The Economic Geography of Climate Change: Recent Progress and Open Questions *

Klaus Desmet — *SMU*

Esteban Rossi-Hansberg — *University of Chicago*

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Abstract

Climate change is a spatial phenomenon, hurting some regions more than others. As a result, global warming will lead to a spatial reallocation of the world's economic geography. Recent spatial integrated assessment models (S-IAMs) project substantial increases in spatial inequality, while predicting modest aggregate losses. However, these global losses may be understated if models fail to account for multiple equilibria or migration-induced conflict. They may also be underestimated if models neglect spatial frictions due to stranded physical assets, endogenous migratory barriers, or moral hazard arising from the overprotection of vulnerable places.

Keywords: spatial integrated assessment models (S-IAMs), climate change, migration, economic geography, spatial frictions

JEL Codes: F18, F22, F64, Q54, Q56, R11, R23

1 Introduction

Climate change is a spatial phenomenon, hurting some regions much more than others. A 2°C or 3°C rise in temperature is not the same when residing in Kinshasa or Toronto. As such, global warming is bound to reshape the world's economic geography.

The recent development of high-resolution spatial integrated assessment models (S-IAMs) reflects a growing recognition of this spatial heterogeneity when evaluating the economic consequences of climate change. These models find relatively modest aggregate output losses of climate change — in the low single digits. For example, the S-IAM of Cruz and Rossi-Hansberg (2024) estimates a global loss of 3.3% in terms of the present discounted value of real GDP, with larger losses in welfare due to the impact of climate change on amenities. While broadly consistent with the predictions of non-spatial, first-generation integrated assessment models (IAMs),[1] these findings contrast sharply with the existential threats often emphasized in public discourse.

Although current quantitative models predict modest aggregate losses, there are at least two reasons why global warming should still be viewed as a pressing concern. First, even if global losses are small, they mask a dramatic rise in spatial inequality. This divergence is likely to trigger climate-induced migratory pressures, potentially fueling

*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.

[1] For example, the non-spatial DICE model estimates damages of 2.1% of global income for a 3°C warming (Nordhaus, 2017).

social tensions and increasing resistance to open-border policies. Second, existing quantitative models might ignore some mechanisms, leading to an underestimation of the true global costs of warming. Indeed, several empirical studies estimate substantially larger damages than those projected by S-IAMs. For example, Nath et al. (2023) estimate that a 3.7°C temperature rise would reduce global GDP by 8-13% by the end of this century, whereas Bilal and Känzig (2024) find an even more severe effect: a 1°C warming could lower world GDP by 12%.

Starting with the first concern, the S-IAM by Cruz and Rossi-Hansberg (2024) projects that some of the world's poorest regions could lose 15% of income per capita, while some of the richest regions could gain 15%. This spatial divergence has to do with the poorest regions being particularly vulnerable to global warming. Many are located in already warm parts of the globe, where any further increase in temperature has large negative effects. Add to this the fact that poor countries often specialize in agriculture, the sector most vulnerable to global warming, and we get a particularly grim picture for developing economies close to the Equator (Conte et al., 2021; Nath, 2020). In contrast, many advanced economies lie in temperate or colder zones, where small temperature increases may be beneficial.

The sharp rise in spatial inequality will require important adjustments in the world economy. In particular, climate change is likely to generate increased migratory pressure, as individuals seek to relocate away from hard-hit regions. In addition, patterns of specialization may have to adapt, as global warming alters the geography of comparative advantage. However, moving people or goods is not free, so the scope for adaptation is constrained by spatial frictions. Recent S-IAMs have quantified these adaptation mechanisms in models featuring realistic migration barriers and trade costs. In some cases, adjustment is local, as when people move to higher ground in the face of sea-level rise (Desmet et al., 2021); in other cases, adjustment is more global, with economic activity shifting from equatorial regions to more productive temperate zones (Conte et al., 2021; Cruz and Rossi-Hansberg, 2024).

