Fifth National Climate Assessment: Chapter 19

Economics

Chapter 19. Economics

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Table of Contents

Introduction

The climate is a national asset that enables and contributes value to diverse economic activities across the United States, from agriculture, finance, and tourism to healthcare, education, and real estate. Changes in the climate are expected to impose substantial new costs to the US economy and adversely affect the economic opportunities of most Americans. Climate change, and the policies adopted in response to it, are also expected to alter both the domestic US economy and the global economy in which the US competes. These economic consequences are projected to be highly uneven across US regions, industries, and communities.

Climate change has *direct* and *indirect* effects on economic outcomes. Direct impacts affect individuals and other basic components of the economy (e.g., buildings, crops). These direct impacts may in turn cause secondary indirect impacts resulting from markets, governments, and other institutions adjusting to direct changes. For example, changes in rainfall patterns and sea level rise put existing homes at risk of flooding, a direct effect. Elevated flood risk in turn causes indirect effects, including lowering home prices, increasing risks to mortgage-providing businesses, and altering the cost of flood insurance provided by the Federal Government.

This chapter assesses the effects of climate change on US markets, budgets, and the economic opportunities of households, businesses, and institutions. This chapter does not assess the economics of climate change mitigation and technological solutions, which are covered elsewhere (e.g., KMs 31.1, 31.2, 17.3).[1,2]

Key Message 19.1

Climate Change Affects the Economy Directly

Climate change directly impacts the economy through increases in temperature, rising sea levels, and more frequent and intense weather-related extreme events (e.g., wildfires, floods, hurricanes, droughts), which are estimated to generate substantial and increasing economic costs in many sectors (*likely*, *high confidence*). These impacts are projected to be distributed unequally, affecting certain regions, industries, and socioeconomic groups more than others (*very likely*, *high confidence*). Adaptation can attenuate some impacts by reducing vulnerability to climate change, but adaptation strategies vary in their effectiveness and costs (*medium confidence*).

Observed Direct Impacts

Direct economic impacts of climate change have been observed in many economic sectors (e.g., Table 19.1a). For example, more frequent extreme events and higher temperatures lead to direct economic losses via infrastructure damage,[3] worker injuries,[4] and crop loss.[5]

Climate change also directly affects valuable resources that are not traded in markets, such as human health and ecosystems. These *nonmarket impacts* are sometimes difficult to quantify but are nonetheless economically important and represent a substantial fraction of the economic burden of climate change on Americans (Table 19.1c). For example, rising temperatures, extreme weather, wildfires, vector-borne diseases, food insecurity, and knowledge of the threat of climate change itself have all been linked to declines in Americans' physical and mental health.[6,7,8,9,10] Additionally, changes in ecosystems caused by climate change have impacted food production, water resources, forestry, human health, real estate values, recreation, and tourism (KM 6.1, 7.3).[11,12,13]

Projected Direct Impacts

While some economic impacts of climate change are already being felt, the impacts of future changes are projected to be more significant and apparent across more sectors of the economy (e.g., Figure 19.1 and Table 19.1b). With every additional degree of warming, the United States is expected to see increasingly adverse consequences. For example, warming global temperatures by 2°F is projected to cause more than twice the economic harm induced by 1°F of warming.[14,15]

As climate change advances, economic risks are projected to grow over time. For example, weather-related disasters currently generate at least $150 billion per year (in 2022 dollars) in direct damages to the US,[16] a cost that is projected to increase due to climate change in the near term.[17,18,19] Over the next few decades, climate change is projected to cause ecosystem disruptions,[20] water stress,[21] and agricultural losses.[22,23,24,25,26,27,28] Over the coming century, the country faces relocation costs and damage to property and infrastructure due to coastal flooding,[29] major adverse impacts on ecosystem services,[30] substantial and unequal health costs,[7] large negative impacts on economic production,[31] and a restructured investment landscape.[32]

While many sectors are impacted by changing weather conditions, agriculture is also directly impacted by higher carbon dioxide (CO_2) levels, because plants use CO_2 during photosynthesis. The effect of a CO_2-enriched environment is not well understood and depends on crop types and the availability of water and soil nutrients.[33] In some cases, CO_2 enrichment increases biomass but causes the nutritional value of agricultural output to decline.[34] Overall, the risks climate change poses to agriculture are expected to outweigh any potential benefits due to CO_2 fertilization or other factors such as longer growing seasons and expanded crop ranges (KMs 11.1, 21.1, 22.4, 23.3, 24.1, 26.2).

Projected economic impacts are not certain, as they depend on factors that cannot be known precisely. The largest source of uncertainty in projected impacts is the unknown trajectory of future greenhouse gas emissions,[35] which depend on mitigation policy, economic development, population growth, and other factors (KM 2.3). The uncertainty caused by climate change is itself an economic burden, since individuals are generally risk averse (Box 19.1).[36,37]

Economic impacts of climate change will vary by location due to different hazards, regional climate change patterns, and historical climate (Figure 19.1; KM 3.4). For example, locations that are hot today are generally projected to suffer greater damage because warming from 100°F to 105°F has a larger effect on human health, energy use, labor supply, and crop yields than warming from 60°F to 65°F.[7,26,38,39] Population density also influences the local economic impacts of climate change, since dense populations exacerbate urban heat islands and groundwater drawdown but improve the cost effectiveness of some public adaptation projects, such as seawalls.[40,41]

Cold regions may benefit from low levels of warming while temperate and hot regions are generally harmed.[15] Within most sectors that have been studied, more Americans are harmed than are helped by climate change (Figure 19.1b).[3,7,42,43,44,45,46,47] Estimates of nationwide impacts indicate a net loss in the economic well-being of American society (Figure 19.1c; e.g., Hsiang et al. 2017;[15] Rode et al. 2021,[46] 2022;[45] Hultgren et al. 2022;[43] Carleton et al. 2022;[7] Martinich and Crimmins 2019[44]).

Table 19.1. Example US Economic Impacts of Climate Extremes and Climate Change

Shown are observed and projected impacts of a sample of climate extremes and climate changes on US economic outcomes, as they are estimated in the context of particular studies. Note that only a subset of climate drivers may have been assessed in each study. Section (**a**) shows impacts on current economic outcomes. Section (**b**) shows projected future impacts. Section (**c**) highlights examples of important but unquantified impacts. All impacts are for the US and in 2022 dollars unless otherwise noted. GDP stands for gross domestic product, a standard measure of total domestic economic production. These estimates are illustrative and not comprehensive. See metadata for table credits.

Key: * indicates an intermediate scenario (e.g., RCP4.5); ** indicates a high scenario (e.g., RCP6.0); *** indicates a very high scenario (e.g., RCP8.5); † indicates 3% discount rate.

