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Disasters in the United States : Frequency, Costs, and Compensation

Vera Brusentsev

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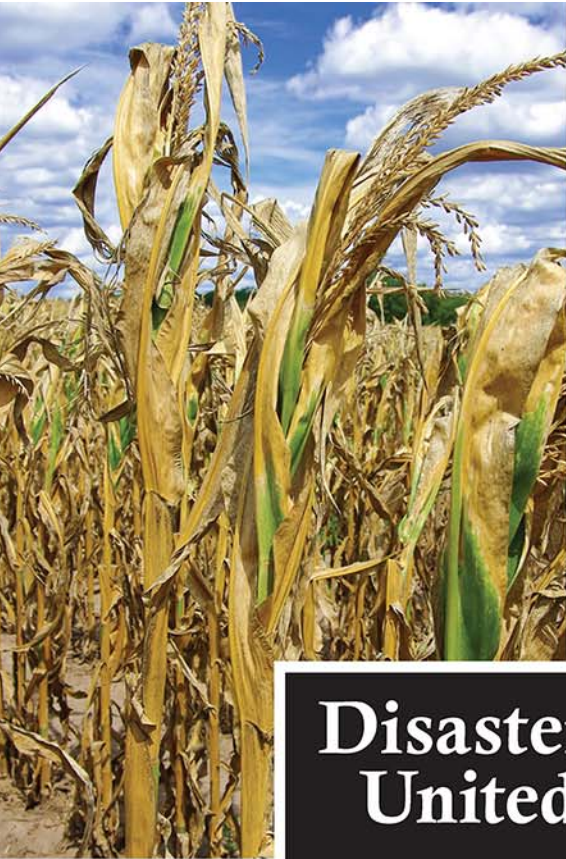
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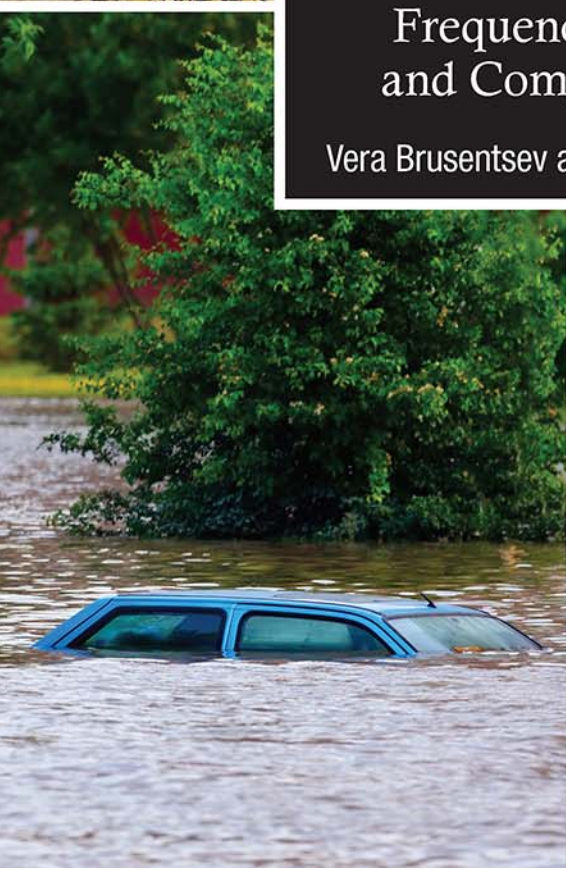
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Disasters in the United States

Frequency, Costs,
and Compensation

Vera Brusentsev and Wayne Vroman



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Abbreviations

BW-12: Biggert-Waters Flood Insurance Reform Act
CDC: Centers for Disease Control and Prevention
CDL: Community Disaster Loans
CEA: California Earthquake Authority
CPI: Consumer Price Index
DOI: U.S. Department of the Interior
DRF: Disaster Relief Fund
D-SNAP: Disaster Supplemental Nutrition Assistance Program
DUA: Disaster Unemployment Assistance
ECLAC: United Nations Economic Commission for Latin America and the Caribbean
EIDL: Economic Injury Disaster Loans Program
FEMA: Federal Emergency Management Agency
FSA: Farm Service Agency
GDP: Gross domestic product
HDL: Home Disaster Loan Program
HUD: Department of Housing and Urban Development
IHP: Individual and Household Program
NAP: Noninsured Crop Disaster Assistance Program
NBCR: Nuclear, biological, chemical, and radiological disasters
NCDC: National Climatic Data Center
NFIP: National Flood Insurance Program
NIFC: National Interagency Fire Center
NOAA: National Oceanic and Atmospheric Administration
OLS: Ordinary least squares
PA: Public assistance
PDSI: Palmer Drought Severity Index
PHDI: Palmer Hydrological Drought Index
SBA: Small Business Administration
SFHA: Special Flood Hazard Area
SNAP: Supplemental Nutrition Assistance Program
TANF: Temporary Assistance for Needy Families
TRIA: Terrorism Risk Insurance Act
TUR: Total unemployment rate
UI: Unemployment insurance
UNISDR: United Nations International Strategy for Disaster Reduction
USDA: U.S. Department of Agriculture
WUI: Wildland–urban interface

1

Setting the Scene

A Guide to This Volume

A disaster occurs when natural phenomena cause physical damage, injury or loss of life and assets, environmental degradation, disruption in the livelihoods and services of individuals and communities, and interruptions in social and economic activity. The Federal Emergency Management Agency (FEMA) of the U.S. Department of Homeland Security administers the primary system for recording disasters in the United States.¹ Major disaster declarations are listed with “DR” followed by a sequence number, emergency declarations with “EM,” and fire management assistance declarations with “FM.” In 2015, FEMA recorded a total of 79 natural disasters. The first major disaster declaration of 2015 was made on January 7 for the *Mississippi Severe Storms and Tornadoes* (DR-4205). By the end of 2015, FEMA had issued 43 major disaster declarations, with the *Oklahoma Severe Storms and Tornadoes* (DR-4247), declared on December 29, as the final one of the year.² Thirteen major disaster declarations were declared in 1953, the first year recorded in the FEMA system.

Are disasters becoming more frequent, as the FEMA declarations and everyday media reports suggest? Today, most disasters are broadcast around the world in real time, through the Internet, radio, television, and social networks. Perhaps the frequency of disasters has not necessarily increased, but our methods of tracking potential disastrous events have improved so that experts notice them more frequently than in the past. Certainly advanced technology has allowed meteorologists to better predict weather-related events. Meteorological organizations around the world are better equipped to provide increasingly accurate hazard assessments on which to base warnings, and early warning systems can effectively activate community-based emergency plans to respond to these warnings. Furthermore, our ability to communicate information has risen, especially with the widespread use of social media.

The initial answer to the question posed above is in the affirmative: Yes, disasters are increasing in frequency throughout the world.³ This

response prompts another important question: Is the frequency of natural hazards increasing? Natural hazards are defined as natural phenomena with the potential to cause destruction. They can be classified into several broad categories: biological, climatological, geological, hydrological, and meteorological.⁴ These natural hazards have been operating throughout history, but they only become noticeable when they negatively affect human populations. Disasters often follow natural hazards: they occur when households and assets are both exposed and vulnerable to natural hazards. Exposure refers to the people, assets, and systems present in hazard zones that are subject to potential losses, whereas vulnerability refers to the characteristics and circumstances of an asset, community, or system that make it susceptible to the damaging effects of a hazard.⁵ Exposure is largely fixed by the location of prior investments in infrastructure, economic development, and urbanization, and by cultural and social attachment to place.

When a hazard has a negative effect on humans and overwhelms their ability to cope (that is, resilience), then it is termed a disaster.⁶ The Intergovernmental Panel on Climate Change (2007) finds that climate change contributes to more frequent, severe, and unpredictable weather-related hazards, such as droughts, floods, heat waves, and tropical cyclones.⁷ Resilience with respect to a hazard is determined by the degree to which a community has the necessary resources available and is capable of organizing itself both prior to the potential hazard occurring and during the incidence of the phenomenon. A disaster causes significant destruction, including loss of life, damage to property and infrastructure, a reduction in economic production, the loss of employment and income, and hardship and suffering caused by the event. The severity of a disaster is commonly measured in the number of deaths (mortality) or the total dollar amount of the destruction it causes.⁸ Given that natural hazards have occurred throughout history and will always be with us, the increase in the frequency of disasters indicates that something else has changed. Moreover, while natural hazards are becoming better understood, the increasing losses associated with them indicate that contemporary society still finds it difficult to prevent hazards from becoming disaster risks.

What can account for the increase in the frequency of disasters? A recent study finds that the increase in global temperatures since pre-industrial times significantly increased the probability of heavy precipi-

tation and high heat extremes throughout the world (Fischer and Knutti 2015).⁹ Rising temperatures and more intense precipitation contribute to the severity of disasters. The weight of scientific evidence finds that the increase in the frequency of disasters is due to both anthropogenic (manmade) and natural phenomena. Evidence also suggests that weather-related disasters are becoming more frequent compared to disasters such as earthquakes and volcanic eruptions. One explanation is that with an increase in human population, exposure and vulnerability to hazards rise because more people will be affected. In addition, development and urbanization in regions susceptible to natural hazards can increase the likelihood that flash floods and coastal floods will cause a disaster. Examples include building on floodplains or on coastlines susceptible to tropical cyclones and tsunamis. And human activity can increase the frequency or severity of a disaster. Deforestation or overgrazing, for example, leads to more severe erosion from floods and landslides.

Every year, the World Economic Forum asks a group of about 1,000 experts from academia, business, government, and not-for-profit organizations about the likelihood of 30–50 perceived risks (both likelihood and severity in the next 10 years) of human interaction with the environment. The perspectives of these experts are published in the *Global Risks* report that highlights the most significant long-term risks worldwide (World Economic Forum 2015). The second most likely perceived risk worldwide is extreme-weather events. Howard Kunreuther, an academic advisor for *Global Risks 2015*, notes that:

Experts and the general public are now much more concerned with weather-related events than they were ten years ago because of the increasing losses from natural disasters around the world. ‘Extreme weather events’ is ranked as the second most likely global risk, and the failure of climate change adaptations is in the top five global risks in terms of potential impact. . . . [T]here are now efforts underway . . . to focus on long-term strategies currently being undertaken by communities to reduce the likelihood of severe catastrophes and to cope with disasters more effectively should they occur.

The United States has developed official definitions of disasters in order to classify and respond to them. The Robert T. Stafford Disaster Relief and Emergency Assistance Act (hereafter, the Stafford Act)

authorizes five categories of committed action either prior to a potential hazard occurring or in response to a disaster.¹⁰ Three types of declarations may be made before a disaster occurs: fire management assistance declarations, the provision of defense resources before a major disaster is declared, and the decision to pre-position resources and supplies. The president of the United States has the authority to issue two types of declarations after a disaster overwhelms the combined resources of local, county, and state jurisdictions: major disaster and emergency.

This book focuses on three disaster-related categories: major disaster declarations, emergency declarations, and fire management assistance declarations. We utilize these official definitions to draw inferences about the frequency, geographic patterns, trends, and financial costs related to disasters. After receiving a request from the governor of an affected state for a major disaster declaration, the president may take one of three possible actions for federal relief and recovery assistance: issue either a major disaster declaration or an emergency declaration, or decline the request. The Disaster Relief Act of 1974 firmly established the process of presidential disaster declarations. A major disaster is considered to be the result of a natural hazard or of an explosion, fire, or flood, regardless of the cause.¹¹ Once a president makes a major disaster declaration, federal resources are assembled for emergency relief and long-term recovery. An emergency declaration is more limited in scope, and certain long-term federal recovery programs are not provided. Fire management assistance grants are provided when a fire is determined to pose a “threat of major disaster.”

Since a major disaster declaration involves a request from a governor to the president, could the election cycle be linked to these declarations? As statewide elections mostly occur in the same years as presidential elections, it is possible that more disasters are declared in election years. In an exploratory investigation of the likelihood, we test for a possible linkage between major disaster declarations and elections using regression analysis. While there is a positive association between major disaster declarations and election years, the results are not statistically significant. Hence, the data for FEMA-designated disaster declarations do not support the election cycle hypothesis.¹²

Overall, from 1953 through the end of 2013 the cumulative total number of declarations in the 50 states and the District of Columbia is as follows: 2,046 major disaster (1953–2013), 355 emergency (1974–

2013), and 1,050 fire management (1970–2013).¹³ The geographic entity used in the reporting system is the state/tribal government, and each declaration identifies the affected counties within that state. For natural disasters that extend across state boundaries, declarations are made for each state.

The increase in the occurrence of disasters requires ever-increasing taxpayer dollars to finance the agencies responsible for improving “our capability to prepare for, protect against, respond to, recover from, and mitigate all hazards.”¹⁴ Concern over the size of federal budget deficits and the national debt has made policymakers more cognizant of the amount of funding the federal government provides to state and local governments for disaster assistance and the processes the federal government uses to provide it. Disaster assistance for large-scale destructive events has usually been financed by funds appropriated outside traditional budget constraints, which implies that taxpayers cover a large proportion of disaster-related costs.

In March 2011, President Obama issued Presidential Policy Directive 8: National Preparedness (PPD-8) aiming to strengthen the security and resilience of the United States to devastating events. The policy directive is a national platform for disaster risk reduction; that is, a mechanism for coordination and policy guidance on disaster risk reduction that is interdisciplinary and multisectoral with public, private, and civil society participation. It is the national instrument for implementing the United Nations International Strategy for Disaster Reduction (UNISDR). The goal of PPD-8 is to be achieved through systematic preparation for the events that could pose the greatest risk to the security of the nation.¹⁵ This book examines a number of major disasters that pose some of the greatest risks to the United States and discusses some of the complex issues associated with mitigation efforts. While the adverse effects of hazards often cannot be completely prevented, their scale or severity can be substantially reduced through disaster risk management.

Our exploration of disasters, however, is limited in scope. First, our investigation is restricted to the United States, despite the fact that disaster risk is a global issue. We are aware of the global component to the topic. It is most comprehensively represented by the UNISDR (n.d.), which states that “[T]here is no such thing as a ‘natural’ disaster, only natural hazards.” The focus of this multilateral strategy is disas-

ter risk reduction: “. . . the concept and practice of reducing disaster risks through systematic efforts to analyse and reduce the causal factors of disasters. Reducing exposure to hazards, lessening vulnerability of people and property, wise management of land and the environment, and improving preparedness and early warning for adverse events are all examples of disaster risk reduction.”

On March 18, 2015, United Nations member-states adopted the *Sendai Framework for Disaster Relief Reduction*. It is a 15-year, voluntary, nonbinding agreement that recognizes the primary role of the government in reducing disaster risk but also recognizes that this responsibility should be shared with other stakeholders. Hence, this book should be of interest to U.S. policymakers, researchers, and stakeholders who are interested in reducing disaster risk.

Second, our empirical analysis is exploratory. As stated previously, the costs of disasters can be measured in terms of mortality or the total dollar amount of destruction. In this book, we focus on financial costs, not mortality. The conceptual and practical issues in measuring these costs and the direct and indirect effects from a disaster are not addressed.¹⁶ Instead, we use publicly available databases: one from the FEMA reporting system and two developed by the National Oceanic and Atmospheric Administration (NOAA). The first is the *U.S. Billion-Dollar Weather and Climate Disaster* data of the National Climatic Data Center (NCDC) and the second is National Weather Service data.¹⁷ Using annual, state-level data we utilize ordinary least squares (OLS) estimation to draw inferences that can provide useful background information for increasing our understanding of disasters. This estimation technique is one of the most basic and most commonly used prediction methods, with applications in fields as diverse as economics, medicine, psychology, and statistics. It is a technique that is relatively easy to analyze and understand, and it produces solutions that can be easily interpreted. Practically speaking, OLS regression makes efficient use of the data, and we can obtain good results with relatively small sample sizes. The technique, however, does not imply a causal relationship: it only shows an association between the variables of interest. More sophisticated statistical methods are appropriate to use with a larger and richer data set, particularly if the focus of the investigation is at the substate level. This point is important to note as most disasters are local events. We refer the interested reader to the extensive literature on

specific disasters, some of which is referenced in subsequent chapters of this book.

Third, we separate the analysis of disasters according to different hazard categories. The UNISDR (2009) classifies hazards on the basis of the originating phenomenon type: biological, geological, hydrometeorological, and technological. Biological hazards are of organic origin or conveyed by biological vectors, such as bacteria, toxins, and viruses, that may cause injury or loss of life to humans and animals, crop failure, damage to assets and property, social and economic disruption, and environmental degradation. Geological hazards include geophysical phenomena arising from such internal processes of the earth as earthquakes and volcanic eruptions, which humans cannot usually predict; and geophysical phenomena that are the result of such external processes of the earth as landslides, mudslides, and sometimes flooding that could be avoided. Disasters originating from external earth processes are often related to anthropogenic alterations to the environment. Hydrometeorological hazards are associated with changes in air and ocean temperature that are responsible for the formation of weather phenomena, such as hurricanes and tornadoes, and climate and precipitation variation that sometimes cause drought, flooding, storm surges, and other hydrological phenomena. The fourth hazard type originates from technological or industrial conditions, including accidents, dangerous procedures, infrastructure failures, or specific human activities that lead to detrimental effects. Disasters that originate from technological hazards can be avoided and prevented.

Classification makes it possible to systematize information on disasters, identify patterns in their impact, and consider their consequences. We look at a subset of all hazards: natural hazards. According to the World Meteorological Organization, hazards related to weather, climate, and water account for nearly 90 percent of all disasters.¹⁸ Natural hazard events can be characterized according to their magnitude or intensity, speed of onset, duration, and area of extent. For example, droughts are slow to develop and dissipate and often affect large regions, whereas earthquakes have short durations and usually affect a relatively small area. Among the disasters considered in this book are droughts, floods, hurricanes, tornadoes, and wildfires, which are discussed in separate chapters. This approach would be of interest to state or regional policymakers, who may be interested in particular types of

disasters as they relate to their own geographic regions. We also briefly examine earthquakes, tsunamis, and volcanic eruptions in addition to anthropogenic hazards, combining this discussion into one chapter. Our decision to combine geological with anthropogenic hazards is informed by the data we use.

We address six questions:

- 1) What do we know about disasters in the United States?
- 2) Has there been an increase in their frequency?
- 3) What are the financial costs associated with disasters?
- 4) What compensation is available to survivors?
- 5) Where is each type of disaster likely to occur?
- 6) How can disasters be mitigated?

There are nine remaining chapters in this book. Chapter 2 utilizes the reporting systems used in the United States for classifying disasters to examine the aggregate trends over time. We find that even though annual data are highly variable, extreme-weather events are occurring with increasing frequency. And there are definite geographic trends in disaster declarations. In our presentation of geographic patterns, we use the classification of the U.S. Census Bureau whereby the United States is divided into four regions: Northeast, Midwest, South, and West. Each of the four census regions is divided into two or more census divisions. The Northeast, the Midwest, and the West have two census divisions while the South has three. The two divisions in the Northeast region are the New England division and the Middle Atlantic division; the East North Central division and the West North Central division form the Midwest region; and the two divisions in the West region are the Mountain division and the Pacific division. The three divisions in the South region are the South Atlantic division, the East South Central division, and the West South Central division.

In Chapter 2, we also consider the association between population density and disasters and the possible linkages of disasters to climate. Our analysis shows that the declaration of disasters has increased at a much faster rate than the rate of population growth, and there is a statistically significant association between disasters and the increase in temperature. The association between disasters and precipitation, however, is not statistically significant.

Those affected by disasters receive compensation in many ways.¹⁹ Chapter 3 introduces the costs associated with the destructive effects of disasters. The returns to capital and the earnings of individuals attached to the labor market both decrease when a disaster interrupts production. Since labor compensation exceeds half of the value added in most industries, reduced earnings are an important element in disaster-related economic losses. Our discussion does not cover, however, the loss of life. Chapter 3 also discusses programs for survivors in disaster-affected areas. Effectively assisting survivors requires government action beforehand: establishing a response to a disaster, instituting a recovery process, and alleviating the damage and hardship of disaster survivors through compensation programs. Those affected by a catastrophe may receive compensation in many ways, both from private arrangements and public disaster assistance programs. Some of the assistance programs are specific to a disaster situation; other programs are more general and are provided by organizations either in disaster situations or delivered to meet regular service requirements.

Among the major disaster declarations between 1953 and 2013, hurricanes stand out for their large-scale destructive effects. While they accounted for about 10 percent of the 2,046 FEMA-designated major disaster declarations, they comprised nearly half of the adverse cost estimates in the NCDC data on billion-dollar disasters. In Chapter 4, we provide a more detailed discussion of hurricanes. All states along the Atlantic and Gulf coasts were affected by several hurricanes between 1953 and 2013. The 15 states with extensive coastlines extending from Massachusetts to Texas accounted for 82 percent of the hurricane-related major disasters during these 61 years. As a consequence, the losses attributable to hurricanes dominate the various programs that provide support to disaster survivors. Hurricanes also have obvious labor market effects: higher total unemployment and increased payments of unemployment insurance (UI) benefits. Similarly, hurricanes figure prominently in the losses of the Disaster Unemployment Assistance (DUA) program.

Between 1953 and 2013, 62 percent of the major disaster declarations in the United States involved flooding. Chapter 5 examines floods, the most frequent of all disasters. States located along major rivers and their tributaries have extensive experiences with river flooding. Coastal floods, northeasters (also nor'easters), storm surges, and tsunamis also

cause flooding.²⁰ We examine the extent of flood insurance coverage and the frequency of compensation paid by the National Flood Insurance Program. The labor market effects of floods are also examined. Unemployment increases considerably with disastrous flooding. Our analysis suggests that the UI benefits paid as a result of flooding represent a significant increment to the benefits paid directly by the DUA program.

Chapter 6 discusses tornadoes. Tornadoes were present in 441 of the 2,046 major disaster declarations between 1953 and 2013. While present in the majority of geographical areas, the most common and most severe tornadoes occur in the Midwest region of the United States. Generally, while tornadoes are responsible for much smaller aggregate destruction compared to hurricanes, drought, and river floods, there is some evidence that tornadoes are having larger damaging effects in recent years.

Of the eight largest billion-dollar disasters, four were hurricanes and three were droughts. Hurricanes and droughts dominate the cost estimates of the billion-dollar disasters, accounting for 72 percent of the NCDC's overall total. Chapter 7 examines drought. The FEMA disaster-designated classification affecting agricultural producers includes floods, hail, severe storms, and winter freezes, but not drought. There is an important contrast between the onset and duration of drought compared to other disasters, which span one or a few days. Drought, in contrast, extends over several months or even years, and drought-related agricultural and other economic losses also accumulate over longer periods.

Drought often contributes to the severity of wildland fires, examined in Chapter 8. Most wildfires occur in the West region of the United States. While wildland fires have always been an integral and natural part of forest and prairie ecosystems, new climatic conditions and increasing human development are changing the scale of wildfires and the length of the wildfire season. More people build homes in and near wildfire-prone areas, exposing individuals and families to greater risks from fires and causing increased fire suppression and recovery costs. A distinguishing feature of our societal arrangements to combat wildfires is that they occur with such regular frequency that we maintain an ongoing capacity to fight wildfires with permanent staffing at federal and state agencies. Hence, the fire management assistance declarations made by FEMA represent only a small fraction of the annual number

of formally recognized wildfires that occur. These wildfire activities are separate from the actions of local fire departments.

Chapter 9 considers geological and technological hazards that occur as a result of human interaction with the environment. Anthropogenic disasters discussed in this chapter include the *Oklahoma Explosion at Federal Courthouse in Oklahoma City* (DR-1048) on April 26, 1995, and the *New York Terrorist Attack* (DR-1391) on September 11, 2001. The likelihood of a geological hazard such as the 1906 San Francisco earthquake occurring is extremely rare and the associated losses would be devastating. It is a catastrophic hazard: a low-probability, high-consequence event. We recognize that looking at the last six decades of disaster experience does not capture such extreme risks.

Chapter 10 examines the role of private insurance and private-public partnerships in providing coverage for adverse events and outlines some of the problems. We emphasize the critical role of incentives (both private and public), institutional arrangements, and the possibilities and limits to governmental actions. Catastrophic risk and the insurance market is more than just the demand, supply, and the market-clearing price for risk. Individuals, economic agents and governments can limit or mitigate the worst effects of catastrophic risk through an intelligent combination of insurance and prevention. The chapter highlights selected findings from this volume and offers some suggestions for national disaster policies, including proposals for legislation and administrative practices to improve planning and responses to disasters. There are many steps one can take to prepare for potential disasters and to respond to them when they occur. A key part of preparedness is the prediction of a potential natural hazard. Forecasts and early warnings of such hazards can help prevent and mitigate disasters, save lives, and reduce damage to property and to the environment. Decision makers can foster the design and installation of warning systems to alert people of extreme-weather events that may be about to occur. Steps need to be taken to increase resilience. For instance, one can develop and enforce building codes requiring that buildings be able to withstand earthquakes, floods, or high winds. Increasing resilience to natural hazards requires a greater understanding of them.

Disasters impose a massive toll of human suffering. Generally speaking, fewer people are dying in disasters but the resulting destruction is more costly. The damage and losses do not originate from the

forces of nature but, rather, from the interaction of natural forces and the misguided choices of humans. The scale of the destruction depends on the choices we make about our lives and our environment, and these choices make us more susceptible to disasters or more resilient to them. While damage and losses from disasters have risen, their increase has been slower than the growth in population, which indicates that appropriate prevention measures and effective emergency preparedness are proving to be successful.

We trust that this book will provide useful information on disasters in the United States as well as highlight some of the issues that need to be addressed. We believe this volume could serve as a basis and inspiration for continuing work on disasters.

Notes

1. Prior to the creation of FEMA, state/tribal and local governments worked with many separate disaster-related federal agencies. In 1979, President Carter centralized the federal emergency functions into one agency. In 2003, FEMA became part of the U.S. Department of Homeland Security.
2. See https://www.fema.gov/disasters/grid/year/2015?field_disaster_type_term_tid_1=All (accessed July 27, 2016). The incident period for DR-4205 was from December 23, 2014, to December 24, 2014, with the major disaster declaration declared on January 7, 2015. The incident period for DR-4247 was from November 27, 2015, to November 29, 2015, with the declaration made on December 29, 2015. We use the FEMA-designated system for recording extreme events as the basis of our investigation of disasters in the United States. One can obtain further information about each event from the agency website.
3. See <http://maps.grida.no/go/graphic/trends-in-natural-disasters> (accessed July 27, 2016). GRID-Arendal works in partnership with the United Nations Environment Programme (UNEP) to support informed decision making and to raise awareness of environmental issues. The World Bank and the United Nations (2010) and the United Nations (2015) also report an increase in global disasters.
4. This classification is the one used by the Emergency Events Database of the Centre for Research on the Epidemiology of Disasters (EM-DAT/CRED), with disasters further divided into 12 types and 30 subtypes. The database has the advantage of providing greater differentiation of disasters that have very different consequences. See Guha-Sapir, Below, and Hoyois (n.d.).
5. See UNISDR (2009). There are many facets of vulnerability, which are a result of various economic, environmental, physical, and social factors. Examples include disregard for prudent environmental management, inadequate protection of assets, lack of public awareness and information, limited official recognition of risks and

- preparedness measures, and unsuitable design and construction of buildings and infrastructure.
6. For a brief explanation of the distinction between a *hazard* and a *disaster*, see World Bank and the United Nations (2010, p. 25, Box 1.2); for formal definitions of disaster-related terminology, see UNISDR (2009).
 7. Climate change is defined by the UNISDR (2009) as changes in climate that may be due to natural phenomena or to persistent anthropogenic changes in atmosphere or in land use. The United Nations Framework Convention on Climate Change (1992, p. 3) definition focuses on anthropogenic alterations: “A change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.” The Intergovernmental Panel on Climate Change (2007) finds that climate change is gradually altering average temperature, the timing and amount of precipitation, and sea levels. There is the potential for more severe changes if carbon emissions are not successfully limited and reduced.
 8. In the assessment of disasters, the literature distinguishes between *damages* and *losses*. The term *damages* refers to the destruction of assets, both human and physical, caused by a disaster. The term *losses* refers to the reduction in the flow of benefits, such as income, that results from the disaster. The United Nations Economic Commission for Latin America and the Caribbean (ECLAC) has developed a methodology for estimating the consequences of a disaster and for determining the finances needed to rebuild affected areas. For the accounting framework used by ECLAC in assessing disasters, detailed information about what is included, and how each category is measured, see ECLAC (2014).
 9. Fischer and Knutti (2015) show that the largest proportion of the most rare and extreme events is anthropogenic and the increase in these events is nonlinear as global temperatures further increase.
 10. The Robert T. Stafford Disaster Relief and Emergency Assistance Act of 1988 amended the Disaster Relief Act of 1974. The legislation establishes the statutory authority for most federal disaster response and recovery activities especially as they relate to FEMA and FEMA programs.
 11. Section 102(2) of the Stafford Act defines the term *major disaster* as “any natural catastrophe (including any hurricane, tornado, storm, high water, wind-driven water, tidal wave, tsunami, earthquake, volcanic eruption, landslide, mudslide, snow storm, or drought), or regardless of cause, any fire, flood, or explosion in any part of the United States, which in the determination of the president causes damage of sufficient severity and magnitude to warrant major disaster assistance under this chapter to supplement the efforts and available resources of state, local governments, and disaster relief organizations in alleviating the damage, loss, hardship, or suffering caused thereby” 42 U.S. C.5122 (2).
 12. To test for a possible association between major disaster declarations and presidential elections, a categorical (dummy) election variable is added to trend regression Equations (2.1.1) and (2.1.2) in Chapter 2. The election dummy variable equals 1.0 in presidential election years and zero otherwise. The regression results

of both equations show that the estimated coefficients of the election variables are positive as hypothesized with values of 2.5–2.6; but with *t*-ratios of only 0.7–0.8, these ratios are far below the level required for statistical significance. Hence, the results do not support the hypothesis of an association between major disaster declarations and presidential elections. Using data from 1960 to 2008, Kunreuther and Michel-Kerjan (2009) control for differences in the incidence of damaging floods by using precipitation and damages as covariates. The adjusted mean is 5.3 in reelection years and 4.4 in other years. Theoretical and empirical investigations of political considerations in disaster declarations are available in the literature, particularly the political science literature. For instance, Healy and Malhotra (2009).