Turning to the second reason for concern, a key question for economic geographers is whether certain spatial mechanisms remain insufficiently captured in current models, and whether these omissions imply that the global cost of climate change might be understated. In this regard, at least four spatial aspects merit further attention. First, because agglomeration economies can give rise to multiple equilibria, climate change may push the economy into a worse spatial allocation. This concern is absent in most calibrated versions of S-IAMs which feature uniqueness of equilibrium for the parameter values used. Second, stranded physical assets may make it difficult to shrink places that are hit by negative climate shocks. Many S-IAMs feature local technology and innovation, but abstract from physical capital. Third, governments may overinvest in protecting vulnerable locations. Incorporating government intervention in S-IAMs could help quantify how this might affect the overall cost of climate change. Fourth, climate-induced migration may trigger conflict or tighten migration restrictions. Each of these spatial mechanisms has the potential to amplify the aggregate cost of climate change, either by making spatial adjustment more difficult or by generating additional direct losses in output.

In what follows, we start by reviewing recent advances in bringing space and geography into integrated assessment models. In doing so, we describe some of the key findings related to the projected rise in spatial inequality. We then turn to discuss the four spatial issues highlighted above as key priorities for the next generation of spatial assessment models of climate change.

2 Space and Climate Change: Recent Progress

From IAMs to S-IAMs. Integrated assessment models (IAMs) are the standard framework for evaluating the economic impact of climate change. Pioneered by Nordhaus (1993), IAMs integrate core insights from climate science into otherwise standard economic models. Ideally, such models should be dynamic and global, in addition to having high spatial resolution. Dynamics are essential because climate change unfolds over decades and centuries; global coverage is required because any CO_2 emissions, regardless of geographic origin, contribute to the atmospheric stock of carbon; and fine spatial resolution is needed for the reasons discussed in the Introduction.

The first generation of IAMs satisfied two of these three criteria: they were dynamic and global. However, even when some of these models distinguished between more than one region (Nordhaus, 2008, 2010), they lacked the granularity to analyze spatially heterogeneous shocks and frictions to moving people and goods. Over the last decade, drawing on advances in quantitative spatial economies, much progress has been made in incorporating geography, giving rise to spatial integrated assessment models (S-IAMs). While early versions of S-IAMs featured one-dimensional space, more recent versions incorporate both latitude and longitude, yielding more realistic geography (Desmet et al., 2021; Conte et al., 2021; Cruz and Rossi-Hansberg, 2024). Other examples of S-IAMs include Nath (2020), Burzyński et al. (2022), Krusell and Smith (2022), Rudik et al. (2022), Conte (2023), Bilal and Rossi-Hansberg (2023), Cruz (2023), and Balboni (2025).

Incorporating geography changes IAMs in two fundamental ways. First, S-IAMs allow global warming to have spatially heterogeneous effects. A defining element of any integrated assessment model are damage functions that capture the effect of temperature on productivity and amenities. These functions are nonlinear: productivity and amenities worsen when temperature is either too hot or too cold. Because average temperatures range from roughly $-20°$C at the North Pole to about $30°$C at the Equator, the impact of a $1°$C increase varies sharply by location. In a model that divides the globe into 20 temperature bins, Cruz and Rossi-Hansberg (2024) estimate that a $1°$C rise increases productivity by 7% in the coldest bin (with a 95% confidence interval between 5% and 11%) but reduces it by 17% (with a 95% confidence interval between 12% and 21%) in the warmest bin.

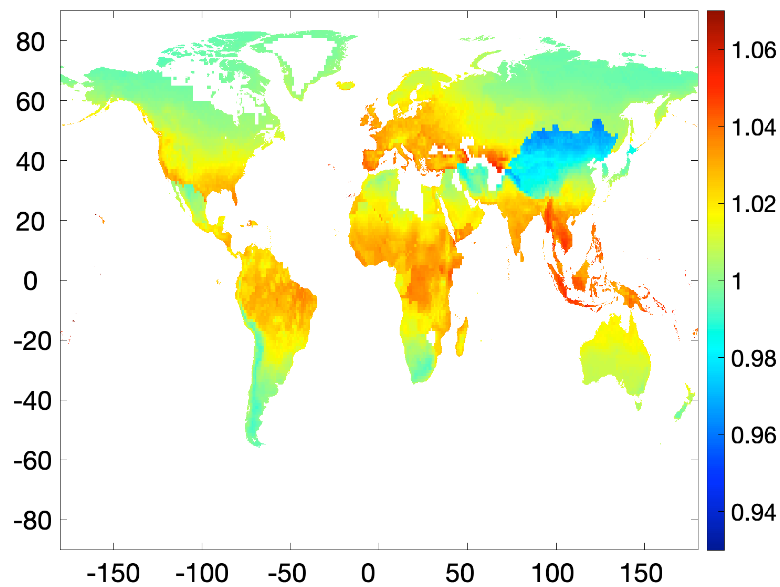
Second, the scope for adaptation depends critically on the magnitude of spatial frictions related to moving people, goods, and technology. Roughly 90% of global GDP is produced on just 10% of the land, so if migration were frictionless, adaptation would be straightforward. However, in reality, migration barriers are substantial, and raising them further would increase the cost of climate change. The S-IAM of Cruz and Rossi-Hansberg (2024) predicts that a worldwide increase in migration costs by 25% would increase the welfare cost of global warming by roughly 3 percentage points (0.03 log points) by the year 2200.