Government Households Health Agriculture Business

Infrastructure Recreation Labor Existence/non-use value Unknown value

a) Sample Current Impact Estimates of Climate Hazards on US Economic Outcomes

Sector	Impact Type	Climate Hazard	Economic Estimate
	Crop insurance payouts	Temperature increases	+19% of federally subsidized payouts[48]
	Rural outmigration	Warming-linked crop failure	+0.17% for 1% crop yield reduction[49]
	Commercial mortgage delinquency	Hurricane	+28% per 10% damage increase[50]
	GDP growthW	Hurricane	−0.45 percentage point annual growth rate per hurricane[51]
	Municipal borrowing costs	Sea level rise	+23.4 basis points annualized bond issuance cost per 1% additional GDP loss due to sea level rise[52]
	Municipal budgets	Wildfire	+25 percentage point increase in likelihood of budget deficit[53]
	Social safety net transfers	Hurricane	+$975–$1,440 per capita[54]
	Housing prices	Flooding	−4.6% (in 100-year floodplain)[55]
	Student learning	Temperature increases	1% decrease in test scores per 1°F hotter school year (no adaptation)[56]
	Property values	Sea level rise	−14.7% (1-foot rise)[57]
	Damage to structures and crops	Flooding	+$235 billion per year[58]
	Earnings	Wildfire smoke	−$144 billion per year[59]
	Work injuries	Heat (≥85°F day)	+5%–15% per hot day[4]

Sector	Impact Type	Climate Hazard	Economic Estimate
	Wages as adult	Heat (≥90°F day)	−0.1% per hot day in utero[60]
	Emergency department costs	Heat (≥80°F day)	+$10,600 per 100,000 people aged 80+[61]
	Mortality	Heat (≥90°F day)	+0.9 deaths per 100,000 people[62]
	Alaska Native village relocation	Warming-linked erosion	$28–$280 million costs per village (adaptation only)[63]

b) Sample Future Impact Estimates of Projected Climate Hazards on US Economic Outcomes

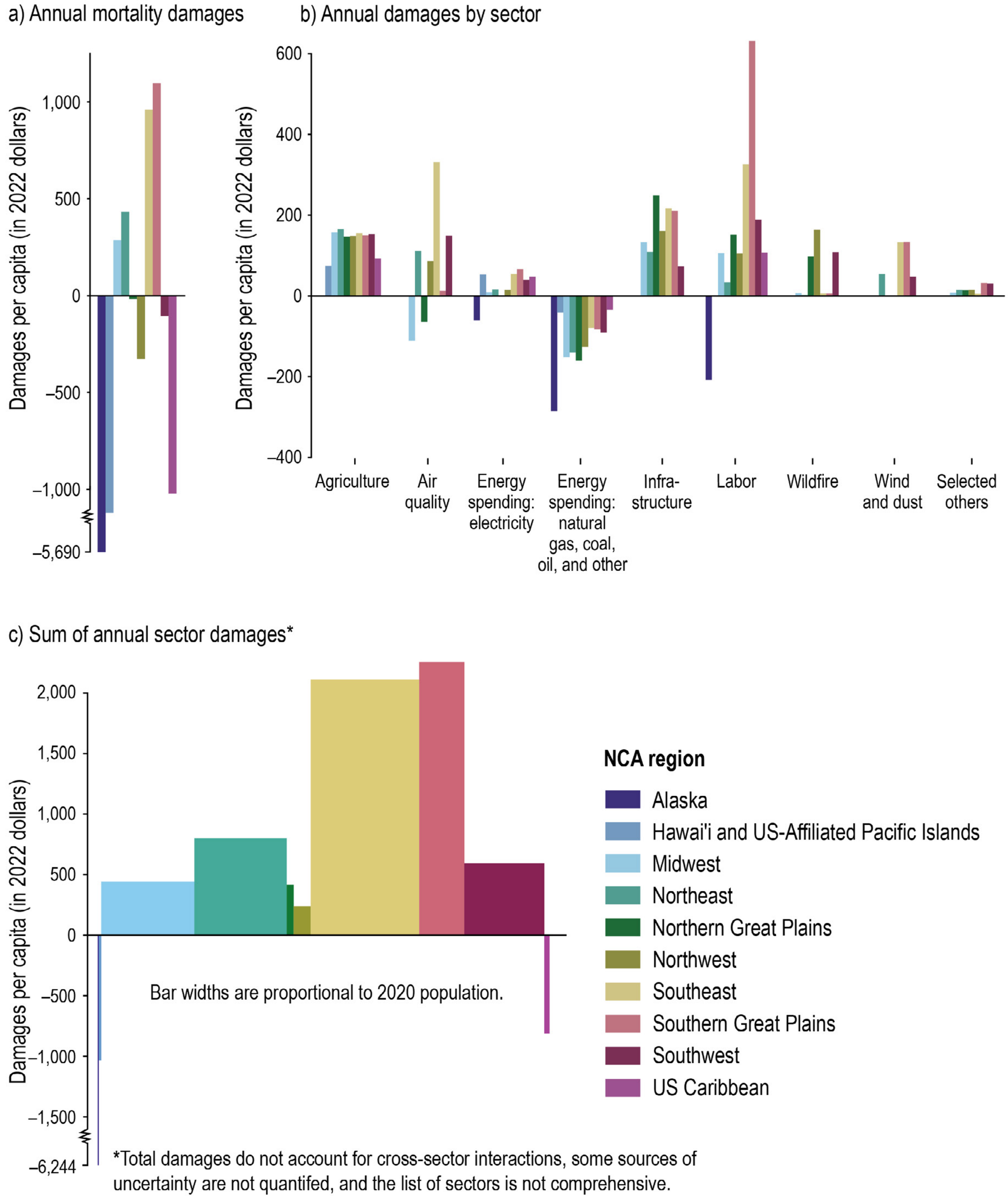
Sector	Impact Type	Climate Hazard	Economic Estimate
	Agricultural yields (maize, soybeans, winter wheat, spring wheat, cotton, and sorghum)	Temperature, moisture changes	12%–29%* decrease (2050–2100)[21] 20%–48%*** decrease (2050–2100)[21]
	Agricultural yields (maize, soybeans, and cotton)	Temperature, precipitation changes	30%–46%* decrease (2070–2099)[26] 63%–82%*** decrease (2070–2099)[26]
	Aggregate multisector impact	Temperature increases	−0.1%–1.7% GDP loss*[15] 1.5%–5.6% GDP loss***[15]
	Airline network disruption	Temperature increases	+16%–50% recovery costs (2035, global)***[64]
	GDP growth	Temperature increases	−0.13 percentage points per year per 1°F warming[31]
	Income	Temperature increases	−19.6% global GDP per capita (3°C [5.4°F] of warming)[31]
	Income	Hurricanes	29% GDP loss**†[65]
	Federal disaster response	Hurricanes	+$5.2 billion* (2050 annual expenditures)[66] +$36 billion*** (2050 annual expenditures)[66]
	National Flood Insurance Program	Flooding	+$3.9 billion annual losses (2050)*[66] +$5.1 billion annual losses (2100)*[66]
	Property tax revenue	Sea level rise	−1.4% (3-foot rise)[67]
	Public services	Temperature increases	+1.45% costs (2050)***[68]
	Coastal damages	Sea level rise	+$550 billion (optimal adaptation)***[40] +$2.6 trillion (no adaptation)***[40]

Sector	Impact Type	Climate Hazard	Economic Estimate
	Electricity outages	Temperature, precipitation changes	+$2.3–$6.8 trillion consumer costs***[69]
	Flooding costs	Flooding	+61% annual losses (2050)*[70]
	Railroad disruption	Temperature increases	+$30–$55 billion* costs from network delays[71] +$43–$73 billion*** costs from network delays[71]
	Road degradation	Temperature, precipitation changes	+$116 billion*** costs†[29]
	Urban drainage degradation	Temperature, precipitation changes	+$29 billion*** costs†[29]
	Alaska Native village relocation and protection costs	Flooding, erosion, permafrost subsidence	+$3.9 billion over 50 years (adaptation only)[72]
	Migration from Mexico to US	Temperature, precipitation changes	+0.7 million* migrants[73,252,253] +3.2 million*** migrants[73,252,253]
	Mortality (all causes)	Wildfire	+9–20 deaths per 100,000 people ≥65 years old (for 50% increase in smoke)[74]
	Suicides	Temperature increases	+5,600–26,000 deaths by 2050***[6]
	Recreation (boating, cycling, hiking, running, water sports)	Temperature, precipitation, snowfall changes	$11.6 billion (annual welfare gains 2050–2100)***[75]
	Recreation (fishing, hunting, skiing, ice skating, snowboarding)	Temperature, precipitation, snowfall changes	$4.6 billion (annual welfare losses 2050–2100)***[75]

c) Sample Impacts That Are Difficult to Quantify in Economic Terms

Sector	Impact type	Climate hazard	Economic estimate
	Happiness	?	?
	Preservation of national landmarks	?	?
	Loss of cultural heritage and resources	?	?
	Subsistence activities	?	?