13. These 2,046 events all occurred in the 50 states plus D.C. An additional 109 major disaster declarations were announced in seven outlying territories: American Samoa, the Federated States of Micronesia, Guam, the Republic of the Marshall Islands, the Northern Mariana Islands, Puerto Rico, and the U.S. Virgin Islands.
14. The quote is part of the mission of FEMA. See <https://www.fema.gov/declaration-process-fact-sheet> (accessed July 27, 2016).
15. The U.S. Department of Homeland Security defines national preparedness as “the actions taken to plan, organize, equip, train, and exercise to build and sustain the capabilities necessary to prevent, protect against, mitigate the effects of, respond to, and recover from those threats that pose the greatest risk to the security of the Nation.” Security is defined as “the protection of the Nation and its people, vital interests, and way of life,” and resilience as “the ability to adapt to changing conditions and withstand and rapidly recover from disruption due to emergencies.” See <http://www.dhs.gov/presidential-policy-directive-8-national-preparedness> (accessed July 27, 2016).
16. The assessment of damage is difficult, prone to both overestimation (for example, double counting) and underestimation (for example, it is difficult to value loss of life or damage to the environment). For information on the conceptual issues in the compilation of U.S. data, see Smith and Katz (2013) and Smith and Matthews (2015).
17. The former National Climatic Data Center (NCDC) is now known as the National Centers for Environmental Information (NCEI) and is “responsible for preserving, monitoring, assessing, and providing public access to the nation’s treasure of climate and historical weather and information.”
18. See <http://public.wmo.int/en/our-mandate/what-we-do> (accessed July 27, 2016).
19. Note that the term *compensation* is actually a misnomer because the amounts people receive in recompense are usually less than what has been lost.
20. A northeaster is a large-scale storm along the upper east coast of the United States and Atlantic Canada.

2

Reporting, Frequency, and Correlates of Disasters

The United Nations Economic Commission for Latin America and the Caribbean (2014) states that disasters derive from a combination of two factors: 1) natural phenomena capable of unleashing processes that lead to physical damage and the loss of human lives and capital, and 2) the vulnerability of individuals and human settlements. These events disrupt the living conditions of communities and individuals and the economic activity of countries.

Disasters impose a massive toll of human suffering. As stated in Chapter 1, fewer people are dying in disasters but the resulting destruction is more costly. The World Bank and United Nations (2010) find that the annual global damage from disasters between 1970 and 2010 (adjusted for inflation) fluctuated, but damage in the recent two decades was significantly greater than in the earlier decades. Has the incidence of disasters increased in the United States? What are the causal factors of disasters? Is there a relationship between extreme-weather events and climate? Is there a geographic pattern? These questions are initially answered in this chapter and discussed in more detail in subsequent ones.

The first section examines the aggregate trends in disaster-related declarations over time. While annual data are highly variable, extreme-weather events in the United States are occurring with increasing frequency. These results are consistent with the research findings of the American Meteorological Society, which investigates extreme events from a climate perspective. A number of their recent studies indicate that human-caused climate change greatly increased the likelihood and intensity for extreme heat waves; a climate influence was found in some instances of such extreme events as droughts, heavy rains, and winter storms, but not in other instances.¹

The second section presents a taxonomy of adverse weather-related events and provides a framework for examining them. The chapter then briefly examines trends in four categories of hazards: floods, tornadoes,

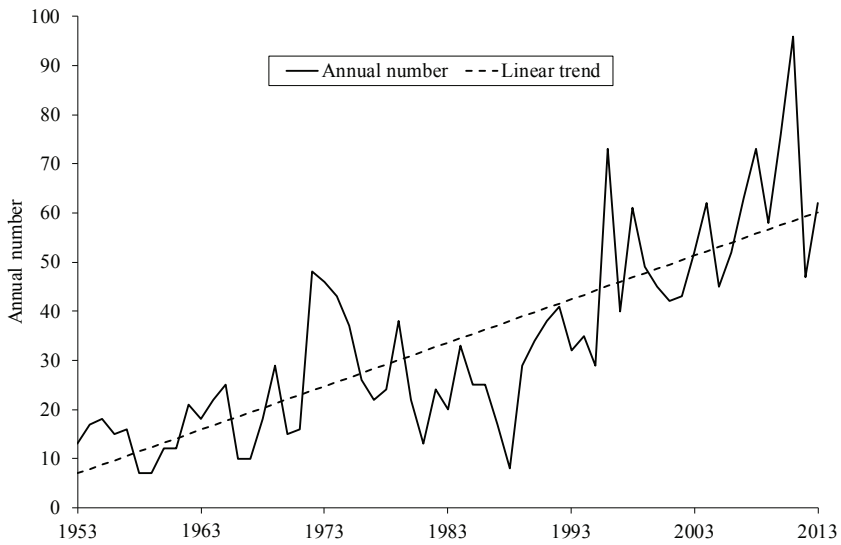
hurricanes, and “all other” hazards. The categories are discussed in more detail in individual chapters of the book. It is possible that population growth and urbanization are responsible for the increasing frequency of disaster-related declarations. The fourth section considers the association between population density and these declarations. From our analysis, it is clear that major disaster declarations have increased at a much faster rate than the rate of population growth since the early 1950s. Two factors that could influence the frequency of catastrophic events are rising temperatures and heavy precipitation. The following two sections examine the possible linkages of disasters to climate and weather and briefly discuss the geographic trends in major disaster declarations. The final section has concluding comments.

AGGREGATE TRENDS IN DISASTER DECLARATIONS

Annual data from the reporting system developed by FEMA show that disaster-related declarations are highly variable. As stated in the Chapter 1, FEMA-designated declarations fall into three categories: major disaster declarations, emergency declarations, and fire management assistance declarations. For both major disaster and fire management assistance declarations there is a significant upward trend. The number of emergency declarations, on the other hand, is highly variable from year to year but does not show a significant trend.

Figure 2.1 displays the number of major disaster declarations from 1953 to 2013. The figure also shows the linear trend from a regression using ordinary least squares estimation. A linear trend is evident when the slope of the regression line is statistically different from zero; a positive slope indicates an increasing trend and a negative slope a decreasing trend.

The regression equation “explains” 62 percent of the time-series variation over the sample period.² The slope coefficient (0.885) of the equation indicates that major disaster declarations increased at an annual rate of slightly less than one per year from 1953 to 2013, the period spanned in Figure 2.1. Thus, the annual number of major disaster declarations averaged 15–20 declarations in the mid-1950s but closer to 60 declarations in recent years.

Figure 2.1 Major Disaster Declarations, 1953–2013

SOURCE: Major disaster declarations data from FEMA. The linear trend is regression Equation (2.1) in Table 2.1.

Figure 2.1 also vividly illustrates that major disaster declarations are highly variable from one year to the next. The standard error of the regression equation exceeds 12.³ Large positive errors are observed in 2008, 2010, and 2011; large negative errors in 1989 and 1990. Finally, note the succession of positive errors during 1962–1965, 1972–1975, and again during 2007–2011. Conversely, the errors were consistently negative between 1980 and 1990. The results of the regression analysis suggest that while there is a persistent and large upward trend in major disaster declarations between 1953 and 2013, large year-to-year variation is also observed.

The second category of declarations examined here is fire management assistance. Measured since 1970 in the FEMA reporting system, fire management assistance declarations also exhibit a positive trend. Figure 2.2 shows the annual number of fire management assistance declarations and a linear trend regression line for the 44 years from 1970 to 2013. Similar to major disaster declarations, a strong upward trend is apparent in Figure 2.2 for fire management assistance declarations.

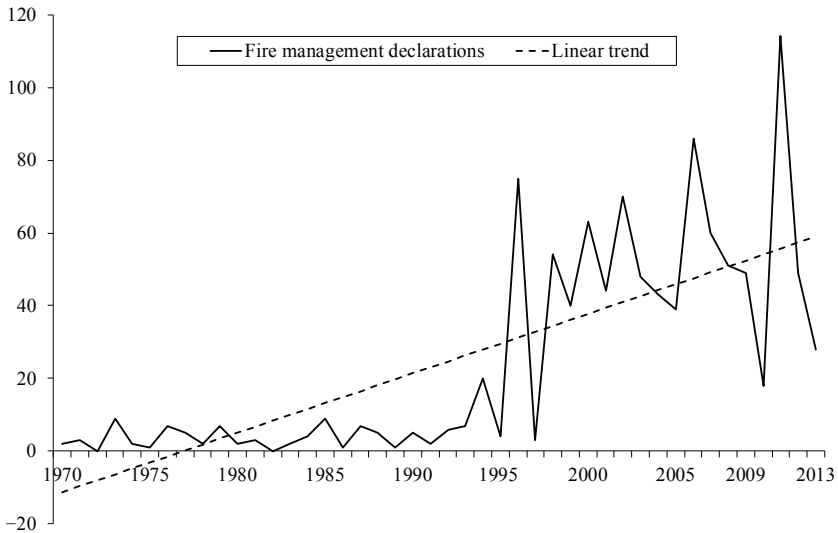
Similarly, there is a wide year-to-year variation since the mid-1990s. Figure 2.2 also shows a sharp increase in the number of fire management assistance declarations in the mid-1990s. Prior to 1995 there were fewer than 10 declarations in any year. Between 1998 and 2013, however, there were at least 39 fire management assistance declarations in 14 of 16 years, all except 2010 (18) and 2013 (28). This break in the data is discussed below and examined in more detail in Chapter 8, which addresses wildfires.

Emergency declarations have been recorded in the FEMA reporting system since 1974. Recall from Chapter 1 that the process of presidential disaster declarations was firmly established in 1974. As seen in Table 2.1, a linear trend between 1974 and 2013 is positive but small. While there is no significant trend in emergency declarations, the annual number is highly variable. The average number of annual emergency declarations was about 9 between 1974 and 2013. Over the same period, these declarations exceeded 15 in 8 different years but fell below 5 in 17 years. Nearly all variation in annual emergency declarations is independent of a linear trend.

Emergency declarations in individual years also show a strong bunching pattern by the type of emergency. These declarations helped local areas address a broad range of disaster situations with highly varied annual rates of occurrence. Drought assistance was unusually prevalent in 1977, while winter storm declarations were numerous in 1993, 2003, and 2005. All 50 states and D.C. received emergency declarations linked to Hurricane Katrina in 2005. The declaration for Hurricane Katrina authorized various types of assistance to be provided to local survivors, as well as aid to individuals and families who moved away from Katrina-impacted areas.⁴ Hurricanes and tornadoes caused numerous emergency declarations in 1999, 2011, and 2012.

Table 2.1 shows the results of a regression analysis that characterize the historical experience for the three categories of declarations. The analysis emphasizes trends and breaks in the data series. Because the three series are available for differing time periods, the starting point for each trend is different. The starting year for major disaster declarations is 1953; for fire management assistance declarations, 1970; and for emergency declarations, 1974.

To increase comparability in long-term trends, each regression equation is centered at zero in 1970, decreased by one in successive earlier

Figure 2.2 Fire Management Assistance Declarations, 1970–2013

SOURCE: Fire management declarations from FEMA. The linear trend is regression Equation (2.3) in Table 2.1.

years and increased by one in subsequent later years. The purpose of the analysis is to test for trends and shifts in the rate of disaster-related occurrences for the three declaration series. The regression equations also test for a possible acceleration in the rate of disaster occurrences. The year selected for the start of the accelerated trend is 1995, chosen after some experiments with specifications.

Equation (2.1.1) in Figure 2.1 is a simple regression of the number of major declarations on a linear trend. Equation (2.1.2) adds a second trend to major disaster declarations, one that commences in 1995. A positive coefficient on the 1995 trend implies an acceleration in the annual occurrence of major disaster declarations. The regression results indicate that major disaster declarations were increasing at a rate of 0.55 for each year between 1953 and 1994, but the rate of change then increased to 1.92 for each year between 1995 and 2013.⁵ These results suggest more than a doubling of the trend rate of increase starting in 1995. The acceleration in the rate of change has important implications for the annual occurrence of major disaster declarations. The projected

Table 2.1 Regression Results of Disasters Declarations

Dependent variable: Declarations	Constant	Long-term trend	New trend in 1995	Dummy variable 1995 = 1	Adjusted R^2	Standard error	Durbin- Watson	Mean
(2.1.1) Major disaster	22.06 (11.4)	0.885 (10.0)			0.623	12.17	1.32	33.56
(2.1.2) Major disaster	22.08 (12.4)	0.555 (4.4)	1.367 (3.4)		0.680	11.20	1.60	33.56
(2.1.3) Fire management	-11.23 (1.9)	1.632 (7.0)			0.529	19.59	2.10	23.86
(2.1.4) Fire management	-1.43 (0.2)	0.493 (1.2)		34.05 (3.2)	0.616	17.68	2.81	23.86
(2.1.5) Fire management	1.86 (0.3)	0.218 (0.4)	0.899 (1.0)	31.094 (2.9)	0.616	17.67	2.87	23.86
(2.1.6) Emergency	2.14 (0.5)	0.287 (1.7)			0.047	12.21	2.02	8.88
(2.1.7) Emergency	9.64 (1.6)	-0.263 (0.7)	1.143 (1.8)		0.097	11.88	2.18	8.88

NOTE: To be precise, the required t -ratio at the 0.05 level of significance under a two-sided t -test is 1.97 and 1.67 under a one-sided t -test. SOURCE: The regression equations explain the number of major disaster declarations, fire management declarations, and emergency declarations from the first available year until 2013. The starting year for major disaster declarations is 1953; for fire management assistance declarations, 1970; and for emergency declarations, 1974. Beneath each coefficient is the absolute value of its t -ratio; a result is statistically significant if the t -ratio is 2.0 or larger.

annual number of occurrences implied by regression Equation (2.1.2) is as follows: 12.6 in 1953, 35.4 in 1994, and 71.9 in 2013. During the earliest 41 years of the time series, the projected increase of occurrences was 22.8, but during the final 20 years the projected increase was 36.5. As predicted by Equation (2.1.2), the annual occurrences of major disaster declarations in 2013 were 5.7 times more numerous than declarations in 1953.

Equations (2.1.3)–(2.1.5), inclusive, in Table 2.1 focus on fire management assistance declarations between 1970 and 2013. The linear trend coefficient in Equation (2.1.3) is highly significant. Recall from Figure 2.2, however, that the annual pattern of fire management assistance declarations shows a sharp discontinuity in the mid-1990s. Equation (2.1.4) adds a categorical (dummy) variable (equal to 1 in 1995 and later years; and equal to 0 before 1995) to the linear trend. The dummy variable adds significantly to the explained variation, resulting in an increase of the adjusted R^2 from 0.529 to 0.616. In Equation (2.1.4), the dummy variable implies that the annual number of fire management assistance declarations was 34.1 higher during 1995–2013 when compared to earlier years. Equation (2.1.5) adds a 1995 trend acceleration variable. While it enters with a positive coefficient, it is not statistically significant.

As stated above, the trend coefficients in Equations (2.1.4) and (2.1.5) are all positive but not statistically significant. Nevertheless, because the coefficient of the 1995 shift dummy is large and positive, the estimated number of fire management assistance declarations is much higher in 1995 and later years compared to earlier years. Projections from Equation (2.1.5) for selected years are as follows: 1.9 in 1970, 7.2 in 1994, 39.3 in 1995, and 60.2 in 2013. As with major disasters, fire management assistance declarations have occurred with much greater frequency from 1995 to 2013 than during earlier years.

In Chapter 8 we highlight wildfires as one of the disasters selected for further discussion. A distinguishing feature of our societal arrangements to combat wildfires is that they occur with such regular frequency that we maintain an ongoing capacity to fight fires with permanent staffing at federal and state agencies. Hence, the fire management assistance declarations made by FEMA represent only a small fraction of the annual number of formally recognized fires that occur, mainly in western states.

As noted earlier in this section, emergency declarations are highly variable. Equations (2.1.6) and (2.1.7) reinforce this observation. Equation (2.1.6) shows the results of a regression that fits the annual number of emergency declarations to a linear trend. While the trend coefficient is positive, it is only marginally significant, and less than 5 percent of the variation between 1974 and 2013 in the time series is explained. Adding a trend acceleration term that starts in 1995 (Equation 2.1.7) implies a small downward trend in emergency declarations before 1995.⁶ From that equation, the estimated number of emergency declarations for three selected years is as follows: 8.8 in 1974, 3.3 in 1994, and 20.0 in 2013.

Overall, the results of the regression analysis in Table 2.1 predict 60–70 major disaster and fire management assistance declarations in 2013. The projected number of emergency declarations, however, is only about one-third of those averages. If we are to reduce the incidence of disasters, then we need to identify the causal factors. The following section introduces a taxonomy for examining adverse weather-related hazards.

TAXONOMY OF ADVERSE WEATHER-RELATED EVENTS

Extreme-weather events are occurring with increasing frequency not only in the United States but throughout the world. The World Bank and the United Nations (2010) examine five extreme-weather events (drought, earthquake, extreme temperatures, floods, and storms) and find a worldwide increase in their frequency. The taxonomy in this section introduces and discusses a framework for examining adverse weather-related events. A more comprehensive taxonomy would incorporate additional categories of societal disasters. These include geological events such as volcanic eruptions and lava flows. A complete taxonomy would also include such anthropological disasters as breaches in canal walls, dam failures, and terrorist attacks. Our framework in this section, however, is limited to extreme-weather events.

Table 2.2 presents a taxonomy of extreme-weather events that shows their correlates in terms of three underlying weather conditions: precipitation, temperature, and wind. The table also includes a fourth dimension: their average duration. The duration averages are derived

Table 2.2 Correlates of Seven Extreme-Weather Events

Extreme-weather event	Precipitation	Temperature	Wind	Average duration (days)
Winter storm, freeze	High	Low		15
Severe storm	High		High	12
Drought	Low	High		191
Wildland fires	Low	High		127
Flooding	High			33
Tornadoes	High		High	4
Hurricanes, tropical storms	High		High	5

SOURCE: The taxonomy is developed by the authors. The estimates of the duration of extreme-weather events are averages from the NCDC database of 170 billion-dollar disasters that occurred between 1980 and 2013.

from the *U.S. Billion-Dollar Weather and Climate Disaster* data developed by the NCDC that includes the duration (in days) of each event.⁷ This comprehensive data set estimates the cost of the most destructive weather and climate events in the United States from 1980 to present.⁸ The taxonomy in Table 2.2 shows the usual correlates of extreme weather and climate events, but not the conditions that must always be present for their occurrence. Drought and wildfires can occur in the absence of high temperatures, winter freezes do not require high precipitation, and tornadoes are not always accompanied by heavy precipitation. Conversely, a severe storm will be more damaging if it is accompanied by high wind.

Table 2.2 displays the typical combination of conditions accompanying extreme-weather events. Generally, the destruction caused by an extreme-weather event occurs over a relatively short period, typically within a week or less. The devastating effects of droughts, wildfires, and floods, however, can extend over a much longer period. The final column of Table 2.2 shows the average duration of the event based on information from the NCDC data on billion-dollar disasters. Droughts and wildfires extend for months, as can river flooding. The destruction caused by hurricanes and tornadoes, in contrast, occurs in just a few days.

The classification used in Table 2.2 closely resembles the categories used by NCDC in its description of billion-dollar disasters. The NCDC categories, however, usually show tornadoes as one element of a combination of extreme-weather events. For instance, in May 2008,

NCDC records a billion-dollar disaster in the Midwest caused by “tornadoes and severe weather.” By definition, tornadoes are characterized by wind speeds that exceed a specific minimum threshold (73 miles per hour) that can add to the destructive potential of a severe storm. Our taxonomy shows tornadoes and severe storms as separate categories.

Unlike precipitation and temperature where high and low ranges can both cause severe damage, wind damage occurs only with high winds. Numeric scales describe the severity (speed) of the damaging high winds that circulate around a low-pressure center for hurricanes, tropical storms, and tornadoes. Wind damage can also be caused by wind events called straight-line winds, which are often present during severe storms and thunderstorms and frequently are downdrafts associated with storms. Straight-line winds have speeds that exceed 50 or 60 miles per hour and often occur in conjunction with flooding and tornadoes. For example, between 2000 and 2013 there were 57 major disaster declarations where part of the damage was caused by straight-line winds. For every one of these 57 events, the FEMA incident description usually associated them with “severe storms.” The FEMA incident description also uses “flood” in 45 and “tornado” in 41 of these 57 major disasters. During a severe storm, straight-line winds can be part of the weather mix that may include floods and tornadoes.

The 2,046 major disaster declarations declared by FEMA between 1953 and 2013 cover a wide range of events. Certain disasters, such as hurricanes and earthquakes, fit easily into distinct categories. The incident descriptions of FEMA for other disasters, however, include two or more descriptors that make it difficult to categorize. For example, a major disaster could be described as having “severe storms, straight-line winds, and tornadoes,” or as “severe storms, flooding, landslides, and mudslides.”⁹ During these 61 years 1,273 major disasters involved flooding and 1,215 involved severe storms. FEMA’s incident descriptions indicate that severe storms and flooding were both present in 969 of these major disasters. Both elements were present in 79.7 percent of the severe storms events (969 of 1,215) and in 76.1 percent of the flood events (969 of 1,273). The high frequency of joint occurrences of these phenomena means the severe storms and floods are difficult, if not impossible, to separate. We make a judgment call and attribute the destruction from flooding as the more important contributor to the disaster. As a consequence, the book includes a discussion of flooding

in Chapter 5 but excludes a discussion of severe storms in a separate chapter.

Over the full period of reporting major disasters since 1953, the FEMA incident descriptions have evolved. In the years before 1970, the majority of major disaster declarations were described with just a single descriptor. For instance, *Louisiana Floods* (DR-84), declared on May 20, 1958, has a single descriptor. Since 1970 most major disaster declarations use two, three, or more descriptors. For instance, *Vermont Excessive Rainfall, High Winds, Flooding* (DR-1184), declared on July 25, 1997, has three descriptors. The following section uses these incident descriptors to assign individual disasters into one of four categories in order to explain the variation in major disasters between 1953 and 2013.

TRENDS IN SELECT DISASTERS

The analysis of major disaster declarations in this section looks at four categories of hazards: floods, tornadoes, hurricanes, and “all other” hazards. The latter is a catch-all category that includes such diverse geological hazards as earthquakes, wildfires, and winter freezes, as well as technological hazards such as anthropogenic disasters. Anthropogenic disasters include events such as the *Oklahoma Explosion at Federal Courthouse in Oklahoma City* (DR-1048), declared on April 26, 1995, and the *New York Terrorist Attack* (DR-1391), declared on September 11, 2001.

Admittedly, the decision rules for assigning individual disasters into these four categories are arbitrary. The classification of hurricanes is the most straightforward, as the incident description is a single word: hurricane. Between 1953 and 2013 there were 208 hurricane-related major disasters caused by 70 separate hurricanes, with an average of 2.7 states affected by each hurricane. We classify a major disaster as a flood if the word appears in the incident description; a similar classification rule is used to identify tornadoes. Where an incident description is labeled with both “flood” and “tornado,” we place the disaster in each category. During 1953–2013, 1,273 major disasters involved floods, 441 involved tornadoes, and 275 were associated with both floods and

tornadoes. The regression analysis of floods and tornadoes uses duplicate counts of these events. The fourth category, “all other,” represents 499 major disasters, almost one-quarter of the 1953–2013 total.

Table 2.3 displays the results of a regression analysis to explain the variation in the four categories of major disasters between 1953 and 2013. For each category there are three specifications: first, a fit of the dependent variable to a linear trend for the full period; second, a trend for the full period and a trend acceleration that starts in 1971; and third, a trend for the full period and a trend acceleration that starts in 1995. All four categories of major disasters exhibit a significant upward trend between 1953 and 2013. For floods, tornadoes, and the “all other” category, the trend is statistically significant, and more than 40 percent of the variation is associated with the trend. The results of the equations for hurricanes have the least explanatory power, where each adjusted R^2 is below 0.20. Hurricanes are the least frequent of the four categories of major disasters examined.¹⁰

The results of tests for an acceleration in the trends yield positive coefficients in all eight equations that included a second (later) trend. Six of the eight trend-acceleration coefficients are statistically significant. The 1995 trend-acceleration coefficient is significant for all four categories of major disasters. For floods in particular, the regression results show that the acceleration was stronger after 1995 than after 1971. The two trend-acceleration variables are of similar importance for hurricanes and the “all other” category. While the results provide significant evidence of an acceleration in the annual occurrence of major disasters, the exact timing of the acceleration between 1971 and 1995 is not obvious.

The results in Table 2.3 reinforce an earlier point made about the remaining unexplained variation in all four categories of major disasters. Of the 12 regression equations, not one has an adjusted R^2 that exceeds 0.55, which implies that much of the association remains unexplained. Despite statistically significant upward trends in the four categories of major disasters, a large share of year-to-year variation requires further explanation. Perhaps a richer data set and more sophisticated statistical methods would have more explanatory power and yield better results. Overall, the results of the regression analysis displayed in Table 2.3 provide strong evidence that the frequency of major disasters has been increasing since 1953.

Table 2.3 Regression Results of Four Types of Major Disasters, 1953–2013

Dependent variable	Constant	Long-term trend	New trend in 1971	New trend in 1995	Adjusted R^2	Standard error	Durbin-Watson	Mean
(2.3.1) Floods	14.85 (10.3)	0.463 (7.1)			0.448	9.02	1.29	20.87
(2.3.2) Floods	15.62 (6.7)	0.584 (2.0)	-0.151 (0.4)		0.441	9.09	1.29	20.87
(2.3.3) Floods	14.88 (10.7)	0.296 (3.0)		0.694 (2.2)	0.483	8.74	1.39	20.87
(2.3.4) Tornadoes	4.04 (5.5)	0.246 (7.3)			0.465	4.63	1.52	7.23
(2.3.5) Tornadoes	2.76 (2.3)	0.045 (0.3)	0.251 (1.4)		0.473	4.59	1.57	7.23
(2.3.6) Tornadoes	4.04 (5.7)	0.159 (3.1)		0.358 (2.2)	0.499	4.48	1.65	7.23
(2.3.7) Hurricanes	2.08 (2.9)	0.102 (3.1)			0.129	4.47	1.75	3.41
(2.3.8) Hurricanes	0.177 (0.2)	-0.197 (1.4)	0.373 (2.2)		0.182	4.33	1.89	3.41
(2.3.9) Hurricanes	2.09 (3.0)	0.024 (0.5)		0.324 (2.1)	0.175	4.35	1.88	3.41
(2.3.10) All other	4.18 (5.0)	0.307 (8.0)			0.514	5.27	1.81	8.18
(2.3.11) All other	1.75 (1.3)	-0.075 (0.5)	0.478 (2.4)		0.550	5.07	1.98	8.18
(2.3.12) All other	4.19 (5.1)	0.216 (3.7)		0.380 (2.1)	0.540	5.13	1.94	8.18

SOURCE: Major disaster declarations data from FEMA. The long-term trend equals 1 in 1971 and increments by 1 for all years before and after 1971. New trend 1971 and New trend 1995 start in the indicated year, increase by one in later years and equal zero in earlier years. Beneath each coefficient is the absolute value of its t -ratio; a result is statistically significant if the t -ratio is 2.0 or larger.

POPULATION DENSITY: A CORRELATE OF MAJOR DISASTERS

Major disasters do not occur randomly across the geographic area of the United States. To emphasize this point, the number of disaster declarations for the 51 jurisdictions (the 50 states plus the District of Columbia [D.C.; hereafter, states]) between 1991 and 2011 is summed for each state and normalized by its size (thousands of square miles). The national average state disaster rate per 1,000 square miles is 0.29. Between 1991 and 2011, the range is from 147.10 in D.C. to 0.03 in Alaska. When the state averages are grouped into the nine Census Bureau divisions, disasters per square mile were most frequent in New England (1.47 per 1,000 square miles) and about half as frequent in three other census divisions (Mid-Atlantic, South Atlantic, and East South Central). Of the nine states with major disaster frequencies greater than 1.0 per 1,000 square miles, five are in the New England division. In contrast, the Mountain and Pacific divisions experience the lowest rates of major disaster occurrences, with both divisions having averages below 0.10 per 1,000 square miles. Of the nine states with disaster frequency of 0.10 or less per 1,000 square miles, six are from the Mountain division.

Since major disasters are becoming more frequent and the population of the United States has also been growing, is there an association between the occurrence of disasters and population density? Population density changes the disaster risk equation. A higher concentration of people reflects a greater concentration and value of productive assets, public infrastructure, and such private assets as homes. The exposure of assets to natural hazards in densely populated areas could, but need not, increase vulnerability.

Between 1991 and 2011 there were 1,105 major disaster declarations in the 51 states. Per capita, D.C. experienced the highest occurrence rate. The 10 major disaster declarations in D.C. represent a disaster rate of 147.10 per 1,000 square miles. The next highest state disaster rate was 4.8. The highest population density among all states is also in D.C. with a density of 8,162 per square mile. This density is more than 7,000 higher than that of the next highest state, New Jersey at 931. To prevent D.C. from dominating the cross section regression analysis, it is

removed from the sample. For the 50 states, the disaster rate average is unchanged at 0.29 per 1,000 square miles, while the average population density is 151.3 per 1,000 square miles.

Population density and the frequency of disasters are highly associated. Table 2.4 shows the results of a regression analysis of disaster frequency on population density using data from 1991 to 2011. As a point of reference, the mean population density (simple average) across the 50 states in 2010 is 74.6 persons per square mile.

Note that the coefficient for population density is positive and statistically significant. Equation (2.4.2) adds categorical (dummy) variables for the census divisions as a test for geographic variability in disaster occurrence rates. The only division with a statistically significant dummy variable is New England, with a positive coefficient.¹¹ When the residuals from Equation (2.4.1) in Table 2.4 are examined, large projection errors are found in four small East Coast states: Delaware, New Hampshire, Rhode Island, and Vermont. Hence, Equations (2.4.1) and (2.4.2) substantially underpredict the disaster occurrence rate for all four states. The combined errors from these four states account for 80 percent of the error variance in these two equations. Since these four states account for 1.5 percent of the population in the United States, it is appropriate to exclude their influence on the estimated population density coefficient.

Equations (2.4.3) and (2.4.4) in Table 2.4 remove the four small states of Delaware, New Hampshire, Rhode Island, and Vermont. Note that their removal improves the goodness-of-fit of the equations but does not critically affect the estimated slope for population density. The coefficients in Equations (2.4.1) and (2.4.3) are similar, as are the coefficients in Equations (2.4.2) and (2.4.4). Removing the four small states reduces the standard errors by more than half but does not change the estimated effect of population density.¹² The states with high population density experience significantly higher rates of major disaster occurrences per square mile vis-à-vis states with low population density.

Finally, note the effect of removing the four small states on the mean disaster occurrence rate per 1,000 square miles of state area. The simple average of the occurrence rate decreased from 0.736 for the 50 states to 0.521 for the 46 states. For most of the country, the disaster occurrence rate from 1991 to 2011 averaged about 0.5 per 1,000 square miles of state area.

Table 2.4 Results of an Analysis Linking Disaster Occurrence Rate with State Population Density

	Constant	Population density	Division dummies	Adjusted R^2	Standard error	Average occurrence rate
(2.4.1) 50 states	0.288 (2.2)	0.00296 (5.4)	No	0.363	0.729	0.736
(2.4.2) 50 states	0.115 (0.4)	0.00212 (2.9)	Yes	0.438	0.685	0.736
(2.4.3) 46 states	0.206 (4.3)	0.00227 (10.8)	No	0.721	0.254	0.521
(2.4.4) 46 states	0.120 (1.2)	0.00207 (7.5)	Yes	0.799	0.216	0.521

SOURCE: The disaster occurrence rate is the number of major disaster declarations from 1991 to 2011 per 1,000 square miles of state area. Beneath each coefficient is the absolute value of its t -ratio; a result is statistically significant if the t -ratio is 2.0 or larger.