When moving people is costly, locations can also adapt by shifting specialization towards sectors that are less vulnerable to rising temperatures. Doing so is easier, the lower the barriers to trade. In a two-sector S-IAM, Conte et al. (2021) show that the roles of trade and migration as adaptation mechanisms are substitutes: higher trade costs limit the scope of locally adjusting by changing specialization, and hence lead to more adjustment through migration.

Beyond moving goods and people, S-IAMs also model frictions to moving technology. Clusters of economic activity emerge as firms make local productivity-enhancing investments. This attracts workers to move there, generating agglomeration economies that further raise productivity. As technology becomes locally embedded, climate shocks affecting high-productivity clusters can generate important losses. For example, if coastal flooding forces outmigration from some of the world's most productive cities, the locally embedded productivity may be lost. At the same time, the spatial diffusion of technology may offset some of these losses.[2]

The case for high spatial resolution. While the case for incorporating spatial heterogeneity into climate assessment models is compelling, there is still the question of how fine the spatial resolution should be. Perhaps dividing the world into a few large regions, as in the RICE model of Nordhaus (2010), suffices to capture the essence of this heterogeneity.

To examine this question, Desmet and Rossi-Hansberg (2024) use the high-resolution S-IAM of Cruz and Rossi-Hansberg (2024) to analyze how averaging damages across space affects the model's predictions. Specifically, they compare the original model, where damages vary at a geographic resolution of $1^\circ \times 1^\circ$, amounting to over 17,000 grid cells with positive land mass, to a version where damages are averaged at the level of seven large regions. This alternative setup implies that damages from climate change are the same in southern and equatorial Africa, and likewise in Florida and Ontario. Apart from damages, all other aspects of the analysis continue to be at the $1^\circ \times 1^\circ$ resolution.



Source: Desmet and Rossi-Hansberg (2024). Map displays the ratio (warming vs. no warming) of the PDV of real GDP when averaging damages at the level of seven World Bank regions, relative to the ratio (warming vs. no warming) of the PDV of real GDP in the baseline without averaging.

Figure 1: PDV of Real GDP when Averaging Damages at Level of World Bank regions, Relative to Baseline

Figure 1 shows the ratio of the present discounted value of real GDP with and without warming for the scenario where damages are averaged at the level of seven regions, relative to the ratio of the PDV of real GDP with and without warming for the baseline with $1^\circ \times 1^\circ$ resolution. That is, it depicts the difference-in-differences (DiD) effect of averaging damages on the effect of global warming. This averaging leads to overestimating the PDV of

[2] In addition, when firms relocate, they may transfer part of their technology to the new location, though they would still lose the original agglomeration economies. This would further mitigate some of the productivity losses.

real GDP in the U.S. South and West, as well as in southern Europe, South Asia, and the equatorial regions of Africa. At the same time, it leads to underestimating the PDV of real GDP in Canada, Scandinavia, Siberia, Argentina, and southern Africa.

Across regions, the impact of global warming on the PDV of real GDP is predicted to be up to roughly 6 percentage points (0.06 log points) lower or higher when ignoring some of the spatial heterogeneity in damages. Overall, averaging damages leads to underestimating the impact of climate change on spatial inequality. For instance, in sub-Saharan Africa, the projected climate-induced drop in the PDV of real GDP declines from 5.4% to 2.9% of real GDP. This underscores the importance of climate assessment models with high spatial resolution.