Example Projected US Economic Damages for 3°F of Global Warming



Projected economic impacts of climate change vary by sector and region, with aggregate impacts resulting in net damages nationally.

Figure 19.1. Shown are estimates of annual economic damages in each National Climate Assessment region for several sectors in a scenario where global surface temperature increases 3°F (1.67°C). Positive damages indicate harm and negative damages indicate benefits. Panels (**a**) and (**b**) show per capita damages by region broken down by sector. Panel (**c**) shows summed per capita damages across sectors by region, with bar width corresponding to 2020 population. Most regions experience positive damages in most sectors. In aggregate, nearly all regions and the vast majority of the American population are projected to experience economic harm from climate change. Note that these damages do not account for cross-sector interactions, some sources of uncertainty are not quantified, and the list of sectors is not comprehensive. See Table 19.1 for further examples of sectors impacted by climate change. Citations for each study underpinning these results are available in the figure metadata. Figure credit: See figure metadata for contributors.

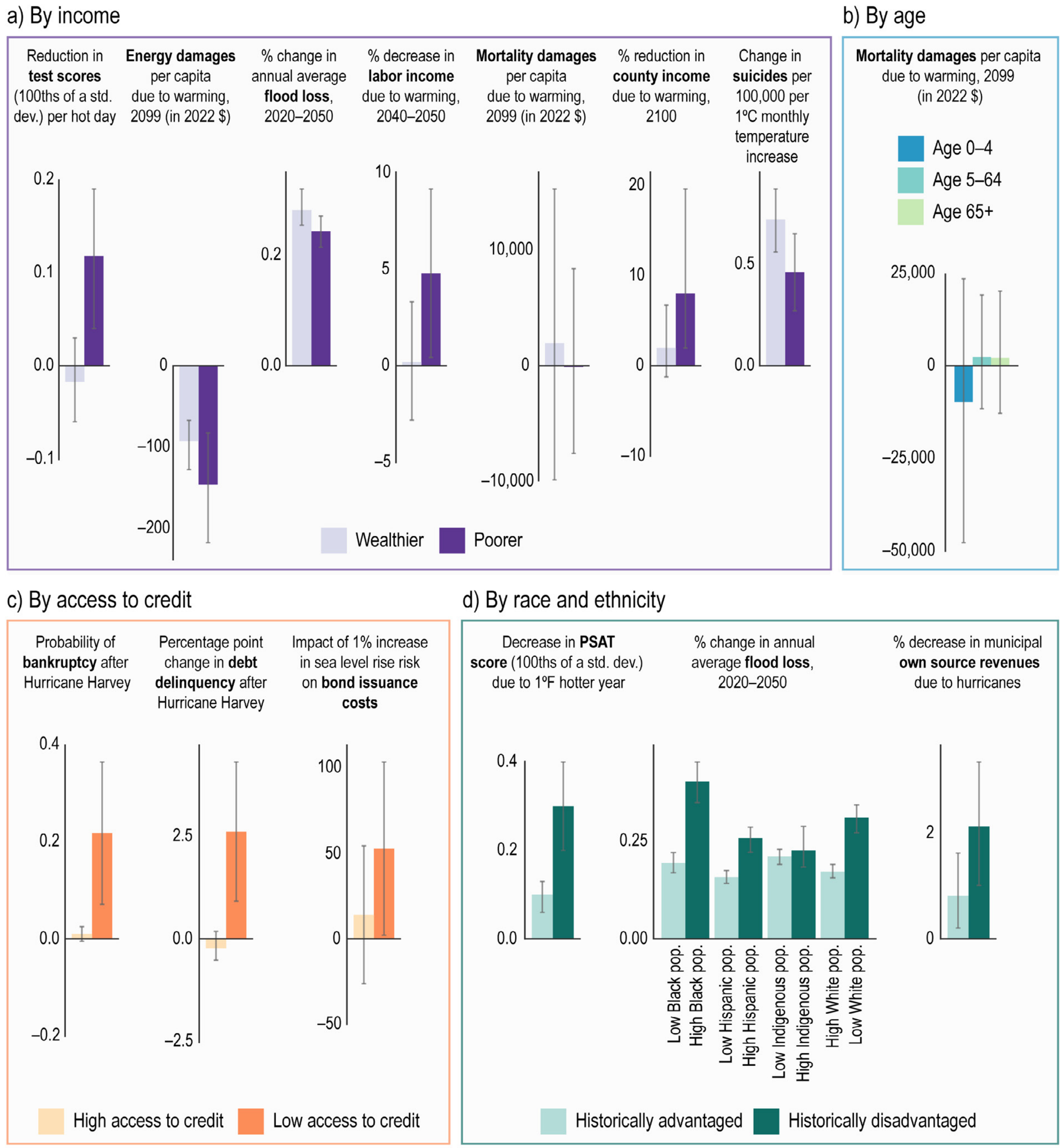
Adaptation

Adaptation to climate change can reduce some economic impacts.[38,40] For example, adaptation is expected to reduce storm-related climate damages by approximately one-third.[76] In some sectors, however, there is limited scope for adaptation (Ch. 31).[77,78] Natural and human systems may not be able to adapt quickly, so gradual warming is expected to be less harmful than rapid warming.[40] Adaptation can occur when populations have access to technologies or opportunities that lower their vulnerability to harmful conditions at sufficiently low cost.[41,79] Around 1% of the US capital stock is estimated to be adaptation capital.[76] Some adaptation strategies require new investments, expenditures, or consumption changes that offset or outweigh their benefits.[7,80,81] These adaptation costs may be large enough to prevent existing technologies from being utilized, particularly among low-income communities.[41,46] Adaptation may also face political difficulties, require behavior changes that populations are reticent to adopt,[82] or depend on technologies that do not yet exist or are in their infancy.[83] These factors make the projected timing and effectiveness of adaptations uncertain.[77]

Economic Vulnerability and Inequality

Economic damages from climate change are distributed unevenly across American society, often amplifying existing inequalities (Figure 19.2). Certain communities and individuals are more sensitive to climate impacts, are more exposed to climate hazards, or lack the resources to adapt to climate changes and recover from damages caused by natural hazards.[18,46,76,84,85,86,87,88,89,90,91,92] For example, people with preexisting health conditions and older adults may be relatively more sensitive to heat or air quality impacts such as wildfire smoke (KMs 14.3, 15.2).[4,93] Families living below the poverty line often live where climatic changes are expected to be the most economically damaging, like the already-hot Southeast (KMs 22.3, 22.4).[15] Climate-driven relocations of Alaska Native communities have already occurred where warming is happening fastest (KMs 16.1, 29.3, 29.5).[94,95] Climatic stressors have also been shown to increase racial segregation,[96] gentrification,[97] income inequality,[98] and low-income communities' reliance on social safety net programs and credit systems.[54,85,99] Climate change also introduces fiscal risks (Figure 19.3; KM 19.2) that may threaten programs vulnerable communities rely on.[100] Broad research gaps remain about unequal climate change impacts across demographics, health status, and socioeconomic background.

Climate Damages by Income, Age, Access to Credit, and Race and Ethnicity



The effects of weather and climate change are often experienced differently by populations according to income, age, access to credit, and race and ethnicity.

Figure 19.2. Each bar plot summarizes findings from a single study with impact estimates for different groups. Whiskers represent 95% confidence intervals, with the exception of the whiskers on the multisector aggregate panel, which are 90% confidence intervals. (**a**) The first set of estimates show unequal impacts by wealth. (**b**) The second set of estimates show unequal impacts across age groups. (**c**) The third set of estimates show unequal impacts by credit access. (**d**) The fourth set of estimates show unequal impacts by historically advantaged and disadvantaged populations. The citations for each study are available in the metadata. Many of these estimates are uncertain, and differences between groups are often not statistically significant. Further examples of unequal climate impacts within National Climate Assessment regions are available in Figure 22.4 and Key Message 20.1. Figure credit: See figure metadata for contributors.

