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Escaping the Rising Tide by Moving

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Global warming is causing the thermal expansion of oceans, the melting of glaciers, and the retreat of the ice sheets of Greenland and Antarctica. If the world continues with "business as usual", the Intergovernmental Panel on Climate Change (IPCC) expects the average sea level to rise by 0.3 to 0.6 meters by the end of the century. This is bound to disrupt life as we know it, especially in many of the world's coastal cities, from Bangkok to Houston.

Researchers have struggled to come up with credible estimates of the economic cost of coastal flooding. Existing studies have often been limited to simple accounting exercises that estimate the current value of structures or income in flood-prone areas. Essentially, using economic data of today, these studies interpret the cost of coastal flooding as the value of housing and GDP that will become permanently inundated as the sea level rises. As such, these assessments implicitly assume that people and economic activity will simply drown, thus obviating the possibility of relocation.

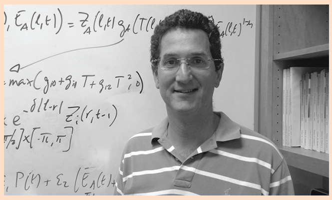
Yet, sea level rise is a gradual process: if Manhattan ends up permanently flooded, this will not happen overnight as a surprise, but slowly over time. As a result, its residents will move to higher ground before disaster strikes. This adjustment will certainly entail important costs. To the extent that part of the productivity of Manhattan is embedded in its economic ecosystem, this will be lost. But as its residents and businesses relocate, they will contribute to economic activity elsewhere. Over time, existing economic clusters on the coast will disappear, while new ones will emerge. Hence, although moving is costly and although the destruction of highly productive coastal agglomerations will be harmful, in the longer run this will at least partly be compensated by the emergence of new urban agglomerations on higher ground.

> Over time, existing economic clusters on the coast will disappear, while new ones will emerge

In this sense, there is a need to refocus the economic assessment of sea-level rise, away from accounting exercises based on the value of lost structures, to a more comprehensive quantitative analysis of the dynamic effects of permanent inundation on the world's economic geography. In such an analysis, the role of mobility and relocation should take center stage.

A high-resolution dynamic model to assess the economic cost of flooding

Properly evaluating the economic cost of sea-level rise therefore requires a high-resolution dynamic framework that models the spatial distribution



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of economic activity. With economists at CREI, Princeton and SMU, we have developed and calibrated such a spatial model at the 1° by 1° grid cell resolution for the entire planet (Desmet, Nagy and Rossi-Hansberg, 2018). The spatial resolution we employ amounts to splitting up the world into 64,800 grid cells which are linked to each other through migration and trade. In more recent work, we have teamed up with climate scientists at Princeton and Rutgers, and have used sea-level rise projections to evaluate the dynamic effects of flooding on population, income and welfare, both at a local and a global scale (Desmet et al., 2020). Importantly, this model allows for individuals to relocate, although moving is not frictionless. In addition to the moving cost itself, sea-level rise can be harmful because it often affects highly productive coastal cities. Flooding-induced migrants may not be able to work at the same level of productivity in the locations they move to, at least not initially. That is, as productive clusters of economic activity disappear due to inundation, it will take time for new such clusters in the hinterland to appear and become productive.

Our baseline results show that permanent inundation will reduce the present discounted value of global real GDP by an average of 0.19 percent and it will lower welfare by 0.24 percent. Coastal flooding is estimated to displace about 1.46 percent of the world population by 2200. In some countries, the effects are more than an order of magnitude larger, with an estimated decline in the present discounted value of real GDP of 7.60 percent in Vietnam, 9.37 percent in Thailand and 5.37 percent in Bangladesh. At the level of cities, the heterogeneity is obviously even greater. Some cities, such as Tianjin, Bangkok, Miami and Ho Chi Minh City will suffer large losses.

There is substantial uncertainty about sea-level rise. One source of uncertainty concerns the future path of greenhouse gas emissions. Much will depend on the energy-intensity of growth and on actions the world takes to limit carbon emissions. The IPCC contemplates different future emissions scenarios, labeled as Representative Concentration Pathways (RCPs). For example, RCP 4.5 is a moderate emissions pathway, RCP 2.6 is a low-emissions pathway consistent with the aspirational goals of the Paris Agreement, and RCP 8.5 is a high-emissions pathway consistent with fuel-intensive economic growth. Another source of uncertainty comes from the parameters that guide the relation between emissions, temperature and sea-level rise. For example, climate scientists are unsure about the impact of a given temperature rise on the degree of melting of the Greenland ice sheet. Some of our coauthors have used Monte Carlo simulations to generate joint probability distributions of local and global sea-level rise (Kopp et al., 2014). Using these projections, we find that 95% of future sea-level rise realizations imply global welfare losses between 0.08 percent and 0.45 percent in the intermediate emissions scenario. When considering an extreme emissions scenario, the maximum loss in real GDP can be as large as 1.36 percent.

The importance of mobility and economic adaptation

Compared to existing studies, an essential contribution of our assessment is permitting economic adaptation. That is, we allow the economy to spatially and dynamically react to flooding. If Ho Chi Minh City becomes permanently inundated, its residents will move elsewhere. By changing the geographic distribution of population, the incentives for innovation in different locations will also change. As such, this will put the economy on a different dynamic spatial path.