For the 46 states included in Equations (2.4.3) and (2.4.4), what is the effect of higher density on the disaster occurrence rate? Population density averaged 139.3 per 1,000 square miles for the 46 states from 1991 to 2011. Equation (2.4.4) projects an occurrence rate of 0.408 disasters per 1,000 square miles in a state with average population density and a rate of 0.609 for a state with twice the average population density. The estimated elasticity of the occurrence rate evaluated at the means of the occurrence rate and population density is 0.56.

What are the implications of this analysis? First, more densely populated states have a significantly higher risk of major disaster occurrences vis-à-vis other states. Second, as population density rises, the increase in the rate of disaster occurrences is about half the rate of increase in population density.

Between 1953 and 2011 the population of the United States nearly doubled, growing from 159.0 to 311.8 million and population density per 1,000 square miles increased from 41.9 to 82.1.¹³ Using Equation (2.4.4), the projected increase in the disaster occurrence rate due to population growth was from 0.207 per 1,000 square miles in 1953 to 0.290 in 2011, an increase of 40.3 percent. Over the same period, the simple regression underlying in Figure 2.1 had a projected increase in major disasters for each year from 7.0 to 60.7, or 756 percent. While population growth has been large since 1953, the increase in major disasters has been about 19 times what would be expected based on population growth alone (756 percent compared to 40.3 percent). The increase in the frequency of major disasters since 1953 may be attributed to a highly nonlinear effect of increased population density, or to factors other than population growth, or both increased population density and other factors. Whatever the explanation, major disasters increased at a much faster rate than population growth between 1953 and 2013.

The preceding analysis examined the cross-section association between population density and the occurrence of major disaster declarations. From the analysis, it is clear that the rate of major disasters has increased much faster than the rate of population growth since the early 1950s. One factor that might influence the frequency of major disaster declarations is climate change. The U.S. Global Change Research Program (2014) finds that the average temperature in the nation has risen and is expected to rise; and average precipitation has increased since 1900 (see Walsh et al. [2014]). Average temperature and annual rain-

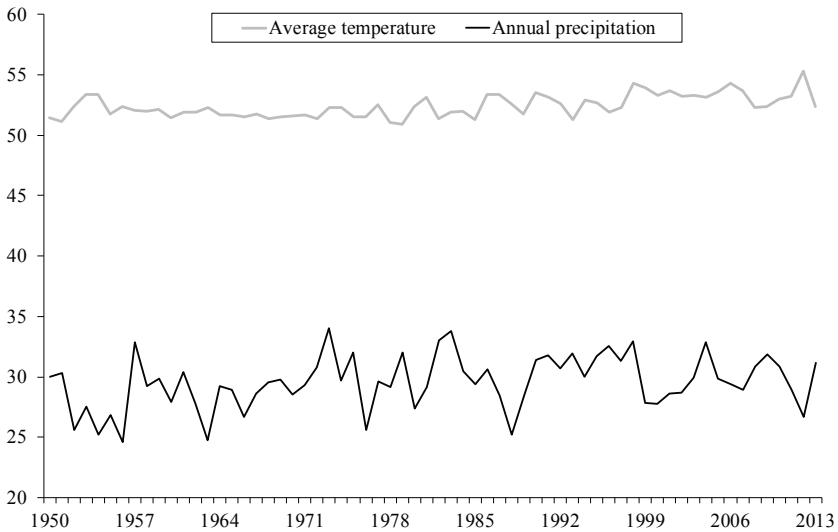
fall, two aspects of weather and climate, are discussed in the following section.

A LINKAGE TO WEATHER AND CLIMATE?

Various aspects of weather and climate, such as average temperature and annual rainfall, have been recorded not only for states, but also substate areas for more than 100 years.¹⁴ Linking the increase in major disaster declarations to the weather, however, presents major conceptual and measurement challenges. Limited observational record and the inability of models to accurately reproduce some extreme events are some of the challenges that face attribution assessment. For readers interested in an explanation of extreme events from a climate perspective, we suggest the extensive literature from the American Meteorological Society, particularly the results of studies presented in their special supplements, or the continuing research of the Intergovernmental Panel on Climate Change.

The NCDC indicators of weather and climate all demonstrate wide year-to-year variability, especially for precipitation. Figure 2.3 traces the evolution of annual average temperature and annual precipitation for the 48 contiguous states of the United States from 1950 to 2013. During these 64 years, the average annual temperature was 52.4 degrees Fahrenheit and average annual precipitation was 29.6 inches. The most obvious feature of Figure 2.3 is the greater year-to-year variability of precipitation. The standard deviations for the period are 0.93 for temperature and 2.23 for precipitation. These statistics imply that the annual variation in precipitation is more than twice that for the annual variation in temperature. While the two series in Figure 2.3 appear to be trendless, there are significant trends in both temperature and precipitation.

Table 2.5 displays the results of a regression analysis that tests for two linear trends, one starting in 1950 and one starting in 1970. For both weather variables two equations are estimated: one ends in 2012, the other in 2013. The coefficients of six of the eight trend variables are statistically significant. There is a significant downward trend in annual temperature starting in 1950, which indicates a per-decade decrease in temperature of about 0.4 degrees Fahrenheit. Annual precipitation start-

Figure 2.3 Annual Temperature and Precipitation, 1950–2013

SOURCE: Annual average temperature (Fahrenheit) and annual precipitation (inches) for the United States. Data are from NCDC.

ing in 1950 is predicted to increase by about 1.19–1.21 inches each decade during the 1950s and 1960s.

In 1970, the trends in both temperature and precipitation start to change. Readers should note the interpretation of the T-1970 slope coefficients: they identify the per-year trend after 1970 measured as a deviation from the earlier 1950–1969 trend. Thus, the net annual trend in temperature commencing in 1970 is 0.0510 degrees ($= 0.0945 - 0.0435$) for Equation (2.5.1) that ends in 2012; 0.0475 degrees ($= 0.0879 - 0.0404$) for Equation (2.5.2) that ends in 2013. After 1970, the trend in annual temperature changes from negative to positive, and the national per-decade increase is about half a degree Fahrenheit in both equations. For annual precipitation the upward trend from 1950 almost disappears after 1970. From Equations (2.5.3) and (2.5.4), the net post-1970 annual trends are 0.0117 and 0.0140, respectively, or a per-decade increase of 0.117 and 0.140 inches, respectively. Average annual precipitation nationwide was essentially unchanged between 1970 and 2013.

Table 2.5 National Trends in Temperature and Precipitation, 1950–2013

Variable and time period	Constant	Trend from 1950	Trend from 1970	Adjusted R^2	Standard error	Durbin- Watson	Mean
(2.5.1) Temperature 1950–2012	53.39 (176.5)	−0.0435 (2.2)	0.0945 (3.9)	0.445	0.699	1.58	52.42
(2.5.2) Temperature 1950–2013	52.27 (173.0)	−0.0404 (2.0)	0.0879 (3.6)	0.413	0.713	1.77	52.42
(2.5.3) Precipitation 1950–2012	27.30 (30.1)	0.1208 (2.0)	−0.1091 (1.5)	0.092	2.135	1.63	29.52
(2.5.4) Precipitation 1950–2013	27.31 (30.4)	0.1186 (2.0)	−0.1046 (1.4)	0.097	2.120	1.70	29.55

SOURCE: Annual average temperature (Fahrenheit) and annual precipitation (inches) from NCDC. Beneath each coefficient is the absolute value of its t -ratio; a result is statistically significant if the t -ratio is 2.0 or larger.

Finally, note the superior goodness-of-fit of the temperature equations in Table 2.5. The adjusted R^2 s are more than four times higher (Equations [2.5.1] and [2.5.2]) compared to their precipitation counterparts (Equations [2.5.3] and [2.5.4]), while the standard errors for temperature are about one-third of those for precipitation. The linear trends are more successful in summarizing the evolution of average temperature than the evolution of annual precipitation during the 64 years.

To develop a more nuanced picture of developments in climate since 1950, a similar regression analysis was undertaken for the 48 states.¹⁵ The results closely mirror those in Table 2.5, the national trends. The trend in annual temperature was downward between 1950 and 1969, then upward after 1970. Nearly all of the state-level trend coefficients during 1950–1969 were negative (42 of 48) while all 48 net trends were positive during the 1970–2012 period. In other words, the sum of the coefficients for T-1950 and T-1970 variables is positive for all 48 states.

The patterns in the state-level trend coefficients for precipitation reproduce the patterns observed in the national data. The 1950 trend coefficient is positive for 34 of 48 states; 27 of 48 post-1970 trends are negative. Considering the effects of both trends in the post-1970 period, 32 net precipitation trends are positive after 1970 while 16 are negative. On average, precipitation increased in most states between 1950 and 1969, but the upward trend decelerated after 1970. For individual states, however, there are many exceptions in trends in annual precipitation.

Further Analysis of Temperature Patterns

Discussions on climate change emphasize that increases in average temperature are not uniform across geographic areas. State-level temperature data highlight this point. For instance, northern states have experienced more rapid increases in temperature than southern states. Table 2.6 summarizes the results of a regression that focuses on changes in temperature since 1950 in 48 states; that is, Alaska, Hawaii, and D.C. are omitted from the sample. The analysis emphasizes the association between average temperature and the latitude of each state.¹⁶ Besides latitude, the analysis controls for mean state elevation since higher elevations are associated with lower temperatures. Some equations also include geographic controls for state location measured with categorical (dummy) variables for the nine census divisions.

Table 2.6 State and Regional Temperature Patterns since 1950

	Constant	State latitude	State elevation	Division dummy	Adjusted R^2	Standard error	Mean
(2.6.1) Average temp. 1950–2012	115.00 (35.0)	-1.564 (18.6)	-0.679 (3.4)	No	0.892	2.513	52.183
(2.6.2) Average temp. 1950–2012	115.54 (34.5)	-1.594 (20.8)	-1.911 (5.7)	Yes	0.964	1.451	52.183
(2.6.3) Projected change 1950–2012	-3.589 (4.4)	0.1055 (5.1)	0.125 (2.5)	No	0.436	0.616	0.786
(2.6.4) Projected change 1950–2012	-4.269 (3.7)	0.1161 (4.3)	-0.344 (2.9)	Yes	0.620	0.506	0.786
(2.6.5) Actual change 1950–2012	-7.276 (3.6)	0.3008 (5.8)	-0.284 (2.3)	No	0.415	1.551	4.077
(2.6.6) Actual change 1950–2012	-9.710 (5.8)	0.3249 (8.5)	-0.154 (0.9)	Yes	0.874	0.720	4.077
(2.6.7) Actual change 1950–2013	-7.673 (9.0)	0.2302 (10.6)	-0.153 (3.0)	No	0.703	0.650	1.127
(2.6.8) Actual change 1950–2013	-7.334 (5.1)	0.2176 (5.9)	-0.453 (3.1)	Yes	0.722	0.628	1.127

SOURCE: Statewide annual temperature (Fahrenheit) from NCDC. State latitude is measured as the latitude of the capital city. Mean state elevation from netstate.com. The regression analysis refers to 48 states excluding Alaska, Hawaii, and D.C. Some regression equations include dummy variables for the nine Census Bureau divisions. Absolute values of t -ratios are shown beneath the coefficients; a result is statistically significant if the t -ratio is 2.0 or larger.

Equations (2.6.1) and (2.6.2) show the strong negative association between state latitude and average statewide temperature from 1950 to 2012. Note that state elevation also enters both equations with a significantly negative coefficient, but the point estimate (coefficient) is sensitive to the inclusion, or exclusion, of the dummy variables for the census divisions. From 1950 to 2012, for each degree of higher latitude, average statewide temperature was lower by approximately 1.56–1.59 degrees Fahrenheit. The increase in latitude from Tallahassee, Florida (latitude 30.46), to Olympia, Washington (latitude 47.04), is 16.58 degrees. Equations (2.6.1) and (2.6.2) suggest that the change in latitude is associated with about a 26-degree difference in average temperature, but the actual difference between these two statewide averages during 1950–2012 was 22.4 degrees.

The principal interest for our present purpose centers on Equations (2.6.3)–(2.6.8), which examine changes in annual temperature since 1950. Equations (2.6.3) and (2.6.4) focus on projected changes in average annual temperature based on the regression results for the 48 states. These state-level regression results with two trends (post-1950 and post-1970) were used to project annual statewide temperature in each state in 1950 and 2012. The dependent variable in Equations (2.6.3) and (2.6.4) is the difference between the 2012 projection and the 1950 projection. In 40 of 48 states, the predicted change in temperature is positive, with seven of the eight projected decreases occurring in southern states.¹⁷

In Equation (2.6.3), the coefficient of the latitude variable (0.1055) is both positive and statistically significant. Geographically, states in higher latitudes experienced above-average increases in temperature between 1950 and 2012. The inclusion of a divisional dummy variable (Equation 2.6.4) does not change the sign or the size of the latitude coefficient, which remains statistically significant. Adding the division dummy variable does change the sign of the state elevation variable from positive to negative.¹⁸ Inclusion of the division dummy variables also increases the goodness-of-fit, with the adjusted R^2 increasing from 0.436 to 0.620.

Equations (2.6.5) and (2.6.6) examine the changes in actual temperature between 1950 and 2012. For both equations the latitude variable remains statistically significant and its slope coefficient is close to 0.3. Recall in Figure 2.3 that average national temperature increased in 2012. This temperature increase is reflected in the mean change

displayed in the final column of Table 2.6; that is, 4.077 in Equations (2.6.5) and (2.6.6) compared to 0.786 for the projected temperature changes of Equations (2.6.3) and (2.6.4). The state latitude variable retains its statistical significance in the final two equations of Table 2.6, which use temperature change data that extend through 2013. The year 2013 had lower temperatures in nearly all states compared to 2012, and the mean statewide increase from 1950 dropped from an average of 4.077 degrees Fahrenheit in 2012 to 1.127 degrees in 2013. Note in the final two equations how the state latitude variable retains its high statistical significance. The point estimates suggest that each degree of higher latitude is associated with a 1950–2013 increase in temperature of about 0.22–0.23 degrees Fahrenheit. Finally, note that the state elevation variable enters with negative coefficients in the final four equations in Table 2.6. Low-elevation states have experienced larger temperature increases than high-elevation states, which are mainly located in the Mountain and Pacific divisions.¹⁹

To summarize, the results of the regression analysis in Table 2.6 indicate that the increase in annual temperature was larger in the more northern states. While the point estimates of the annual temperature increases vary in size across these equations, from 0.1055 to 0.3249 per degree of latitude, all six are consistent with the finding that since 1950 northern states experienced larger increases in average temperature than other states. The U.S. Global Change Research Program (2014) finds that not only has the average temperature in the nation risen, it is expected to rise; how much the increase will be depends primarily on the amount of heat-trapping gasses emitted globally. Our results indicate that the effects of global warming in the United States since 1950 have been occurring at a noticeably faster pace in the more northern states than elsewhere.

Further Analysis of Precipitation Patterns

Similar analysis was undertaken for the geographic patterns in precipitation since 1950.²⁰ The principal conclusion one can draw is that state-level precipitation patterns have been quite stable. There is a substantial degree of variation, however, across census divisions in the projected change in precipitation between 1950 and 2012. The most important contrasts were above-average increases in New England and above-average reductions in the Pacific division.

From the analysis, two comments about precipitation are warranted. First, state precipitation is far more varied (both average levels and annual changes) than state temperature. Second, the results of our analysis provide weak evidence that northern states experienced larger reductions in annual rainfall than southern states since 1950. Research by the U.S. Global Change Research Program (2014) provides stronger evidence that average precipitation in the nation has increased since 1900, and that there are regional differences; some areas have experienced larger increases and other areas have seen decreases. The authors responsible for investigating the effects of climate find that more winter and spring precipitation is projected for the northern United States and less for the Southwest.

CONCLUSIONS

The disasters outlined in this chapter all present physical danger and impose financial costs among affected individuals, agricultural producers, businesses, and governments. The evidence presented in this chapter shows that disasters are occurring with increasing frequency. Other researchers confirm this finding. For instance, using more sophisticated techniques than OLS estimation, Smith and Katz (2013) show that an increasing trend in annual aggregate losses is primarily attributable to a statistically significant increasing trend of about 5 percent per year in the frequency of billion-dollar disasters.

Major disaster declarations have increased at a much faster rate than the rate of population growth since the early 1950s. Research by the World Bank and the United Nations (2010) on climate-induced catastrophes finds that even without climate change, population growth is expected to increase the baseline damages from extreme events over the next century. These findings have implications for the agencies responsible for providing disaster-related assistance in the United States. In recent years, concern over the size of federal budget deficits and the national debt has made policymakers more cognizant of the amount of funding the government provides to state and local governments for disaster assistance, and the processes the federal government uses to provide that assistance. Disaster assistance for large-scale adverse

events has usually been financed by funds appropriated outside traditional budget constraints, which implies that taxpayers cover a large proportion of disaster-related losses compared to private insurance coverage or other means.

The primary responsibility for providing disaster-related assistance to affected parties rests with FEMA. Various other federal agencies provide assistance to disaster survivors as well as state and local government agencies, private insurance companies, and nongovernmental organizations. As well as supporting individuals and communities during and after a disaster, social protection is increasingly recognized as a means for increasing predisaster resilience (see UNISDR [2015]). If a disaster causes unemployment, for example, the affected worker may be eligible to collect unemployment insurance benefits or disaster unemployment assistance. Details of the cash benefits and other services to disaster survivors are provided in Chapter 3.

Precipitation (rain, hail, or snow), or its absence, usually accompanies the classification of each extreme-weather event. Such information is useful to insurance providers. The National Flood Insurance Program is widely utilized by homeowners, businesses, and governments. This program includes flood hazard mapping, flood insurance, and floodplain management. More detailed information about the program is provided in Chapters 3 and 5.

Floods, hail, severe storms, and winter freezes affect agricultural producers. These disastrous events span one or a few days. Drought, in contrast, extends over several months or even years, and drought-related agricultural and other economic losses also accumulate over longer periods. The federal crop insurance program provides a safety net for agricultural producers as they face the uncertainties of markets and adverse weather. Farm commodity programs, programs to conserve the nation's natural resources, disaster relief programs, and emergency assistance programs for agricultural producers are discussed in Chapter 3.

Notes

1. See Herring et al. (2015). For instance, climate change also decreased the Antarctic sea ice extent and increased the likelihood of high sea surface temperatures in both the Atlantic and Pacific Oceans.
2. See Equation (2.1.1) in Table 2.1.
3. The standard error of the regression equation is the average distance between the regression line and the actual number of major disaster declarations.
4. Much has been written about the disaster-related responses to and the consequences of Hurricane Katrina. One consequence was the massive out-migration from Katrina-impacted areas.
5. The annual rates of increase are calculated from the trend coefficients: 0.555 for the 1953–1994 period and 1.922 for the 1995–2012 period.
6. Note that the adjusted R^2 remains less than 0.10 and the standard error is large.
7. The former National Climatic Data Center (NCDC), now known as the National Centers for Environmental Information (NCEI), records a start date and an end date for each billion-dollar event.
8. For information on the compilation of the data, see Smith and Katz (2013) and Smith and Matthews (2015).
9. The incidents are, respectively, *Illinois Severe Storms, Straight-line Winds, and Tornadoes* (DR–4157) declared on November 26, 2013, and *North Carolina Severe Storms, Flooding, Landslides, and Mudslides* (DR–4153) declared on October 29, 2013.
10. In the FEMA incident descriptions of major disasters between 1953 and 2013, 208 were attributed to hurricanes and 441 to tornadoes, the next lowest total.
11. A test of significance for adding the full set of census division dummies was performed, but the results are not statistically significant.
12. The better goodness-of-fit is indicated by the higher values for the adjusted R^2 s and lower standard errors.
13. The data refer to the population aged five years and older.
14. Our usage of the terms *weather* and *climate* follows standard definitions. Weather refers to short-term phenomena, such as today's temperature and rainfall. Climate is weather averaged over a long period, such as a decade.
15. The results of the regression analysis are available from the authors.
16. For the analysis, the latitude of the capital city is used to approximate the latitude of each state.
17. The eight are Georgia, South Carolina, Alabama, Mississippi, Tennessee, Oklahoma, Texas, and Maine.
18. The explanation for the negative coefficient is not obvious, but it is likely related to the fixed effects of the census division dummy variables. Note that state elevation enters with a negative coefficient in regression Equations (2.6.4) to (2.6.8) in Table 2.6.
19. Ten of the 11 states with mean elevation above 2,500 feet are in the Mountain and Pacific divisions.
20. The results of the regression analysis are available from the authors.

3

Providing Compensation to Survivors of Disasters

Prevention requires procedures that reduce the risk of death, injury, and damage from disasters. Early warning systems, preparedness, rapid response, and recovery measures all play key roles in disaster prevention. Disaster risk management in the United States focuses on disaster management, preparedness, and response. A national disaster risk reduction framework defines an overall strategic vision and specifies policies to increase disaster risk management efforts. The National Disaster Recovery Framework of the Presidential Policy Directive 8, National Preparedness (PPD-8), enables disaster-recovery managers to operate in a collaborative manner as they provide support in disaster-affected areas. It also addresses the roles of individuals, communities, private entities and organizations, and government in the preparedness mission. As noted in Chapter 1, the United Nations's *Sendai Framework for Disaster Relief Reduction* not only recognizes the primary role of the government in reducing disaster risk, but also the responsibility of other stakeholders.

What are the respective roles and responsibilities of the private and public sectors in creating long-term strategies to strengthen resilience to extreme events? How are disasters currently administered and financed? What kinds of assistance programs are available to compensate disaster survivors? In recent years, concern over the size of federal budget deficits and the national debt has made policymakers more cognizant of the amount of funding the federal government provides to state and local governments for disaster assistance and the processes the federal government uses to provide that assistance. In addition, disaster assistance for large-scale catastrophes has usually been financed by funds appropriated outside traditional budget constraints, which implies that taxpayers cover a large proportion of disaster-related losses compared to private insurance coverage or other means.

The first section of the chapter discusses the costs of disastrous events. The second section outlines the primary disaster-assistance pro-

grams administered by the federal government. Not all the programs that various federal agencies provide in disaster or emergency situations are outlined. While assistance programs are provided by various agencies, they are generally aimed at four broad categories of disaster survivors: 1) individuals and families; 2) state, territorial, and local governments; 3) small businesses and nonprofit organizations, with separate programs specifically for agricultural producers; and 4) a general category. The third section outlines two unemployment compensation programs available to individuals whose employment or self-employment is lost or interrupted as a direct result of a disaster.

The financial consequences resulting from adverse events may be ameliorated by the advance purchase of insurance to cover the hazard in question. The fourth section of the chapter discusses the role of insurance in compensating disaster survivors. The widespread use of homeowners insurance provides coverage against many natural hazards, including fire, hail, lightning, sleet, snow, storm, weight of ice, and wind. Catastrophic losses have affected the willingness of private insurers to provide coverage against certain hazards. When the private insurance market fails to provide coverage for disaster-related property losses, the government could intervene. The fourth section also discusses private–public partnerships. Nonprofit entities, nongovernmental organizations, and governments provide other disaster-related initiatives to support disaster survivors. The fifth section briefly examines these general assistance programs, and the final section draws conclusions.

THE COSTS OF DISASTERS

As noted in Chapter 1, the severity of a disaster is commonly measured in the number of deaths or in terms of the total dollar amount of the destruction the event causes.¹ The financial costs of disasters include physical damage to private property (residences, commercial structures, and equipment), infrastructure (public buildings, transportation and communication networks, and public utilities), and agricultural assets. In addition, there is the financial strain associated with health

care and the loss of life. The returns to capital and the earnings of individuals attached to the labor market both decrease when a disaster interrupts production. Since labor compensation exceeds half of the value added in most industries, reduced earnings comprise an important element in disaster-related costs.

Annual estimates of the costs associated with extreme-weather events in the United States are published by three entities: the Insurance Information Institute, which is supported by private insurance companies; Munich Re, an international reinsurance entity headquartered in Munich, Germany; and NOAA of the U.S. Department of Commerce. The Insurance Information Institute and Munich Re estimate the total costs associated with extreme-weather events in the United States during 2012 to be \$100 billion with insured costs totaling \$58 billion. Between 1980 and 2012, these extreme-weather costs exceeded \$50 billion (measured in 2013 prices) in 8 of the 33 years. The greatest single costs were incurred in 2005, the year of the catastrophic destruction from Hurricane Katrina, as \$196 billion in 2013 dollars.

The NCDC compiles and publishes cost estimates on weather and climate disasters that reach or exceed \$1.0 billion. While the threshold is arbitrary, these billion-dollar events account for about 80 percent of the total costs for all combined severe weather and climate events.² The information from the NCDC reflects the direct effects of weather and climate events and it constitutes total loss estimates, both insured and uninsured, but it does not take into account the financial strain associated with health care or the loss of life.³ Between 1980 and 2013, the NCDC noted that there were 170 billion-dollar disasters, about 7 each year.⁴ Because of the delays in reporting and delays in servicing insurance claims, detailed cost estimates of the published billion-dollar disaster series from the NCDC are available only for the 170 disasters to the end of 2013. Estimated cumulative losses from 1980 to 2013 are almost \$1.0 trillion. The NCDC measures the costs associated with each disaster in the current dollars of the disaster year and also in billions of 2013 dollars using the Consumer Price Index (CPI) to convert the original estimates into a constant price series.

Table 3.1 reorganizes the information from the NCDC into seven natural hazard categories using a similar taxonomy developed in Chapter 2. Again, the sorting into these categories reflects some arbitrary

Table 3.1 Billion-Dollar Weather and Climate Disasters, 1980–2013

	Number	Total loss	Average loss	Multistate events	Deaths
Winter weather, freeze	17	54.0	3.2	11	959
Drought, heat wave	21	278.2	13.2	21	18,779
Hurricane, tropical storm	33	490.4	14.9	29	3,148
Severe storm	45	82.1	1.8	41	610
Flood	17	85.7	5.0	13	373
Tornado	25	60.7	2.4	24	941
Wildfire	12	23.6	2.0	9	151
Total	170	1074.7	6.3	148	24,961
Drought-Hurricane	55	768.6	14.0	50	21,927
Rest	115	306.1	2.7	98	3,034

SOURCE: NCDC data on billion-dollar disasters measured in 2013 dollars.

decisions. In particular, the distinction between severe storms and tornadoes is subjective. The decision rule is based on the first word used by the NCDC to describe the incident.

One obvious characteristic of the NCDC estimates is the multistate nature of most the disasters. Of the 170 disasters, 148 involved two or more states. Ten or more states were affected for at least 30 of the multistate disasters. The multistate dimension is important to recognize because FEMA bases its major disaster declarations on individual states. Thus, Hurricane Sandy generated 13 major disaster declarations in the FEMA reporting system and an estimated \$65.7 billion disaster in the NCDC reporting system. The financial costs associated with major disasters can be estimated accurately only with the passage of time following their occurrence. Hurricane Sandy, for example, generated initial estimates of \$75 billion; the estimate in early 2015 was \$65.7 billion. Using the 2012 and 2013 disasters as currently priced, the 1980–2013 total is \$1.07 trillion.

Droughts and hurricanes dominate the cost estimates. The combined cost of droughts and hurricanes (\$768.6 billion) accounts for 72 percent of the overall total across all billion-dollar disasters. These two types of weather-related disasters incur much larger costs per event compared to the remaining five categories. The bottom two rows of Table 3.1 show two broad groupings of weather and climate disasters. The respective

averages for the two broad groupings of costly disasters are \$14.0 and \$2.7 billion. A typical drought or hurricane leads to approximately five times the financial costs of the other types of billion-dollar disasters. Across the 170 costly weather-related disasters as measured by the NCDC, the 55 droughts, hurricanes, and tropical storms accounted for 32 percent of all billion-dollar events but 72 percent of total costs.

In recent years the NCDC summaries of tornado-related events frequently record the number of tornadoes, which often exceed 100 so that average cost per individual tornado is only a small fraction of the \$2.4 billion average shown in Table 3.1. Of the 25 tornado events in the NCDC data, just two incurred total costs that exceeded \$5.0 billion, and both occurred in 2011.

While it is not obvious from Table 3.1, certain categories of weather-related disasters have a definite geographic locus. Hurricanes and tropical storms disproportionately affect states along the East and Gulf Coasts. Floods are concentrated in states near the largest rivers, such as the Mississippi and Missouri. All 12 billion-dollar wildfires occurred in states west of the Mississippi River.

The NCDC billion-dollar disasters have been occurring with increased frequency since 1980. Between 1980 and 1989 there were 27 billion-dollar disasters; between 2000 and 2009 there were 54. For the 34 years from 1980 to 2013, a regression analysis of the count of annual billion-dollar disasters on a linear trend explains over 40 percent of the variation in the occurrence of these disasters annually.⁵ The coefficient on the trend variable shows an increase in billion-dollar disasters of 2.1 per decade. A regression-based prediction for the current decade suggests there will be 81 billion-dollar disasters between 2010 and 2019. The projected count from the regression analysis for 2010–2013 was 33; somewhat below the actual four-year count of 41 billion-dollar disasters.

The total cost in 2013 dollars (CPI-adjusted) of the 170 billion-dollar disasters that occurred between 1980 and 2013 was \$1.075 trillion. Of the 170, however, the eight largest disasters accounted for \$488 billion (45.4 percent of the total) for an average of \$61.0 billion for each large disaster. Within this octet of large disasters, the costs associated with Hurricane Katrina were the largest by far, estimated at \$148.8 billion while the second-highest was Hurricane Sandy (\$65.7 billion). The smaller 162 disasters accounted for \$586.9 billion, or an average of

\$3.6 billion for each disaster. On average, the eight large disasters were more than 15 times costlier than the other billion-dollar disasters.

Table 3.2 shows a breakdown of the 170 billion-dollar disasters with attention to the type of hazard and size of the associated costs. Of the eight largest disasters, four were hurricanes, three were droughts, and one was a flood.⁶ As estimated by NCDC, all eight disasters incurred costs of at least \$25 billion (2013 dollars). Table 3.2 again highlights the predominance of hurricanes and drought in these cost estimates. Not only did they account for 72 percent of the total costs of all billion-dollar events, they were also responsible for seven of the eight large disasters identified in the table. Hurricanes alone were responsible for 46 percent of the aggregate estimated costs.

For each of the three categories of events identified in Table 3.2, note the comparative size of the average costs from the large disasters relative to all other events in the same category. For all three types of events, the large events had average costs that were about 10 times the average costs of the other (smaller) billion-dollar disasters.

Since these NCDC data identify both the number and estimated costs for the different categories, an analysis of their average size is also possible. Two regression equations are fitted to test for possible trends in the average cost per disaster. One equation tests for a trend in the average cost for all 170 events, while the second tests for a trend in the average financial cost after removing the eight large disasters from the sample. The results of both regression equations indicate there is no trend in the average size of the billion-dollar disasters between 1980 and 2013. Thus, the growth in the aggregate costs of these events arises from their increased annual frequency, not from the average cost of each disaster.

