantial welfare losses due to sharp cooling. In contrast, we would expect intermediate and more equatorial latitudes, where global warming is harmful, to see improved outcomes. This pattern is borne out in Figure 5, which reports the ratio of welfare under an AMOC collapse to welfare under a baseline with global warming but no collapse. Canada, Russia, and Scandinavia experience welfare losses, whereas northern Africa,

Brazil, and Southeast Asia experience welfare gains. The qualitative patterns are similar under RCP 8.5 (top panel) and RCP 4.5 (bottom panel), though gains in intermediate latitudes are larger under the high-emissions scenario. This result is intuitive: because welfare losses in these regions are convex in the degree of global warming, the temperature reductions associated with an AMOC shutdown generate disproportionately larger benefits.

Figure 6 provides an alternative way of showing that regions suffering the largest welfare losses from global warming tend to benefit the most from an AMOC collapse. It plots the welfare impact of an AMOC shutdown (relative to a global warming baseline without a collapse) against the welfare impact of global warming (relative to a counterfactual without global warming). The left panel includes all grid cells of the world, whereas the right panel focuses on Europe and Russia. The negative relationship indicates that locations experiencing smaller losses (or larger gains) from global warming tend to gain less (or lose more) from an AMOC shutdown.

Figure 6: Welfare Impact of AMOC Collapse and Losses from Climate Change



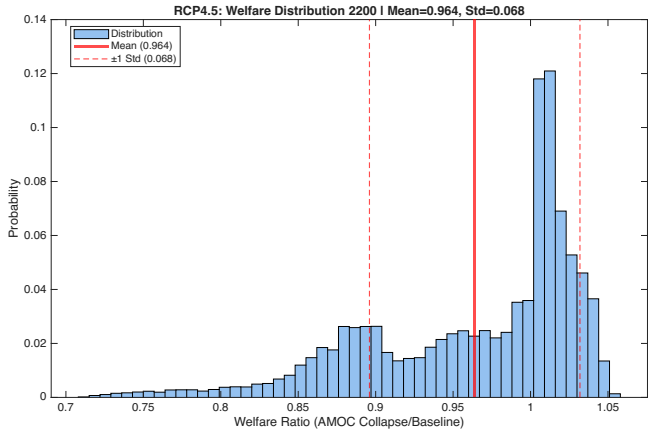
(a) World

(b) Europe and Russia

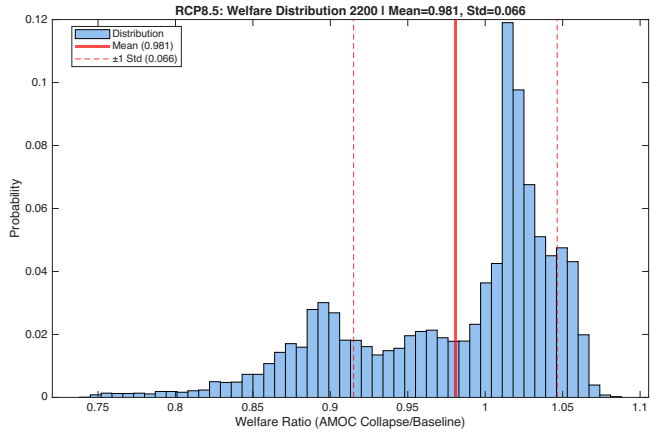
To further examine the losses and gains from an AMOC collapse, Figure 7 shows the distribution of welfare changes associated with the shutdown. Several findings stand out. First, although an AMOC collapse reverses some of the welfare effects of global warming, its overall impact is negative. Under RCP 4.5, the average grid cell experience a welfare loss of 3.6%. Second, because global warming is more damaging under RCP 8.5, the cooling induced by an AMOC collapse is beneficial in a larger number of grid cells, resulting in a smaller average welfare loss of 1.9%. Third, the distribution of welfare changes is asymmetric. Gains are modest and concentrated in the range of 1-5%, whereas losses exhibit a long left tail, with many locations losing more than 10%, and in some cases more than 20%. These large losses are concentrated in the northernmost latitudes, where cooling is most severe.