Key Message 19.2

Markets and Budgets Respond to Climate Change

Markets are responding to current and anticipated climate changes, and stronger market responses are expected as climate change progresses (*medium confidence*). Climate risks are projected to change asset values as markets and prices adjust to reflect economic conditions that result from climate change (*very likely*, *high confidence*). New costs and challenges will emerge in insurance systems and public budgets that were not originally designed to respond to climate change (*high confidence*). Trade and economic growth are projected to be impacted by climate change directly and through policy responses to climate change (*likely*, *medium confidence*).

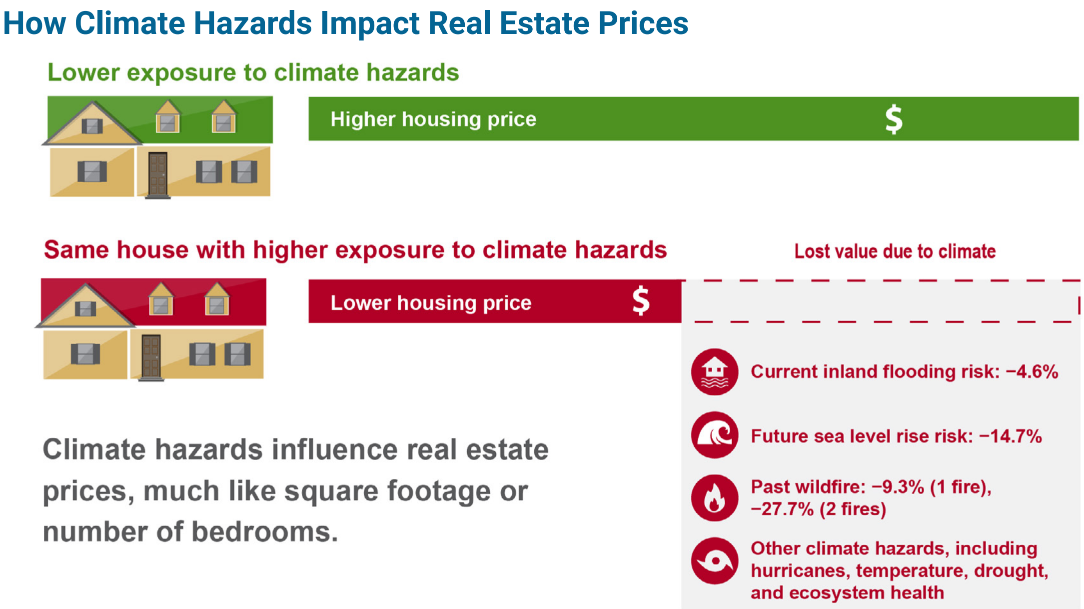
Markets

Markets aggregate information from many individuals and firms, generating system-level outcomes (e.g., market prices). Prices in well-functioning markets will reflect assets' exposure to future climate risks and expected adaptation costs. For example, anticipation of future flood risk has begun to reduce the prices of vulnerable properties (Figure 19.3).[57,101] But there are barriers that sometimes prevent market prices from adjusting to reflect climate risks,[102] such as inaccurate information or incomplete understanding of relevant climate risks.[103,104,105,106] Increasing awareness of climate change is expected to tighten the link between asset prices and climate risks in financial markets and may lead to abrupt price adjustments.[52,57,107,108,109]

Changes in prices due to climate change can have different impacts on producers and consumers. For example, higher temperatures around the globe are expected to lead to a reduction in global production of corn, wheat, rice, and soybeans.[43] This reduction in supply is expected to increase crop prices.[110] In some cases, these higher prices could financially offset the reduction in yields for farmers, but US consumers would face the burden of the higher food prices.[111]

Insurance markets are important for financial resilience to changing climate extremes, but insurance coverage is costly, and prices may exceed what households and businesses are willing or able to pay.[112] As the risk of climate extremes grows, private insurers are expected to abandon high-hazard areas, as is occurring in some wildfire- and hurricane-prone locations.[113] Uninsured consumers face greater financial distress post-disaster,[114] and public-sector insurance programs, such as crop insurance and the National Flood Insurance Program, see increasing demand when private insurance markets contract. To account for the growing risks, fiscal costs of public insurance programs will rise.[66,115]

Stock and bond market prices generally reflect anticipated climate risks,[116] but pricing can be incomplete or distorted.[102,117] Anticipated policies to curb emissions can impact stock prices of emissions-intensive companies,[108,118] and long-term bonds issued by municipalities exposed to future climate risks tend to have lower prices.[52,119] In the absence of strong global mitigation policies, some forward-looking financial institutions are preemptively responding to potential impacts by restructuring portfolios.[120,121]



Exposure to climate hazards has a negative effect on real estate values.

Figure 19.3. Exposure to past climate events and to present and future climate risks affects the values of otherwise identical properties. The market price for real estate is reduced when the property is exposed to adverse climate extremes or risks. Percentages shown are example estimates from studies. Homes located in the present-day 100-year floodplain cost 4.6% less than comparable homes outside the floodplain;[55] homes projected to be inundated by 1 foot of sea level rise cost 14.7% less;[57] and homes located near one recent wildfire cost 9.3% less, while those located near two recent wildfires cost 27.7% less.[122] Note that these are examples from specific studies, some of which are not nationally representative. Other climate hazards including hurricanes,[123] droughts,[124] temperature,[125] and ecosystem health,[126] among others, also affect real estate prices. Figure credit: See figure metadata for contributors.

Public Budgets, Healthcare, and Infrastructure

Climate change will affect public budgets at all levels of government through changes in revenues, spending, and borrowing costs (Figure 19.4).[127,128,129] For example, sea level rise, wildfires, and hurricanes can decrease incomes[65,130] and housing values (Figure 19.3),[109,131] and thus tax revenues,[100] while simultaneously increasing public expenditures for healthcare, income support,[54] disaster assistance,[132] and defense spending.[133] This combination of declining revenue and increasing expenditures increases municipal borrowing costs.[52,53,100,119]

Climate change is expected to further increase the costs of public programs, such as crop insurance subsidies,[48,115] wildfire suppression,[66,134,135] endangered species protection,[136] and healthcare provision.[68,137,138] Given these demands, achieving sustainable public budgets in a changing climate is expected to require additional revenues or other expenditure reductions.[68,128]

US healthcare is provided by public systems and private markets, both of which will be impacted by climate change. Extreme weather events, such as hurricanes, damage healthcare facilities and impede medical care delivery[139,140,141] and create competition for healthcare services.[142] The direct health impacts of climate change (e.g., Ch. 15; Limaye et al. 2019[143]) are expected to generate higher medical costs, raising health insurance premiums, out-of-pocket spending, and expenditures on prevention efforts.[7,144,145]

Essential infrastructure, such as water, energy, communication, and transportation systems, will increasingly be compromised by the compounding effects of climate change impacts (Chs. 4, 5, 12, 13; Focus on Compound Events). Degradation or disruption of these assets, many of which are publicly owned, can have substantial repercussions on other sectors and the well-being of households (Table 19.1).