While aggregate costs of billion-dollar disasters since 1980 now exceed \$1.0 trillion, it is important to keep in mind the relative scale of the financial costs. The gross domestic product (GDP) of the U.S. economy in 2014 was \$17.4 trillion. Cumulative real GDP from 1980 to 2013 was \$342.7 trillion (in dollars of 2009 purchasing power) and \$365.8 trillion (in dollars of 2013 purchasing power). Relative to cumulative real GDP in 2013 dollars, the \$1.0 trillion cost of billion-dollar disasters represent 0.29 percent of real GDP, or slightly more than one-quarter of 1 percent.⁷ One observation conveyed by this calculation is the enormous size of the U.S. economy. The total costs of the 170

Table 3.2 Billion-Dollar Disasters by Type of Event and Size, 1980–2013

	Number	Total cost (\$ billions)	Average costs (\$ billions)
Total 170 disasters			
Total	170	1,074.7	7.0
Large	8	487.8	61.0
Rest	162	586.9	3.6
Hurricanes and tropical storms			
Total	33	490.4	14.9
Large	4	288.5	72.1
Rest	29	201.9	7.0
Drought and heat wave			
Total	21	278.2	13.2
Large	3	165.5	55.2
Rest	18	112.7	6.2
River flood			
Total	17	88.7	5.0
Large	1	33.8	33.8
Rest	16	51.9	3.2

SOURCE: NCDC data on billion-dollar disasters measured in 2013 dollars.

billion-dollar disasters are relatively small when placed into a macro-economic context.

The Insurance Information Institute-Munich Re (III–Munich Re) data on the costs associated with disasters cover a broader set of major weather events than the FEMA disaster declarations. For example, III–Munich Re estimated that the \$100 billion catastrophic cost in 2012 was caused by 184 weather events, including 115 severe thunderstorms, 38 wildfires, 19 floods, and 8 other events. For that same year, the FEMA disaster declarations were as follows: 47 major disaster, 16 emergency, and 49 fire management.

FEDERAL DISASTER RELIEF PROGRAMS

Chapter 2 outlines the declaration process of the Stafford Act for catastrophic events. The legislation instituted a first response to a disas-

ter that introduced long-term recovery strategies and established disaster assistance programs. Grants are provided for the care of disaster survivors, clearance of debris, restoration of damaged or destroyed facilities, mitigation of the impact of future disasters, and financial aid for those with uninsured critical needs. In addition, the legislation authorizes loans to communities that incur significant revenue losses as a result of a catastrophe, disaster-related unemployment assistance, and the use of federal agency resources to assist with local and state response and recovery efforts.

This section summarizes the primary disaster assistance programs provided by the federal government.⁸ As stated in Chapter 1, not all programs provided by federal agencies in disaster or emergency situations are outlined. Disaster assistance programs are administered by two federal agencies: FEMA and the U.S. Small Business Administration (SBA). Other federal agencies administer assistance programs that may be provided in a disaster situation or as part of regular service delivery. The U.S. Department of Agriculture (USDA) administers a number of programs that provide assistance to individuals and families, landowners, farmers, ranchers, and other agricultural producers affected by a major disaster or emergency.⁹ The two USDA agencies discussed in this section are the Food and Nutrition Service and the Farm Service Agency. Among the many other federal agencies responsible for administering disaster-related assistance are the U.S. Department of Housing and Urban Development (HUD), the Employment and Training Administration of the U.S. Labor Department, and the U.S. Department of Transportation. The assistance provided by these agencies may be funded through their own budgets, but in most cases it is requested and paid for by FEMA.

Congress appropriates funds to the Disaster Relief Fund (DRF) to ensure that federal assistance is available to help individuals and communities overwhelmed by severe disasters.¹⁰ Annual appropriations to fund the DRF commence with the formulation of a budget request for the DRF account by the administration. The DRF, which is managed by FEMA, is a no-year account used to finance disaster response activities and to fund ongoing recovery programs.¹¹ Supplemental appropriations are generally required each fiscal year to meet the crucial needs of catastrophic disasters. Additional funds to the DRF are made through

supplemental appropriations legislation. The use of this procedure concerns some legislators because these additional funds are designated as emergency appropriations, providing amounts in excess of discretionary spending limits (see Lindsay, Painter, and McCarthy [2013]). In addition, the legislation often moves through Congress on an expedited basis that sometimes limits debate and leaves little opportunity for amendments.

The Stafford Act establishes the eligibility requirements for different disaster-related programs. Disaster assistance may be in the form of grants, low-interest loans, or loan guarantees. The funds are limited either to a fixed dollar amount or to a percentage of the eligible costs. The provisions of the Stafford Act stipulate the cost-share requirements of the federal and state governments. In most cases, federal taxpayers finance 75 percent of the approved costs and states contribute 25 percent.

The initial response to a catastrophic event is the activation of local government emergency services. Depending on the extent of the disaster, local government may not be able to respond to the relief effort by itself, and other governments are called to assist. Local and state governments typically have reciprocal aid pacts in place whereby they help each other in emergency situations. Disaster relief is provided from nearby counties, state agencies, and volunteer organizations. Once a presidential declaration of a major disaster is made, emergency federal resources expressly for activities authorized by the Stafford Act are assembled. Essential assistance authorizes federal agencies to distribute aid to disaster survivors through state and local governments and voluntary organizations to perform life- and property-saving assistance, clear debris, and conduct search and rescue missions, among other immediate response services. The disaster relief effort is coordinated and funded by FEMA for search and rescue, restoration of electrical power, and the provision of basic human needs.

The long-term recovery process and the alleviation of the damage and hardship of disaster survivors follow the initial response to a catastrophic event. The long-term recovery phase of a major disaster places severe financial strain on individuals, families, and local and state governments. Some of the financial strain can be eased through the provision of compensation programs.

Assistance for Individuals and Families

Both FEMA and the SBA provide disaster assistance programs for individuals and families. Three main disaster assistance programs are provided by FEMA: the Individual and Household Program (IHP), crisis counseling, and legal services. The IHP grants are the primary source of direct federal aid for households who sustain damage from a disaster. The other programs are less significant in terms of coverage. The SBA provides one primary program for households: the Home Disaster Loan Program (HDLP). The IHP and HDLP are the primary sources of disaster-related funding for individuals and families.

The IHP provides direct compensation to households for uninsured losses related specifically to the disaster. Direct assistance is delivered through the provision of temporary housing units (mobile homes) to households who were displaced because their homes were seriously damaged or destroyed. Disaster housing grants may be used to rent alternative housing and may be available for up to 18 months to individuals and families who were displaced from their homes. The federal share of temporary housing assistance is 100 percent. Financial grants are also available to alleviate disaster-related needs and necessary expenses not covered by private insurance and other assistance programs. Limited financial assistance is available for housing repairs and replacement, transportation costs, the replacement of personal property, and uninsured personal needs (medical, dental, funeral, or other personal expenses). Statutory matching requirements mandate that states contribute 25 percent for uninsured personal needs. Grants may not exceed a fixed dollar amount (currently \$29,900) for each household.

The crisis counseling program provides grants for immediate crisis counseling services, when required, to disaster survivors for relieving mental health problems caused or aggravated by a major disaster or its aftermath. Cost-share requirements are not imposed on crisis counseling assistance. This assistance is short term and community oriented. While the regulations specify that program funding generally ends after nine months, an extension may be approved if requested by the state and approved by FEMA officials.

Disaster legal services offer free legal assistance to individuals affected by a major federal disaster. The legal assistance typically includes help with insurance claims, preparing powers of attorney, help

with guardianship, and the preparation of new wills and other legal documents lost in the disaster. There are no cost-share requirements or time limitations for legal services assistance.

The HDLP of the SBA is the second major source of disaster-related assistance for individuals and families. As the disaster assistance in the form of a loan, it needs to be repaid to the federal government. Low-interest loans are available to homeowners, renters, and personal property owners located in a declared disaster area to cover uninsured or underinsured property losses from the disaster. The HDLP falls into two categories: personal property loans and real property loans. A personal property loan provides up to a fixed dollar amount (currently \$40,000) to an eligible homeowner or renter to repair or replace personal property items damaged or lost in a disaster. These loans can cover personal items such as automobiles, clothing, and furniture. A real property loan provides up to a fixed dollar amount (currently \$200,000) to an eligible homeowner to repair or restore the primary residence to its predisaster condition. These loans may not be used to upgrade homes or build additions, unless upgrades or changes are required by local building codes. A real property loan may be increased by 20 percent if hazard mitigation is undertaken to the damaged property.

Assistance for State, Territorial, and Local Governments

When a disaster occurs, public property is damaged or destroyed and public functions are disrupted. Roads, utilities, and recreational facilities may need to be restored. Public buildings may need to be repaired or rebuilt. Administrative units, the criminal and civil justice systems, and regulatory bodies may need assistance to resume their functions. The federal government provides assistance to finance part of the costs of the rebuilding, long-term recovery, and hazard mitigation efforts.

Four disaster-related programs are provided by FEMA to assist state, territorial, and local governments in their long-term recovery efforts. Public assistance grants are the primary assistance programs for state and local governments. They may be used to repair, replace, or restore disaster-damaged, publicly owned facilities and undertake other activities such as the removal of debris, repair of roads and bridges, and repair of public buildings and water control facilities.

Hazard mitigation grants are provided to state and local governments to reduce the risks and impact of future disasters. The Hazard Mitigation Grant Program provides grants to each state in which a major disaster has been declared. The funds may be used to implement any eligible hazard mitigation activity in the state, not necessarily related to the catastrophe that led to the declaration. There is a statutory matching requirement of 25 percent for the program. By comparison, predisaster mitigation grants are not related to major disaster declarations. This program provides financial and technical assistance to states, territories, and local communities to undertake hazard mitigation measures that complement a comprehensive hazard mitigation program.¹² The objective is to reduce injuries, loss of life, and the damage and destruction of property of future disasters. Federal funds generally finance 75 percent of the cost of approved mitigation projects.

The Community Disaster Loan (CDL) program provides loans to local governments that have incurred a substantial loss of revenue from taxes and other sources in jurisdictions included in a major disaster declaration. The state governor must specifically request the program, and Congress needs to appropriate funds into the CDL account. There is no statutory matching requirement for a CDL loan. The local government must demonstrate, however, that there is a need for financial assistance, and the funds can only be used to maintain existing county functions. Typically, the loan may not exceed 25 percent of the annual operating budget of the local government for the fiscal year of the disaster and a loan may not exceed a fixed dollar amount (currently \$5 million). While the statute does not impose a time limitation on the loan, the usual term is five years.

Assistance for Small Businesses and Nonprofit Organizations

The SBA administers three types of disaster-related loans for small businesses and nonprofit organizations. Physical disaster loans are available to both nonprofit organizations and businesses. The other business disaster loans are limited to small businesses.

Any business or nonprofit organization, regardless of size, in a declared disaster area can apply for physical disaster loans to compensate uninsured physical damage and losses. The loans are intended to compensate for the repair and replacement of real property, equipment,

fixtures, inventory, leasehold improvements, and machinery not covered by insurance. The maximum loan amount is up to a fixed dollar amount (currently \$2.0 million). The potential duration of the loan may be 30 years. Businesses that receive physical disaster loans may use up to 20 percent of the loan amount for mitigation measures to help prevent loss from a similar disaster in the future. Nonprofit organizations whose physical disaster loan applications are rejected or are approved for less than the requested amount may be eligible for grants from FEMA. There is no statutory matching requirement for this program.

The Economic Injury Disaster Loans Program (EIDL) offers loans and loan guarantees to help small businesses recover from economic injury sustained as a result of a disaster. The program is limited to small businesses, the size of which varies by industry.¹³ If the secretary of agriculture designates an agriculture production disaster, small farms and small cooperatives are eligible for EIDL loans and loan guarantees. The businesses must be located in a declared disaster area and contiguous counties.¹⁴ These low-interest loans are designed to provide small businesses with operating funds until the business recovers. The maximum loan amount is up to a fixed dollar amount (currently \$2.0 million). The potential duration of EIDL loans may be 30 years. There is no statutory matching requirement for this program.

The SBA may make low-interest, fixed-rate, predisaster mitigation loans to small businesses. These loans are used to finance hazard mitigation measures to protect commercial property, leasehold improvements, or contents from disaster-related damages that may occur in the future (see McCarthy and Keegan [2009]). The business applying for the loan must be located in a Special Flood Hazard Area. A small business that participates in the program may be eligible to receive up to a fixed dollar amount (currently \$50,000) each fiscal year.

Assistance for Agricultural Producers

The USDA provides several programs to help agricultural producers recover from the financial losses associated with natural disasters.¹⁵ All the programs have permanent authorizations and only one requires a federal disaster designation (the emergency loan program). The funding for most of the programs is not subject to annual discretionary appropriations; instead, the programs receive “such sums as are necessary.”

The mission of the Farm Service Agency (FSA) of the USDA provides a safety net for agricultural producers as they face the uncertainties of markets and adverse weather. The agency administers farm commodity programs, programs to conserve the nation's natural resources, disaster relief programs, and emergency assistance programs that help improve the stability of the agricultural economy.¹⁶ The Agricultural Act of 2014 made major changes to commodity programs, added new crop insurance options, streamlined conservation programs, and expanded programs for beginning farmers and ranchers, bioenergy, organic farmers, rural development, and specialty crops.¹⁷

The federal crop insurance program, administered by the Risk Management Agency of the USDA, is discussed in the following section. The programs discussed in this subsection are all administered by FSA and fall into four broad categories: the Noninsured Crop Disaster Assistance Program (NAP); livestock and fruit tree disaster programs; emergency agricultural land assistance programs; and emergency disaster loans.

Agricultural producers who grow a crop that is currently ineligible for federal crop insurance may apply for NAP.¹⁸ The program provides financial assistance to producers of commercially produced agricultural commodities not only for crop losses but also planting prevented by a natural disaster.¹⁹ The program covers *eligible* producers for *eligible* crop losses and planting prevented by an *eligible* cause of loss. The NAP defines an eligible producer as a landowner, tenant, or sharecropper who undertakes the risk of producing a crop and who is entitled to an ownership share of that crop. Agricultural commodities for which the catastrophic level of federal crop insurance is unavailable are classified as eligible crops in the program. An eligible cause of loss is any of the following: damaging weather, such as drought, excessive moisture, excessive winds, freeze, hail, or hurricanes; an adverse natural occurrence, such as earthquake or flood; a condition related to damaging weather or an adverse natural occurrence, such as excessive heat, insect infestations, plant disease, volcanic smog; or any combination of these conditions. While a catastrophic level of coverage is provided under the program, producers can apply for additional coverage. Agricultural producers who elect for additional coverage pay a premium in addition to the service fee. Crops intended for grazing, however, are not eligible for additional coverage.

A number of emergency programs provide disaster assistance for agricultural losses resulting from drought, fire, flood, freeze, pest infestation, tornadoes, and other hazards.²⁰ The Agricultural Act of 2014 indefinitely extended three disaster assistance programs for livestock and one for fruit trees. In addition, the legislation provides retroactive authority for compensating agricultural losses back to October 1, 2011. Eligibility for these disaster assistance programs under the current legislation does not require producers to purchase crop insurance or NAP coverage, which was mandated under the previous legislation.

The Livestock Forage Disaster Program provides compensation to eligible livestock producers who incurred grazing losses due to drought or fire. Producers are compensated for the grazing losses on land that is native, on improved pastureland with permanent vegetative cover, or on land that is planted specifically for grazing. The grazing losses must be the result of drought conditions during the normal grazing period for the county. The program also provides compensation to eligible livestock producers who incurred grazing losses on rangeland managed by a federal agency if they are prohibited by the federal agency from grazing their livestock on rangeland because of a wildfire.

The Livestock Indemnity Program provides compensation to eligible livestock producers for livestock deaths in excess of normal mortality caused by adverse weather conditions.²¹ The livestock must have been maintained for commercial use and excludes wild free-roaming animals, pets, and animals used for recreational purposes. The program payment rate is equal to 75 percent of the market value of the livestock on the day before the date of their death. The USDA publishes a payment rate for each type of livestock for each year.

The Emergency Assistance for Livestock, Honeybees, and Farm-Raised Fish Program (ELAP) provides assistance for losses due to disease, adverse weather, or other conditions not adequately covered by any other disaster program, such as blizzards and wildfires. Four categories are covered by ELAP for livestock losses: livestock death losses caused by an eligible loss condition, livestock feed and grazing losses that are not due to drought or wildfires on federally managed lands, losses resulting from the additional cost of transporting water to livestock due to an eligible drought, and losses resulting from the additional cost associated with gathering livestock for treatment related to cattle tick fever. ELAP provides assistance specifically for the loss of

honeybee colonies in excess of normal mortality. In order to meet the eligibility requirements for honeybee colony losses, they must be the direct result of an eligible adverse weather or loss condition such as colony collapse disorder, eligible winter storm, excessive wind, and flood.

The Tree Assistance Program provides financial assistance to qualifying orchardists and nursery tree growers to replant or rehabilitate eligible stock damaged by a natural disaster.²² Eligible trees, bushes, and vines are those from which an annual crop is produced for commercial purposes. Nursery trees include ornamental, fruit, and nut produced for commercial sale. Trees used for pulp or to harvest timber are ineligible.

Several permanent disaster assistance programs help agricultural producers repair damaged land following disasters.²³ Three programs offer financial and technical assistance to agricultural producers to repair, restore, and mitigate the damage on private land that was caused by a disaster. The Emergency Conservation Program provides funding and technical assistance for farmers and ranchers to rehabilitate land damaged by a disaster, and to undertake emergency water conservation measures during periods of severe drought. The Emergency Forest Restoration Program provides funding and technical assistance for farmers and ranchers to rehabilitate land damaged by a disaster, and to undertake emergency water conservation measures during periods of severe drought. The program provides financial assistance to eligible owners of nonindustrial private forestland to restore forests damaged by natural disasters. For both programs, participants are paid a percentage of the cost to restore the land to a productive state.

The Natural Resources Conservation Service of the USDA and the U.S. Forest Service administer the Emergency Watershed Protection (EWP) program and its floodplain easement program. The EWP assists landowners and operators in implementing emergency recovery measures for runoff retardation and erosion prevention to relieve the imminent hazards to life and property created by natural disasters. The EWP floodplain easement program is a mitigation program that finances permanent easements on private land with the aim of safeguarding lives and ameliorating property damage from future floods, drought, and the effects of erosion.

When either the president or the secretary of agriculture declares a county as a disaster area, agricultural producers in that county may become eligible for low-interest emergency disaster loans.²⁴ Agricultural

producers in contiguous counties also become eligible for an emergency disaster loan. Loan funds may be used to help eligible farmers, ranchers, and aquaculture producers recover from production losses or from physical losses. Production losses are associated with a significant loss of an annual crop in the disaster year. Physical losses cover expenses such as repairing or replacing damaged or destroyed structures or equipment, reorganizing farming operations, replanting permanent crops, paying essential family living expenses, and refinancing certain debts. A qualified applicant may borrow up to 100 percent of actual production or physical losses up to a maximum fixed amount (currently \$500,000).

General Assistance Programs

General federal assistance supports state and local governments in facilitating the distribution of consumable supplies; authorizes federal agencies to provide resources to support evacuations, response, and recovery efforts; and provides a range of technical and advisory help.

The Food and Nutrition Service of the USDA has the primary responsibility of coordinating state, local, and voluntary organizations that provide emergency nutrition assistance.²⁵ In a major disaster, the first response is to send food commodities needed for mass feeding operations to organizations such as the Red Cross, the Salvation Army, faith-based organizations, and other voluntary relief organizations.²⁶ In limited situations, food is provided to these relief organizations for household distribution.

Short-term food assistance may be provided to individuals and families through the Disaster Supplemental Nutrition Assistance Program (D-SNAP).²⁷ Eligible disaster survivors receive one month of benefits to purchase food at authorized grocery stores. To be eligible for D-SNAP, a household must live in the disaster designated area, have been affected by the disaster, and meet the criteria for D-SNAP eligibility.²⁸ Households cannot receive both disaster distribution food commodities and D-SNAP benefits at the same time. The Food and Nutrition Service authorizes states to issue D-SNAP benefits, which are provided through an electronic benefit transfer card that can be used at authorized food retailers. Those individuals who are already participating in the regular SNAP program may be eligible to receive additional benefits under the D-SNAP program.

A disaster causes significant destruction, including a reduction in economic production and the loss of employment and income. The following section outlines two unemployment compensation programs available to individuals whose employment or self-employment is lost or interrupted as a direct result of a disaster.

UNEMPLOYMENT INSURANCE AND DISASTER UNEMPLOYMENT ASSISTANCE

Individuals whose employment is lost or interrupted as a direct result of a disaster may receive financial assistance through the regular UI program or the DUA program.²⁹ The Employment and Training Administration of the U.S. Department of Labor oversees the federal–state unemployment compensation system and provides support to the state workforce agencies that administer these programs. For the DUA program, FEMA finances benefit payments and state-level administrative costs.

The federal–state UI program provides unemployment payments (benefits) to eligible persons who are unemployed through no fault of their own and who meet other state-based eligibility requirements.³⁰ Unemployment insurance benefits are intended to provide temporary financial assistance to unemployed individuals who meet the requirements of state law. Each state administers a separate UI program within the guidelines established by federal legislation. State legislation determines the eligibility requirements for UI, the amount of the benefit and the length of time these benefits are available. To be eligible for UI benefits, individuals need to meet the state requirements for wages earned or time employed in market work during an established period of time referred to as a “base period.” In addition, administrators need to determine that individuals became unemployed through no fault of their own and verify that these unemployed individuals meet other eligibility requirements of state law.

Individuals whose employment or self-employment is lost or interrupted as a direct result of a major disaster, and who are not eligible to receive regular UI benefits, can obtain DUA.³¹ Assistance is generally available to those who lived, worked, or were scheduled to work in

the disaster area and because of the catastrophic event no longer have “a job or a place to work; or cannot reach the place of work; or cannot work due to damage to the place of work; or cannot work because of an injury caused by the disaster.”³² Individuals can receive DUA benefits for the weeks of unemployment in the disaster assistance period. The period begins with the first day of the week following the declaration of the major disaster and continues for up to 26 weeks after the declaration date. The amount of the maximum weekly benefit depends on the UI provisions of the state in which the disaster occurred. The amount of the minimum weekly benefit, however, is 50 percent of the average benefit amount in the state.

While many survivors of disasters receive UI benefits, there is no systematic ongoing measurement of the number of recipients or the amount of UI benefits associated with disasters. Chapters 4 and 5 show estimates of UI benefit payments caused by hurricanes and floods. The methodology we use is described in these chapters.

Data on the receipt DUA cash benefits for individual major disasters are available starting in 1983. Between 1983 and 2013 DUA benefits were paid to survivors of 600 major disasters, or 42.7 percent of the 1,405 major disasters from 1983 to 2013. During these 31 years the share of disasters that resulted in DUA benefits varied systematically. Table 3.3 displays the results of four regressions that summarize developments in the DUA reciprocity proportion; that is, the proportion of major disasters for which DUA cash benefits were paid.

The equations test for trends and for differential reciprocity rates for three categories of disasters: hurricanes, floods, and tornadoes. Both linear trends are highly significant. In Equation 3.3.1 in Table 3.3, the post-1983 trend indicates that the reciprocity proportion increased by 0.0196 per year or by 0.196 per decade in the years immediately after 1983. The post-1995 trend, however, is negative and larger in absolute value than the post-1983 trend. Thus, Equation (3.3.1) indicates that the reciprocity rate decreased by 0.0148 ($= 0.0196 - 0.0344$) each year after 1995 or by 0.148 per decade. While both trends are statistically significant, Equation (3.3.1) explains only about 40 percent of the annual time-series variation in the DUA reciprocity rate. The standard error of 0.094 indicates that the average annual projection error over the sample period reaches almost 10 percentage points.

Table 3.3 Disaster Unemployment Assistance Receipt in Major Disasters, 1983–2013

Regression	Constant	Trend 1983	Trend 1995	Disaster type	Adjusted R^2	Standard error	Durbin- Watson
(3.3.1) Two trends	0.341 (6.3)	0.0196 (3.2)	-0.0344 (4.1)		0.393	0.094	1.83
(3.3.2) Two trends + hurricanes	0.330 (5.9)	0.0199 (3.3)	-0.0350 (4.2)	0.109 (0.1)	0.389	0.094	1.83
(3.3.3) Two trends + floods	0.362 (3.7)	0.0192 (3.1)	-0.0340 (4.0)	-0.028 (0.2)	0.377	0.095	1.83
(3.3.4) Two trends + tornadoes	0.247 (3.9)	0.0201 (3.6)	-0.0350 (4.6)	0.338 (2.5)	0.491	0.088	1.49

SOURCE: Disaster Unemployment Assistance (DUA) reciprocity rates are measured as the proportion of major disasters with some weeks of DUA cash benefits paid. Trend 1983 and Trend 1995 are measured as linear trends. Beneath each coefficient is the absolute value of its t -ratio; a result is statistically significant if the t -ratio is 2.0 or larger. The mean annual DUA reciprocity rate for the 1983–2013 period was 0.445.

Regression Equation (3.3.1) reveals large trend-related changes in the DUA reciprocity rate over the sample period. The projected reciprocity rate increased from 0.361 in 1983 to 0.562 in 1995 but then decreased to 0.296 in 2013. The likelihood of receiving DUA benefits following a major disaster has decreased substantially since 1995. As noted below, there is no obvious explanation for the decrease.

Figure 3.1 displays the actual reciprocity rates and the rates projected by regression Equation 3.3.1 from 1983 to 2013. The reversal of the reciprocity rate after 1995 has been dramatic. The upward trend through the mid-1990s saw the reciprocity rate increase substantially, but then decrease by even more during the most recent two decades. Tracking changes in the projected proportion, the increase through the mid-1990s was more than 0.20 but the subsequent decrease was at least 0.30.³³ The projected reciprocity rate in 2013 was only about half of the rate in 1995.

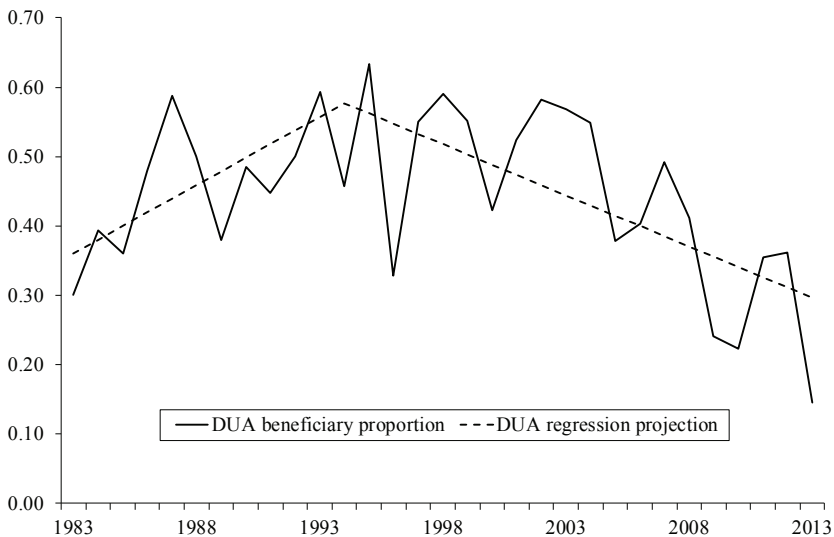
Chapter 2 explores trends in major disasters with an emphasis on hurricanes, floods, and tornadoes. Equations (3.3.2), (3.3.3), and (3.3.4) test for the effects of these three hazard categories on the DUA reciprocity rate. The three categories span almost the full range of average losses per disaster with hurricanes having the highest average and tornadoes one of the lowest averages.³⁴ Each category is measured as a proportion of all major disasters, and this proportion is added to the

regression equations that also include the trends from 1983 and 1995. The results from the three regressions are surprising. The one category that contributes significantly to explained variation is the tornado proportion of major disasters (Equation 3.3.4) and not hurricanes (the most costly) or floods (the most common).

The decline in the DUA reciprocity proportion since 1995 has no obvious explanation. Program eligibility rules have not changed over the past 20 years, but the downtrend is apparent as early as 2007. Also, the tornado proportion retains significance when the estimation period is shortened to 2007, while the hurricane and flood proportions remain insignificant with shorter estimation periods.

The decline in DUA reciprocity could reflect a decline in knowledge about the program among potential participants (mainly the self-employed). The most recent data indicate that the decline may have accelerated. The reciprocity proportion in 2013 was 0.145 and 0.140 in 2014. These are the two lowest proportions of the entire 1983–

Figure 3.1 Disaster Unemployment Assistance Reciprocity Rates, 1983–2013



SOURCE: Disaster Unemployment Assistance (DUA) beneficiary proportion, the proportion of major disasters where DUA cash benefits were paid to survivors of the disaster.

2014 period. Explaining why reciprocity has declined is an important endeavor in order to ensure that DUA will continue to support disaster survivors in future years.

PRIVATE INSURANCE AND PRIVATE–PUBLIC PARTNERSHIPS

The financial consequences of many casualty losses may be ameliorated by the advance purchase of private insurance. For instance, disability insurance, health insurance, and life insurance are privately sold policies that provide compensation to individuals for the specified casualty loss. Property insurance is a private mechanism that provides compensation to those who suffer covered losses to physical property (both real and personal property). Homeowners insurance may pay not only for the rebuilding or repair of a damaged home, but also for temporary living costs. Business interruption insurance can partially substitute for temporarily lost income or pay for temporarily higher expenses. While private insurance policies are primarily used to cover the risk loss in nondisaster settings, they can also operate in the event of a major disaster.

The most common private insurance policy for homeowners in the United States is Homeowner-3 (HO-3). A standard HO-3 policy provides broad coverage for losses due to “perils,” as they are called in the insurance industry, such as explosions, fire, hail, lightning, smoke, storms, theft, tornadoes, vandalism, and wind.³⁵ In some areas prone to hailstorms, there is a deductible specifically for hail damage. There are some restrictions in coverage for windstorm damage if one lives near the Atlantic or Gulf Coasts because of the high risk of hurricanes. Similarly, if one lives in certain parts of the Midwest, where tornadoes are common, windstorm damage is not usually covered.

Some disasters, such as damage from hail, lightning, volcanic eruptions, and windstorms, are covered under homeowners insurance; damage from perils that lead to widespread disastrous consequences are specifically excluded. Earthquake insurance can be purchased for an additional premium under a standard HO-3 policy in all states except California.³⁶ The cost of this coverage varies significantly from one area

to another, depending on the likelihood of a major earthquake. Flood coverage, however, is not available as additional coverage. Hurricanes and other windstorms are often accompanied by flooding. In many cases, flooding can cause far more damage to a home and other property than high winds. Neither homeowners insurance nor a separate wind-storm policy covers flood damage. Neither does property insurance cover the destruction of one's home or other buildings if the destruction was the result of a flood.

Catastrophic losses from earthquakes, floods, hurricanes, nuclear radiation, and terrorism have affected the willingness of private insurers to provide coverage against these perils. In the case of floods, private insurance companies provided flood insurance until the late 1920s. Following the heavy losses the insurance industry experienced as a result of the Mississippi floods in 1927, private flood insurance coverage was discontinued.³⁷ Floods were perceived to be uninsurable for three reasons. First, adverse selection meant that only households and firms in flood-prone areas would purchase coverage. Second, risk-based premiums were too costly for the average household. Third, private insurers could not generate sufficient premiums to insure against a catastrophic flood event.