Figure 8 compares the time path of population-weighted welfare under a collapse of the AMOC with that of the baseline. As can be seen, a shutdown slightly reduces welfare, with larger losses under RCP 4.5 than under RCP 8.5. As discussed above, cooling is less detrimental in the high-emissions scenario, because global warming is more harmful in that case.

Figure 7: Distribution of Welfare Losses and Gains from the Collapse of AMOC

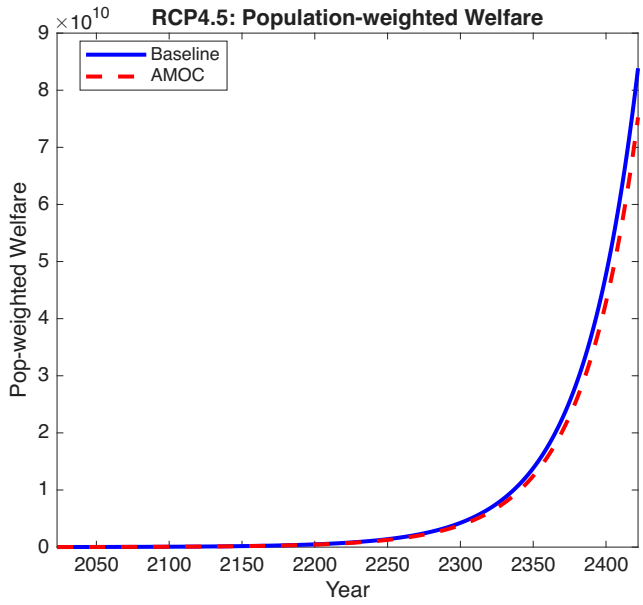


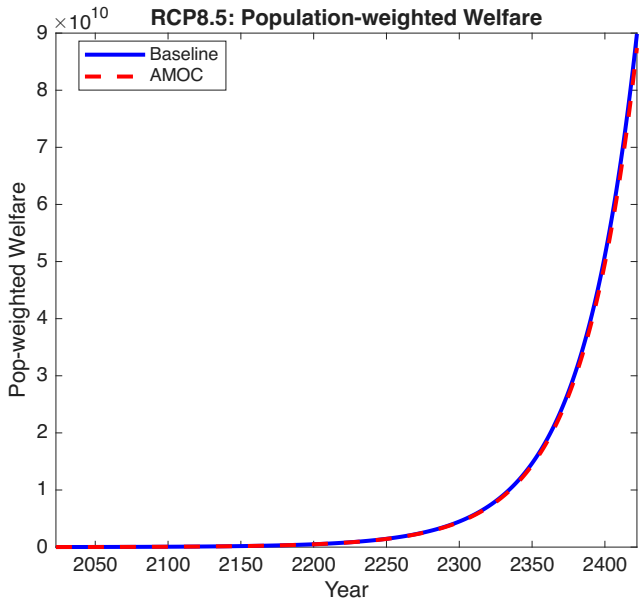
(a) Welfare ratio, RCP 4.5 in 2200
(relative to warming without collapse)



(b) Welfare ratio, RCP 8.5 in 2200
(relative to warming without collapse)