Migration, Trade, and Growth

Future climate changes are expected to affect migration patterns, although how these shifts will occur is uncertain. Historical events that have shaped migrations include extended droughts, which drove rural populations toward urban centers,[124] and hurricanes, which have had persistent impacts on where people live.[146,147,148] Projections of increased flood risks due to sea level rise (KM 2.2) are expected to displace substantial populations.[149,150,151] Climate-driven economic changes abroad, including reductions in crop yields, are expected to continue increasing the rate of immigration to the United States.[73,152]

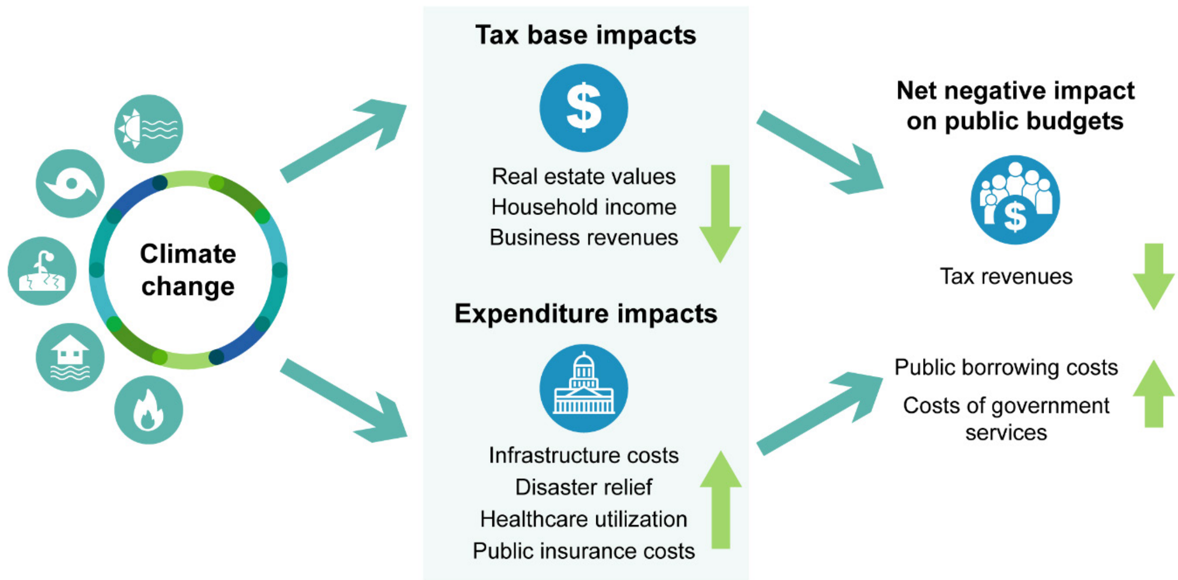
Global supply chains can transfer, amplify, or reduce the direct impacts of climate change (Focus on Risks to Supply Chains). Climatic events in other countries impact trade with the United States,[153] which in turn affects domestic markets (Ch. 17).[154] Climate impacts that affect multiple countries simultaneously amplify costs due to interacting disruptions and linked trade.[155] However, geographic diversification of supply chains would allow for businesses to flexibly adjust supplies to partially reduce their exposure to climate-associated risks.[156]

High annual temperatures and tropical cyclones are associated with lower growth in GDP,[31,65,157,158] with responses from multiple industries contributing to this overall effect. For each 1°F increase in global average surface temperature, annual US GDP growth is projected to slow roughly 0.13 percentage points,[31,157,158] with larger effects for larger temperature changes. These changes in growth rates can in turn affect stock market prices and interest rates.[159,160]

Innovation

Economic impacts of climate change will motivate some investments in innovations aimed at reducing or limiting climate damages. For example, development of low-cost air-conditioning[38] and arid-tolerant crop varieties reduced the impact of historical climate conditions.[161] Future innovations may reduce costs or result in new adaptation technologies. However, some adaptation challenges have proven difficult to overcome,[162] and novel adaptive technologies are sometimes costly, often limiting their accessibility to high-income communities.[46] Nonetheless, strategic investments in key adaptation technologies have the potential to generate large social and private returns.

Fiscal Risks of Climate Change



Climate change puts pressure on public budgets.

Figure 19.4. Climate change increases demand for government services while also reducing governments' ability to fund those services, creating new risks for the fiscal sustainability of government budgets at local, state, and federal levels. Tax revenues may fall due to decreased real estate values, household income, and business revenues.[53,100,163] Meanwhile, expenditures on infrastructure,[164] disaster relief,[132] healthcare,[54,68] and public insurance[135] are expected to increase. Together, this fiscal risk increases the cost to government for borrowing funds (e.g., the sale of bonds) by reducing the rating of public debt, which in turn further harms the ability of governments to fund services. Figure credit: See figure metadata for contributors.

Box 19.1. Economic Decision-Making Under Uncertainty

Economists use economic and financial models to understand the potential impacts of climate change on our economy and markets. Projected economic outcomes depend on many uncertain factors, including technological developments, economic growth, mitigation policies, individual behavioral responses, and Earth system processes. Recognizing this uncertainty is important for decision-making and should be factored into economic planning and risk analysis.

Economic uncertainty due to climate change is costly. Individuals and investors dislike uncertainty as it can drive up costs of action by requiring planning for multiple possible futures. Society thus benefits from actions that can reduce this uncertainty (e.g., obtaining better information on damages). When uncertainty cannot be reduced, some investments may be valuable specifically because they serve as a hedge against climate risks,[159] and it may be prudent to preserve and develop options and invoke decision strategies that seek robustness against a range of future outcomes. For example, in the face of uncertainty around future climate conditions, the California Public Utilities Commission now asks energy utilities to use downscaled climate projections for a very high scenario (RCP8.5) for climate adaptation planning, investment, and operational purposes (see KM 18.3).[165]

Key Message 19.3

Economic Opportunities for Households, Businesses, and Institutions Will Change

Climate change is projected to impose a variety of new or higher costs on most households and to impact their employment, income, and quality of life (*very likely*, *high confidence*). Climate change will alter the economic landscape that businesses face, generating new risks but also creating new opportunities (*likely*, *medium confidence*). Institutions and governments are expected to see existing programs used more intensively or in new ways as populations cope with climate change, generating new system-wide risks (*medium confidence*). Design, evaluation, and deployment of adaptation technologies and policies will strengthen our national preparedness for climate change (*high confidence*).

American Households

Climate change will have different economic implications for American households depending on their occupation and where they live.[84,157] On average, climate change is projected to reduce future income gains compared to what households would achieve in the absence of climate change.[166]

Climate change is expected to impact employment by changing demand for workers, reducing worker safety,[4] altering the location of available jobs,[49] and changing workplace conditions in heat-exposed jobs.[45,167] Households may also lose wealth through declines in the value of real estate (Figure 19.3).

Climate change will affect household spending,[168] for example, by changing energy use (Ch. 5),[169] increasing medical costs (Ch. 15),[143] elevating food prices (Ch. 11),[111] raising insurance premiums, and requiring more frequent repairs and replacement of assets damaged by extreme events.[16]

Children's economic prospects will be affected by climate change. For example, higher temperatures in utero negatively impact adult economic outcomes,[60] while higher temperatures during childhood reduce learning[56,170] and cognitive performance.[171,172]

Climate change is expected to alter the quality of life for American households[125] by reducing life expectancy,[7] increasing crime and domestic violence,[15,173] damaging sleep quality,[174] harming mental health,[6,175] reducing happiness,[176] and altering recreation in both positive and negative ways (Table 19.1).[75,177,178,179]

Adapting to climate change generates new household costs and can alter living and work arrangements. For example, homes may be relocated or retrofitted to withstand weather extremes,[180,181] and consumption patterns may change to offset harms from the climate.[62] Importantly, lower-income households may face greater risks from climate change and have fewer resources to support the costs of adaptation (KMs 22.3, 22.4).[98]

American Businesses

Climate change is projected to reduce labor productivity and economic output across many sectors—including agriculture, finance, real estate, insurance, and services—and across many regions and states.[15,80,157] Extreme weather events can reduce output for extended periods, altering GDP growth rates.[158] In projections, these effects can compound over time, generating large cumulative losses.[9,31,157,182]

Businesses will face increasing exposure to climate-related risks at local, national, and international levels. For example, more intense heatwaves will reduce local productivity, greater wildfire smoke will lower demand for outdoor services, and more frequent extreme events around the world will disrupt international trade, supply chains, and foreign demand for American products (KM 17.3).

