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An American Prospectus

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AN AMERICAN PROSPECTUS

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AND A FOREWORD BY MICHAEL R. BLOOMBERG, HENRY M. PAULSON JR., AND THOMAS F. STEYER

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FOREWORD

MICHAEL R. BLOOMBERG, HENRY M. PAULSON JR., AND THOMAS F. STEYER

COCHAIRS, RISKY BUSINESS PROJECT

HOW much economic risk does the United States face from climate change? The answer has profound implications for the future of our economy and the American way of life. But until recently there was no systematic, analytically rigorous effort to identify, measure, and communicate these risks.

It was the looming, unknown scale of these risks that led us to launch the Risky Business Project in summer 2013 and to commission the research that became the *American Climate Prospectus* report, published here in its entirety as *Economic Risks of Climate Change: An American Prospectus*. Our aim is to quantify the economic risks of climate change to the U.S. economy and then communicate these risks to the business sector.

In applying a standard risk-assessment approach to future climate impacts, this research provides specific, local, and actionable data for businesses and investors in both the public and private sectors. We hope its findings help spur an active, rigorous conversation among economists, business executives, investors, and public-policy makers about how best to manage these risks, including taking prudent action to prevent them from spiraling out of control.

Over the years, the scientific data have made it increasingly clear that a changing climate, driven by carbon pollution from human activities, will lead to overall global warming. These rising temperatures in turn lead to specific and measurable impacts such as sea-level rise, melting ice and glaciers, and more observable weather events such as droughts, wildfires, coastal and inland floods, and storms. But, until recently, scant analytical work has been done to connect these broad climate changes to the daily workings of our economy.

In our view, the significant and persistent gap between the fields of climate science and economics makes businesses, investors, and public-sector decision makers dangerously vulnerable to long-term and unmanageable risks. How can we make wise financial decisions without understanding our exposure to such risks as severe floods or prolonged drought or storm surge? How can we plan for and build new, more resilient infrastructure and manage our limited public resources responsibly without taking into account the probable changes to our coastlines, our agricultural lands, and our major population centers?

These were the questions that led to the formation of the Risky Business Project. We knew from the outset that, to be effective, the project must be grounded in the same sort of rigorous analytical framework typically used by investors and business leaders in other areas of risk management. The American business community has been slow to assess and address climate risk in part because of a lack of actionable data. Without these data, businesses cannot create risk-assessment models that effectively capture the potential impact of climate change. So it's no surprise that most corporate risk committees, even in industries and sectors at significant risk of climate-driven disruption, do not consistently include climate risk in their disclosures to investors or overall management priorities.

The success of our efforts was dependent on our ability to point business leaders toward exactly the kind of path-breaking analysis contained in this book. To be credible, the research had to be methodologically unassailable and strictly independent. To be useful, the data it produced had to be detailed, relevant, and highly localized—what climate modelers call "downscaled"—in a way that would allow businesses to incorporate it into their existing risk-management protocols and strategies.

The Risky Business Project and this book are critical first steps toward this goal. The study does not tackle the entire U.S. economy but instead focuses on a few important sectors (agriculture, energy demand, coastal property, health, and labor). In examining how climate change will introduce new risks to these sectors, this research builds on the best available climate science and econometric research, reviewed by a panel of world-class scholars.

This work is also unusual—and unusually relevant to the business sector—in its level of detail and specificity to particular geographic regions. In the following chapters, readers will find a nearly unprecedented level of geographic granularity. Probable climate impacts have been modeled down to the county level, which is the scale at which many business decisions—such as crop planting and harvesting and real estate development—are actually made. This level of geographic detail also underscores the broad regional disparities we can expect from climate change. In a country as large and diverse as the United States, not all states or even counties will face the same type or level of risk. Economy-wide studies, focused on Gross Domestic Product impact or national productivity, completely mask these disparities.

When we undertook this project, it was clear that simply quantifying the economic risks of climate change would not be enough. The data needed to take a form that was meaningful within companies' existing risk-assessment frameworks. Thus, while this report is in many ways novel and groundbreaking, it's also notable in that it makes use of the same risk-assessment approach that businesses and investors use on a daily basis.