Figure 8: Aggregate Welfare Effect of a Collapse of AMOC





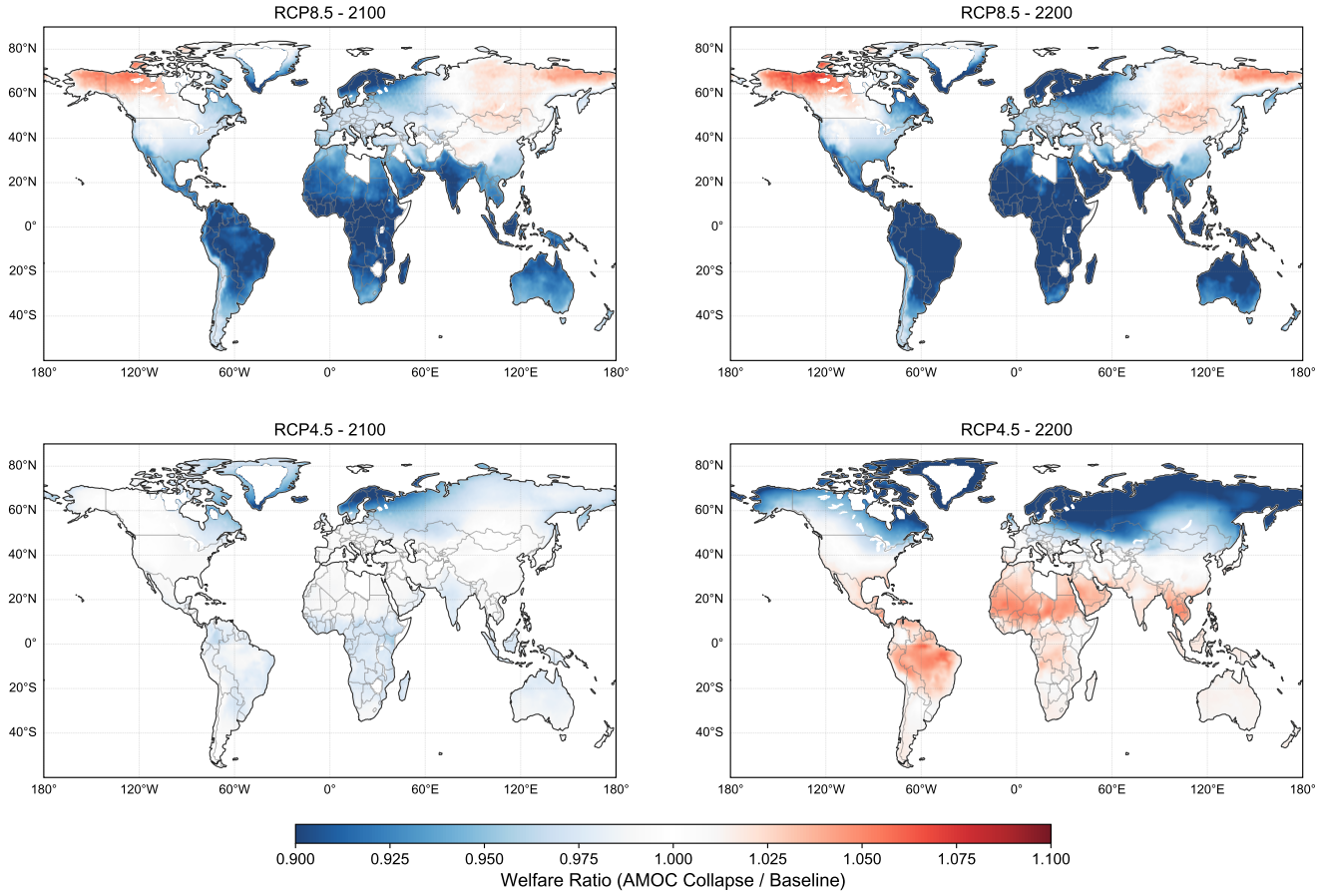
3.3 Second Comparison: AMOC Collapse Relative to World Without Warming

As a second comparison, we examine the welfare impact of an AMOC collapse relative to a world without global warming. Whereas the previous subsection compared global warming with and without an AMOC shutdown, here we assess the overall impact of climate change under the assumption that an AMOC collapse will occur once the global mean temperature exceeds the +3°C threshold.

Figure 9 depicts the ratio of welfare under an AMOC collapse to welfare in a counterfactual world without global warming for the years 2100 and 2200, under both RCP 8.5 (top panels) and RCP 4.5 (bottom panels). Assuming that the AMOC will indeed collapse if temperatures rise sufficiently, this figure can be interpreted as

the effective overall impact of global warming.