Climate change will also affect business investment planning. For example, the location of firm capital investments may change in response to more frequent weather disasters,[183] and regional adaptation efforts may be funded via corporate taxes or impact the rate of return on other investments.[184] Investment strategies for climate-resilient technologies and the total cost of insurance for capital investments are both expected to be impacted by climate change. In addition, uncertainty in impacts and the effectiveness of adaptation may delay investments (see Box 19.1).

The management of climate-related business risks can draw on established practices for general risk management. For example, regulators and investors are increasingly requiring businesses to disclose climate risks and management strategies. To support this, risk assessment tools for quantifying physical risks are currently being developed in public and private sectors.[185,186]

Governments and Institutions

Local, regional, national, and international governments and institutions (e.g., universities, professional associations, nongovernmental organizations) play a major role in facilitating individual and coordinated adaptation responses and enabling cost-effective decisions. Federal agencies are required to develop adaptation plans[187] and assess and mitigate climate-related financial risks,[188] while some states, local governments, and Tribal governments are developing plans varying in scope and complexity (KMs 31.1, 31.3, 31.4, 32.5).

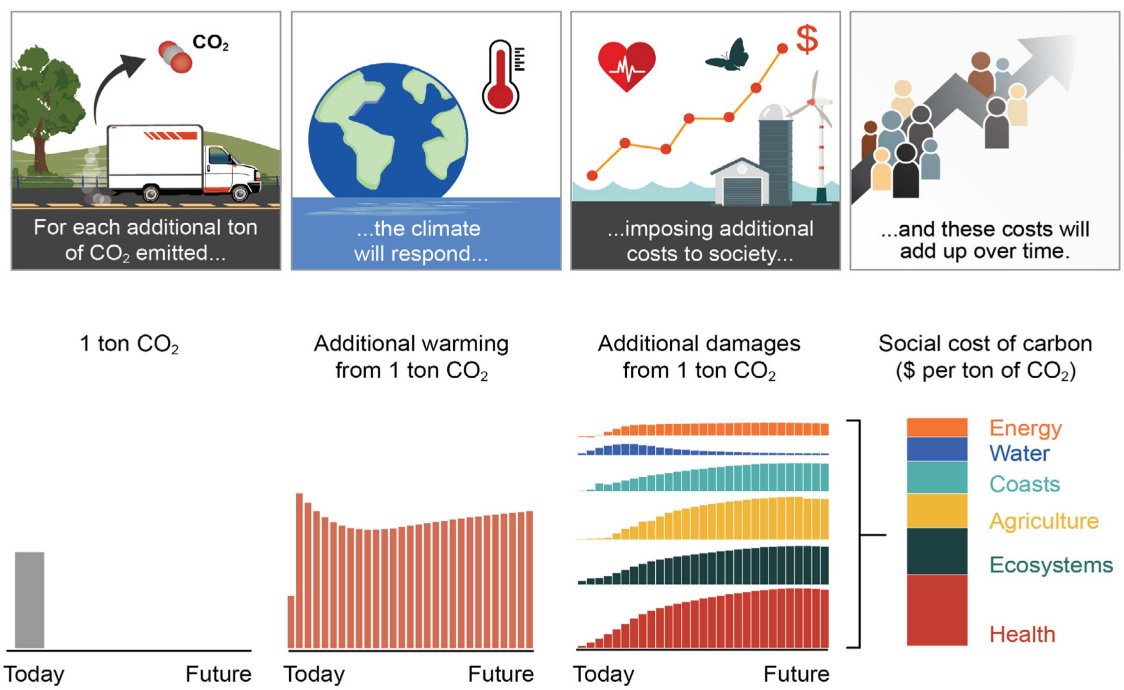
Governments at all levels would benefit from preparing for the fiscal impacts of climate change, considering impacts on revenues, expenditure requirements (e.g., healthcare, income support), and borrowing costs.[53,68,128] Reducing the overall societal cost of extreme events may be possible through investments in public infrastructure, healthcare, and community resilience programs[189,190,191] and through public support for private adaptation, including fiscal support,[76] updated building codes (Ch. 12),[192,193,194] and better climate-risk information and disclosures.[195] Such public programs also have the potential to reduce the inequitable impacts of climate change.[98,196] Financial preparedness by households and public entities, such as through insurance take-up,[52,197] improved credit,[52,85] and specialized financial instruments,[198] can shift risk or reduce losses. However, public insurance support or provision can decrease incentives for private adaptation.[76,199]

It is sometimes important for governments or institutions to quantify the overall economic impact of climate changes caused by certain current activities, for example, in analyses of whether the benefits of a new climate policy exceed its costs. A succinct summary description of the benefits of emissions reductions widely used in economic analyses is the "social cost of greenhouse gases," defined as the cumulative global economic harm to society caused by additional greenhouse gas emissions (Figure 19.5).[200] Institutions and governments considering the economic consequences of emissions may find estimates of this measure helpful, although they should familiarize themselves with the analytical and ethical judgments used in its construction. In 2010, twelve agencies from the Federal Government developed a process for estimating the social cost of greenhouse gases and periodically updated it based on scientific advances.[201] The current interim estimate used by the Federal Government, adjusted to 2022 dollars, is $57, $1,700, and $20,000 per ton of carbon dioxide, methane, and nitrous oxide, respectively, for 2020 emissions using a 3% discount rate.[201] There is ongoing research to update these values in accordance with recommendations from the National Academies of Sciences, Engineering, and Medicine.[200]

There is growing concern that climate change could pose a systemic risk to financial stability.[202,203,204,205,206,207] Negative economic impacts on even a limited number of entities could, in principle, lead to cascading effects, causing wider failure in the financial system. For example, declines in property values due to climate change could adversely affect mortgage markets and financial institutions' balance sheets, potentially leading to financial distress, especially if climate risks are imperfectly priced or if they are concentrated in government-sponsored enterprises.[202,206,207,208,209,210] While more research is needed to understand these systemic effects, some underlying risks can be managed. For example, the risk of future asset price corrections, driven by misalignment between current prices and the expected effects of climate change,[57,101,102,103,109,211] can be reduced through communication and disclosure of climate risks to market actors.[109,195]

Climate change has the potential to undermine conditions that support overall societal stability, which may threaten economic stability, and vice versa. Global warming has the potential to impede the ability of institutions and governmental organizations to function smoothly[175,212] and to increase political turnover,[213] and it is directly implicated in increasing rates of violence and unrest.[214,215] Some extreme events have triggered widespread mortgage delinquency,[216] insurer default,[217] breakdown in support for leaders,[218] and the migration of large populations domestically[219,220] and internationally[221,222]—which in turn impacts downstream markets.[146,223] Coping with these destabilizing effects may require investment in systems that buffer and stabilize economic and social conditions, such as social safety nets, insurance, defense spending, and confidence-building mechanisms.[54,133,224]

The Social Cost of Greenhouse Gases



The social cost of greenhouse gases is a monetary estimate of the total economic impact of an additional greenhouse gas emission today.

Figure 19.5. The social cost of greenhouse gases provides an estimate of the economic benefits to society of mitigating emissions, which can then be compared against the costs of doing so. This conceptual illustration shows how the social cost of reducing emissions of a particular greenhouse gas is computed. From left to right, the effect of one ton of carbon dioxide (CO_2) emitted into the atmosphere is illustrated in terms of additional warming or other physical impacts like sea level rise; these changes are translated into costs and benefits expected in representative market sectors such as agriculture, energy services, and water and coastal resources, as well as nonmarket impacts to human health and ecosystems; lastly, impacts that occur around the world and into the future are added up into a single measure using weights that reflect preferences around time, risk, and equity. The values shown in the figure are illustrative and may differ from estimates used for regulatory purposes. Figure credit: See figure metadata for contributors.