Two federal government insurance programs were created to provide coverage for a peril that the private insurance market was unwilling to underwrite: the federal crop insurance program and the National Flood Insurance Program (NFIP). Before the federal crop insurance program was established, private insurers had difficulty providing affordable insurance policies because of the inherent risks and potential for widespread catastrophic losses associated with agricultural production. The NFIP was created in the wake of the widespread flooding in the mid-1960s and calls for a reduction in the financial burden on taxpayers for providing assistance to flood survivors. Because private insurance was not available, the federal government decided to provide coverage in order to safeguard the economic interests of households, agricultural producers, businesses, communities, and taxpayers.

To help the agricultural sector recover from the combined effects of the Great Depression and the Dust Bowl, Congress passed the Agricultural Adjustment Act of 1938 and the Federal Crop Insurance Act. The legislation established the federal crop insurance program and created the Federal Crop Insurance Corporation to administer the program.

The program's aim is threefold: to protect the income of agricultural producers against crop failure or price collapse, to protect individuals and families against food shortages and price fluctuations, and to assist business and employment by providing a consistent flow of agricultural commodities.

The federal crop insurance program is designed to help protect agricultural producers against either the loss of their crops from a natural disaster (crop-yield insurance), or the loss of revenue from lower agricultural commodity prices (crop-revenue insurance). According to the National Crop Insurance Services, farmers spent approximately \$4.5 billion in 2013 to purchase more than 1.2 million crop insurance policies that protected 128 different kinds of crops.³⁸ Crop insurance is divided into two categories: the federally subsidized multiple-peril crop insurance and the state-regulated private crop insurance.

The multiple-peril crop insurance program provides coverage for the losses associated with the unavoidable risks of adverse weather, and weather-related plant diseases and insect infestations. It provides insurance for crops and livestock against damage caused by droughts, floods, hail, and winter freezes.³⁹ Crop insurance is available for most major crops and many specialty crops (including fruit, tree nut, vegetable, and nursery crops), as well as forage and pastureland for livestock producers. An agricultural producer who chooses to purchase an insurance policy must do so by an administratively determined deadline date, which varies by crop and usually coincides with the planting season.

The Risk Management Agency of the USDA operates and manages the Federal Crop Insurance Corporation, which provides crop insurance to farmers and ranchers. Private-sector insurance companies sell and service these policies. The federal government subsidizes the administrative and operating expenses of the private insurance companies, develops and/or approves the premium rate, approves and supports products, and reinsures the companies. The largest category of the insurance payments is associated with droughts, but compensation from floods is also common.

A number of legislative changes have modified the federal crop insurance program.⁴⁰ The most recent modification was with the Agricultural Act of 2014. The legislation expands the scope of the federal crop insurance program by covering a greater share of agricultural losses, and makes other modifications that broaden policy cover-

age. It makes major changes in commodity programs, adds new crop insurance options, and expands programs for specialty crops, organic farmers, bioenergy, and rural development. In addition, the legislation introduces new products to help agricultural producers expand their protection against losses due to natural disasters or price declines.⁴¹

Under the current crop-yield insurance, part of the federal crop insurance program, an agricultural producer who grows an insurable crop selects a level of crop yield and price coverage and pays a premium. Premiums increase as the level of yield and price coverage rise. All eligible agricultural producers can receive catastrophic coverage, however, without paying a premium. Although eligible agricultural producers do not pay a premium for catastrophic coverage, they are required to pay an administrative fee (currently \$300) per covered crop for each county where the crop is grown.

For many insurable commodities, an eligible producer can purchase crop-revenue insurance. Under such a policy, a farmer can potentially receive an indemnity payment when actual farm revenue for a commodity falls below the target level, regardless of whether the deficit in revenue was caused by a shortfall in production or low farm commodity prices. Insured agricultural producers can also be eligible for reduced coverage if they are late in planting or prevented from planting because of flooding.

The second government insurance program discussed in this section is the NFIP. In 1968, Congress passed the initial legislation that created the program to address the increasing costs of taxpayer-funded disaster relief for flood survivors and the increasing damage caused by floods. While the program has been expanded and modified several times, it has consistently pursued a comprehensive flood risk management strategy: flood hazard mapping, flood insurance, and floodplain management.⁴² Flood hazard mapping is designed to identify and map flood-prone communities across the nation. Purchasing flood insurance encourages property owners in NFIP-participating communities to protect their property against flood losses. Flood plain management requires communities in flood-prone zones to adopt and enforce approved floodplain management ordinances to mitigate the risk of future flood damage.

The Federal Insurance and Mitigation Administration, part of FEMA, administers NFIP in close coordination with private companies that provide property insurance to households and businesses.⁴³ Partici-

pation in NFIP is based on an agreement between the federal government and local communities to provide insurance if a community will implement and enforce mitigation measures to reduce future risks in flood-prone areas.

The NFIP has grown extensively since its inception; as of January 2015 the program has more than 5.1 million policies in 22,000 communities and provided \$1.25 trillion in coverage. Insurance coverage tends to be concentrated in coastal states, with nearly 40 percent of the entire program (in the number of policies, premiums and coverage) concentrated in Florida and Texas. In the aftermath of the hurricane seasons in the last decade, the NFIP borrowed approximately \$27 billion from the U.S. Treasury to meet its claims obligations. In response to these increasing obligations, Congress passed the Biggert-Waters Flood Insurance Reform Act (BW-12) in July 2012. The legislation applied the tools of risk management to the peril of flooding. Among its provisions, BW-12 required that floodplain maps be updated, local building code enforcement be strengthened, insurance subsidies for certain properties be removed, and risk-related premiums be charged.

Some residents, particularly those who received insurance premium subsidies, were confronted with large price increases. Originally, BW-12 was to gradually phase out the subsidized rates for about 20 percent of property owners, half were to pay 25 percent more per year and the rest were to move to the full cost for flood insurance upon purchase of an older property. Because FEMA did not issue the new rates for 15 months, many households bought property before they could be warned of the retroactive rate increase. Other households saw rate quotes that were inaccurate and well above the intended 25 percent increase. In the face of significant challenges to BW-12, Congress passed the Homeowner Flood Insurance Affordability Act in March 2014. This legislation should resolve most of the unintended consequences of BW-12. In an effort to encourage mitigation measures, reduced premiums will be available for households who flood-proof or undertake other methods to elevate property. If there are affordability issues with low-value homes, nonprofit organizations, churches, or small businesses, FEMA is obliged to propose solutions to Congress. In addition, FEMA is required to monitor the implementation of the legislation and complete a comprehensive affordability study to help guide future congressional action.

If a private–public insurance program were to be provided, then it would need to be linked with other initiatives. Given the reluctance of individuals to voluntarily purchase insurance against damages, regulations could be passed that require catastrophic insurance coverage for all individuals who face risk. Insurance premiums would be risk-based to provide appropriate signals about the hazards individuals face and enable insurance providers to lower premiums for properties where mitigation is undertaken.

OTHER SUPPORT

In the aftermath of a major disaster, the government is not the only actor that provides compensation to disaster survivors. Private actors, individuals, or local groups of people spontaneously extend assistance. Nonprofit entities and nongovernmental organizations also step in to provide disaster relief assistance. The Red Cross was set up in advance with the mission of responding to disasters and emergencies.⁴⁴ In order to encourage the participation of the private sector, the government needs to define its role as supplementing and not supplanting the assistance of others.

Even though social insurance and social assistance programs are not restricted to disaster settings, they come into play after a major disaster. Social insurance is aimed at personal loss, not property loss. For example, the social security program in the United States effectively requires workers to partially insure against the loss of income from retirement or death, and the unemployment compensation program requires workers to partially insure against the loss of wages arising from involuntary unemployment.

Social insurance can be viewed as a scheme that mandates individuals to contribute in advance their own “fair share” to a program that will help them in times of personal need, rather than rely on taxpayers when the need arises. When people suffer personally from a major disaster, social insurance is already in place, and so certain survivors of disasters (and their families) can call on these programs to help compensate for income loss, medical costs, and other expenses.

Income-conditioned social assistance programs are also available to survivors of a catastrophic event. For instance, individuals who lose income, employment, or health insurance may become eligible for programs that are not specifically intended for disaster relief. Social assistance is intended to help individuals (and their families) who experience personal disasters. It includes income support provided by welfare programs such as Temporary Assistance for Needy Families (TANF), housing support programs such as public housing units and housing vouchers provided by HUD, job training under the Workforce Investment Act, Medicaid, the State Children's Health Insurance Program (S-CHIP), food assistance for disaster relief, and so on.

Under programs such as the Social Services Block Grant or Community Development Block Grant, state or local officials have the discretion to use funds to meet disaster-related needs. Other federal agencies may offer assistance to state and local governments, the U.S. Economic Development Administration (EDA), and the U.S. Army Corps of Engineers. The role of EDA in disaster recovery is "to facilitate delivery of federal economic development assistance to local governments for long-term community economic recovery planning, reconstruction, redevelopment and resiliency."⁴⁵ Within the context of the National Disaster Recovery Framework, EDA coordinates the activities of a diverse group of partner agencies in support of community economic recovery.

CONCLUSIONS

Given the occurrence of disasters in the United States, there is a need to encourage those at risk to invest in mitigation measures to reduce future risks prior to a catastrophic event. Together with risk management programs, insurance can play an important role in disaster risk reduction. Insurance is a well-known form of risk transfer: coverage of a risk is obtained from an insurance provider in exchange for ongoing premiums paid to the provider. Insurance is designed to spread risk by using an insurance pooling mechanism for those who choose to live in high-risk areas. Each policyholder would pay a relatively small

premium to an insurance provider who would then be able to cover the large losses suffered by a few. In an ideal situation, those who undertake loss-prevention measures would be rewarded by a reduction in the price of their coverage to reflect their lower expected claims.

When the private insurance market fails to provide insurance coverage for property losses from certain disasters, the government could intervene. For instance, state and federal governments could work with private insurers facing a similar peril to provide coverage for that risk and make each insurer cover its “fair share.” Or the government could create a fund paid for by private insurers that covers the target peril. Alternatively, the government could become the insurer of the risk and offer the coverage. It could enlist private insurers to sell the policies, collect the premiums, and even process the claims if the covered risk were to occur.

Disaster survivors and public entities need to be encouraged to avoid the potential risks of future disasters to life and property. Local, state, and federal governments could take steps to encourage potential disaster survivors to engage in loss prevention (or reduction) measures. It is possible that current zoning regulations are encouraging unwise construction in high-risk areas. Land-use planning can help mitigate disasters and reduce risks by discouraging settlement and construction in hazard-prone areas, particularly such key installations as power, sewage and water, and service routes for transportation.

Building codes necessary to ensure human safety and welfare could be encouraged, including resistance to collapse and damage. Building regulations could require specific enhancements to structures to limit the damage caused by earthquakes of certain magnitudes or the force of strong winds. Governments could provide information to building owners about these measures, provide financial incentives to owners to utilize them, and penalize owners who failed to take such measures and suffered harm in a subsequent extreme event. Similar actions could be taken by governments to encourage precautionary measures for other potentially catastrophic risks, such as floods or tornadoes. For example, chronically flood-damaged homes could be relocated from flood-prone areas or houses could be elevated. It is not only the adoption of adequate codes and standards by local, state, and federal governments that is required for mitigation, but also the enforcement of building codes

and standards. As the UNISDR (2009) notes, a systematic regime of enforcement is a critical supporting requirement for effective implementation of building codes.

Current insurance is not effectively meeting two important objectives to those at risk: delivering information to those residing in hazard-prone areas about the nature of the risks they face, and providing incentives for undertaking loss-reduction measures prior to a disaster. Public-private partnerships can encourage investment in protective measures prior to a disaster, manage the issue of affordability, and provide insurance coverage for catastrophic risks. In order to reduce risk, the rate structure of premiums would reflect risk based on accurate information about the perils faced by those residing in hazard-prone areas. Accurate information is needed to determine the price of risk-based premiums.

To address the issue of affordability, means-tested vouchers could be provided to individuals who undertake cost-effective mitigation measures. Long-term loans for mitigation would encourage expenditure on cost-effective mitigation measures. An additional motivation for undertaking loss-reduction measures is well-enforced building codes. Given economic development in hazard-prone areas, the need for making communities more resilient to natural disasters by investing in loss reduction measures is critical.

Notes

1. For an accounting framework in assessing disasters, see Economic Commission for Latin America and the Caribbean (2014).
2. See <http://www.ncdc.noaa.gov/billions> (accessed September 16, 2016). Recall that the former National Climatic Data Center (NCDC) is now the National Centers for Environmental Information (NCEI).
3. The insured and uninsured direct loss components include physical damage to residential, commercial, and government/municipal buildings; material assets within a building; losses due to businesses interruption; vehicles, boats, offshore energy platforms; public infrastructure; and agricultural assets.
4. In 2014 and 2015, the NCDC added 18 more incidents to its list.
5. The regression is as follows with *t*-ratios appearing in parentheses beneath the coefficients; a result is statistically significant if the *t*-ratio is 2.0 or larger.
 NOAA number = 1.251 + 0.2142 × Trend 1980
 Adjusted R^2 = 0.414. Standard error = 2.49 (1.4) (4.9)
 Durbin-Watson = 1.83 Mean = 5.00

6. The four hurricanes and the cost estimates of the destruction (in billions of 2013 dollars) were Katrina (\$148.8), Sandy (\$65.7), Andrew (\$44.8), and Ike (\$29.2). The three drought-heat waves occurred in 1988 (\$78.8), 1980 (\$56.4), and 2012 (\$30.3), while the large flood event was the Great Flood of 1993 (\$33.8).
7. A scaling procedure is generally used in comparisons across economies even though GDP is a flow concept, while damage is a stock concept. The reason is that absolute damage in affluent economies is considerably greater because they have more assets. In a sample of 175 economies, the World Bank and United Nations (2010, p. 32) found that damage is less than 1 percent of GDP for 86 percent of the sample.
8. For a more comprehensive list, see Torsell (2012).
9. The authority of the USDA to provide emergency assistance for its various disaster relief programs exists under the Stafford Act, secretary of agriculture disaster designations, Food and Nutrition Act of 2008, as well as other authorizing legislation. For an overview of the emergency disaster designation and declaration process, see https://www.fsa.usda.gov/Internet/FSA_File/ed_desig_process2012.pdf (accessed July 28, 2016).
10. The Budget Control Act of 2011 amended the Balanced Budget and Emergency Deficit Control Act of 1985. The 2011 legislation reinstated the discretionary spending limits that had expired after 2002 and made adjustments to those limits.
11. No-year funding appropriations are available until expended which is helpful in disaster recovery since infrastructure repair and mitigation projects can extend over several years.
12. See <https://www.dhs.gov/presidential-policy-directive-8-national-preparedness> (accessed October 10, 2016).
13. PPD-8 defines mitigation as “the capabilities necessary to reduce loss of life and property by lessening the impact of disasters. Mitigation capabilities include, but are not limited to, community-wide risk reduction projects; efforts to improve the resilience of critical infrastructure and key resource lifelines; risk reduction for specific vulnerabilities from natural hazards or acts of terrorism; and initiatives to reduce future risks after a disaster has occurred.” See <http://www.dhs.gov/presidential-policy-directive-8-national-preparedness> (accessed June 15, 2016). For further information, see Dilger (2012).
14. The president, the administrator of the SBA, or the secretary of agriculture can make a declaration.
15. For further information, see Shields (2015).
16. For a full list of FSA programs, see <http://www.fsa.usda.gov/programs-and-services/index> (accessed August 8, 2016)
17. See <http://ers.usda.gov/agricultural-act-of-2014-highlights-and-implications.aspx> (accessed June 15, 2016).
18. The NAP has permanent authorization under Section 196 of the Federal Agricultural Improvement and Reform Act of 1996. 7 U.S.C. 7333
19. To receive financial assistance, the natural disaster must occur before or during harvest (the coverage period) and directly affect the eligible crop. Depending on the crop, the coverage period varies. For more information on NAP see <http://>

- www.fsa.usda.gov/Internet/FSA_File/nap_2015_subsqnt_yrs.pdf (accessed June 15, 2016).
20. See <http://www.fsa.usda.gov/programs-and-services/disaster-assistance-program/index> (accessed July 27, 2016).
 21. The program also provides compensation for attacks by animals reintroduced into the wild by the federal government, including wolves and avian predators.
 22. Losses in crop production are generally covered by federal crop insurance or NAP.
 23. For more information on these programs, see Stubbs (2012).
 24. See https://www.fsa.usda.gov/Internet/FSA_File/emloanpr_sept12.pdf (accessed June 15, 2016).
 25. The mission of the FNS is to increase food security and improve health outcomes in the United States. In partnership with cooperating organizations, the FNS administers nutrition assistance programs and provides nutrition education to children and low-income individuals. The Agricultural Act of 2014 reauthorized SNAP, the largest domestic food security program, and modified some its provisions.
 26. The Stafford Act directs the president to ensure that adequate stocks of food commodities be available for mass feeding in a disaster situation. See <http://www.fns.usda.gov/disaster/food-assistance-disaster-situations> (accessed June 15, 2016).
 27. The Food Stamp Act of 1977 and the Stafford Act give the secretary of agriculture authority to issue emergency SNAP benefits in response to catastrophic events.
 28. See http://www.fns.usda.gov/sites/default/files/disaster_handout.pdf (accessed June 15, 2016).
 29. The Stafford Act authorizes the president to provide benefit assistance to individuals unemployed as a direct result of a major disaster.
 30. See <https://oui.doleta.gov/unemploy/uifactsheet.asp> (accessed June 16, 2016).
 31. See <http://www.fema.gov/recovery-directorate/disaster-unemployment-assistance-fact-sheet> (accessed June 16, 2016).
 32. See <http://www.ows.doleta.gov/unemploy/disaster.asp> (accessed June 16, 2016).
 33. Because of the substantial short-run noise in the annual reciprocity rates as shown in Figure 3.1, the changes in reciprocity discussed in the text rely mostly on the regression line rather than the actual annual proportions.
 34. Recall from the NCDC data in Table 3.1 that the average cost for hurricanes was \$14.9 billion (2013 dollars), for tornadoes it was \$2.4 billion, and \$1.8 billion for severe storms.
 35. See <http://www.iii.org/article/am-i-covered> (accessed July 27, 2016).
 36. Earthquake coverage for residents in California can be purchased through the California Earthquake Authority, which is a state-run earthquake insurance program. Earthquake coverage for business firms in California is usually included in a commercial policy or can be purchased from private insurers as separate coverage. See Chapter 9.
 37. For more detailed information on the history of flood insurance, see Michel-Kerjan (2010) and Knowles and Kunreuther (2014).
 38. See http://www.naic.org/cipr_topics/topic_crop_insurance.htm (accessed June 16, 2016).

39. See <http://www.rma.usda.gov> (accessed June 16, 2016).
40. Changes to the federal crop insurance program were introduced in 1980, 1994, 2000, and 2008. The Federal Crop Insurance Act of 1980 encouraged program participation by authorizing a subsidy for premiums. It also added coverage for additional crops and regions of the country. The Federal Crop Insurance Reform Act of 1994 expanded program participation by increasing subsidies and making coverage mandatory for certain benefits previously offered for free. The Risk Management Agency was created in 1996 to operate and manage the FCIC and the requirement for mandatory enrollment was lifted. The Agriculture Risk Protection Act of 2000 added \$8.2 billion in new federal spending over a five-year period to the program primarily through more generous premium subsidies to help make the program more affordable to agricultural producers. The aim was to enhance participation levels and reduce the need for ad hoc emergency disaster payments. The Food, Conservation, and Energy Act of 2008 created a permanent disaster assistance program.
41. For an overview of the changes, see http://www.naic.org/cipr_newsletter_archive/vol11_ag_act_2014.pdf (accessed June 16, 2016).
42. Major changes were made to the program in 1973, 1994, and 2004. After Hurricane Agnes in 1972, Congress enacted the Flood Disaster Protection Act of 1973 that established a mandatory flood insurance purchase requirement for structures located in a Special Flood Hazard Area. Federally regulated lenders were obligated to require flood insurance on loans in a FEMA-designated Special Flood Hazard Area in a participating community. After the Great Flood in 1993, Congress strengthened lender compliance through the mandatory purchase provisions in the National Flood Insurance Reform Act of 1994. Recognition of the impact of properties prone to repetitive flooding on the financial solvency of the program led to the passage of the Flood Insurance Reform Act of 2004 that established a pilot program for the mitigation of severe repetitive loss properties (SRLPs) and the funding of mitigation activities for individual SRLPs.
43. See <http://www.fema.gov/national-flood-insurance-program> (accessed June 16, 2016).
44. See <http://www.redcross.org/index.html> (accessed June 16, 2016).
45. See <http://www.eda.gov/about/disaster-recovery.htm> (accessed June 16, 2016).

4

Hurricanes

Among the seven types of major disasters introduced in Chapter 2, the large-scale destructive effects of hurricanes stand out for the magnitude of their financial costs. While hurricanes accounted for just 195 of the 2,046 FEMA-designated major disasters declared between 1953 and 2013, they comprised nearly half the billion-dollar disasters (NCEI, n.d.).

The large financial costs associated with hurricane-related disasters reflect several hurricanes, not just a few wildly destructive ones such as Hurricanes Katrina and Sandy. It was noted in Chapter 3 that the financial costs of four of the eight billion-dollar disasters that exceeded \$25 billion (2013 dollars) were hurricanes. Seven of the 13 disasters with financial costs between \$10 and \$25 billion and eight of the 22 with costs between \$5 and \$10 billion were also hurricanes. Thus, of the 43 billion-dollar disasters with financial costs of \$5 billion or more that occurred between 1980 and 2013, 19—nearly half—were caused by hurricanes.

Hurricanes also figure prominently in the large financial losses recorded in other disaster-related statistical series. The NFIP publishes information of each flood event with paid losses of 1,500 or more. Between January 1978 and December 2013, the NFIP records indicate that there were 22 separate flood events with 10,000 or more paid losses, and 14 were due to hurricanes. Similarly, hurricanes figure prominently in the losses of the DUA program. Hurricanes were responsible for 8 of the 20 disasters between 1983 and 2013, during which DUA made payments of more than 40,000 weekly benefits. In short, the financial losses attributable to hurricanes dominate the various programs that are responsible for providing support to disaster survivors.

The first section introduces terminology that differentiates between tropical depressions, tropical storms, hurricanes, and major hurricanes. It also outlines the Saffir-Simpson Hurricane Wind Scale used to classify hurricanes. Like all major disasters, hurricanes generate several types of adverse effects on individuals, families, and the economy. Since labor compensation exceeds half of the value added in most industries,

reduced earnings comprise an important element in disaster-related economic losses. The second section analyzes the labor market effects of the four hurricanes that caused the largest financial losses. These hurricanes were (in descending order) Katrina, Sandy, Andrew, and Ike. Four destructive hurricanes also impacted Florida between mid-August and late September in 2004. The regression analysis also examines the labor market effects of these combined “Florida Four” hurricanes. The third section examines property damage and compensation from hurricanes using data from the NCDC, the NFIP program, and the DUA program. The last section provides concluding comments.

TERMINOLOGY

Hurricanes are tropical cyclones (defined below) or severe tropical storms that form over oceans and other large bodies of warm water. Atlantic hurricanes form in the Atlantic Ocean, the Caribbean Sea, and the Gulf of Mexico. Occasionally hurricanes that affect the United States form off the west coast of Mexico. In the United States, most states affected by hurricanes border the Atlantic Coast and the Gulf of Mexico, but occasionally hurricanes affect Hawaii and states along the Pacific Coast. The Atlantic hurricane season extends from June to November, with peak activity from mid-August to late October. The Eastern Pacific hurricane season extends from mid-May through November.

A tropical cyclone is a warm-core circular wind pattern that originates in warm or tropical waters. It is characterized by closed surface wind circulation about a well-defined center or eye, high circular wind speeds, and thunderstorms. Over water a hurricane is sustained by extracting heat energy from warm water while exporting energy at a low temperature in the upper atmosphere. Destruction from hurricanes is caused by heavy rainfall, strong winds, and storm surges along coastal areas but can also entail flash flooding and mudslides. Typically, the destructive effects of hurricanes are most serious along the coast but can extend inland for hundreds of miles.

The severity and potential damage from a tropical cyclone is evaluated by its maximum sustained surface wind speed as classified by the

Saffir-Simpson Hurricane Wind Scale (SSHWS). A tropical depression has a maximum sustained surface wind speed of 38 miles per hour (mph) or less. Tropical cyclones with wind speeds between 38 and 73 mph are termed tropical storms, while those with wind speeds of 74 mph or higher are termed hurricanes. Hurricanes, in turn, are classified into five categories depending on maximum sustained wind speeds: Category 1 (74–95 mph), Category 2 (96–110 mph), Category 3 (111–129 mph), Category 4 (130–156 mph), and Category 5 (157 mph or higher). Hurricanes in Saffir-Simpson Categories 3, 4, and 5 are commonly termed major hurricanes.

The National Weather Service of the National Oceanic and Atmospheric Administration (NWS-NOAA) has documented cyclone and hurricane activity for more than 100 years. Since 1962, NWS-NOAA has published annual summary information of the Atlantic hurricane season using the SSHWS classification system, an arrangement extending from tropical depressions through Category 5 hurricanes.¹ Between 1962 and 2013 there were 847 tropical depressions, 593 tropical storms, 316 hurricanes, and 119 major hurricanes. Across these 52 years about 70 percent of tropical depressions became tropical storms; about half of tropical storms became hurricanes, and about one-third of hurricanes were major hurricanes. On average, only about 14 of each 100 tropical depressions became major hurricanes.

The SSHWS classification system has been used consistently to classify hurricanes in all years since the FEMA major disaster reporting system was initiated in 1953. Between 1953 and 2013, 70 separate hurricanes resulted in major disaster declarations. As noted in the introductory chapter, the geographic entity used in the FEMA reporting system is the state/tribal government. Given that major disaster declarations are recorded by state, the number of hurricane-related major disasters was much larger at 195. Hurricane Sandy, for example, caused major disasters in 13 states in the FEMA reporting system.

Between 1953 and 2013 there were 372 Atlantic hurricanes and four Eastern Pacific hurricanes that affected the United States. Of the 376, only 70 resulted in major disaster declarations. Major hurricanes (SSHWS categories 3, 4, and 5), however, were more likely to result in major disaster declarations than lesser hurricanes. Of the 223 lesser hurricanes, only 16 ($= 0.072$) resulted in major disaster declarations, whereas 54 of the 153 ($= 0.353$) major hurricanes resulted in major

disaster declarations. Major hurricanes were about five times more likely to cause catastrophic destruction compared to lesser hurricanes.

All states along the Atlantic and Gulf coasts were affected by several hurricanes between 1953 and 2013. The 15 states with extensive coastlines extending from Texas to Massachusetts accounted for 159 of the 195 (or 82 percent) hurricane-related major disasters during these 61 years. Florida, Louisiana, and North Carolina experienced the largest absolute numbers with 26, 17, and 17, respectively. Each of these 15 coastal states, however, was affected by at least six hurricane-related major disaster declarations during the period.

Table 2.2 in Chapter 2 reported the results of a regression analysis on the frequency of major disaster declarations caused by hurricanes. Between 13 and 18 percent of the time series variation in the annual number of hurricanes between 1953 and 2013 was explained in regression Equations (2.2.7), (2.2.8), and (2.2.9). These most destructive of natural disasters vary widely in frequency from year to year. The regression results also indicated that the frequency of hurricane-related disaster declarations increased after 1995.

Since the NWS-NOAA has been tracking tropical depressions and hurricanes for more than 100 years, it may be instructive to provide a brief review of the trends in recent decades. Table 4.1 displays decade averages since the 1950s for five hurricane-related series. Columns (1)–(4) show annual averages from the NWS-NOAA reporting system for Atlantic hurricanes. Note that the occurrence of tropical depressions has not changed, whereas most other series in Table 4.1 have been occurring more frequently in recent decades compared to earlier decades (consistent with the earlier the regression results from Table 2.2).

Three results are apparent in Table 4.1. First, tropical depressions have progressed to tropical storms with more frequency in recent decades compared to the 1960s, increasing from about 60 percent to about 90 percent. Other things equal, this tendency is likely to increase the potential adverse effects of a given annual number of tropical depressions. Second, the progression of tropical storms to hurricanes and of hurricanes to major hurricanes both display downward trends between the 1950s and recent years. Third, the progression from hurricanes and major hurricanes to major disasters has become increasingly likely. Major disasters in the FEMA reporting system were about 40 percent of Atlantic hurricanes in the 1950s. Since 2000, however, the compa-

Table 4.1 Annual Averages of Hurricane-Related Events, 1950–2013

	Tropical depressions (1)	Tropical storms (2)	Hurricanes (3)	Major hurricanes (4)	Major disasters (5)
1950–1959	n/a	10.8	6.9	3.7	2.7 ^a
1960–1969	14.1 ^b	9.5	6.1	2.8	1.6
1970–1979	21.1	9.5	4.9	1.6	1.4
1980–1989	14.7	9.3	5.2	1.7	1.8
1990–1999	12.8	10.6	6.1	2.0	4.6
2000–2009	17.3	15.1	7.4	3.6	5.1
2010–2013	18.8	17.8	7.8	2.8	8.0

NOTE: n/a = not available.

^a1953–1959 average.

^b1962–1969 average.

SOURCE: Columns (1)–(4) from the NWS-NOAA reports on Atlantic tropical depressions and related weather series. Column (5) from FEMA data on major disaster declarations.

rable statistic has been about 80 percent. Hurricanes have become more likely to lead to major disaster declarations in recent years.

Major disasters generate several types of adverse effects on individuals, families, and the economy. Since labor compensation exceeds half of the value added in most industries, reduced earnings comprise an important element in disaster-related economic losses. The following section looks at the effects of hurricanes in the labor market.

HURRICANES AND THE LABOR MARKET

Hurricanes affect the labor market in several ways. A recent analysis by Groen, Kutzbach, and Polivka (2015) examines the effects of Hurricanes Katrina and Rita on individual labor market participants in Alabama, Louisiana, Mississippi, and Texas. The focus of their analysis is the changes in employment and earnings of individuals affected by hurricane damage. The authors pay attention to personal characteristics (age, race, gender, and schooling) and provide detailed geographic data on the extent of hurricane damage by residential area and place

of employment. They track information on employment and earnings from two years prior to the hurricanes to five posthurricane years. Their analysis utilizes different control group methodologies based on samples of “comparable” individuals from other geographic areas in Southeastern states that were not impacted by hurricanes. Using a large, rich sample of micro data, they document quarterly time profiles of the effects on the employment and earning of individuals from local areas who experienced differing degrees of hurricane damage.