In the wake of Hurricane Sandy, New York City created a comprehensive resilience blueprint that measures climate risk across all major vulnerable areas, from the power grid to hospitals to the coastline. We should not wait for a national disaster to create the same blueprint for the U.S. economy as a whole. We hope that this analysis is useful not only for the data it provides but also as a framework for a more effective dialogue among scientists, economists, and the business community—one that will provide decision makers with the information they need to decide how much climate risk they are comfortable taking on.

As we said in the October 2013 *Washington Post* op-ed that launched this entire effort: We believe the Risky Business Project and this book bring a critical missing piece to the national dialogue about climate change while helping business leaders and investors make smart, well-informed, financially responsible decisions. Ignoring the potential costs could be catastrophic—and that's a risk we cannot afford to take.

PREFACE

ROBERT KOPP, SOLOMON HSIANG, KATE LARSEN, AND TREVOR HOUSER

HUMAN civilization is reshaping Earth's surface, atmosphere, oceans—and climate. In May 2013, at the peak of its seasonal cycle, the concentration of carbon dioxide (CO_2) in the atmosphere spiked above 400 parts per million (ppm) for the first time in more than 800,000 years; within the next couple of years, it will exceed 400 ppm year-round. This elevated CO_2 concentration is the result of human activities—primarily the combustion of coal, oil, and natural gas and, secondarily, deforestation. The physics linking increased concentrations of greenhouse gases like CO_2 to higher global average temperatures has been known since the work of Joseph Fourier and Svante Arrhenius in the nineteenth century. And as early as 1938, Guy Stewart Callendar provided evidence that an elevated CO_2 concentration was, in fact, warming the planet. By the early twenty-first century, the scientific evidence of human-caused warming (briefly summarized in chapter 2) was unequivocal.

It is equally certain that climate change will affect the economy and human well-being. Quantifying these impacts and the value of avoiding them has, however, been a major challenge, because the climate, the economy, and their interface are all highly complex. Modern economic analyses of climate change date to the pioneering works of William Nordhaus, William Cline, Samuel Fankhauser, and others in the early 1990s. One central insight from this early work was that investing in heavy-emissions mitigation too early can carry substantial opportunity costs because investments elsewhere in the economy may yield larger returns. However, subsequent work showed that accounting for uncertainty in climate damage could, when combined with risk aversion, motivate more rapid mitigation.

In 2007, Lord Nicholas Stern (co-commentator for part 4) led a groundbreaking analysis of the macroeconomic costs and benefits of climate-change policies. The Stern Review and the dialogue it triggered clarified the critical role of social discount rates in economic evaluations of climate-change policies. In 2010, the U.S. government attempted to quantify the economic cost of climate change and benefits of mitigation. In that year, a working group cochaired by Michael Greenstone (commentator for part 2) issued the U.S. government's first estimates of the social cost of carbon, which are used to integrate climate change into the benefit-cost analyses that guide regulatory decision making.

These contributions have played a central role in both building our understanding of the economics of climate change and elucidating critical gaps in our existing knowledge. One such gap was the weak understanding of the way in which economies are affected by the climate. In previous global analyses, it was often simply assumed that total economic costs grew as a theorized function of global average temperature. This assumption originally arose out of necessity, as there was little empirical research to constrain these "economic damage functions," and evaluating localized impacts *en masse* would have been too computationally challenging.

Early in 2012, two of us (Solomon Hsiang and Bob Kopp) met for the first time and realized that we could fill this knowledge gap by leveraging a recent explosion in econometric analyses of climate impacts, decades of research in climate modeling, and advances in modern computing. Together with Michael Oppenheimer (commentator for part 1), we designed a new framework for assessing the economic costs of climate change that took advantage of these three recent advances. We proposed the development of an assessment system that would automate the calculations needed to stitch together results from econometricians and climate modelers to calibrate the mathematical machinery used in integrated policy models (Kopp, Hsiang, & Oppenheimer 2013). Using modern computing, we could provide the necessary "translation" needed for the physical science, econometric, and integrated assessment communities to share results with one another efficiently and effectively. Furthermore, we wanted to achieve this goal in a risk-based framework: one that took into account uncertainty in projections of future changes, uncertainty in statistical analyses of the past, and the natural uncertainty of the weather, and which could be used by decision makers accustomed to managing other forms of risk. Presenting this ambitious vision at a national conference of academics in December 2012, we were told by a grinning colleague, "good luck with that!"