Figure 9: Welfare Impact of Global Warming with Collapse of AMOC



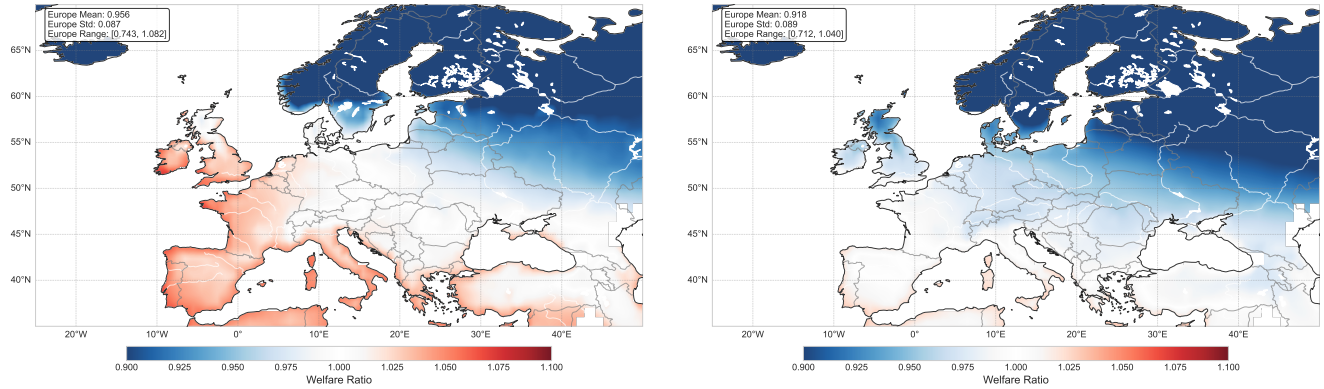
Comparing the top panels of Figures 9 and 4, a key finding is that under RCP 8.5 fewer regions benefit from global once the possibility of an AMOC collapse is taken into account. When an AMOC shutdown is ignored, northern latitudes tend to gain from global warming. When instead allowing for a shutdown, the extreme cooling in the North Atlantic offsets these gains, so that Scandinavia and parts of Russia and Canada lose from global warming. Only the region around Alaska continues to benefit from climate change. Losses in some other regions, such as North Africa, are partially mitigated, although the welfare impact there remains negative.

Under RCP 4.5, accounting for an AMOC collapse overturns some of the standard findings of spatially integrated assessment models (S-IAMs). As shown in the bottom-right panel of Figure 9, global warming hurts most regions north of roughly the US-Mexico border and the southern Mediterranean, while much of Africa, Latin America and Southeast Asia gains. Recall that when ignoring an AMOC shutdown, the welfare impact of global warming in 2200 under RCP 4.5 is minimal, reflecting the small temperature changes relative to 2021. More generally though, many standard S-IAMs find that the gains and losses from global warming are distributed in a way that increases spatial inequality by disproportionately harming developing regions. Our results imply the opposite: once we take into account the collapse of the AMOC, advanced economies are the big losers from global warming.

4 A Tale of Two Europes

The European media have at times described a potential AMOC shutdown in apocalyptic terms. For example, the *Daily Express* tabloid warned that it would "plunge Europe and [the] UK into [the] ice age" (November 12, 2025), while *The Economist* wrote that a shutdown "could freeze Europe" and suggested that "it could lay waste a continent—specifically, Europe—to an extent that only a nuclear war could outmatch" (August 14, 2025). Because Europe is likely to be among the regions most affected by an AMOC collapse, it is useful to zoom into what our model predicts for this continent.

Figure 10: Welfare Impact of Collapse of AMOC in 2200



(a) AMOC collapse 2200
(RCP 8.5 relative to no collapse)

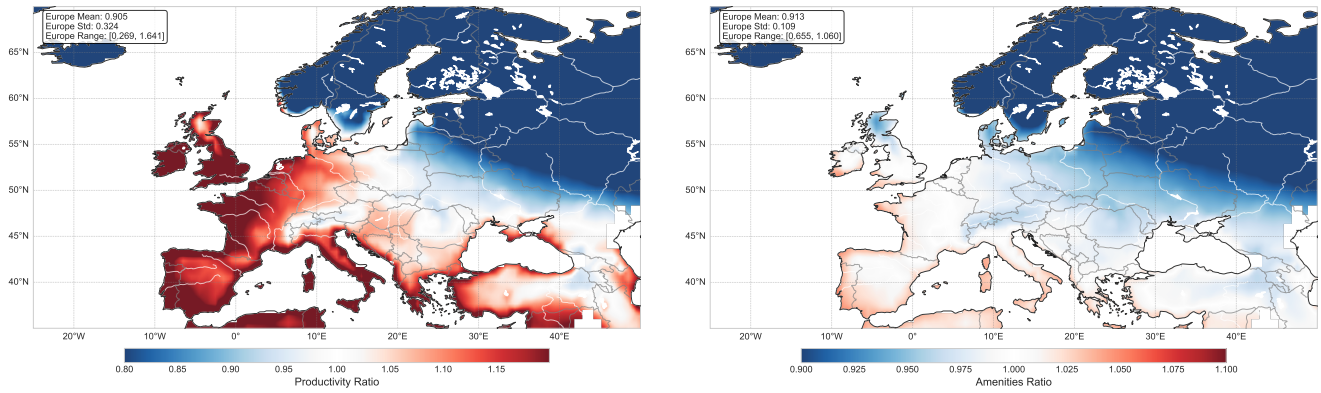
(b) AMOC collapse 2200
(RCP 4.5 relative to no collapse)