3 Space and Climate Change: Open Questions

The relatively modest aggregate losses predicted by S-IAMs raise the question of whether certain spatial mechanisms remain insufficiently explored, and whether such omissions imply that the true aggregate cost of climate change is higher than presently estimated. In what follows, we discuss four such aspects.

Multiple equilibria. Many economic geography models give rise to multiple equilibria. Intuitively, this tends to occur when agglomeration economies are sufficiently strong relative to congestion forces. Consider, for example, an economy with two equally sized locations that share identical fundamentals. If a temporary shock causes one location to become larger than the other, and agglomeration economies are strong enough, that location will become permanently larger at the expense of the other. However, if agglomeration economies are weak compared to congestion effects, the economy will revert to its original allocation of two equally sized locations.

How might the existence of multiple equilibria lead to potentially larger economic losses from climate shocks? To illustrate this possibility, suppose that a highly productive coastal city loses land due to sea-level rise, prompting some people and firms to initially relocate to a nearby place with much worse fundamentals. If agglomeration economies are weak, this initial 'mistake' of moving to an unproductive location will self-correct over time. However, in a world with multiple equilibria and strong agglomeration forces, this initial shift is more likely to become locked in, resulting in larger economic losses.

Current versions of S-IAMs tend not to generate these more adverse outcomes because their calibration yields parameter values consistent with a unique equilibrium. However, these calibrations are subject to future revisions. This makes the possibility of multiple equilibria an important area for future exploration, particularly because it could imply greater economic losses than currently predicted. A relevant recent paper that investigates uniqueness, though it is not specific to climate change, is Allen and Donaldson (2022). Using a dynamic spatial framework with static and dynamic spillovers, they derive parameter conditions for uniqueness, persistence and path dependence. When estimating the model based on U.S. data from 1800 to 2000, they find a unique spatial equilibrium when only considering static spillovers. However, when including dynamic spillovers, they find the possibility of multiple steady states. If so, climate shocks might have more uncertain, and in some cases more severe, effects than suggested by existing S-IAMs.

Housing and infrastructure. The presence of housing and other physical structures magnifies the economic cost of climate change, for at least two reasons. First, if climate-related shocks generate a stranded asset problem, then losses in the value of structures should be taken into account. Second, the impossibility of moving physical assets can slow adjustment through spatial reallocation. As noted by Glaeser and Gyourko (2005), durable goods make the process of shrinking cities sluggish. When locations are hit by negative shocks and house prices decline, residents may stay on because physical depreciation is slow.

Many S-IAMs do not explicitly model capital and housing, so they do not allow these forces to operate. That said, these models do typically include local innovation and productivity, which is further enhanced by agglomeration economies. As with stranded physical assets, the local embeddedness of technology slows down outmigration from places affected by negative shocks.

Desmet et al. (2021) argue that the loss of local technology when economic activity relocates is more important than the loss of physical assets. Because global warming is a gradual process, climate-induced shocks such as sea-level rise take longer to inflict damage than the standard time it takes for housing and other structures to depreciate. As a result, the cost of physical capital destruction may not be that high. Instead, it is the loss of local technology and agglomeration economies that is the primary concern. Using the example of Manhattan, they argue that the value of real estate has more to do with the productivity of New York than with the replacement cost of its physical structures.

In contrast, in a S-IAM with physical capital for the U.S., Bilal and Rossi-Hansberg (2023) show that housing and physical capital are key contributors to keeping people in the same place when hit by climate shocks. They demonstrate that some of this spatial inertia can be mitigated if people anticipate future climate change. Anticipation leads to lower investment in vulnerable locations. This keeps house prices relatively high and lowers wages, thereby incentivizing people to relocate. Anticipating future climate change also matters for infrastructure investment. Using a quantitative spatial model, Balboni (2025) studies this question in the context of road investments in Vietnam.

These findings suggest that incorporating physical capital into a global S-IAM may be useful. On the one hand, doing so would worsen the stranded asset problem, thereby raising the estimated cost of climate change. On the other hand, forward-looking behavior could accelerate the spatial reorganization of the economy towards less vulnerable regions.