Luck we had. In 2013, shortly after we ironed out these ideas, the opportunity to implement them arose through the Risky Business Project. The Risky Business Project—led by New York City mayor Michael Bloomberg, former Bush administration treasury secretary Hank Paulson, and former hedge-fund manager Tom Steyer—aimed to move the discourse and U.S. response to climate change beyond its partisan stalemate. Their primary objective was to engage risk managers in the investment and business communities and provide them the basis for incorporating climate risk into their decision making. Bloomberg, Paulson, and Steyer convened and chaired a nonpartisan "Climate Risk Committee" that also included former treasury secretaries Robert Rubin and George Shultz, former Housing and Urban Development secretary Henry Cisneros, former Health and Human Services secretary Donna Shalala, former U.S. Senator Olympia Snowe, former Cargill CEO Greg Page, and Al Sommer, dean emeritus of the Bloomberg School of Public Health at Johns Hopkins University. The Risky Business Project commissioned Rhodium Group, the economic research company where two of us (Trevor Houser and Kate Larsen) are employed, to conduct an independent climate-risk assessment to inform its deliberations. Trevor invited Bob and Solomon to implement a U.S.-focused version of their proposed assessment system, integrating Rhodium's energy sector and macroeconomic analysis and the coastal storm modeling capabilities of Risk Management Solutions (RMS), another project partner. The *American Climate Prospectus*, which forms the core of this volume, was thus born.

The primary goal of the *American Climate Prospectus* is to provide decision makers, the public, and researchers with spatially resolved estimates of economic risks in major sectors using real-world data and reliable, replicable analyses. Achieving this goal requires the careful evaluation of uncertainty in climate projections and economic impacts at a local level, as well as the harmonization and integration of findings and methods from multiple disciplines. In practice, these tasks are difficult; in many cases, the underlying research needed to implement the assessment for specific sectors or effects does not yet exist. The *American Climate Prospectus* platform is therefore designed to grow and expand with the frontier of scientific and economic knowledge, as we learn more about the linkages between the planet's climate and the global economy. The analysis in this volume is novel, and we hope its substance is useful, but we are acutely aware that our findings will not be the last word on these questions. We are building on the work of our predecessors, and we hope that others will build on this contribution. Because of this, we intentionally designed our analysis system to be *adaptive* to new discoveries and better models that will be achieved in the future. As we learn more about our world and ourselves, the assessment system we have built will incorporate this new information, allowing our risk analysis to reflect this new understanding. This may be the first *American Climate Prospectus*, but we do not expect it to be the last.

To help place our findings in context and to point the way forward for researchers to build on this work, we have invited six distinguished researchers—Michael Oppenheimer, Michael Greenstone, Karen Fisher-Vanden, Nicholas Stern, Bob Ward, and Geoffrey Heal—to provide commentaries on each of the five sections of this analysis. We have asked them, as experts on these topics, to be critical of our analysis, to help readers digest both the benefits and the weaknesses of our work, and to highlight future avenues of investigation that will improve our collective understanding.

While we fully recognize that future analyses will revise the numbers we present here, we believe our analysis makes several methodological innovations. Some highlights are:

- We provide new, probabilistic projections of climate changes that are localized to the county level while also being consistent with the estimated probability distribution of global mean temperature change. These projections include information on the distribution of daily temperatures and rainfall, wet-bulb temperature, and sea-level rise.
- We developed a Distributed Meta-Analysis System (DMAS) that continually and dynamically integrates new empirical findings, which can be crowd-sourced from researchers around the world, using a Bayesian framework. DMAS allows our assessment to be easily updated with new results in the future.
- We used econometrically derived empirical findings to develop fully probabilistic impact projections that account for climate-model uncertainty, natural climate variability, and statistical uncertainty in empirical econometric estimates.
- We modeled the energy-market consequences of empirically validated climate-driven changes in heating and cooling demand.
- We conducted the first nationwide assessment of the impact of sea-level rise on expected losses from hurricanes and other coastal storms that combines probabilistic local sea-level rise projections with both historical and projected rates of hurricane activity.
- We developed spatially explicit impact projections at the county level, allowing us to characterize the distribution of winners and losers in different sectors. These projections allowed us to compute the first estimate of the equity premium arising from the distributional impact of climate change within the United States.
- We developed a framework for integrating empirically based dose-response functions into computable general equilibrium models so that damage functions no longer need to be based on theoretical assumptions.