Traceable Accounts

Process Description

The chapter lead author was identified in July 2021, and the author team was recruited in July–August of 2021. Authors were selected based on their expertise on broad topics critical to the economic impacts of climate change on the US economy. Technical contributors were recruited by January of 2022 and were identified based on their expertise on specific types of impact. Efforts were made to ensure that both the author team and technical contributors represented a diverse range of backgrounds from across the country, including representation from academia, the private sector, nongovernmental organizations, and economic units of the Federal Government. The Economics chapter hosted an online engagement workshop on January 31, 2022. The authors also considered other outreach with stakeholders and inputs provided in the public call for technical material and incorporated the available scientific literature to write the chapter.

Discussion within the team during multiple virtual meetings and email exchanges, along with consideration of a systematic review of available scientific literature developed by the technical contributors, led to the development of three Key Messages. Because previous National Climate Assessments did not have a chapter on economics, the team focused on scientific material that was not previously discussed in other chapters of prior Assessments. Based on scoping by the National Climate Assessment Federal Steering Committee, the Economics chapter focused on the economic impact of climate change on the US economy and did not consider economic aspects of potential mitigation policies, which was out of scope. Particular attention was paid to the emerging scientific understanding of inequity of impacts across the country, which informed all Key Messages. Figures were developed by the author team, with support from technical contributors, to highlight key concepts that support the Key Messages. Entries to the tables of example impacts (Table 19.1) were selected, based on an evaluation of their topical importance and breadth of coverage, from a much larger database of more than 300 entries collected by the author team and technical contributors in their review of scientific evidence.

Key Message 19.1

Climate Change Affects the Economy Directly

Description of Evidence Base

There is mounting evidence of climate change impacts on economic costs. This literature requires multidisciplinary expertise bridging the physical sciences and economics. Broadly, the approaches to estimating climate impacts include biophysical process models, structural economic models, statistical or empirical methods, and hybrid approaches, with each methodology having strengths and weaknesses. A common finding in the above literature[26,38,39,225] is that moderate temperature and/or rainfall are usually beneficial, while cold and heat spells negatively affect a sector, as do droughts and floods. This implies that impacts will vary by 1) the baseline climate, 2) the predicted change, and 3) the vulnerability to such changes. First, colder places might actually benefit from warming as colder temperatures are replaced with moderate ones. Most of the above papers find an asymmetric relationship with regard to temperature, where being too hot is worse than being too cold. Hence, the effect of an increase in extreme heat is the dominant driver for most places in the US leading to a net loss. Second, predicted climate change is not uniform around the world, and higher latitudes (farther removed from the equator) are predicted to see higher warming. Third, vulnerabilities vary significantly across groups; for example, the sensitivity to extreme heat is larger in cold places,[226] and poorer places tend to have higher mortality effects of hotter temperatures.[7]

The literature addresses adaptation either by assessing it directly or assuming results are inclusive of adaptive responses.[7] Examples of directly assessing adaptation include study of the development and penetration of air-conditioning to reduce future temperature-related mortality,[38] the use of drought-tolerant crop varieties to limit the impact of some historical climate events,[161] and the building of seawalls and nourishment of beaches to protect infrastructure and ecosystems from sea level rise.[40] Research often assumes optimal adaptation, but some studies have considered partial adaptation to be more reflective of observed reality.[227]

Major Uncertainties and Research Gaps

A major source of uncertainty in estimates of climate change's economic impacts is representing complex interactions among physical, natural, and social systems. There are a number of critiques of the existing literature but also many important advances. Major uncertainties arise around unmeasured impacts, damages due to non-gradual weather or climate changes, interactions between regions and sectors, projections of population and income growth and technological change, risk aversion, distributional effects, and accounting for adaptation processes and costs. Improving the robustness of economic impact estimates is an active area of research. Scientific advancements in the last decade (National Academies of Sciences, Engineering, Medicine 2017[200] and others) have improved estimates of economic impacts, as well as our understanding of key uncertainties.

One point of uncertainty regards the shape or functional form of the climate damage function. While many empirical studies have found that the increase in global, regional, and sectoral damages as the climate warms can be approximated by a quadratic damage function,[15,47,228] disagreement remains, particularly for higher temperatures. Several studies (Nordhaus 2019; Dietz et al. 2021; Kemp et al. 2022;[229,230,231] see also Dietz et al. 2022[232] reply to comments by Keen et al. 2022[233]) argue that the damage function should become substantially steeper at higher levels of warming.

Damage projections in many sectors do not fully account for expected reductions in future vulnerabilities, for example, as has been observed in the past for temperature-related mortality.[7,38] More study of how the relationship between sensitivity of impact sectors (such as agricultural yields, mortality, or energy consumption) to weather fluctuations and income has changed over time may improve this area of research, as it remains unknown whether confounding factors influence cross-sectional comparisons sometimes used to estimate patterns of adaptation. Damage projections also rely on projections of future population, income, and technology, which are themselves uncertain.

Description of Confidence and Likelihood

There is *high confidence* that climate change will directly affect the economy and that impacts will be unevenly distributed, because numerous information sources document these results across many sectors, and studies of the same outcomes generally agree on the sign and magnitude of these impacts. Many findings are replicated by distinct author teams. Furthermore, insights from biology and physiology, derived from experimental and/or observational data, often support econometric findings. However, the changes in the primary drivers of some of these impacts have complex patterns (e.g., wildfires, floods, drought, hurricanes), while some regions or impact categories may see benefits from warming (e.g., avoided heating expenditures). Therefore, taken together, the finding regarding the substantial cost of these impacts is deemed only *likely*. This same complexity supports the finding of unequal distribution of impacts, so that finding is deemed *very likely*. This unequal distribution is a direct consequence of the different baseline climate (known by looking at current climate), different amount of warming (consistent finding in climate models), and different underlying vulnerabilities due to social determinants such as sensitivity and adaptive capacity. The finding that currently warm places are more negatively impacted by additional warming than colder places is widely supported and garners *high confidence*. Similarly, the fact that vulnerabilities vary by income and education has also been repeatedly observed. Neither point is controversial in the literature.

Given the breadth of approaches to analyzing adaptation, the literature is more varied in conclusions drawn regarding the level of risk that adaptation is expected to ameliorate, the cost of the adaptation actions, and the likelihood that these adaptation actions will actually be implemented. Future innovations may reduce the costs of existing adaptation technologies, or they may result in entirely new technologies. However, some adaptation challenges have proven difficult to overcome,[162] and, ultimately, success is uncertain and there do not exist established approaches for forecasting these innovations. Furthermore, public efforts to adapt to the climate sometimes have perverse outcomes, and it is unclear that similar efforts will be dramatically more successful in the future. For example, in the United States, public provision of both crop insurance subsidies and disaster aid have been estimated to increase vulnerability to extreme weather.[76,199] For all of these reasons, there is only *medium confidence* in findings regarding adaptation.