To better understand the importance of incorporating the dynamic spatial reaction of the economy, *Figure 1* compares the quantitative prediction of our model to an alternative evaluation that completely eliminates the possibility of moving when faced with flooding. Under this alternative assessment, we take, for each year, our model's prediction in the absence of flooding, and compute the fraction of GDP that would get flooded based on the median sea-level rise projection under RCP 4.5. That is, we assume that in each year the cost of flooding is equivalent to the share of GDP located on land that becomes inundated. In Figure 1 we refer to this as the "no mobility" scenario. To understand the effect of economic adaptation, it should be compared to the "baseline" model in the same figure. If we focus on the year 2200, the possibility of economic adaptation through mobility is substantial: the loss in real GDP increases from 0.11% in the benchmark to 4.5% in the no-adaptation model.

> The possibility of economic adaptation through mobility is substantial

The large difference in economic losses is because when locations become permanently inundated, people can generally relocate, albeit at a cost. As a result, the loss in real GDP in flooded coastal regions is (partly) offset by the gain in real GDP in the interior hinterland. Needless to say, it is easier to move to higher ground in a country with a large landmass, such as the United States, than in small island nations in the Pacific. Correspondingly, the economic cost of rising oceans differs greatly across countries and locations.

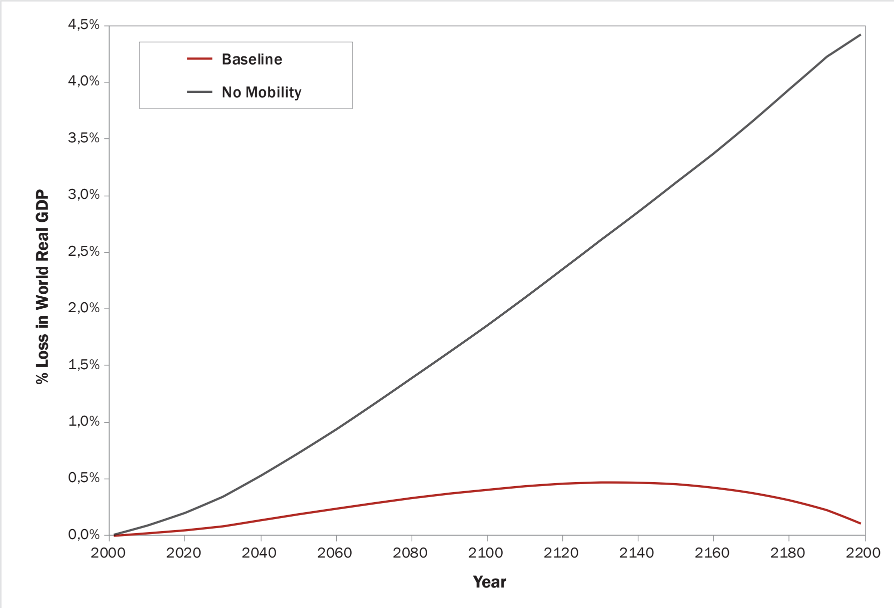

Figure 1:
World Losses in Real GDP in baseline (red curve) and in alternative model without economic adaptation and mobility (grey curve)

Climate refugees

The political economy of migration is complex. If coastal flooding leads to massive population movements, the cost of migration might very well rise. However, it is once again worth remembering that climate change is a slow-moving process. Unlike wars or earthquakes, it will not create sudden surges of millions of refugees. In addition, in many countries much of the adjustment can happen through internal migration, without the need for people to move across national borders. Recent work by Burzyński et al. (2019) confirms this finding. It somewhat mitigates concerns about rising conflict due to climate refugees.

> Climate change is a slow-moving process. Unlike wars or earthquakes, it will not create sudden surges of refugees

Because of the slow-moving nature of sea-level rise, it is only in the distant future that the spatial distribution of population might look radically different from today's. Large changes in the world's economic geography have happened before: 200 years ago, only 3 percent of the world's population lived in the Americas, compared to 14 percent today, whereas the share of Europe has declined from 21 percent to 12 percent. This does not mean that relocating people will be equally easy in the future. One important difference is that since 1800 the world population has increased six-fold, making it more difficult to move people.

What about housing and other structures?

While focusing on mobility frictions, we have not said much about the loss in physical structures. Our intuition is that in the grand scheme such losses will be relatively minor, for two reasons. First, because sea-level rise occurs gradually, the damage plays out over longer time periods than capital depreciation. By the time a structure becomes inundated, standard depreciation would have required it to be rebuilt anyway. If so, the structure could be moved to higher ground. Second, the physical damage from flooding in large coastal cities has more to do with the loss of agglomeration economies than with the cost of physical capital per se. Manhattan's buildings are valuable primarily because of where they are, not because of the cost of rebuilding them.

Migration policy should become an integral part of the debate on climate change

Storm surges, desertification, ...

In this paper we have analyzed one aspect of climate change: permanent inundation. Needless to say, rising temperatures affect many other dimensions of economic life. The warming of the oceans may lead to an increase in the frequency and intensity of extreme-weather phenomena, such as storm surges and hurricanes (Burzyński et al., 2019). Higher temperatures will bring about desertification and dropping agricultural yields in some parts of the world. Air conditioning will become more needed at intermediate latitudes (and heating less needed at more northern latitudes). These other dimensions of climate change have one thing in common with flooding: they also consist of shocks that play out over time and differ across space. As such, analyzing them also requires a spatial dynamic model. With good enough data, we can use the framework we have developed to do a more comprehensive assessment of the total economic cost of climate change.

This policy brief is based on Desmet, K., Kopp, R., Kulp, S., Nagy, D., Oppenheimer, M., Rossi-Hansberg, E. and Strauss, B.,"Evaluating the Economic Cost of Coastal Flooding," *American Economic Journal: Macroeconomics*, 2020, conditionally accepted.