Taking advantage of these innovations, we are able to characterize how climate change will increasingly affect certain dimensions of the U.S. economy. The novel quantitative risk assessment of the *American Climate Prospectus* focuses on six particular impacts that we felt we could reliably estimate given the state of both scientific and economic research in early 2013. These six impacts are:

- the impact of daily temperature, seasonal rainfall, and CO_2 concentration changes on major commodity crops—wheat, maize, soy, and cotton (chapter 6);
- the impact of daily temperature on the number of hours people work, especially in "high risk" outdoor and manufacturing sectors (chapter 7);
- the impact of daily heat and cold on mortality rates across different age groups (chapter 8);
- the impact of temperature on violent and property crime rates (chapter 9);
- the impact of daily temperature on energy demand and expenditures (chapter 10); and
- the impact of sea-level rise and potential changes in hurricane activity on expected future coastal storm–related property damage and business-interruption costs (chapter 11).

For the first four impacts, we implemented the statistical framework we sketched out with Michael Oppenheimer in 2013. For changes in energy demand and expenditures, we used Rhodium's version of the National Energy Modeling System—the tool developed by the U.S. Energy Information Administration for projecting the future of the U.S. energy system. For coastal impacts, we used RMS's North Atlantic Hurricane Model, which is used by RMS to advise its insurance and finance industry clients.

The *American Climate Prospectus* does not attempt to *predict* the costs the future United States *will* experience from climate change. Rather, it is an estimate of the risks the country faces *if it maintains its current economic and demographic structure and if businesses and individuals continue to respond to changes in temperature, precipitation, and coastal storms as they have in the past.* It is not a projection of likely damage given the socioeconomic changes that necessarily will take place; in this, it differs from integrated assessment models such as those developed by Nordhaus and others and used in the Stern Review and by the U.S. government in estimating the social cost of carbon. Rather, we use the structure of the modern economy as a benchmark to inform decision makers as they evaluate how to manage climate risk.

In a risk assessment, it is important to be aware of the different sources of uncertainty (chapter 3). Our assessment focuses on five key sources of uncertainty: (1) emissions, (2) the global temperature response to changes in the atmosphere, (3) the regional temperature and precipitation response to global change, (4) natural variability on timescales ranging from daily weather to multidecadal variations, and (5) statistical uncertainty in our estimation of historical economic impacts.

Future greenhouse-gas emissions are controlled by economics, technology, demographics, and policy—all inherently uncertain, and some a matter of explicit choice. The climate-modeling community has settled upon four Representative Concentration Pathways (or RCPs) to represent a range of plausible emissions trajectories. They are named RCP 8.5, RCP 6.0, RCP 4.5, and RCP 2.6, based on the climate forcing from greenhouse gases that the planet would experience from each pathway at the end of this century (respectively, 8.5, 6.0, 4.5, and 2.6 watts per square meter). RCP 8.5 is the closest to a business-as-usual trajectory, with continued fossil-fuel–intensive growth; RCP 4.5 represents a moderate emissions mitigation trajectory, while RCP 2.6 represents strong emissions control. (RCP 6.0, for idiosyncratic reasons having to do with the construction of the pathways, is of limited use in impact analyses comparing different pathways.) Throughout the *American Climate Prospectus*, we present results for RCP 8.5, 4.5, and 2.6; we focus on RCP 8.5 as the pathway closest to a future without concerted action to reduce future warming.

To generate the projections of temperature and precipitation underlying the risk assessment, we combined projections of the probability of different levels of global average temperature under different RCPs with spatially detailed projections from advanced global climate models (chapter 3 and appendix A). In addition to regional spatial patterns, the resulting projections also incorporate weather and climate variability on timescales ranging from days to decades. To assess impacts on coastal property, we developed new, localized estimates of the probability of different levels of sea-level change that are consistent with the expert assessment of the Intergovernmental Panel on Climate Change. Our approach provides full probability distributions and takes into account all the major processes that cause sea-level change to differ from place to place.