Key Message 19.2

Markets and Budgets Respond to Climate Change

Description of Evidence Base

Multiple lines of evidence, including theoretical and empirical analyses, demonstrate effects of anticipated climate risks on financial markets. For example, anticipated increases in flood risks due to sea level rise reduce the prices of vulnerable coastal properties[57,101,103] and the prices of long-term bonds issued by vulnerable municipalities.[52,119] These effects have increased over time, coinciding with increasing investor attention to climate change.[57,119,234] Emerging evidence demonstrates potential sources of market inefficiencies due to government policies. For example, existing securitization programs by government-sponsored enterprises, such as Fannie Mae and Freddie Mac, unintentionally encourage banks to issue mortgage loans to properties that are exposed to hurricane risks.[209]

For public budgets, adverse fiscal impacts of more frequent and intense natural disasters are well established. Hurricanes increase public expenditure requirements for healthcare and other programs,[54,132] decrease local tax revenues,[100] and increase municipal borrowing costs.[100] Wildfires have similarly been shown to increase public expenditures on fire suppression and other programs.[53,68,135,192,235,236,237] Evidence on natural disaster impacts on tax revenues is mixed across event types and levels of government (e.g., Liao and Kousky 2022[53]) find positive local revenue impacts of wildfires in California, due to a unique state law that freezes property assessments for taxes until a sale, and Miao et al. (2018)[163] fail to detect significant tax revenue impacts of disasters at the state level). Certain climate impacts may also have partial fiscal benefits, although the evidence is less strong (e.g., EPA 2017;[164] Barrage 2023[68]). However, the same evidence base also suggests negative *net* impacts. For example, Liao and Kousky (2022)[53] estimate large increases in the probability of municipal deficits as a result of wildfire events. Conceptually, disasters such as hurricanes and flooding can also have adverse impacts on tax bases, such as through negative effects on economic growth[51,65,101] and property values.[109,123,131] Finally, the literature documents other fiscal climate costs, such as from infrastructure,[164] the Endangered Species Act,[136] and increasing exposure to flood risk in the balance sheets of financial institutions[208] and government-sponsored enterprises.[209]

For insurance, private markets are important for financial resilience and climate adaptation, but these markets may be stressed by climate change. For example, it is well understood that as climate risks grow, it is increasingly difficult for insurers to offer policies at rates that both reflect risks accurately and that consumers are able and willing to pay, leading to a growing disaster insurance gap (e.g., Issler et al. 2020;[238] Netusil et al. 2021;[239] Kousky 2022[113]). Current risk and, thus, insurance pricing systems may become outdated with changing climatic conditions (e.g., GAO 2021[240]). Evidence suggests that households and businesses with insurance tend to recover better and faster from disasters (reviewed in Kousky 2019,[114] also Billings et al. 2022[85]).

There is growing evidence that global supply chains can transfer, amplify, or reduce the direct impacts of climate change. Multiple studies have documented that climate events in other countries impact trade with the United States, which in turn affects US domestic market conditions.[110,153,154] A smaller number of studies have identified ways that climate change also causes physical events that impact entire regions, generating costs that can be amplified by production networks.[155,241] It is theoretically well understood that flexible supply chain networks can also enable adaptation to climate change by enabling geographic diversification,[156] although there is not a large body of empirical evidence to demonstrate how this occurs in practice.

Major Uncertainties and Research Gaps

There is considerable uncertainty regarding the estimated effects of climate risk exposure on asset values. For example, estimates of the effect of sea level rise risk on coastal real estate prices vary from as large as −20%[57] to zero.[211] There is also substantial uncertainty about the extent of exposure of financial institutions to climate-related risks.[205] More research would be needed to understand how climate risks affect prices and quantities in debt markets, especially the mortgage market and mortgage-backed security market, and to understand the potential sources of market inefficiencies in pricing and allocating climate risks.

For public budgets, while evidence suggests that many public program costs may be affected by climate change, many of these impacts remain unquantified (e.g., law enforcement and military expenditure changes due to potential increases in crime and international conflict, respectively). Research is also limited on interactions between different climate impacts, such as on migration and fiscal outcomes. For both public budgets and insurance markets, policy uncertainty and uncertainty over adaptation compound the difficulty in projecting climate impacts.

Description of Confidence and Likelihood

There is evidence of market responses to climate change, although the literature on this topic varies in terms of estimates of the magnitude and timing of the response, which leads to a determination of *medium confidence* for this finding. However, climate risk factors are *very likely* to be an important driver of asset values in the future. There is already a significant body of research documenting the capitalization of weather-related risks into the prices of durable assets (real estate, stocks, long-term bonds, etc.), including a growing number of papers finding a reflection of the assets' exposure to future climate risks (e.g., sea level rise, flooding, wildfires, or anticipated carbon policies), leading to a determination that this linkage is *very likely*, although the magnitude varies and estimates of how price changes will unfold over time are uncertain. The literature on this is robust enough to warrant *high confidence*. There is *high confidence* that climate change will stress insurance systems and public budgets that were designed before global warming. This is supported by a large academic literature that considers direct effects of climate change on insured assets such as crops and flood-prone homes, direct effects on publicly funded disaster assistance, and indirect effects on healthcare utilization and social safety net programs. There is also research confirming negative impacts on municipal budgets from natural disasters and projected losses to other public sector budgets. In addition, there is mounting observational evidence of climate stress already impacting markets in certain regions of the country such as Louisiana, Florida, Texas, and California. There is *medium confidence* that trade and economic growth are both *likely* to be impacted by climate changes and by the policy responses designed to mitigate climate change. There is broad agreement that climate change will affect trade, but the magnitude and structure of those changes are complex and not fully understood. Similarly, many studies find that climate change affects economic growth, but there is substantial variation in quantitative results depending on which methods and data are used.

Key Message 19.3

Economic Opportunities for Households, Businesses, and Institutions Will Change

Description of Evidence Base

Substantial literature supports the conclusion that climate change will impose new costs on households and businesses.[15,84,157] In particular, research has focused on income,[15,31,157,166,242,243,244] employment,[4,39,49,167] and changes in real estate value.[57,101,103,105,211] Businesses face increased costs in a variety of areas. These costs include reduced productivity due to heatwaves, lower demand for outdoor activity at more distant locations due to wildfire smoke, supply chain disruption due to hydrologic extreme events (e.g., tropical cyclones in Asia, where semiconductor manufacturing is concentrated), property damage and business interruption losses from weather-related extremes,[245,246] and reduced foreign demand for American products.[5,84,156]

Literature also supports the fact that it is possible to reduce the societal cost of extreme climate-related events through investments in hazard mitigation,[3,76,247] including updated building codes[192,193,194,248,249] and public provision of better climate-risk information, such as flood risk disclosures.[195,250] Research has also shown that existing and new programs and activities associated with public and private institutions will need to play a role in helping to mitigate and adapt to climate change.[52,53,54,68,100,128,135,163] Household financial preparedness and specialized financial instruments[198] can also play a role in reducing losses from climate extremes. While insurance against natural disasters can financially protect households and businesses, these markets are themselves being stressed by climate change, with much natural disaster coverage now offered through fully or quasi-public programs.[113] It remains the case that those most in need of the financial protection of insurance are least able to afford it. There is strong evidence that public healthcare and social support programs can reduce climate vulnerability in certain settings.[190,191]

Major Uncertainties and Research Gaps

It is challenging to anticipate all the ways that households, businesses, and institutions will change in the face of a wide range of climate impacts; continued research on observed and projected responses to climate changes will refine and improve quantitative estimates of the implications of these changes. In particular, systemic risks have proven more difficult to conceptualize and model, and while they could be extremely costly, they have received less research attention. We also have limited understanding of nonlinearities in the costs or threshold effects that may materialize in both natural and human systems. Public programs can potentially moderate the inequality of climate impacts in important ways, but more research would be required to identify cost-effective and scalable strategies.[251] There are also uncertainties regarding how to target healthcare and other social support programs to achieve the largest net benefits.

Description of Confidence and Likelihood

There is a large literature base and high agreement regarding the variety of new or higher costs of climate change, leading to the finding of *very likely* and *high confidence* for this statement. There is less literature available characterizing the alteration of the economic landscape due to climate change, and while new risks predominate, there is a subset of papers that discuss the potential for new opportunities that business can take advantage of: this leads to the *likely* and *medium confidence* finding. Similarly, there is less literature regarding the response of institutions to changing climate conditions, leading to a *medium confidence* finding. There is extensive literature and a high level of agreement that private and public investments in adaptation and mitigation can reduce household and business costs, leading to the assessment of *high confidence*.

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