Government intervention. When faced with the existence of multiple equilibria and the problem of stranded assets, can government intervention help mitigate the economic costs of climate change? It depends.

On the one hand, in a world with multiple equilibria, government intervention can act as a coordination mechanism to select the more desirable equilibrium. If private agents fail to fully internalize future climate damages, the government might also use policy to avoid excessive investment in vulnerable locations.

On the other hand, government intervention might also worsen outcomes. If political power is decentralized, local authorities might be inclined to overdefend vulnerable places. Consider the case of Miami under threat from sea-level rise: if the decision to invest in protective infrastructure lies with the federal government, costly interventions may be less likely than if the decision lies with local authorities. Because Miami's city government is unlikely to fully internalize the benefits of relocation to safer regions, it has stronger incentives to save the city.

Another reason why government intervention might be detrimental is the moral hazard that arises from the inability to commit. As argued by Hsiao (2023), although a government might ex ante prefer not to protect coastal areas, it might end up doing so ex post, after developers build in vulnerable locations. Because developers do not internalize the future cost of protection, the commitment failure of the government leads to overdevelopment.

Hsiao (2023) uses a dynamic spatial model to quantify this problem in the context of the construction of a sea wall in Jakarta.

Although governments could, in principle, accelerate spatial adaptation to climate change, the evidence suggests that they often do the opposite. S-IAMs that emphasize adaptation through costly migration may therefore underestimate the true costs of climate change. A recent example of a S-IAM that considers the role of government intervention is Henkel et al. (2022), who study the impact of post-disaster policies on sorting into vulnerable areas.

Conflict and endogenous migration barriers. Climate-induced migration may increase inter-group tensions and trigger conflict. A counterargument is that climate change is a gradual process, making massive population shifts over short periods unlikely. This makes climate-driven migration different from recent large shocks, such as those that led over a quarter of Venezuelans and Syrians to flee their countries due to economic collapse and war.

However, not all the manifestations of climate change are gradual. The frequency of severe weather and storms may increase because of global warming, and so might the severity of droughts. In a recent meta-analysis, Burke et al. (2024) conclude that a one standard deviation increase in local temperature is associated with a 2.5% increase in inter-group conflict. This violence is often linked to migration leading to increased competition over scarce resources. For instance, McGuirk and Nunn (2025) find that droughts in the territories of transhumant pastoralists in Africa lead to conflict, as these groups migrate to nearby regions occupied by sedentary agriculturalists.

Because conflict depresses economic output, it is important to incorporate the link between climate and conflict into S-IAMs. One such attempt is Burzyński et al. (2022), who model the income loss due to climate-induced conflict. Another relevant recent paper is Couttenier et al. (2025), who estimate and simulate a quantitative spatial model of trade and violence, though without focusing on climate change.

Tensions arising from migratory pressures may also translate into an endogenous tightening of migration barriers. S-IAM tend to assume that the cost of moving remains constant over time. Allowing for the possibility that migratory restrictions could intensify in response to migration would amplify the projected economic costs of climate change. Earlier, we noted that climate-induced migration is expected to unfold gradually, suggesting that the impact on migration barriers might be limited. However, a slow-moving process that persists over decades can still generate large cumulative effects. Cruz and Rossi-Hansberg (2024) project that by the year 2200, almost half a billion people will have been displaced due to climate change. How this increased stock of migrants might affect endogenous migration policy remains an open question that deserves to be further analyzed in the context of S-IAMs.

4 Conclusion

In this brief commentary, we have reviewed recent advances in bringing space and geography into integrated assessment models. Using high-resolution S-IAMs to evaluate the economic impact of climate change is crucial for two main reasons. First, global warming generates spatially heterogeneous damages at a relatively fine scale. Second, spatial frictions to the movement of people, goods, and technology are essential for accurately estimating the global and local costs of climate change.

S-IAMs project substantial increases in spatial inequality due to global warming, while aggregate losses are expected to be relatively modest. In the second part of this commentary, we have argued that global losses may be understated if models fail to allow for multiple equilibria or migration-induced conflict. The aggregate impact of climate change may also be larger if stranded physical assets or endogenous migratory barriers result in greater spatial frictions to adaptation than currently assumed. There remains much work for economic geographers to further improve and refine spatial integrated assessment models.

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