The projections paint a stark picture of the world in the last two decades of the twenty-first century under the business-as-usual RCP 8.5 pathway (chapter 4). In the median projection, with average temperatures in the continental United States 7°F warmer than those in the period 1980–2010, the average summer in New Jersey will be hotter than summers in Texas today. Most of the eastern United States is expected to experience more dangerously hot and humid days in a typical summer than Louisiana does today. By the end of the century under RCP 8.5, global mean sea level is *likely* to be 2.0 to 3.3 feet higher than it was in the year 2000, and there is an approximately 1-in-200 chance it could be more than 5.8 feet higher. Regional factors in some parts of the country—most especially the western Gulf of Mexico and the mid-Atlantic states—could add an additional foot or more of sea-level rise. On top of these higher seas, higher sea-surface temperature may drive stronger Atlantic hurricanes.

Combining these probabilistic physical projections with statistical and sectoral models yields quantitative risk estimates for the six impact categories identified earlier. Were the current U.S. economy to face the climate projected for late in the century in the median RCP 8.5 case, the costs of these six impacts would total 1.4 to 2.9 percent of national GDP; there is a 1-in-20 chance that they would exceed 3.4 to 8.8 percent of GDP. (The low ends of the ranges assume no increase in hurricane intensity and value mortality based on lost labor income; the high ends include hurricane intensification and use the $7.9 million value of a statistical life discussed later to account for mortality.) For a sense of scale, other researchers estimate that, on average, civil wars and currency crises in other countries cause their GDPs to fall by roughly 3 and 4 percent, respectively (Cerra & Saxena 2008). These potential costs are distributed unevenly across the country. The projected risk in the Southeast is about twice the national average, while that in the Northeast is about half the national average; the Pacific Northwest may even benefit from the impacts that we have assessed.

Of the six impacts we quantified, the risk of increased mortality poses the greatest economic threat (chapter 8). The statistical studies underlying this projection account for all causes of death. The most important causes of heat-related deaths are cardiovascular and respiratory disease; low-temperature deaths are dominated by respiratory disease, with significant contribution from infections and cardiovascular disease.

In the median projection for RCP 8.5 toward the end of the century, the United States is projected to experience about 10 additional deaths per 100,000 people each year—roughly comparable to the current national death rate from traffic accidents. There is a 1-in-20 chance the hotter climate could cause more than three times as many deaths. The additional deaths are not spread evenly across the United States but are instead concentrated in southeastern states, along with Texas and Arizona. Florida, Louisiana, and Mississippi are all projected to experience more than 30 additional deaths per 100,000 people annually by late century in the median case, with a 1-in-20 chance of more than 75 additional deaths. The colder regions of the country are *likely* to see reduced mortality from warmer winters, with the greatest reductions in Alaska, Maine, New Hampshire, and Vermont.

Climate-change mitigation significantly reduces the mortality risk, both nationally and regionally. In RCP 4.5, the nation is projected to experience about 1 additional death per 100,000 each year by the end of the century in the median case, with a 1-in-20 chance of 12 additional deaths—a threefold to ninefold reduction in risk. Even Florida, the hardest-hit state, sees a twofold to fourfold reduction in risk under RCP 4.5. Further mitigation to RCP 2.6 has only a modest effect at the national level but in Florida gives rise to a sixfold to sevenfold reduction in mortality risk relative to RCP 8.5.

When the U.S. Environmental Protection Agency quantifies the benefits and costs of regulations, it uses a value of a statistical life—an estimate of the amount a typical American is willing to pay to reduce societal mortality risk—equal to about $7.9 million per avoided death. Using such a value to translate lives lost into dollar terms, the cost of increased mortality under RCP 8.5 amounts to about 1.5 percent of GDP in the median case, with a 1-in-20 chance of a loss of more than 5.4 percent of GDP.

Increased mortality has a smaller economic price if we consider only the labor income lost, although this is an admittedly limited way to value human lives. The expected income lost under RCP 8.5 by late century amounts to about 0.1 percent of GDP, with a 1-in-20 chance of a loss exceeding 0.4 percent of GDP. The economic consequences of these losses are amplified because reduced labor supply in a particular year affects economic growth rates in subsequent years; we assess this amplification when combining impacts in a computable general equilibrium model.

The second greatest economic risk comes from the reduction in the number of hours people work (chapter 7). This effect is most pronounced for those who engage in "high-risk," physically intensive work, especially outdoors. The high-risk sectors identified by statistical studies include agriculture, construction, utilities, and manufacturing. The labor-supply risk is spread more evenly across the country than mortality risk but is highest in states such as North Dakota and Texas, where a large fraction of the workforce works outdoors. It yields a late-century reduction of about 0.5 percent in GDP in RCP 8.5 in the median case, with a 1-in-20 chance of a loss exceeding 1.4 percent of GDP. The labor-supply risk can be moderately reduced through mitigation—by about a factor of 2 by switching to RCP 4.5 and by another factor of 2 by further reducing emissions to RCP 2.6.