The literature about the adverse effects of hurricanes is expanding. For instance, Kunreuther and Michel-Kerjan (2011); Kunreuther, Pauly, and McMorrow (2013); and Smith and Katz (2013) consider total property losses and reimbursement from hurricanes. Brown, Mason, and Tiller (2006) and Belasen and Polachek (2009) examine the employment and unemployment effects of hurricanes. Strobl (2011) investigates the effects of hurricanes on economic growth, Jarmin and Miranda (2006) examine the association between hurricanes and business establishments, and Paxson et al. (2012) look at the traumatic and psychological stress associated with hurricanes. This literature is large and growing and also includes important analyses of the consequences of hurricanes in other economies.

The following discussion focuses on labor markets. Statewide monthly data for three series are examined: the total unemployment rate (TUR) as measured in the U.S. Bureau of Labor Statistics data from its Local Area Unemployment Statistics program, weeks compensated in the UI program, and weeks compensated in the DUA program. Using “weeks compensated” as the variable of interest in these programs avoids the comparability problem of a nominal series such as weekly UI and DUA compensation that incorporates the effects of inflation. Our series are measured as weekly averages; that is, we divide the monthly UI and DUA series by 4.333 to convert them into weekly averages.

The strategy is to examine those hurricanes that are associated with the largest financial costs, as reported in the NCDC billion-dollar disaster series. The four costliest hurricanes were (in descending order) Katrina, Sandy, Andrew, and Ike, with estimated costs of \$148.8, \$65.7, \$44.8, and \$29.2 billion (in 2013 dollars), respectively. Four destructive hurricanes that impacted Florida between mid-August and late September occurred in 2004.² The analysis also tests for the combined effects of these Florida Four hurricanes. While these four hurricanes

collectively caused 152,000 DUA weeks compensated across all states, 138,000 weeks (89 percent) were paid to Floridians. Almost all the payments to disaster-survivors were made between September 2004 and April 2005 (99 percent).

Recall that the unit of observation used by FEMA is the state/tribal government and counties within the state. For each hurricane-impacted state, an adjacent state is selected as a control to provide a counterfactual for the time path of the labor market variable. The following combinations of hurricanes, hurricane-impacted states, and control states are used in our analysis: Katrina-Louisiana-Texas, Katrina-Mississippi-Alabama, Katrina-Alabama-Georgia, Sandy-New York-Pennsylvania, Sandy-New Jersey-Pennsylvania, Andrew-Florida-Georgia, Ike-Texas-Oklahoma, and the 2004 Florida Four hurricanes-Florida-Georgia.

Hurricane Katrina

Of all the disasters experienced since 1980, Hurricane Katrina was the most destructive.³ The NCDC estimated the total cost at \$148.8 billion, about twice as large as the second-largest major disaster, the drought of 1988 (\$78.8 billion). As noted, Katrina also caused the largest DUA weeks compensated and associated DUA payouts, as well as the largest number of NFIP paid losses and associated compensation for flood damage (see Table 4.4).

The devastating impact of Katrina was concentrated primarily in Louisiana. Significant destruction was sustained in Mississippi and some in Alabama. Indicative of the scale of financial losses in these three states, in the fall of 2005 Congress made appropriations for the UI program in Louisiana, \$400 million; Mississippi, \$80 million; and Alabama, \$20 million.

Table 4.2 reports the results of a regression analysis that help describe the extent of the labor market effects caused by Hurricane Katrina. In both Louisiana and Mississippi, Katrina had obvious effects on statewide unemployment and UI benefit payments. In contrast, the analysis did not find statistically significant effects in the statewide data from Alabama.

The top panel in Table 4.2 displays the results of the regression analysis to explain the statewide unemployment rates. The specification in each regression uses two control variables: the TUR in an adjacent

Table 4.2 Katrina, State Unemployment, and State Unemployment Insurance Weeks Compensated

State	Constant	Control state variable ^a	Katrina1 dummy variable ^b	Katrina2 dummy variable ^c	Adjusted R^2	Standard error	Durbin-Watson	Mean dependent variable
State unemployment rate (TUR)								
Louisiana	0.679 (1.2)	0.766 (8.3)	6.494 (58.8)		0.991	0.132	2.26	5.372
Mississippi	5.009 (5.4)	0.498 (5.6)	2.593 (17.1)		0.976	0.186	1.33	6.934
Alabama	-0.834 (0.7)	1.003 (12.2)	-0.108 (1.1)		0.996	0.121	1.16	5.086
State UI average weekly beneficiaries								
Louisiana	5,148 (1.0)	0.154 (4.6)		121,048 (15.3)	0.730	16,840	1.98	32,661
Mississippi	3,793 (5.4)	0.500 (25.3)		19,038 (17.8)	0.890	2,432	1.95	21,265
Alabama	2,255 (1.8)	0.497 (30.1)		-730 (0.5)	0.971	2,146	2.55	32.840

^aControl states: Texas is the control state for Louisiana; Alabama for Mississippi; and Georgia for Alabama.

^bKatrina1 dummy variable = 1.0 September to November 2005, 0.333 December 2005, and 0.0 in other periods.

^cKatrina2 dummy variable = 1.0 September 2005 to February 2006, and 0.0 in other periods.

SOURCE: The regression equations are fitted with monthly state-level data. Beneath each coefficient is the absolute value of its t -ratio; a result is statistically significant if the t -ratio is 2.0 or larger. Unemployment rates in percentages of the state labor force. All regressions fitted for the 108 months from January 2001 to December 2009. All regressions adjust for first order autocorrelation.

state and a categorical (dummy) variable for the months immediately after Katrina hit in late August 2005. The dummy variable in the TUR equation equals 1.0 from September to November 2005 and 0.333 in December 2005. For Louisiana, the TUR in Texas that is used as the control variable is statistically significant, as is the post-Katrina dummy variable. The coefficient on the dummy variable indicates that Katrina increased the statewide TUR by about 6.5 percentage points between September and December 2005. The effects on the statewide TUR, however, did not extend into 2006. In fact, by January 2006 the seasonally adjusted TUR of 4.5 percent was lower than it was in August 2005 (4.9 percent).

The unemployment rate equation for Mississippi uses the TUR from Alabama as the adjacent state cyclical control variable.⁴ It is statistically significant. The post-Katrina dummy variable is also statistically significant, suggesting that Katrina increased the TUR of Mississippi by 2.6 percentage points during September–December 2005. The TUR in Alabama also closely mirrored that of an adjacent state (Georgia), but the results of the regression do not suggest an independent effect from Katrina (it is not significantly different from zero). Hence, there is no evidence of any effect from the hurricane on the TUR in Alabama.

Three other results from the unemployment rate equations in Table 4.2 are noteworthy. First, for both Louisiana and Mississippi the statewide TURs in the early months of 2006 were lower than that projected by the regression equations. This pattern was consistently observed between February and June 2006. Second, the residuals from all three states displayed high autocorrelation. The patterns of significant increases in the TURs of Louisiana and Mississippi during September–November 2005 were unchanged whether or not the equations included corrections for autocorrelation. Third, the point estimates for the Katrina dummy variables did not change when a different estimation period was used (that is, the months of 2001–2007 as opposed to 2001–2009). In short, the results displayed in Table 4.2 regarding statewide unemployment rates are robust to alternative estimates. For Louisiana and Mississippi, Katrina caused large but temporary increases in statewide unemployment during the fall of 2005.

The bottom panel of Table 4.2 displays the results of tests for an impact of Katrina on weekly beneficiaries in the UI programs of the three states. These regression equations also use developments in adja-

cent states to control for general developments in UI benefit reciprocity. For all three states, the variable for adjacent state average weekly beneficiaries enters with a positive and statistically significant coefficient. The equations also test for the effect of Katrina using a dummy variable for post-Katrina months. In these equations, however, the “on” period lasted from September 2005 to February 2006. For the six months of the “on” period the dummy variable coefficients suggest UI weekly beneficiaries increased by about 121,000 in Louisiana and 19,000 in Mississippi, but they were unchanged in Alabama.

During the six months from September 2005 to February 2006, weekly DUA beneficiaries in Louisiana averaged 59,164, or 42 percent of weekly UI beneficiaries, which averaged 141,391 for the same period. In Mississippi the corresponding DUA and UI weekly averages were 8,762 and 34,223, or DUA weeks averaging 26 percent of UI weeks. Again, to reinforce the earlier point about low participation in Alabama, weekly DUA recipients averaged 271 during these six months, or only 1.2 percent of UI weekly beneficiaries, which were 22,677.

Recall from Chapter 3 that DUA is reserved for individuals who are not eligible to receive regular UI benefits. One problem with the statistical reports of the UI program is that the data do not distinguish persons who receive disaster-related UI benefits from other UI recipients. An indirect way to estimate the effect of Katrina on UI weeks compensated is to use a dummy variable approach. The results are displayed in the bottom panel of Table 4.2 and suggest that DUA weeks compensated caused by Katrina were strongly associated with regular UI weeks compensated in both Louisiana and Mississippi, but not in Alabama.

The regular UI and DUA data from Hurricane Katrina may also suggest a different timing in the payment of increased UI benefits compared to DUA benefits. In Louisiana, for example, 1.538 million weeks of DUA were paid between September 2005 and February 2006, and 1.053 million weeks were paid between March and June 2006. The coefficient on the Katrina dummy variable for Louisiana in Table 4.2 (121,048) refers to the six months between September 2005 and February 2006. When the Katrina dummy variable for Louisiana was extended to June 2006, the goodness-of-fit of the equation decreased (the adjusted R^2 decreased from 0.730 to 0.632). A similar decrease also occurred in Mississippi. At least following Katrina, the payment of increased DUA benefits persisted considerably longer than the pay-

ment of increased regular UI benefits. Since total unemployment in both states had already decreased below pre-Katrina levels by February 2006, one can ask if the DUA benefits after February 2006 were paid to individuals actively seeking work.

Hurricane Sandy

Following Hurricane Sandy, FEMA made major disaster declarations in 13 states extending from Virginia to New Hampshire and included Ohio, Pennsylvania, and West Virginia.⁵ The destruction, however, was concentrated mainly in the coastal areas of New York and New Jersey, and these two states accounted for 99 percent of DUA cash benefits paid through the end of 2013. The total financial costs of Sandy were estimated at \$65.7 billion (in 2013 dollars) in the NCDC billion-dollar disaster series.

In contrast to Katrina, where there were immediate and large effects on statewide unemployment and weekly UI beneficiaries in two states, the effects of Sandy in New York and New Jersey were much smaller. Table 4.3 displays summary results of the regression analysis for New York and New Jersey, applying the same specifications used above to examine the effects of Katrina. The adjacent state that serves as the control state for both New York and New Jersey is Pennsylvania. The table examines monthly state unemployment rates and average weekly UI beneficiaries.

The unemployment rates in both New York and New Jersey are strongly associated with the unemployment rate in Pennsylvania (both adjusted R^2 s exceed 0.99). In neither state, however, does the dummy variable coefficient for Hurricane Sandy suggest that it raised the unemployment rate. The most likely inference to make is that the adverse effects from Sandy did not raise the unemployment rate in either state. The bottom panel in Table 4.3 indicates that there was a positive effect of the hurricane on UI weeks compensated in both states. The positive coefficients on the dummy variable suggest that Sandy increased weekly beneficiaries by about 9,200 in New Jersey and by about 29,500 in New York during the six months from November 2012 to April 2013.

When the estimated increments in UI weeks compensated are multiplied by the respective weekly UI benefits in the two states (\$291.65 in New York and \$373.23 in New Jersey), the increases in UI benefit

Table 4.3 Hurricane Sandy, State Unemployment, and State Unemployment Insurance Average Weekly Beneficiaries

	Constant	Pennsylvania TUR and UI beneficiaries	Sandy dummy ^a	Adjusted R^2	Standard error	Durbin- Watson	Mean dependent variable
State unemployment rate (TUR)							
New Jersey	0.405 (0.6)	1.067 (14.2)	-0,053 (0.8)	0.998	0.088	2.29	7.509
New York	0.878 (1.6)	0.914 (13.9)	-0.095 (1.8)	0.998	0.075	1.81	7.011
State UI average weekly beneficiaries							
New Jersey	37,768 (12.5)	0.509 (33.1)	9,209 (3.5)	0.869	11,346	2.06	133,471
New York	63,325 (4.8)	0.814 (12.1)	29,294 (2.0)	0.783	28,140	2.15	216,688

^aThe categorical (dummy) variable equals 1.0 from November 2012 to April 2013 and zero in all other months.

SOURCE: Regression analysis fitted with monthly state-level data. Beneath each coefficient is the absolute value of its t -ratio; a result is statistically significant if the t -ratio is 2.0 or larger. The unemployment rate is the percentage of the state labor force. Monthly weeks compensated are divided by 4.333 to yield a weekly average. All regression equations are fitted for the 96 months from January 2006 to December 2013. All regression equations adjust for first order autocorrelation.

payments are estimated to be \$223.6 million in New York and \$89.4 million in New Jersey. Since total DUA benefit payments in the two states through the end of 2013 totaled just \$8.9 and \$5.3 million, respectively, the estimates suggest that added UI benefits due to Sandy were many times larger than the direct payments of DUA weekly benefits. In fact, the estimated increases in UI benefit payments due to Sandy represented 12.6 percent of regular UI benefits paid in New York during these six months and 6.8 percent of UI benefits paid in New Jersey over the same period.

Other Large Hurricanes

As the NCDC estimates in its billion-dollar disaster series, Hurricane Andrew in August 1992 and Hurricane Ike in September 2008 were the third and fourth costliest hurricanes with estimated costs of \$44.8 and \$29.2 billion (in 2013 dollars), respectively.⁶ A quartet of hurricanes battered Florida during August and September 2004— three crossed the center of the state, while the fourth (Ivan) crossed south Florida. The cost of the combined total destruction as estimated by the NCDC was \$55.4 billion. The combined DUA weeks compensated totaled 152,000 for the quartet of hurricanes in Florida. Of total DUA weeks compensated across all states, 135,000 weeks (88 percent) was paid to Florida residents, and 131,000 of these weeks were paid between September 2004 and March 2005. If one considers these four hurricanes as a single extended disaster event, then their total damage would rank fifth among the billion-dollar disasters of the NCDC, third among DUA weeks compensated, and fourth among the paid losses of NFIP.⁷

We analyze the effects of Hurricanes Andrew, Ike, and the Florida Four on state unemployment and weekly UI beneficiaries.⁸ Our results provide no statistically significant effect of Hurricane Andrew in raising the unemployment rate in Florida in the posthurricane months. Neither do the results support the hypothesis that Hurricane Andrew caused a significant increase in UI reciprocity in Florida between September 1992 and March 1993. For Hurricane Ike, our analysis does not find statistically significant effects on the state unemployment rate nor the receipt of UI benefits in Texas during the months from September 2008 to March 2009. While the months near the time of this event saw major increases in both unemployment and UI reciprocity due to the Great

Recession, the results do not show a separate significant effect from Hurricane Ike. The effects of the Florida Four hurricanes on unemployment and UI weeks compensated in Florida are not statistically significant; they are best described as minuscule—essentially zero.

Summary of Labor Market Effects

The analysis of the labor market effects of five separate hurricane-related major disasters yields mixed results. Hurricane Katrina had large effects on state unemployment rates and the receipt of UI benefits in both Louisiana and Mississippi. The results of the regression analysis of Hurricane Sandy found no statistically significant effect on the state unemployment rates in New York and New Jersey. In contrast, there were measurable increases in the receipt of regular UI benefits in both states during the six months following the devastation of Sandy on their coastal areas.

The results of the analysis of Hurricanes Andrew, Ike, and the Florida Four did not identify any statistically significant statewide effects in Florida or Texas, nor did they find statistically significant increases in state unemployment rates or the weekly number of UI beneficiaries.

There are at least three possible explanations for the lack of statistically significant results in Florida and Texas. First, the analysis was conducted using statewide data. An analysis based on substate geographic areas would be expected to yield findings of significant labor market effects in counties directly in the path of the hurricanes. For instance, the analysis by Groen, Kutzbach, and Polivka (2013) illustrates the advantage of analysis based on detailed local geographic areas that experienced differing degrees of destruction.

Second, Florida and Texas are both large states, ranking twenty-third and twenty-second in land area, respectively. While the hurricanes were very destructive in certain local areas, their statewide effects may not have been large relative to the economies of these states. In Florida, the hurricanes largely missed the Miami area, with effects of Hurricane Ivan arising from wind speeds that did not reach minimum wind speeds of a tropical storm.⁹ Given the large volume of DUA claims in Florida that followed the fall 2004 hurricanes, it is surprising that UI claims did not show an effect from the Florida Four. Louisiana and Mississippi are further down the distribution of state size by land area,

ranking thirty-first and thirty-second, respectively, among all the states. Their smaller size, coupled with the direct impact of Hurricane Katrina on New Orleans, undoubtedly provide much of the explanation for the large effects on both states.

Third, Florida and Texas consistently have very low rates of UI benefit recipiency, among the lowest in the state UI system.¹⁰ The receipt of UI benefits (as a ratio to total unemployment) in both states is about two-thirds of the national average. The low recipiency rate in this long-standing social insurance program could mean that information about UI benefit availability is below-average in both states and may partially explain why receipt of UI did not show a significant increase following Hurricane Andrew in 1992, Hurricane Ike in 2008, or the four hurricanes that crossed Florida in the fall of 2004.

COSTS AND COMPENSATION

Chapter 2 notes that hurricanes were responsible for a large share of the total costs of major disaster declarations. The following section describes the importance of hurricanes in the costs and compensation recorded by four data series: billion-dollar disasters as estimated by the NCDC (2013 dollars); the number compensated for flood-related losses by the NFIP program; the NFIP compensation amount (2013 dollars); and DUA weeks compensated.

Table 4.4 highlights the estimated costs and compensation from all hurricanes and from the four most destructive hurricanes in the NCDC data: Katrina, Sandy, Andrew, and Ike, plus the four (Charley, Frances, Ivan, and Jeanne) that impacted Florida in August–September 2004. For the latter hurricanes, Table 4.4 shows their combined statistics in the Florida Four row as well as their individual details. While all the data series extend through 2013, they have different start dates: the NCDC data start in 1980, NFIP recipients and benefits commence in 1978, and DUA weeks compensated start in 1983.

To help highlight the importance of hurricanes, columns (2)–(5) show the rank of each hurricane among all disasters from their respective start dates to 2013 in parentheses. The bottom four lines of Table 4.4 show the totals for all hurricanes, all major disasters, the hurricane

Table 4.4 Effects of the Most Destructive Hurricanes Since 1980

Hurricane	Year	NCDC costs	NFIP	NFIP	DUA weeks
		(billions of 2013 \$)	recipients (000s)	payments (billions of 2013 \$)	compensated (000s)
	(1)	(2)	(3)	(4)	(5)
Katrina	2005	148.8 (1)	168.0 (1)	18.922 (1)	3,011.5 (1)
Sandy	2012	65.7 (3)	129.0 (2)	8.030 (2)	66.3 (13)
Andrew	1992	44.8 (5)	5.6	0.255	78.0 (9)
Ike	2008	29.2 (8)	46.6 (3)	2.892 (3)	46.3 (18)
Florida Four ^a	2004	55.4 (5)	41.2 (5)	2.327 (4)	152.1 (3)
Charley	2004	18.5 (11)	2.6	0.061	42.9 (20)
Frances	2004	11.1 (17)	5.0	0.184	55.1 (15)
Ivan	2004	17.2 (12)	28.3 (7)	1.929 (4)	43.8 (19)
Jeanne	2004	8.6	5.4	0.153	10.2
All hurricanes		480.9	720.2	42.86	3,860.0
Program total		1,074.7	1603.0	61.53	5,740.0
Hurricane share		0.447	0.449	0.697	0.672
Top 20 hurricanes		11	14	16	8

^aRank of the Florida Four hurricanes of 2004 if treated as a single event.

SOURCE: Data on billion dollar disasters from NCDC and refer to 1980–2013; NFIP recipients from FEMA and refer to 1978–2013; DUA weeks compensated from U.S. Department of Labor and refer to 1983–2013. Numbers in parentheses in columns (2)–(5) show the rankings of the individual hurricanes.

share of the total, and the count of hurricanes in the 20 largest disasters for each data series.

A prominent feature of Table 4.4 is the quantitative importance of Hurricane Katrina relative to all other major disasters. It ranks first, accounting for between 10.5 and 52.5 percent of the program totals over the 31-plus years spanned by the data. A second prominent feature of the table is the major importance of hurricanes in all four data series. Hurricanes accounted for about 45 percent of all billion-dollar costs and NFIP recipients (columns [2] and [3]). They accounted for about two-thirds of all NFIP real compensation and DUA weeks compensated (columns [4] and [5]). Because average NFIP compensation for hurricanes is much larger than the average compensation for other flood-related events, the hurricane share of compensation (0.697) is much larger than their share of compensated survivors (0.449).

Note also that several hurricanes were of major quantitative importance. The bottom row in Table 4.4 shows the number of hurricanes in the top 20 of each data series. The count ranges between 8 and 16. The table also shows the importance of the four individually identified hurricanes plus the Florida Four. Their rankings within the top 20 of each series are shown in parentheses in Table 4.4. If we treat the Florida Four hurricanes as a single event, then the ranks across the four columns are between 3 and 5.

Table 4.4 also illustrates the variability of costs and compensation across the three reporting systems. Because the destruction from Andrew was confined largely to inland areas, NFIP compensation was modest, with just 5,600 NFIP recipients. Hurricane Sandy generated limited DUA weeks compensated (66,300) and ranked thirteenth in this data series, whereas it ranked third among all billion-dollar disasters and second among NFIP recipients and the NFIP amount compensated. Among the Florida Four note that only Ivan generated large amounts of NFIP compensation (column [4]), whereas Charley and Frances also resulted in costs that exceeded \$10.0 billion (column [2]) and more than 40,000 DUA weeks compensated (column [5]). Only Jeanne of these four did not generate costs or compensation that ranked in the top 20 of the four series in Table 4.4. Combined, however, these four hurricanes devastated large areas in Florida with destruction spread throughout the months of August and September 2004.

CONCLUSIONS

Of all categories of major disasters, hurricanes cause the greatest destruction. Average financial costs per hurricane were \$14.9 billion (in 2013 dollars) for the 33 hurricanes and tropical storms present in the NCDC billion-dollar disaster series from 1980 to 2013. The frequency of hurricanes is highly variable from one year to the next. In Chapter 2, the trend regression analysis of Table 2.3 explains less than 20 percent of the time series variation in annual occurrences between 1953 and 2013. While our regression results provide some evidence of acceleration in annual occurrences after 1971 or 1995, the underlying year-to-year variability stands out in the historical record. The

U.S. Global Change Research Program (2014) finds that the intensity, frequency, and duration of North Atlantic hurricanes, as well as the frequency of the strongest hurricanes, have all increased since the early 1980s. Moreover, hurricanes are projected to increase as the climate continues to warm.

Hurricane Katrina was by far the most destructive of all hurricanes since 1953, both in terms of property damage and mortality. The NCDC estimate of \$148.8 billion represents 13.8 percent of all the cost estimates from major disasters between 1980 and 2013. The number of fatalities from Katrina is estimated to be 1,833 lives. We do not discuss the loss of lives nor the assistance provided to individuals and families who moved away from Katrina-impacted areas. Interested readers can refer to the extensive literature on the disaster-related responses and the consequences of Katrina-impacted areas, particularly the devastating effects in New Orleans (see, for example, Brinkley [2006]).

Hurricanes were responsible for 11 of the 20 most destructive disasters. And the combined 33 hurricane-tropical storm events accounted for 44.7 percent of the estimated costs of the billion-dollar disasters during the 34 years from 1980 to 2013. Hurricanes were also responsible for a large share of the compensation provided to flood survivors in the NFIP program (69.7 percent) between 1978 and 2013. Because they also caused large-scale interruptions of business activity, hurricanes accounted for 67.2 percent of total weeks compensated through the DUA program between 1983 and 2013. In short, hurricanes on average cause the most damage to property and the most disruption to economic activity of all the categories of major disasters in the United States.

While hurricanes are the most destructive of the major disasters identified in Chapter 2, it is useful to place their destructive impact into a macroeconomic perspective. This chapter tested for the effects on statewide unemployment rates. Our analysis estimated that Katrina raised the TUR by 6.5 percentage points in Louisiana and 2.6 percentage points in Mississippi during the fall of 2005. There were no significant effects on state unemployment rates from Sandy, Andrew, Ike, or the Florida Four. Our analysis of the impact of Katrina on weekly UI beneficiaries found significant effects in Louisiana and Mississippi between September 2005 and February 2006. Sandy was estimated to have increased weekly UI beneficiaries significantly in New Jersey and New York between November 2012 and April 2013. For the other three

large hurricane events (Andrew, Ike, and the Florida Four of 2004), the analysis did not find statistically significant increases.

The effects of the latter three large and destructive hurricane events did not register in the statewide data of our investigation. Nearly all hurricanes, the most destructive of the major disasters examined in this book, have modest effects when the geographic unit of analysis is the entire state. While the extensive financial costs attributable to hurricane destruction shown in Table 4.4 are very large indeed, they are modest when compared to the total size of the economy of an entire state.

This finding reinforces the one made in the previous chapter (see Tables 3.1 and 3.2). The cumulative real GDP of the U.S. economy from 1980 to 2013 was \$365.8 trillion (in 2013 dollars). Relative to cumulative real GDP in 2013 dollars, the large-scale destructive losses of major disasters represent slightly more than one-quarter of 1 percent of real GDP (0.29 percent). Overall, the total financial costs of major disasters are relatively small when placed into a macroeconomic context.

Notes

1. The Saffir-Simpson Hurricane Wind Scale (SSHWS) system has been applied to the five categories of hurricanes for over 100 years, but estimates of annual tropical depressions are available only since 1962.
2. The four hurricanes were Charley, Frances, Ivan, and Jeanne.
3. Four declarations were made by FEMA for Hurricane Katrina: DR-1602 for Florida on August 28, DR-1603 for Louisiana, DR-1604 for Mississippi, and DR-1605 for Alabama. The latter three declarations were announced on August 29, 2005.
4. Note that Alabama also incurred financial costs from the adverse effects of Hurricane Katrina. The destruction was limited, however, so that no statistically significant effect is found in our analysis. The small scale of the impact in Alabama is clearly illustrated in Groen, Kutzbach, and Polivka (2015, Figure 3).
5. Thirteen declarations were made for Hurricane Sandy. Three were declared on October 30, 2012: DR-4085 for New York; DR-4086 for New Jersey; and DR-4087 for Connecticut. Ten other declarations followed: DR-4089 for Rhode Island on November 3; DR-4090 for Delaware on November 16; DR-4091 for Maryland on November 20; DR-4092 for Virginia on November 26; DR-4093 for West Virginia on November 27; DR-4095 for New Hampshire on November 28; DR-4096 for D.C. on December 5; DR-4097 for Massachusetts on December 19; DR-4098 for Ohio on January 3, 2013; and DR-4098 for Pennsylvania on January 10, 2013.
6. Two declarations were made by FEMA for Hurricane Andrew: DR-954 for Florida

on August 24; DR-955 for Louisiana on August 26, 1992. Six declarations were made for hurricane-related damage from Ike: DR-1791 for Texas and DR-1792 for Louisiana on September 13, 2008; DR-1797 for Alabama on September 26; DR-1802 for Kentucky on October 9; DR-1804 for Arkansas on October 22; and DR-1805 for Ohio on October 24, 2008. By October, Hurricane Ike had been downgraded as a tropical storm or a tropical depression.

7. Only Hurricane Katrina and the upper Midwest floods of 1993 paid more weeks of DUA benefits, while Hurricane Rita of 2005 paid about the same number of weeks as these four combined. Only Hurricanes Katrina, Sandy, Ike, and Irene had more NFIP paid losses at 167,000, 128,000, 46,000, and 44,000 compared to the 41,000 paid losses of these four 2004 hurricanes.
8. The results of the regression analysis are available from the authors.
9. Hurricane Ivan took a most unusual track, initially grazing the extreme of western Florida (the panhandle) on September 16–17. After continuing north as far as Virginia, it reentered the Atlantic Ocean on September 18–19 and moved south and crossed south Florida on September 21. By that date, however, its wind speeds were so low that NOAA classified it as an extratropical storm, that is, with sustained wind speeds below 38 mph.
10. Average UI reciprocity rates for the years 2000 to 2013 were computed across 51 UI programs. Florida and Texas ranked 47 and 49, respectively. Their average reciprocity rates of 0.206 and 0.195 were about two-thirds of the national average (0.304) for the same 14 years.

5

Floods and Their Consequences

Chapter 1 notes that the cumulative total number of major disaster declarations in all the states was 2,046 from 1953 to 2013. In the same period, 1,273 (62 percent) of these major disasters involved flooding. The geographic entity that FEMA uses in its reporting system is the state/tribal government, and each declaration identifies the affected counties within that state. For catastrophic events that extend across state boundaries, multiple declarations are made.

States located along major rivers and their tributaries have extensive experiences with catastrophic events caused by river flooding. Flooding that started in May 1993 and lasted through September affected approximately 150 major rivers and tributaries and led to major disaster declarations in nine Midwest states.¹ Fifty flood-related deaths occurred. Hundreds of levees failed along the Mississippi and Missouri Rivers. The magnitude and severity of the disaster was overwhelming, and it ranks as the largest and most significant flood event experienced in the United States since 1950. Described as the Great Flood of 1993, this riverine flood was unusual in the scale of damage, geographic extent, the height of river crests, the duration of high waters, and the number of levees that failed to restrain floodwaters (see Larson [1993]).

Compensation in the form of DUA payments commenced in July 1993, extended to the fall of 1994, and totaled \$74.2 million. Of this total, \$39.0 million was paid to flood survivors in Iowa. The NCDC estimated the total damage of the Great Flood of 1993 to be \$21.0 billion (\$33.8 billion in 2013 dollars), the sixth highest of the 170 billion-dollar disasters that occurred between 1980 and 2013.²

The first section of the chapter documents the frequency of disasters caused by river flooding in individual states located along major rivers, such as the Mississippi and the Missouri, that were affected by the Great Flood of 1993. The number of major disasters experienced by these nine states is high, and the flood events are concentrated during spring and early summer, when rain and snow melt combine to increase river flow. The second section of the chapter examines the occurrence of unemployment due to three major floods in the Missouri-Mississippi

river systems: the Great Flood of 1993, and the floods of 1997 and 2008. These floods were the most destructive of the NCDC billion-dollar flood-related disasters. Our calculations suggest that the UI benefits paid for these flood events represented a significant addition to the benefits paid directly by the DUA program.

The chapter then examines the extent of flood insurance coverage. Because FEMA identifies the individual counties in each state/tribal government when it makes major disaster or emergency declarations, one can document the frequency of compensation paid by the NFIP to survivors in individual counties. Repeated hurricane-related disasters occur in coastal communities and, more than likely, similar patterns are present for counties in inland states located along major rivers. We apply the methodology used in Chapter 4 for estimating the effects of Hurricane Katrina to riverine floods. Our analysis shows that major flood-related disasters do not exhibit an obvious linkage to NFIP coverage. The fourth section examines the financing of NFIP and the financial solvency of the program in light of the increasing obligations of catastrophic flooding, and the final section provides concluding comments.