Figure 10 shows the welfare impact in 2200 of an AMOC collapse relative to a world with global warming but no AMOC shutdown. It is a closeup of the two right panels in Figure 5. Under RCP 8.5, with the exception of Scandinavia and Russia, most of Europe experiences a welfare gain from an AMOC collapse. Under RCP 4.5, the boundary between losers and winners shifts southward. In this intermediate-emissions scenario, all of northern and northwestern Europe loses, including the UK, Germany, the Benelux and parts of France, while only regions close to the Mediterranean benefit. Overall, an AMOC collapse splits Europe into losers and winners, with the location of the boundary between the two depending on the emissions scenario. Given that welfare losses from global warming tend to be convex in temperature, the cooling due to an AMOC shutdown is more beneficial for more regions under the high-emissions scenario.

To unpack the overall welfare effect of an AMOC collapse, we decompose the associated temperature shock into its effects on productivity and amenities. As shown in panel (a) of Figure 11, under RCP 8.5 a collapse of the AMOC improves productivity in most of Europe, with the exception of Norway, Sweden, Finland, and Russia. In contrast, when looking at the effect on amenities in panel (b), the boundary between losers and winners shifts southward, with parts of Germany, Scotland, Switzerland and much of Eastern Europe experiencing worse amenities.

This divergence reflects subtle differences in the damage functions of productivity and amenities. The temperature that maximizes productivity is slightly lower than the temperature that maximizes amenities. As a result, cooler temperatures may improve productivity while simultaneously reducing amenities in some regions. Western Europe lies in a temperature range where these two effects go in opposing directions.

Figure 11: Effect of an AMOC Collapse on Productivity and Amenities in 2200



(a) RCP 8.5, productivity ratio

(b) RCP 8.5, amenities ratio

5 Spatial Reallocation due to an AMOC Collapse

Previous studies on the economic impact of an AMOC collapse estimate the effect on output of the projected local temperature changes without incorporating spatial linkages. More specifically, these studies rely on country-specific damage functions and evaluate the country-level impact on output of the temperature change induced by an AMOC shutdown. In doing so, they abstract from the possibility that individuals may migrate in response to productivity changes, and from how such population reallocation affects trade and innovation. To illustrate how spatial reallocation operates in our S-IAM, this section examines how population and GDP reallocate across space following an AMOC collapse.

Table 1: Projected Effect of an AMOC Collapse on Population and GDP in 2200

	%Δ Population due to AMOC Collapse		%Δ GDP due to AMOC Collapse	
	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
Oceania	-0.79%	-1.66%	-0.65%	-1.14%
Middle East & North Africa	1.65%	2.70%	3.23%	5.91%
Central & South Asia	0.02%	0.07%	0.93%	1.63%
East & Southeast Asia	-1.23%	-0.86%	-0.31%	1.02%
Latin America & Caribbean	1.51%	1.12%	2.14%	2.22%
Sub-Saharan Africa	0.82%	0.37%	1.60%	1.64%
Europe (excluding Russia)	-7.59%	-3.12%	-6.67%	0.01%
Russia	-17.76%	-15.36%	-20.64%	-16.79%
North America	-4.08%	-3.05%	-3.52%	-1.62%
Total	0.00%	0.00%	0.45%	1.43%

Note: This table reports the percentage change in population and GDP in 2200 by region of the world of an AMOC collapse compared to a model with global warming but without an AMOC collapse.