The next two largest risks come from impacts on energy demand (chapter 10) and coastal communities (chapter 11).

Nationally, energy expenditures are expected to increase by about 12 percent by late century under RCP 8.5 (with a 1-in-20 chance that they will increase by more than 30 percent) as a result of climate-driven changes in energy demand. These increased energy expenditures amount to about 0.3 percent of GDP (with a 1-in-20 chance of exceeding 0.8 percent of GDP). They are concentrated in the southern half of the country, with the Pacific Northwest even seeing a reduction in energy expenditures in the median projection. RCP 4.5 reduces energy demand risk by a factor of about 2 to 3; further reducing emissions to RCP 2.6 reduces the risk by another factor of 2 to 3. These estimates do not include temperature-related reductions in the efficiency of power generation and transmission, which will likely further increase energy costs.

Both sea-level rise and potential changes in hurricane activity will be costly for the United States, with geographically disparate impacts. Considering only the effects of sea-level rise on coastal flooding, the percentage increase in average annual storm losses is likely to be largest in the mid-Atlantic region, with New Jersey and New York experiencing a median increase of about 250 percent by 2100 under RCP 8.5 (with a 1-in-20 chance of an increase greater than 400 percent). The absolute increases in coastal storm risk are largest in Florida, with losses increasing by about $11 billion per year (relative to current property values) in the median RCP 8.5 case by 2100. If hurricanes intensify with climate change, as many researchers expect, losses may increase nationally by a further factor of 2 to 3. The effects of greenhouse-gas mitigation on sea-level rise are more muted than for many other impact categories, as the oceans and ice sheets respond to warming relatively slowly; switching from RCP 8.5 to RCP 2.6 yields about a 25 percent reduction in coastal storm risk.

The national economic risk from both agriculture (chapter 6) and crime (chapter 9) is relatively small as a fraction of output (about 0.1 percent of GDP in the median late-century RCP 8.5 case for agriculture, with a 1-in-20 chance of about 0.4 percent of GDP; and a 19-in-20 chance of less than 0.1 percent for crime). That is not to say they are not significant—agriculture accounts for a small fraction of U.S. economic activity but is nonetheless of great importance to the nation's well-being, and increases in crime also affect human well-being in ways that do not show up in simple measures of economic output.

Agricultural risk is highly uneven across the country. Provided they have a sufficient water supply—a key uncertainty that remains a topic of investigation—irrigated crops, as are common in the western half of the United States, are less sensitive to temperature than the rain-fed farms that dominate in the eastern half. In addition, higher CO_2 concentrations are expected to increase crop yields. Accordingly, major commodity crops in the Northwest and upper Great Plains may benefit from projected climate changes, while in the eastern half of the country they are likely to suffer if farmers continue current practices. Differences between emissions scenarios are considerable, with median projected losses in RCP 8.5 three times those in RCP 4.5 by mid-century (a 3 percent reduction in crop yield vs. a 1 percent reduction in crop yield) and more than four times by late century (15 percent vs. 3 percent). It is important to bear in mind that the treatment of agriculture in the *American Climate Prospectus* omits some potential key factors; these include risks arising from sustained drought, inland flooding, and pests.

The relationship between crime and climate is well known in law, sociology, and popular culture—even figuring in an episode of the HBO show *The Wire*. Only recently, however, have statistical analyses clearly quantified this relationship in ways that are useful for climate-risk analysis. Applying the observed relationship to the *American Climate Prospectus* temperature projections indicates that violent crime is likely to increase by about 2 to 5 percent across the country under RCP 8.5 by late century, with smaller changes for property crimes. Mitigation moderately reduces these risks; the projected increase in violent crime is lower by about a factor of 2 in RCP 4.5 relative to RCP 8.5 and by another factor of 2 in RCP 2.6 relative to RCP 4.5.