MAJOR DISASTERS DUE TO FLOODS IN THE MIDWEST REGION

As noted in the first chapter, 1,273 (62 percent) of the 2,046 major disaster declarations involved flooding, mostly riverine flooding. While the Great Flood of 1993 was the most extensive in the period 1953–2013, numerous riverine floods have occurred, especially in the Midwest region of the United States. Recall that the U.S. Census Bureau divides the United States into four census regions and nine census divisions. The Midwest region is divided into two divisions: East North Central, and West North Central. The states included in the East North Central Division are Illinois, Indiana, Michigan, Ohio, and Wisconsin; in the West North Central Division are Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, and South Dakota.

Table 5.1 shows nine states from the Midwest region where major disaster declarations associated with river flooding were declared between 1984 and 2013. All nine states border the Missouri and/or Mis-

Table 5.1 Major Disasters from River Flooding in the Midwest Region, 1984–2013

Year	First month	States	DUA weeks
1984	June	MO, KS, IA, NE, SD	0
1986	October	WI, IL, MO, KS	0
1989	May	MN, ND	0
1990	May	MO, IA	175
1993	July	MN, WI, IL, IA MO, SD, NE, KS, ND	461,589
1995	May	ND, SD, IL, MO	132,604
1997	April	IL, ND, SD, MN	95,119
1998	May	IA, ND, SD	81,643
2000	May	KS, MO, SD, WI, MN, ND	99,747
2001	May	KS, IA, IL, WI, MN	54,978
2004	April	IL, ND, NE, IA	30,058
2008	May	SD, MO, IA, NE, WI, IL, MN	30,651
2009	April	MN, ND	5,647
2010	July	SD, IA, KS, WI, MO, IL	7,095
2011	May	MO, ND, MN, SD, IL, IA	14,705
2013	July	SD, IA, ND, MO, MN, WI	0

SOURCE: FEMA major disaster declarations.

Mississippi rivers.³ Seven states are from the West North Central Division and two are from the East North Central Division (Illinois and Wisconsin). The year 1984 is selected because the DUA program was introduced in 1983. To be included in Table 5.1, at least two of the nine states were required to have experienced a major riverine disaster on the same date or proximate dates, the month FEMA made the major disaster declaration. This requirement ensures that the flood is of a substantial scale.

Two features of Table 5.1 are obvious: the number of major disaster declarations experienced by these nine states, and the concentration of flood events during spring and early summer. Fifteen of the 16 earliest declaration dates occurred between April and July, months when rain and snow melt combine to increase river flow. During 16 of the 30 years, two or more of the nine states experienced a flood-related major disaster.

Table 5.1 identifies 75 major disaster declarations, an average of 8.3 per state. Eight of the nine states are listed at least six times in the table, and the ninth (Nebraska) is listed four times. The largest number

of major floods, 10, was declared in Iowa, Missouri, North Dakota, and South Dakota. On average, the nine states experienced a major river-flooding disaster at a rate of about once every four years. Table 5.1 also displays the number of weeks compensated by the DUA program for each of these flood events. The Great Flood of 1993 sustained the highest number of weeks compensated by the DUA program: 461,589 weeks. Six other flood-related events, however, generated between 50,000 and 133,000 weeks of compensation. Note also that the six years with more than 50,000 DUA weeks compensated were concentrated between 1993 and 2001, with smaller totals occurring in earlier and later years.

Flood-related major disasters cause unemployment among the self-employed and other labor market participants not eligible for UI benefits. Since 1989, however, labor market participants who become jobless because of natural disasters and who are eligible to collect UI benefits are expected to file for UI rather than DUA. In effect, DUA is reserved for the unemployed not covered by UI, such as the self-employed, and persons with UI coverage but who are ineligible. Individuals who are ineligible to receive UI payments may have exhausted their benefits because of previous spells of unemployment or because they lack sufficient prior earnings in UI covered employment.

The following section examines the effects of riverine disasters on the receipt of UI benefits and unemployment. Table 5.1 shows that flood-related disasters in the Midwest region have a direct effect on the receipt of DUA benefits. While these floods have a direct effect on DUA receipt, their possible effect on UI benefits is not routinely measured. A test for estimating the effects on the receipt of UI benefits and associated UI program costs is presented below. The basic idea is relatively simple: we compare the seasonal pattern of UI reciprocity during a flood year with the pattern in adjacent years.

MIDWEST FLOODS AND UNEMPLOYMENT INSURANCE

The previous section highlighted the numerous flood-related major disaster declarations in the Midwest region. Between 1984 and 2013 there were 16 separate years with major floods in two or more of the

nine states that border the Missouri and Mississippi rivers. By far the most extensive and severe flooding was the Great Flood of 1993. As mentioned in Chapter 1, the NCDC estimated the total damage from the 1993 flood at \$33.8 billion (in 2013 dollars), the sixth highest total among the 170 billion-dollar disasters between 1980 and 2013. The analysis in this section examines two other floods in the Missouri-Mississippi river systems, the floods of 1997 and 2008.⁴ While less extensive and severe than the Great Flood of 1993, these floods ranked second and third among Midwest region floods with the damage estimated by NOAA (in 2013 dollars) at \$5.4 billion in 1997 and \$16.2 billion in 2008.

The receipt of UI benefits, termed reciprocity, displays a strong seasonal pattern in nearly all states. Reciprocity is highest during January–March and lowest during summer and early fall. Our analysis uses the seasonal pattern in the immediate pre-flood and post-flood years to predict reciprocity in the year of the flood. A categorical (dummy) variable is added to the specification, which equals 1.0 in the immediate post-flood months; for example, August and September for a flood occurring in late June. The maintained hypothesis is that after controlling for seasonality, the coefficient on the post-flood dummy variable will yield a point estimate of the increase in UI reciprocity due to the flood. Since floods can also disrupt state and regional labor markets, separate regression equations test for an effect on total unemployment in flood-affected states. The regression analysis further tests for the duration of flood effects by extending the “on” period for the post-flood dummy variable.

Table 5.2 displays the results of six regression equations that test for the effects of three flood-related disasters on reciprocity (the number of UI weekly beneficiaries) and on total unemployment. For each flooding incident, data are combined for several affected states in the year of the flood: for the Great Flood of 1993, the data of nine states are combined; for the 1997 major flood, three states; and for the 2008 flood-related disaster, four states.

All six regression equations explain at least half the variation in the monthly patterns during flood years. Perhaps because the Great Flood of 1993 was the largest of the three, the best average goodness-of-fits (adjusted R^2) were obtained in 1993. As expected, the effects of the pre- and post-year monthly averages are uniformly positive, and all six coef-

Table 5.2 Regression Analysis of Flood Effects on Unemployment Insurance Beneficiaries and Unemployment

	Constant	Pre-post seasonal pattern	Postflood dummy	Adjusted R^2	Standard error	Durbin- Watson	Mean dependent variable
UI weekly beneficiaries							
1993 Flood ^a	2.492 (0.2)	0.993 (23.0)	7.965 (1.3)	0.984	7.316	3.29	254.7
1997 Flood	-0.347 (0.3)	1.019 (32.2)	4.664 (3.8)	0.990	1.596	1.88	36.3
2008 Flood ^b	-5.554 (0.2)	0.756 (3.3)	-0.889 (0.7)	0.512	11.151	1.08	80.9
Total unemployment							
1993 Flood ^a	-56.580 (0.4)	1.135 (7.1)	25.936 (2.3)	0.845	13.839	1.49	923.7
1997 Flood	135.583 (15.6)	0.124 (2.4)	4.872 (3.8)	0.553	1.568	2.66	156.6
2008 Flood ^b	-343.966 (3.2)	1.766 (5.9)	0.818 (0.1)	0.823	8.593	1.13	288.1

^a Ten months with January and February omitted.

^b Ten months with November and December omitted.

SOURCE: UI measured as average weekly beneficiaries. Total unemployment measured as the weekly average. Absolute values of t -ratios appear beneath the coefficients; a result is statistically significant if the t -ratio is 2.0 or larger. Data are in thousands.

ficients are statistically significant. The monthly pattern in the year of the flood closely tracks the average monthly pattern of the two adjacent years for both reciprocity and total unemployment. The results indicate that the effects of floods on reciprocity and unemployment are statistically significant. For each major flood, the postflood dummy variable equals 1.0 in the two months immediately following the flood: August–September in 1993, April–May in 1997, and July–August in 2008. Five of the six postflood dummy coefficients are positive and three are statistically significant.⁵

For each of the three floods, FEMA supplies information on the total weeks compensated and the benefit payments for the DUA program. For the Great Flood of 1993, total weeks were 461,589; for the 1997 flood, 95,119; and for the 2008 flood, 30,651 (see Table 5.1). The total weekly benefits paid by the DUA program in 2013 dollars were \$119.4 million, \$15.1 million, and \$7.8 million for the three floods, respectively.

Our calculations for 1993 and 1997 suggest that, as a result of river flooding, the UI benefits paid represented a significant increment to the benefits paid directly by the DUA program.⁶ Note in the top panel of Table 5.2 that the dummy variables for added UI weeks are positive for both 1993 and 1997. These dummy variables suggest that 68,773 additional weeks of UI benefits were paid in 1993 and 41,423 additional weeks in 1997. When these estimates are multiplied by UI average weekly benefits, the estimated addition to total UI benefits was \$12.47 million in 1993 and \$7.88 million in 1997. Compared to their DUA counterparts, the estimated proportional increments to UI weeks compensated (change in UI weeks/DUA weeks) were 0.149 and 0.425 for 1993 and 1997, respectively. And the proportional increases in benefit payments were 0.168 and 0.760, respectively. While the proportional addition to benefit payments is almost always larger than the addition to weeks compensated (because of higher weekly benefits in the UI program compared to the DUA program), the contrast in 1997 reflects an unusually large difference in the two weekly benefit amounts. Our analysis suggests that the UI program paid about \$3.00 for every \$4.00 in DUA benefits in the states of the Midwest region affected by river floods in 1997.

FLOODS AND FLOOD INSURANCE COVERAGE

Table 2.2 in Chapter 2 shows that flood-related declarations have been increasing in frequency. The annual average number major disaster declarations as a result of floods was 7.1 between 1953 and 1959, but more than four times higher at 30.5 between 2000 and 2009. Despite the growth in the frequency of major floods, comparatively few households have property insurance policies that include flood insurance.

As noted in Chapter 3, the most common private insurance policy for homeowners in the United States is Homeowner-3 (HO-3). A standard HO-3 policy provides broad coverage for losses from a number of perils and insurance for widespread damage from certain other perils can be purchased for an additional premium. Flood damage, however, is not available as additional coverage. Private insurance companies did provide flood insurance until the late 1920s. Following the heavy losses incurred by the insurance industry following the Mississippi floods in 1927, private flood insurance coverage was discontinued. The NFIP was created in 1968 in the wake of the widespread flooding in the mid-1960s and calls for a reduction in the financial burden on taxpayers for providing assistance to flood survivors. The NFIP had about 5.6 million active policies at the end of 2012 but covered less than 5 percent of all households.

A private-public partnership between the federal government and local communities, the NFIP provides insurance if a community will implement and enforce mitigation measures to reduce future risks in flood-prone areas. The program follows a comprehensive flood risk management strategy: flood hazard mapping, flood insurance, and floodplain management. Flood hazard mapping is designed to identify and map flood-prone communities across the nation. Updating and making maps of flood plains easily accessible would help make developers and property owners more aware of the risks and more motivated to build appropriately.⁷ The purchase of flood insurance encourages property owners in NFIP-participating communities to protect their property against flood losses. Systematic mechanisms for tracking information related to the changing nature of risk, and translating it into risk-related property valuations, would increase the incentives for prevention. Flood plain management requires communities in flood-prone

zones to adopt and enforce approved ordinances to mitigate the risk of future flood damage.

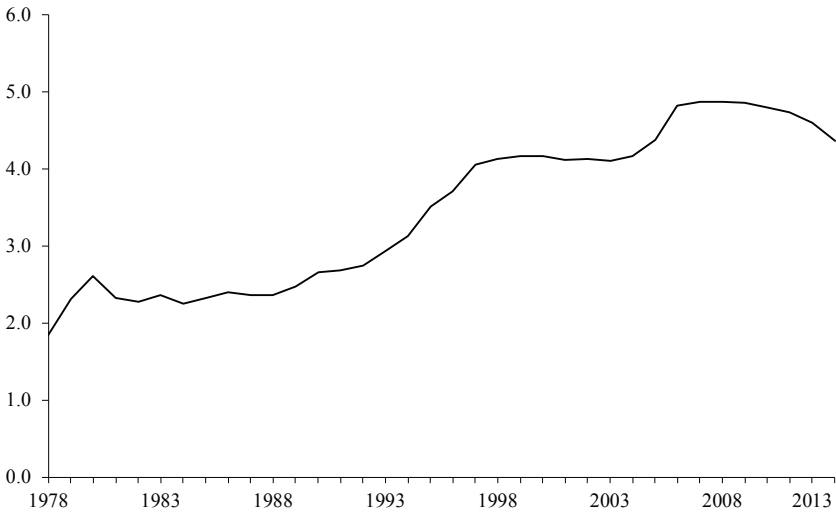
As noted in Chapter 3, the Federal Insurance and Mitigation Administration administers the NFIP in close coordination with private companies that provide property insurance to households and businesses. While the payment of NFIP benefits is federally administered, insurance carriers mainly collect the NFIP premiums, which are usually part of the property insurance premiums paid by homeowners and businesses to private carriers that are then forwarded to the Federal Insurance and Mitigation Administration. To secure NFIP coverage, local governments are required to establish a minimum set of floodplain management policies. This set includes mandating NFIP coverage for local areas identified as being at risk of flooding; for example, areas in 100-year and 500-year flood zones.

While NFIP coverage has gradually increased since the program was established in 1968, coverage has remained limited. The largest increases in coverage occur after major flood-related disasters, such as the catastrophic flooding caused by Hurricane Katrina. For example, between the end of 2004 (eight months before Katrina) and the end of 2006 (16 months after Katrina), NFIP coverage increased by 988,000—the largest two-year increase in NFIP history.

Figure 5.1 displays NFIP coverage of households in national data from 1978 to 2014. There is a clear upward trend through 2007, increasing from less than 2.0 percent of households in 1978 to nearly 5.9 percent in 2007. Since 2007, however, the coverage percentage has plateaued and actually decreased in recent years. Hurricane Sandy in late 2012 did not have an obvious effect to increase the coverage percentage. In fact by 2014 the coverage of households was more than half a percentage point lower than during 2007–2010. The experience of the most recent years does not follow the historic pattern of increased coverage immediately following a major hurricane.

Some areas that have experienced frequent floods, however, have had consistently low NFIP coverage. The low take-up rate was a major reason for enacting the Flood Disaster Protection Act of 1973 after Hurricane Agnes in 1972. The legislation established a mandatory flood insurance purchase requirement for structures located in special flood hazard areas. Federally regulated lenders were obligated to require

Figure 5.1 Percent of Households with NFIP Coverage, 1978–2014



SOURCE: National Flood Insurance Program, U.S. Census Bureau, and www.statista.com.

flood insurance on mortgages for property located in these areas in a participating community.

The nine states in the Midwest region experienced an average of 21.4 flood-related major disaster declarations between 1991 and 2013. This average was 57 percent higher than the national average of 13.6 major flood disasters per state for the same 23-year period. Of the nine states, Wisconsin had the lowest total with 18 major flood-related disasters. For this group of states, however, NFIP coverage is low. At the end of 2011, eight of the nine states had NFIP coverage rates below 2.5 percent of households, while only North Dakota had a higher coverage rate at 7.1 percent. After the Great Flood of 1993, Congress passed the National Flood Insurance Reform Act of 1994, which strengthened lender compliance through the mandatory purchase provisions in the legislation.

Unlike hurricanes, which have a strong effect on the NFIP coverage, major floods do not show an obvious linkage to NFIP coverage. Coverage rates (active NFIP policies as a fraction of households) by state at the end of 2011 are examined across 51 states in a cross section

regression analysis. Two explanatory variables are used: the number of hurricane-related major disasters (1953–2013) and the number of flood-related major disasters (1953–2013). The number of hurricanes is positively and significantly linked to the NFIP coverage rate, while the number of floods does not have a statistically significant effect.⁸ Half of the interstate variation in the 2011 NFIP coverage rate is explained by knowing the history of hurricane-related disasters in each state. In contrast, knowing the past history of river flooding does not help to explain the state-level NFIP coverage rate.

Recall from Chapter 3 that the costs associated with the destruction from hurricanes are much larger on average than riverine floods. Their respective average costs are \$14.9 billion and \$5.0 billion; that is, the average cost of a hurricane-related disaster is three times the average of a flood-related disaster. Moreover, NFIP coverage is highly concentrated with nearly 70 percent of policies in five states: California, Florida, Louisiana, New Jersey, and Texas (Kunreuther and Michel-Kerjan 2011). Furthermore, NFIP coverage tends to be concentrated in coastal states, with nearly 40 percent of the entire program (number of policies, premiums, and coverage) concentrated in Florida and Texas. Hence, these differences may partially explain the lack of statistical significance of flood-related disasters as a determinant in interstate variation in state-level NFIP coverage rates.

The results of the regression equation used to explain flood insurance coverage rates had a standard error of 0.040. For 8 of the 51 states, the standard error exceeded 0.060. Large underprediction errors are observed for Florida, Louisiana, Hawaii, and North Dakota. Even knowing the number of hurricane-related disasters, there was more NFIP coverage in those states than projected. Substantial overprediction errors are observed in Alabama, North Carolina, New York, and Pennsylvania.

Since Florida and Louisiana have experienced large and repeated catastrophic losses from hurricanes, this cross-section finding might suggest a nonlinear response of household NFIP coverage to disasters. To test this hypothesis, the squares of the number of hurricane-related disasters and the number of flood-related disasters are used as explanatory variables. The results of the analysis show an improvement in the explained variation (the adjusted R^2 increases from 0.498 to 0.641), and the projection errors decrease for six of the eight states with the largest

projection errors.⁹ The biggest improvement is in Florida, where the projection error decreased from 0.100 to 0.015. All of the improvement in the goodness-of-fit reflects a larger contribution from the hurricane variable but continued insignificance of the river flood variable. Hence, in using statewide NFIP coverage data, a greater frequency of major floods is not associated with an increase in the coverage rate.

Two continuing challenges remain for NFIP: to secure coverage among at-risk households, and to maintain coverage among existing policyholders. At the end of 2006 there were 5.514 million NFIP policies in force. The number of households in the United States grows by about 1 percent per year. Had the coverage rate remained at its 2006 level, there would be 5.972 policies in force in 2014. The actual number at the end of 2014 was 5.478 million, or about 0.5 million less than the projected number.

A recurrent pattern is for coverage to increase immediately after a flood-related major disaster but then decline as households fail to renew their NFIP policies. Kousky and Kunreuther (2009) conducted an analysis of floods and flood insurance coverage with specific reference to St. Louis, Missouri. They created a database for NFIP policies effective in St. Louis County during 2000–2005, a database for claims related to the Great Flood in 1993, and a summary file of claims for the 30 years from 1978 to 2007. Despite a history of flooding, the researchers found a low rate of NFIP coverage in St. Louis County, only 1 percent of single-family homes countywide despite a history of flooding.

Mortgage lenders require any residence within a FEMA-designated Special Flood Hazard Area (SFHA) to purchase flood insurance. The SFHAs are zones where the annual flood risk is 1 in 100 or higher. The enforcement and participation, however, is not uniform. Dixon et al. (2006) find that only about 15 percent of residences located in the 100-year floodplain of St. Louis County have NFIP coverage. The authors suggest that low take-up in St. Louis County partially reflects low take-up in the Midwest. There is also spatial bias in flood insurance policy coverage depending on the number of single-family houses that exist in the SFHAs, where the mandatory purchase of flood insurance applies. The authors find that NFIP participation is 16 percent in communities with 500 or fewer homes in the SFHA, 56 percent in communities with 501–5,000 homes in the SFHA, and 66 percent in communities with more than 5,000 homes in the SFHA zone. In addition, the chances of

purchasing flood insurance are higher for SFHA communities subject to coastal flooding/storm surge (63 percent) compared to communities more at risk to riverine flooding (35 percent). Furthermore, flood insurance coverage outside a high-risk flood area is very low (less than 10 percent). Yet, NFIP data show that 25 percent of all flood insurance claims come from the low to moderate risk areas beyond the 100-year floodplain, which are largely uninsured losses (FEMA 2014).

Maintaining required policies is also a major challenge for the NFIP program, as documented in a number of studies.¹⁰ For a sample of policies active in 2000 in St. Louis County, Kousky and Kunreuther (2009) find that only about one-third were still active in 2006. Michel-Kerjan and Kunreuther (2011) followed longitudinally all new NFIP policies initiated between 2001 and 2009. One-year policy continuation rates varied between 67 percent and 80 percent across eight separate years with similar rates for properties in 100-year flood zones compared to other areas. By 2009 only 20 percent of policies newly initiated in 2001 were still active.¹¹ In short, there is a strong and well-documented tendency among property owners to discontinue their NFIP policies when they do not experience any losses over a succession of years.

Payments from the NFIP program to survivors of Hurricane Sandy rank second only to payments to survivors of Hurricane Katrina, \$130,000 compared to \$168,000 (a total of \$8.03 billion versus \$18.9 billion in 2013 dollars). Yet, as illustrated by Figure 5.1, the disastrous effects of Sandy did not have a significant effect on NFIP coverage. At the end of December 2012, just two months after Sandy, NFIP coverage stood at 5.620 million policyholders. Two years later, at the end of 2014, coverage had declined by about 269,000 to 5.370 million policyholders. This pattern of lower postdisaster coverage contrasts sharply with the post-Katrina pattern of increases in coverage. If the post-Sandy coverage pattern becomes the new norm, it suggests the NFIP program will decline in importance as a source of compensation to future survivors of major flood events. Understanding the reason(s) for the changed coverage dynamics since 2012 is important if the NFIP program is to sustain its important role in compensating flood survivors.

Local governments play a key role in the NFIP program. Kousky and Kunreuther (2009) identify six specific challenges for local governments in managing the risk of river flooding. First, many property owners do not purchase flood insurance, and among those who initially

purchase insurance, many fail to maintain their policies. Second, many individuals underestimate the risk associated with flooding. Third, the FEMA flood maps are frequently outdated and do not accurately reflect current flood risks. Fourth, strong reliance is placed on levees to protect property in low-lying areas. This reliance causes overdevelopment in areas protected by levees and leads to increased losses when levees fail. Fifth, the risk of flooding is increasing over time. A number of factors contribute to increased risk, such as economic development (which increases runoff), channel straightening, and climate change. Finally, property owners may be willing to rebuild in areas previously flooded.

The rebuilding phenomenon seems to occur frequently in repetitive loss properties. Jenkins (2005), for example, finds that repetitive loss properties represented only about 1.0 percent of properties insured by NFIP but 25–30 percent of claims. Recognition of the negative impact of properties prone to repetitive flooding on the financial solvency of the program led to the passage of the Flood Insurance Reform Act of 2004, which established a pilot program for the mitigation and funding of severe repetitive loss properties.

From the diversity of issues identified in the preceding list, it is obvious that NFIP faces several challenges in providing effective compensation against the risk of flooding. The most important one is that few households purchase coverage for flood risk. Despite the growth in the frequency of major floods, comparatively few households have property insurance policies that include flood insurance.

FINANCING FLOOD INSURANCE

Although NFIP began in 1968, detailed program statistics are readily available only since 1978. The NFIP provides information on aggregate financial flows (premium income and losses from floods), as well as data on more than 100 large, flood-related disasters since January 1978. Cumulative NFIP payments to insured property owners from January 1978 through March 2014 were \$50.5 billion. Each of the major flood events had at least 1,500 paid losses. Hurricanes Katrina and Sandy dominate the NFIP time series data. As of March 2015, the paid losses from Katrina were 168,000 and totaled \$16.3 bil-

lion (\$18.9 billion in 2013 dollars), while the paid losses from Sandy were 129,000 and totaled \$7.9 billion (\$8.0 billion in 2013 dollars). The third-largest major flood-related disaster was caused by Hurricane Ike, with payments of \$2.7 billion (\$2.9 billion in 2013 dollars) for 46,568 paid losses.

At present, NFIP policies can insure homeowners for up to \$250,000 for single-family residences and up to \$100,000 for contents. Commercial properties can be insured for up to \$500,000 each for buildings and contents. In February 2014, 3.578 million policies insured both buildings and contents, 1.803 million policies insured buildings, and 0.097 million policies insured only contents.

The NFIP flood insurance rates are set using Flood Insurance Rate Maps. The maps identify each SFHA where the annual flood risk is 1 in 100 or higher. Premium rates also distinguish between A zones and V zones, the latter of which are located in coastal areas that have a significant risk of storm surge flooding in addition to damage from high waters. Other determinants of NFIP premium rates depend on the characteristics of the building, such as the number of floors, the presence of a basement, and the height of the lowest floor relative to the height of floodwaters of a 100-year flood. As previously noted, properties located in SFHAs are required to purchase flood insurance if they have a federally backed mortgage.

Prior to Hurricane Katrina, NFIP had a history of financial solvency with cumulative receipts from insurance premiums exceeding cumulative loss payouts. The payouts from Katrina, however, exhausted NFIP reserves and required a financial transfer from the U.S. Treasury to meet its obligations. The program has continued to have a cumulative deficit since 2005. The large increase in NFIP payouts (about \$8.0 billion) caused by Sandy increased the size of the deficit. In the aftermath of the major flood-related disasters of the past decade, the NFIP borrowed approximately \$27 billion from the U.S. Treasury to meet its claims obligations.

Table 5.3 provides an overview of NFIP financing from 1978 through 2012, with data arranged in five-year intervals. Note that cumulative policy premiums exceeded program losses through 2002. However, losses from Katrina (2005–2007) exceeded premiums, exhausted NFIP reserves, and necessitated borrowing from the Treasury. The program's year-end debt to the Treasury averaged \$17–\$19 billion between

Table 5.3 National Flood Insurance Financial Flows, 1978–2012
(\$ millions)

	Policies in force (1)	Policy premiums (2)	Total paid losses (3)	Losses from significant floods (4)
1978–82	1,842	1,023	1,187	625
1983–87	2,032	2,342	1,294	564
1988–92	2,415	3,433	1,944	1,385
1993–97	3,428	5,820	3,713	2,689
1998–02	4,382	8,654	3,604	2,790
2003–07	5,073	10,316	22,037	20,255
2008–12	5,661	15,486	16,531	14,328

SOURCE: NFIP website and unpublished NFIP data. Column (1) shows five-year averages while columns (2) through (4) show five-year totals. Significant floods compensate at least 1,500 policyholders.

2006 and 2012. Sandy had a similar effect in generating losses that exceeded premiums and necessitated a second financial infusion from the Treasury. At the end of 2013 the program's debt to the Treasury totaled \$24 billion.

Partly in response to these increased payouts and increased debt, Congress passed the Biggert-Waters Flood Insurance Reform Act (BW-12) of 2012. The legislation applied the tools of risk management to the peril of flooding. Among its provisions, BW-12 required that floodplain maps be updated, local building code enforcement be strengthened, insurance subsidies for certain properties be removed, and risk-related premiums be charged. Certain policyholders had been paying premium rates that were below actuarially fair rates. Approximately 20 percent of policyholders with subsidized rates were to have their rates increased gradually during the succeeding five years to bring their premium rates into alignment with actuarial risks.

The changes to improve program financing affected three groups: those with subsidized policies on nonprimary and secondary residences, those with properties that experienced severe or repeated flooding, and those with subsidized policies on businesses or nonresidential properties in SFHAs. Starting in 2013 these groups were to experience annual increases in premium rates until their rates reflected the actuarial risks

of floods. Certain transactions involving primary residences in SFHAs were also to undergo rate increases. For example, NFIP policies lapsed when properties were sold, new policies commenced, and large or repeated losses were incurred. Finally, grandfathered rates were to end when a community adopted a new flood insurance rate map. Collectively, these changes would have reduced the subsidies realized by a substantial minority (about 20 percent) of flood insurance policyholders, increased NFIP premium income, and substantially improved the long run balance in the program between revenue and outlays.

As a result of BW-12, some residents, particularly those who received insurance premium subsidies, were confronted with large price increases.¹² When the new increased rates were implemented in 2013, a large backlash commenced. Facing significant challenges to BW-12, Congress passed the Homeowner Flood Insurance Affordability Act in March 2014, which overturned the rate increases of BW-12. The 2014 legislation also instructed FEMA to minimize the number of NFIP policies with annual premium rates above 1.0 percent of the insured value of the property. To keep the fiscal effect of the changes revenue neutral, the 2014 legislation also imposed surcharges on all existing NFIP policies (\$25 on policies for primary residences and \$250 for all other policies). The net effect of the surcharges increased the degree of cross subsidization in NFIP, the opposite of the effect intended by BW-12. Furthermore, the 2014 legislation goes against the principle of having NFIP premium rates accurately reflect the actuarial risks from flooding.

Kousky and Kunreuther (2014) explore several financing alternatives to the 2014 legislation. Similar to most insurance practitioners, they argue that NFIP premium rates should reflect the risks and expected losses from flooding to the greatest extent possible. This approach to insurance pricing is most appropriate for achieving appropriate consumer decisions in situations involving the risk of loss from natural phenomena such as floods. If households who currently reside in flood zones cannot afford the implied premiums, there needs to be an explicit subsidization of their insurance rates rather than the inappropriate pricing of their premium rates. The subsidies could address the problem of affordability without distorting the price signals important in conveying an accurate picture of the risks of flood-related losses.

The approach described for flood insurance rate setting would not only yield appropriate price signals but also address the issue of afford-

ability for those residing in flood zones with limited incomes. Kousky and Kunreuther's (2014) proposal would set NFIP premium rates to reflect flood risks and address the affordability issue by instituting flood insurance vouchers. The vouchers would be financed by general revenue and administered by a public program that serves the low-income population. The authors identify four candidate programs, including the Housing Choice Voucher (HCV) program administered through local offices of HUD and the Food Stamp/SNAP program administered by the Department of Agriculture.¹³ The HCV-HUD program would seem to be the most likely candidate, since the subsidies are directed toward family residential situations. Regardless of administrative entity chosen, the arrangement would combine appropriate insurance price signals with financial relief for low-income residents in at-risk areas. This arrangement would be superior to the one instituted under the 2014 legislation.

The BW-12 legislation extended NFIP for five years; the current authorization of the program expires in 2017. A congressionally mandated study of NFIP coordinated by the National Academy of Sciences (NAS) is currently under way. The NAS study reviews NFIP financing, the setting of premium rates, and flood mitigation activities. The study will produce three reports and legislative recommendations. The full results of the NAS analysis and the associated policy recommendations will be available by the time of the NFIP reauthorization. Recommendations related to setting premium rates will be of major interest and influential in the reauthorization deliberations. Chapter 9 notes the NAS study as part of a discussion of possible changes in the NFIP program.

CONCLUSIONS

The number of flood-related major disasters experienced by states located along major rivers is high, and they are concentrated during spring and early summer when rain and snow melt combine to increase river flow. Therefore, it seems anomalous that the extent of flood insurance coverage is relatively low.