Table 1 reports the percentage changes in population and GDP by world region resulting from an AMOC collapse, relative to a baseline scenario with global warming but without such a collapse. Under RCP 4.5, Russia experiences a population decline of 17.76%, compared to losses of 7.59% in Europe and 4.08% in North America. In contrast, the Middle East, Africa, and Latin America register modest gains of approximately 1–2%. The overall world population is unchanged by construction. Under RCP 8.5, population losses in Europe decline to 3.12%, reflecting the fact that the larger temperature increase associated with global warming partly offsets the cooling induced by an AMOC collapse.

The effects on economic size, as measured by GDP, are qualitatively similar to those on population: Russia experiences somewhat larger losses, whereas Europe's losses are slightly smaller. As Europe's population shifts from the less densely populated regions of Scandinavia toward the more densely populated central and southern parts of the continent, stronger local agglomeration economies emerge, partially offsetting the GDP decline associated with the continent's population loss.

6 Concluding Remarks

This paper has evaluated the spatial economic impact of a potential collapse of the Atlantic Meridional Overturning Circulation (AMOC). To this end, we have used a spatially integrated assessment model (S-IAM) that allows for costly adaptation through trade, migration and innovation. While this tipping point event is projected to have a limited negative impact on the world's overall welfare, we find that it partly overturns the standard finding that global warming increases spatial inequality as a result of developing regions bearing the brunt of the economic cost of climate change. Because an AMOC shutdown is predicted to induce severe cooling in the northernmost latitudes, alongside more modest cooling across much of the Northern Hemisphere, many developing regions in northern Africa, parts of Latin America, and Southeast are projected to gain if such a collapse occurs.

References

Anthoff, D., F. Estrada, and R. S. Tol (2016). Shutting Down the Thermohaline Circulation. *American Economic Review 106*(5), 602–606.

Cruz, J.-L. and E. Rossi-Hansberg (2024, March). The Economic Geography of Global Warming. *The Review of Economic Studies 91*(2), 899–939. rdad042.

Desmet, K., D. K. Nagy, and E. Rossi-Hansberg (2018). The Geography of Development. *Journal of Political Economy 126*(3), 903 – 983.

Dietz, S., J. Rising, T. Stoerk, and G. Wagner (2021). Economic Impacts of Tipping Points in the Climate System. *Proceedings of the National Academy of Sciences 118*(34), e2103081118.

Ditlevsen, P. and S. Ditlevsen (2023). Warning of a Forthcoming Collapse of the Atlantic Meridional Overturning Circulation. *Nature Communications 14*(1), 1–12.

Drijfhout, S., J. R. Angevaare, J. Mecking, R. M. van Westen, and S. Rahmstorf (2025). Shutdown of Northern Atlantic Overturning After 2100 Following Deep Mixing Collapse in CMIP6 Projections. *Environmental Research Letters 20*(9), 094062.

Fox-Kemper, B., H. Hewitt, G. Xiao, G. Aðalgeirsdóttir, S. Drijfhout, T. Edwards, N. Golledge, M. Hemer, R. Kopp, G. Krinner, A. Mix, D. Notz, S. Nowicki, I. Nurhati, L. Ruiz, J.-B. Sallée, A. Slangen, and Y. Yu (2021). Chapter 9: Ocean, Cryosphere and Sea Level Change. In V. Masson-Delmotte, P. Zhai, A. Pirani, S. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J. Matthews, T. Maycock, T. Waterfield, Ö. Yelekçi, R. Yu, and B. Zhou (Eds.), *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, pp. 1211–1362. Cambridge University Press.

IPCC (2013). In *Climate Change 2013: The Physical Science Basis: Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, United Kingdom and New York, NY: Cambridge University Press.

Rossi-Hansberg, E. and J. Zhang (2025, February). Local gdp estimates around the world. (33458).

van Westen, R. M. and M. L. J. Baatsen (2025). European Temperature Extremes Under Different AMOC Scenarios in the Community Earth System Model. *Geophysical Research Letters 52*(12), e2025GL114611. e2025GL114611 2025GL114611.

van Westen, R. M., E. Y. P. Vanderborght, M. Kliphuis, and H. A. Dijkstra (2024). Substantial Risk of 21st Century AMOC Tipping Even Under Moderate Climate Change. *arXiv preprint arXiv:2407.19909*.