The six economic risks quantified here are—as already noted—far from a complete picture (chapter 16). In the agricultural sector alone, the *American Climate Prospectus* does not cover impacts on fruits, nuts, vegetables, or livestock (chapter 6). Reductions in water supplies and increases in inland flooding from heavy rainfall (chapter 17), weeds and pests (chapter 6), wildfires (chapter 18), changes in the desirability of different regions as tourist destinations (chapter 19), and ocean acidification all pose economic risks. Impacts may interact to amplify each other in unexpected ways. Changes in international trade, migration, and conflict will have consequences for the United States (chapter 20). The Earth may pass tipping points that amplify warming, devastate ecosystems, or accelerate sea-level rise (chapter 3). In the twenty-second century under RCP 8.5, the combination of heat and humidity may make parts of the country uninhabitable during the hottest days of the summer (chapter 4).

To cope with climate risk, decision makers have two main strategies: to work toward global greenhouse-gas emissions mitigation (chapter 21) and to adapt to projected impacts (chapter 22). The comparison between the different RCPs highlights both the power of and limits to mitigation as a risk-management tool. However, decision makers should utilize these insights in conjunction with information on the costs of mitigation policies and technologies. The *American Climate Prospectus* does not address these costs, estimates of which are abundantly covered elsewhere. The Intergovernmental Panel on

Climate Change Working Group 3 report, the publications of the Energy Modeling Forum 27 exercise, and the International Energy Agency's World Energy Outlook and Energy Technology Perspective reports are useful starting points for interested readers.

Many of the impacts we assess can be moderated through adaptation, although most adaptations will come with their own costs (chapter 22). Expanded air-conditioning may reduce mortality impacts, although projections for the Southeast—where air-conditioning is already ubiquitous—suggests that benefits may be limited, concentrated in areas where adoption is not already saturated. Labor-productivity risks can be managed by shifting outdoor work to cooler parts of the day or through automation, but there are other constraints that may prevent a complete shift away from all outdoor exposure. Crop production may become more resilient to temperature extremes, perhaps by use of more irrigation or by migrating toward cooler locations, both of which come at substantial cost. Coastal impacts can be managed through protective structures, building codes, and abandonment of coastlines, all of which will be critical to our future economic well-being, but which will not come for free. We point to the importance of adaptation in limiting the economic cost of future climate changes by demonstrating how our empirically based techniques can be leveraged to estimate the potential size of these gains. This exercise, however, makes it clear that we know very little about the potential scope, effectiveness, and economic cost of potential adaptations—so much so that uncertainty over these values easily dominates all other uncertainty in projections. This result indicates the importance of future research and analysis into the drivers and constraints of adaptation.

In 2013, we set out with both a research goal (i.e., to pilot an innovative framework for fusing detailed physical climate modeling with modern economic studies of the historical effects of climate variability) and a practical goal (i.e., to provide private- and public-sector decision makers with a prospectus surveying key economic risks the United States faces as a result of our planet's changing climate). The success of this seemingly overwhelming endeavor depended on many factors—most critically the members of our team, all of whom made key contributions and shaped the *American Climate Prospectus* into the volume in your hands. D. J. Rasmussen transformed the products of large-scale global climate models into probabilistic climate projections useful for risk analysis. Amir Jina constructed our econometric analysis and designed most of the figures in this book. James Rising built DMAS and integrated climate and economic data into projections. Robert Muir-Wood and Paul Wilson led RMS's work developing high-resolution forecasts of the impact of sea-level rise and potential changes in hurricane activity on expected coastal storm damage. Michael Mastrandrea provided invaluable support in qualitatively describing climate impacts we were unable to quantify in the *American Climate Prospectus*. Shashank Mohan and Michael Delgado modeled energy-sector impacts and integrated all the impact estimates in a consistent economic framework. Without this eclectic team of mavericks, who have been a joy to work with, the *American Climate Prospectus* would not exist.

Trying to peer into the future, one always sees a fuzzy picture. However, thoughtful consideration of the blurry image provides us with far more information than shutting our eyes tight. As a nation, we are making difficult decisions that will determine the structure of the economy in which we, our children, and our grandchildren will compete and make our livings. In navigating these decisions, we need the best possible map—and if it is blurry, we need to know how blurry. The last thing we want is to drive off a cliff that is nearer to the road than we expect. Rational risk management is about identifying when it is safe to drive fast around a turn and when we should slow down. In your hands is the best map we could assemble for navigating America's economic future in a changing climate. Like any map, it has blank regions and will improve in the future . . . but ignoring the information we have now is just as dangerous as driving with our eyes closed.

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