Significant changes to the NFIP may be required if the program is to continue providing flood protection to homeowners and businesses. As

the program currently stands, there is widespread consensus that it faces financial and structural challenges. For instance, an analysis of the entire portfolio of the NFIP in the United States showed that the median tenure of flood insurance was between two and four years, while the average length of time in a residence was seven years (see Michel-Kerjan, Lemoyne de Forges, and Kunreuther [2012]). If a multiyear insurance policy were tied to the property, it would deter policyholders from cancelling their policies if they did not incur losses for several years.

Second, greater program participation is needed to reduce uninsured property losses. Many homeowners do not completely recognize or internalize their flood risk and tend to be overly optimistic about the extent of the flood risk to which they are exposed. Consequently, the NFIP has not achieved the level of participation originally envisioned by Congress. In the absence of flood insurance, the cost of repairing flood-damaged property is usually borne either by the property owner from personal financial resources or by federal disaster relief assistance. The result is billions of dollars of uninsured property losses that translate into higher social costs. It may be that flood survivors think the purchase of flood insurance is not necessary in order to receive some compensation for flood-related losses from the federal government.

Third, NFIP premiums do not adequately reflect the magnitude of the risk involved. The availability of federal subsidies in flood-prone areas encourages people to locate these areas and deters them from taking appropriate measures to mitigate loss. As a consequence, uncompensated flood-related losses are transferred to taxpayers through federal disaster assistance. The assurance of federal assistance in the event of a repeated disaster creates a moral hazard as it lowers the incentives to avoid the risk. Insurance premiums need to be based on risk in order to provide individuals with accurate signals about the perils they face and to encourage them to engage in cost-effective mitigation measures. In addition, risk-based premiums would help address the long-term financial solvency of the program. Timely dissemination of accurate information and updated flood maps could encourage appropriate mitigation measures.

Finally, the NFIP needs to address the issues of equity and affordability. It is important that only low-income households currently residing in hazard-prone areas should receive financial assistance with their insurance premiums. Rather than insurance premium subsidies, how-

ever, the funds could come from general public funding. One option is to give property owners who cannot afford insurance vouchers that are tied to low-interest loans so they can implement flood mitigation strategies.

A private-public insurance program needs to be linked with other initiatives. Given the reluctance of individuals to voluntarily purchase insurance against losses, regulations could be passed that required catastrophic insurance coverage for all individuals who face risk. Insurance premiums would be risk-based to provide appropriate signals about the hazards individuals face and enable insurance providers to lower premiums for properties where mitigation is undertaken.¹⁴

If state and the federal governments were to provide insurance against catastrophic losses, then they could mandate risk-reducing mitigation as a required part of the policy. For instance, building codes would require property owners to meet standards not only on new structures but also require owners to retrofit existing structures. Governments could also offer tax incentives to encourage property owners to adopt mitigation measures.

Notes

1. The nine Midwest states affected by the flooding were Illinois, Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, South Dakota, and Wisconsin.
2. Recall that the records of billion-dollar disasters maintained by NCDC for the United States commence in 1980, and NCDC is now known as the NCEI.
3. These are the nine states affected by the Great Flood of 1993. Montana is not included in this analysis, even though the Missouri River flows through the state. The U.S. Census Bureau places Montana in the Mountain Division of the West Region.
4. The 1997 flood resulted in major disaster declarations in Minnesota, North Dakota, and South Dakota. The major disaster declarations in 2008 were in Iowa, Missouri, Nebraska, and South Dakota.
5. Specification tests using a longer postflood dummy (three months rather than two months) do not improve the goodness-of-fit.
6. Because the postflood dummy variables were not statistically significant in the regression equations for 2008, the results suggest that UI benefits did not increase following the flood of 2008.
7. The World Bank and the United Nations (2010) report that even though FEMA has updated coastal flood maps, it is finding it difficult to get U.S. Gulf coast communities to accept them because such information would reduce property values.

8. The regression equation is:

$$\text{NFIP Coverage} = 0.0126 + 0.00717 \times \text{NumHur} - 0.00015 \times \text{NumFlood}$$

(1.0) (7.1) (0.4)

where NFIP coverage is the share of households in the state with active NFIP policies; NumHur is the number of hurricane-related major disasters between 1953 and 2013; and NumFlood is the number of flood-related major disasters between 1953 and 2013. The absolute value of the *t*-ratios appear beneath each coefficient; a result is statistically significant if the *t*-ratio is 2.0 or larger.

Adjusted $R^2 = 0.498$; Standard error = 0.0400; Mean coverage rate = 0.0376

9. The projection errors increased only in Hawaii and North Carolina, but both increases were modest, from 0.093 to 0.103 in Hawaii and from -0.094 to -0.108 in North Carolina.
10. See Michel-Kerjan (2010); Michel-Kerjan and Kunreuther (2011); King (2011); Michel-Kerjan et al. (2012); Kunreuther, Pauly, and McMorro (2013); and Knowles and Kunreuther (2014).
11. These continuation rates are displayed in Table 7.1 of Kunreuther, Pauly, and McMorro (2013).
12. Originally, BW-12 was to gradually phase-out the subsidized rates for about 20 percent of property owners, half were to pay 25 percent more per year, and the rest were to move to the full-cost for flood insurance upon purchase of an older property.
13. Two other programs are also identified: the Low Income Home Energy Assistance Program administered by the U.S. Department of Health and Human Services and the Universal Service Fund administered by the Federal Communications Commission.
14. An important part of a private-public partnership is well-enforced building codes and land-use regulations to control development in hazard-prone areas.

6

Tornadoes

A methodology for classifying disasters that arise from adverse weather was introduced in Chapter 2. Table 2.2 presents a taxonomy of extreme-weather events and shows their correlates in terms of three underlying weather conditions: precipitation, temperature, and wind. Tornadoes are one of the seven types of major disasters discussed in this book; they are the most violent of all atmospheric storms but are not always accompanied by heavy precipitation. Conversely, a severe storm will be more damaging if it is accompanied by high wind, which is typical of a tornado. As such, tornadoes pose a serious threat to life and property to those in its path. As noted in Chapter 1, evidence suggests that weather-related disasters are becoming more frequent, and one explanation is the increase in human population. Chapter 2 examines the correlation between population density and the occurrence of major disasters. With a larger population, vulnerability to a tornado rises because more people will be affected. In addition, development and urbanization in regions susceptible to tornadoes can increase the likelihood that they will cause a natural disaster.

The first section of this chapter introduces some terminology relevant to the discussion of tornadoes. It introduces the Fujita Tornado Damage Scale, which is used to classify each tornado by intensity and area. It also presents an outline of the enhanced scale introduced in 2007 to rate tornadoes in a more consistent way. The regression analysis in the second section is exploratory. It examines the frequency of tornadoes in the United States since 1953 using data that are publicly available from the National Oceanic and Atmospheric Administration (NOAA) and FEMA. Using annual, state-level data we utilize OLS estimation to draw inferences that can provide useful background information for increasing our understanding of tornadoes. The geographic pattern in the occurrences of tornadoes is also explored. The third section examines the financial costs associated with tornado-related disasters. Given the data, we concentrate on economic damages and do not examine mortality and morbidity from tornado-related events. Generally, while tornadoes are responsible for much smaller aggregate destruction com-

pared to hurricanes, drought, and river floods, there is some support for the idea that tornadoes are having larger damaging effects in more recent years. The last section provides concluding comments.

TERMINOLOGY

According to the National Severe Storm Laboratory of NOAA, a tornado is defined as “a narrow, violently rotating column of air that extends from the base of a thunderstorm to the ground” (National Severe Storms Laboratory, n.d.) Unless a tornado forms a condensation funnel comprised of water droplets, dust, and debris, it is difficult to see. Researchers do not fully understand how tornadoes form, but they do know that the “most destructive and deadly tornadoes occur from supercells, which are rotating thunderstorms with a well-defined radar circulation called a mesocyclone” (National Severe Storms Laboratory, n.d.).¹ Results from the Verification of the Origins of Rotation in Tornadoes Experiment (VORTEX) program suggest that once a mesocyclone is under way, tornado development is related to the temperature differences across the edge of downdraft air wrapping around the mesocyclone.²

Approximately 1,200 tornadoes occur each year in the United States, of which a relatively high frequency occur in the central part of the country.³ The occurrence of a tornado event is measured in a number of ways: by all tornadoes, tornado county-segments, and strong and violent tornadoes only. These various ways of measuring a tornado occurrence provide a wide range of information relevant to different areas of investigation.

While tornadoes can occur at any time of year, they tend to strike during particular months. The time of year when the United States experiences the most tornadoes is termed the tornado season. The peak season for the Gulf coast is spring, for the southern Plains it is in May and early June, and in the northern plains and upper Midwest the tornado season is in June or July.

The strength of a tornado is determined by the damage it causes, and the extent of the damage is used to estimate the wind speeds. Dr. T. Theodore Fujita introduced the Fujita Scale (F-Scale) in 1971 to

classify each tornado by intensity and area: F0 (Gale), F1 (Weak), F2 (Strong), F3 (Severe), F4 (Devastating), and F5 (Incredible). Table 6.1 shows the tornado scale and the typical damage associated with the wind speed of the tornado.

In 2007, the National Weather Service of NOAA implemented an Enhanced Fujita Scale (EF-Scale) to rate tornadoes in a more consistent and accurate manner. The EF-Scale includes more variables than the original F-Scale to assign a wind speed rating to a tornado. The enhanced scale includes 28 damage indicators that describe the typical construction for that category such as building type, structures, and trees. For each damage indicator, the degree of damage is determined using an eight-point classification. The degree of damage in each category is given an expected estimate of wind speed, a lower bound of

Table 6.1 Fujita Tornado Damage Scale

Scale	Wind estimate (mph)	Typical damage
F0	>73	Light damage. Some damage to chimneys; branches broken off trees; shallow-rooted trees pushed over; signboards damaged.
F1	74–112	Moderate damage. Peels surface off roofs; mobile homes pushed off foundations or overturned; moving autos blown off roads.
F2	113–157	Considerable damage. Roofs torn off frame houses; mobile homes demolished; boxcars overturned; large trees snapped or uprooted; light-object missiles generated; cars lifted off ground.
F3	158–206	Severe damage. Roofs and some walls torn off well-constructed houses; trains overturned; most trees in forest uprooted; heavy cars lifted off the ground and thrown.
F4	207–260	Devastating damage. Well-constructed houses leveled; structures with weak foundations blown away some distance; cars thrown and large missiles generated.
F5	261–318	Incredible damage. Strong frame houses leveled off foundations and swept away; automobile-sized missiles fly through the air in excess of 100 meters (109 yards); trees debarked; incredible phenomena will occur.

wind speed and an upper bound. While more detail is incorporated into the EF-Scale, the original F-scale historical database has not changed. For instance, an F5 tornado rated in years prior to 2007 remains an F5 under the enhanced scale, but the wind speed associated with the tornado may be less than previously estimated.

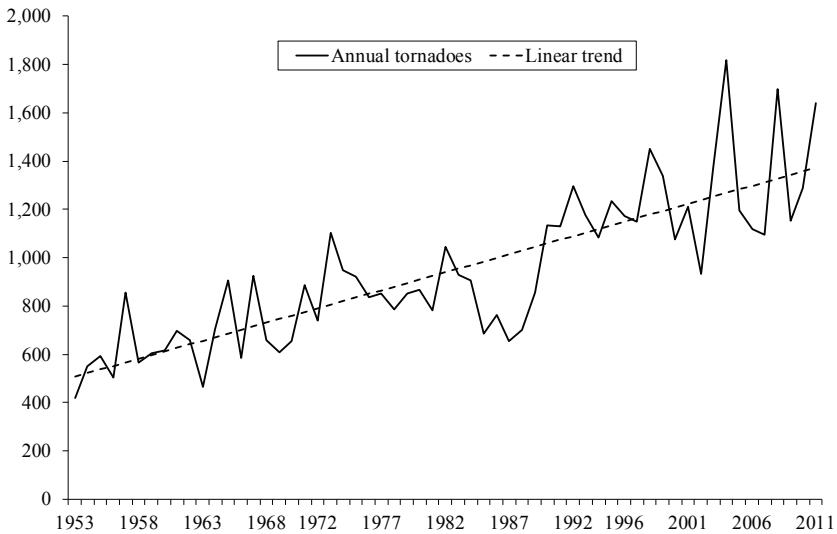
TORNADO PATTERNS

Tornadoes are present in a considerable number of major disaster declarations designated by FEMA. For example, 441 of the 2,046 FEMA-designated disaster declarations between 1953 and 2013 were attributable to tornadoes. In some major disasters straight-line winds compound the damage from tornadoes. Both types of destructive wind events were present in 55 major disaster declarations of the 1953–2013 period.

Most single and multiple tornado outbreaks do not result in a major disaster declaration by FEMA, even though they cause extensive damage in local areas. The NCDC has information on tornado activity since 1916.⁴ Figure 6.1 uses historical data from 1953 to 2011 to plot annual tornado outbreaks. The figure shows a discernible upward trend in the annual occurrence of tornadoes. For instance, between 1953 and 1959 the annual number of tornadoes averaged 585, while between 2000 and 2009 the average was 1,268.

Besides large year-to-year variation in tornado frequency, a significant upward trend is clearly noticeable in the figure. Projections from the linear trend regression in Figure 6.1 exceed 1,200 in all years between 2000 and 2011, whereas all projections from 1953 to 1959 fall below 600.

Table 6.2 displays the results of a regression analysis of the frequency of tornadoes in the United States since 1953. The first two regression equations focus on national trends. A linear trend from 1953 explains about two-thirds of the time series variation for the 1953–2011 period. The slope of the trend indicates that the annual number of tornadoes increased by about 15 during these 59 years. The second regression equation tests for an acceleration in tornado frequency starting in 1985. The decision rule for selecting the year 1985 for the break

Figure 6.1 Annual Number of Tornadoes, 1953–2011

SOURCE: Annual data from the NCDC. The linear trend is regression Equation (6.2.1), which is shown in Table 6.2.

in the series is arbitrary: it is approximately the middle of the period from 1953 to 2011. The trend acceleration coefficient is positive, but its t -ratio of 1.8 is of borderline significance at the 0.05 level.⁵ The two trend coefficients in the second regression equation suggest that the annual number of tornadoes increased by 10.56 in years before 1985 but nearly doubled to 20.24 after 1985.

Regression Equations (6.2.3) and (6.2.4) repeat Equations (6.2.1) and (6.2.2) but add two years of data, 2012 and 2013. Note how the proportion of explained variation drops when 2012 and 2013 are added. Also in Equation (6.2.4), note how the estimated post-1985 trend acceleration drops to less than three tornadoes per year. The contrast between Equations (6.2.1) and (6.2.2) and Equations (6.2.3) and (6.2.4) is yet another illustration of the extreme volatility of annual disaster occurrences; in this instance, the nationwide occurrences of tornadoes.⁶

The data from NOAA also have information about serious tornadoes; that is, tornadoes in classes 5–9 based on the scale of property

Table 6.2 Measures of Tornado Frequency since 1953

	Constant	Trend 1953	New trend 1985	Adjusted R^2	Standard error	Durbin- Watson	Mean	Sample period
(6.2.1) U.S. total	492.6 (10.5)	14.91 (11.0)		0.673	177.8	1.72	939.9	1953–2011
(6.2.2) U.S. total	561.0 (9.4)	10.56 (3.8)	9.68 (1.8)	0.685	174.4	1.82	939.9	1953–2011
(6.2.3) U.S. total	522.9 (10.5)	13.44 (9.6)		0.602	192.8	1.65	939.4	1953–2013
(6.2.4) U.S. total	543.9 (8.2)	12.12 (4.0)	2.77 (0.5)	0.597	194.1	1.65	939.4	1953–2013
(6.2.5) U.S. serious tornadoes	66.9 (3.8)	5.43 (10.8)		0.667	65.6	1.54	229.6	1953–2011
(6.2.6) U.S. serious tornadoes	60.3 (2.7)	5.83 (5.6)	−0.90 (0.4)	0.662	66.1	1.54	229.6	1953–2011
(6.2.7) Serious tornado proportion	0.167 (12.7)	0.0023 (5.9)		0.367	0.050	1.05	0.234	1953–2011
(6.2.8) Serious tornado proportion	0.126 (8.4)	0.0048 (7.0)	−0.0058 (4.3)	0.514	0.044	1.40	0.234	1953–2011
(6.2.9) Major disasters with tornadoes	−0.381 (0.3)	0.246 (7.3)		0.465	4.63	1.52	7.230	1953–2013
(6.2.10) Major disasters with tornadoes	1.656 (1.1)	0.118 (1.7)	0.267 (2.0)	0.492	4.51	1.63	7.230	1953–2013
(6.2.11) Major disasters: tornadoes or straight- line winds	−0.439 (0.4)	0.271 (7.9)		0.508	4.69	1.48	7.951	1953–2013

(6.2.12) Major disasters:	1.762	0.133	0.289	0.537	4.55	1.60	7.951	1953–2013
tornadoes or straight-	(1.1)	(1.9)	(2.2)					
line winds								

SOURCE: National tornado data in Equations (6.2.1)–(6.2.8) from NOAA. Tornadoes and straight-line winds in major disasters in Equations (6.2.9)–(6.2.12) from FEMA major disaster data. The absolute value of the *t*-ratios appears beneath each coefficient; a result is statistically significant if the *t*-ratio is 2.0 or larger. Note that the sample periods depend on data availability.

damage.⁷ Equations (2.6.5) and (2.6.6) explain the trend in serious tornadoes. Equation (2.6.5) indicates that serious tornadoes increased by slightly more than 5 per year from 1953 to 2011. The test for an acceleration in serious tornadoes starting in 1985, however, is not statistically significant.⁸ The absence of an acceleration in the frequency of serious tornadoes starting in 1985 is confirmed in Equations (6.2.7) and (6.2.8), which examine serious tornado occurrences as a proportion of all tornadoes. There is an upward trend from 1953 in Equation (6.2.8), but the trend acceleration coefficient is negative, statistically significant, and nearly the same size as the post-1953 trend. In other words, Equation (6.2.8) suggests there has been no significant change in the share of serious tornadoes since 1985. The inference from Equations (6.2.7) and (6.2.8) is that since 1985 the increase in tornado frequency has been concentrated among less serious tornadoes; that is, those with estimated financial costs below \$50,000.

As noted at the start of this chapter, 441 of the 2,046 FEMA-designated disaster declarations between 1953 and 2013 involved tornadoes. Most descriptions of the 441 incidents in the FEMA declarations, however, also included one or more other phrases such as “severe storm” or “flooding.” While tornadoes were responsible for wreaking destruction in these disasters, one or more other destructive factors may also have been present. High winds were also present in another 44 major disasters between 1953 and 2013 as straight-line winds.

Equations (6.2.9)–(6.2.12) in Table 6.2 show descriptive trend results for these high-wind events associated with major disasters. Equations (6.2.9) and (6.2.10) focus just on tornadoes, while Equations (6.2.11) and (6.2.12) add incidents with straight-line winds. Equation (6.2.9) suggests that the trend-wise increase in major disasters involving tornadoes was about one every four years between 1953 and 2013, while Equation (6.2.10) suggests a significant acceleration starting in 1985. Equations (6.2.11) and (6.2.12) show that the upward trends are slightly larger when straight-line winds are included. Perhaps most interesting is the strong suggestion in Equations (6.2.10) and (6.2.12) that major disasters involving these wind-related phenomena were noticeably more frequent starting in 1985. The post-1985 trend acceleration coefficients are more than twice the size of those for the longer post-1953 trend.

Note the contrasting findings regarding a possible acceleration in tornado frequency starting in 1985. The NOAA series on all tornadoes and those causing major damage suggest an increase in the frequency of all tornadoes starting in 1985 (Equation [6.2.2]), but the increase did not occur in tornadoes that cause major damage (Equation [6.2.6]). The FEMA major disaster data, on the other hand, suggest an acceleration after 1985 in the frequency of major disasters involving tornadoes (Equation [6.2.10]) and major disasters involving either tornadoes or straight-line winds (Equation [6.2.12]). Because most FEMA major disaster declarations with tornadoes had other contributing factors, the separate contribution of tornadoes to the acceleration in wind-related major disasters cannot be identified in the FEMA data.

As noted earlier, tornado frequency is higher in the Midwest and the South than elsewhere in the nation. Table 6.3 displays the results of a descriptive regression analysis to illustrate the contrasts in the frequency of tornadoes in individual states across the nine U.S. Census Bureau divisions. The measure of tornado frequency is the number of tornadoes per 10,000 square miles of state land area.

Three measures of tornado frequency are examined: the annual average frequency of all tornadoes by state from 1953 to 2011; the average frequency by state of major disasters involving tornadoes for the period 1953–2013; and counts by state of the most severe category of tornadoes, the 59 EF-5 tornadoes recorded between 1950 and 2013. The regression analysis in Table 6.3 uses regional categorical (dummy) variables as explanatory variables and includes average temperature and average precipitation as additional arguments. Table 6.3 displays the results for five regression equations, two for the 1953–2011 annual average of all tornadoes per 10,000 square miles, two for all major disasters involving tornadoes between 1953 and 2013 per 10,000 square miles, and a single regression for the 59 EF-5 tornadoes of the 1950–2013 period.

For all series, the divisional dummies explain over 45 percent of the state-to-state variation in tornado frequency. Large, positive, and statistically significant divisional dummies are observed for the East North Central, West North Central, East South Central, and West South Central divisions; small or negative coefficients are observed for the other five divisions. Average temperature and average precipitation also add to the explained variation with uniformly positive coefficients that are

Table 6.3 State Tornado Frequency by Census Bureau Division

Census division	Annual average 1953–2011 (1)	Annual average 1953–2011 (2)	Major disaster 1953–2013 (3)	Major disaster 1953–2013 (4)	EF5 Major tornadoes 1950–2013 (5)
New England	1.52 (2.5)	-5.18 (2.6)	1.49 (3.5)	-1.99 (1.3)	
Mid-Atlantic	0.71 (0.7)	0.59 (0.6)	0.98 (1.6)	-0.50 (0.7)	
East North Central	2.72 (3.1)	3.09 (3.7)	2.91 (6.3)	1.76 (2.8)	0.044 (3.9)
West North Central	3.54 (4.3)	4.64 (5.1)	1.94 (5.0)	1.29 (1.9)	0.041 (4.2)
South Atlantic	2.70 (3.5)	1.54 (2.0)	1.23 (3.6)	-0.73 (1.2)	
East South Central	3.54 (3.7)	1.80 (1.9)	5.23 (10.1)	2.91 (4.0)	0.066 (5.4)
West South Central	4.51 (4.8)	3.31 (3.4)	3.07 (5.9)	1.23 (1.7)	0.035 (2.9)
Rocky Mountain	-0.69 (0.9)	1.29 (1.1)	0.09 (0.0)	0.10 (0.1)	
Pacific	-1.23 (1.4)	-0.62 (0.6)	0.00 (0.0)	-0.84 (1.2)	
Mean temperature		0.078 (2.8)		0.026 (1.3)	
Mean precipitation		0.071 (2.2)		0.051 (2.1)	
Adjusted R^2	0.619	0.697	0.642	0.673	0.484
Standard error	1.466	1.307	1.034	0.987	0.023
Mean	3.194	3.194	1.665	1.665	0.0178

NOTE: EF-5 tornadoes are the most severe with only 59 between 1950 and 2013. Tornado frequency measured per 10,000 square mile of state area in (1) to (4). Beside each coefficient in parentheses is the absolute value of the t -ratio; the result is statistically significant if the t -ratio is 2.0 or larger.

SOURCE: Annual average tornadoes 1953–2011, mean temperature 1951–2000 and mean precipitation 1951–2000 from NOAA. Major disasters involving tornadoes, 1953–2013, from FEMA.

statistically significant in three of four instances. Knowing the location of a state, average temperature, and average annual precipitation is sufficient information to explain 48–70 percent of the interstate variation in tornado frequency per 10,000 square miles of state area.

The results of the regression analysis in column (5) in Table 6.3 are quite illuminating. All 59 of the EF-5 tornadoes affected residents in just the four central census divisions. Not one of the EF-5 tornadoes affected a single state in the three East Coast divisions, nor the two Western census divisions. This finding is particularly relevant for regional policymakers, who need to consider appropriate public policy tools to reduce the mortality and morbidity associated with tornado-related events.

FINANCIAL COSTS OF TORNADOES

Tornadoes are one of the eight categories of natural catastrophes recorded in the billion-dollar disaster series of NOAA. Between 1980 and 2012 there were 19 tornado outbreaks that caused destruction estimated to be at least \$1.0 billion (in 2013 dollars). Among these 19, NOAA estimated that just two were responsible for destruction that exceeded \$4.0 billion and both occurred in 2011: the Southeast-Midwest tornadoes of late April and the Midwest-Southeast tornadoes of late May. Both these outbreaks were devastating (the combined estimated cost was \$19.9 billion in 2013 dollars) and deadly (498 combined deaths).⁹ The devastation in Joplin, Missouri, in late May received extensive media coverage.

The combined cost of the 19 billion-dollar tornados was estimated at \$51.7 billion (in 2013 dollars). Nine of the 19 incurred financial costs of \$2.0 billion or more, but only 1 of the 9 occurred before 2008; the other 8 happened between 2008 and 2012. Based on this fact and the size of the two largest tornado-related disasters of 2011, tornado outbreaks appear to be becoming more damaging, as reflected in the NOAA data. On average, while tornadoes wreak much smaller aggregate destruction compared to hurricanes, drought, and river floods, the NOAA data provide some support for the impression that tornadoes are having much larger destructive effects in more recent years.

Tornadoes are frequently part of a suite of destructive events described as severe storms that can also include heavy rain, hail, flooding, and mudslides. The NOAA billion-dollar disaster data also include severe storms as a separate category of destructive events. In the data, 33 severe storms resulted in billion-dollar disasters between 1980 and 2012, and 7 included tornadoes in their description. It is not a simple matter to separately estimate the destructive effects of tornadoes; frequently it is not possible to separate the individual components of a disaster-related event.

Unlike hurricanes that are individually identified and tracked, tornadoes typically occur in groups, carry group descriptions, and extend over many states at the same time. In more recent years the NOAA tornado-related billion-dollar disasters have included estimates of the number of tornadoes involved in the event. This description is true of 15 of the 19 tornado-related billion-dollar disasters. Counts of the number of tornadoes are also included in about half of the 33 billion-dollar disaster events described by NOAA as “severe storms.” These descriptions appear as either a separate count or as a generic descriptor, “numerous.” For 17 events that include the number of counts of tornadoes, the range is between 22 and 400, with a mean of 120. This large number per event may help to explain why the destructive effects of tornadoes can extend over a wide geographic area.

CONCLUSIONS

The analysis of tornadoes suggests at least four conclusions. First, all data series examined in this chapter show a strong upward trend in the annual number of tornadoes. It implies that the risk of a tornado occurring that causes physical harm or financial loss is also increasing. In part, the risk is increasing because of changing climatic conditions. Disaster risk reduction can be enhanced through complementary action from individuals, the private sector, and all levels of government. The federal government can coordinate the efforts of local and state governments by providing information, policy and legal frameworks, and financial support.

One disaster risk-reduction strategy is an early warning system. This system would disseminate timely and meaningful warning information that would enable individuals and communities threatened by a tornado to prepare and to act appropriately and in sufficient time to reduce the possibility of harm or loss. Simmons and Sutter (2005) found that the use of Doppler radar to identify tornadoes while still in the clouds has led to a longer lead time for tornado warnings (from 5.3 to 10.0 minutes). The UNISDR (2009, p. 12) suggests a people-centered early warning system comprised of four key elements: “knowledge of the risks; monitoring, analysis and forecasting of the hazards; communication or dissemination of alerts and warnings; and local capabilities to respond to the warnings received.” An appropriate and effective response to warnings is essential in reducing disaster risk.

Second, there is a definite geographic pattern in the occurrences of tornadoes. North Central and South Central states have much higher rates of occurrence per square mile compared to states along the Atlantic and Pacific coasts. The results of the regression analysis show that census division dummy variables alone explain 45–70 percent of the interstate variation in the frequency of tornadoes. Disaster risks are amplified for those living in exposed areas. Improved housing and more resilient infrastructure systems could significantly reduce vulnerability and exposure in tornado-prone areas. Effective risk governance and the alignment of policies and incentives could strengthen community resilience. Local decision makers could encourage mitigation measures through building regulations. Adherence to model building codes can mean the difference between life and death or whether structures remain standing or are completely destroyed. Building codes can offer enhanced protection against the threat of a natural disaster and make communities more resilient and sustainable. An important issue that needs to be addressed, but is not discussed in this chapter, is the lack of affordable tornado shelters in some states within the central census division—an absence that leads to unnecessary mortality. Funding is available for the building of safe rooms.¹⁰ Information on tornado preparedness is available from FEMA.¹¹

Third, the average cost of the destruction caused by tornadoes is much smaller in scale than the destruction wrought by hurricanes, drought and even river floods. Yet mitigating the risks from tornadoes is important and requires a combination of active measures. A key ele-

ment in reducing the potential destruction of tornadoes is community education and involvement. Active measures include those that reduce the risk itself (such as reducing the chances of damage through tornado-proofing measures in homes and communities), limit the exposure to risk (such as encouraging the purchase of insurance protection), and provide financial resources to help people recover from tornadoes (such as disaster assistance or insurance payouts). Policy instruments include public-private finance partnerships, loans, regulations, and risk-sharing and transfer mechanisms. Risk-financing mechanisms, such as insurance, can contribute to increasing resilience.

Homeowners share responsibility for protecting themselves and their property from potential tornado damage. For tornadoes, this responsibility is voluntary and not enforced by statewide law or insurance company practices. As such, these practices can decrease equity. Given the reluctance of individuals to voluntarily purchase insurance against property damage, regulations could be passed that require catastrophic insurance coverage for all individuals who face tornado-related risks. Government could play a key role either as a regulator or an insurer of last resort.

Finally, the evidence on the increase in severe tornadoes and the associated scale of destruction is mixed. The FEMA data on major disasters suggest that there has been a more rapid growth in tornado-related major disaster declarations since 1985. On the other hand, the national tornado data from NOAA suggest that there has been no significant growth in severe tornadoes since 1985. The NOAA billion-dollar disaster data also suggest that the average destruction caused by tornadoes has been increasing. The number of events (19), however, is too small to draw strong inferences.

Notes

1. Supercells can also produce damaging hail, flash floods, severe non-tornadic winds, and unusually frequent lightning.
2. The VORTEX program is a set of field projects that study tornadoes. Scientists involved with VORTEX1 researched the evolution of a tornado with an array of instrumentation to gain a greater understanding of the processes involved with tornado genesis. VORTEX2 seeks to explain how tornadoes form, how long they last, and what causes them to dissipate.

3. “Tornado Alley” is a label used by the media for a broad area of relatively high tornado occurrence in the central part of the United States.
4. See NCDC (2012).
5. The required t -ratio at the 0.05 level of significance under a two-sided t -test is 1.97 and under a one-sided t -test it is 1.672. Thus the trend acceleration coefficient is statistically significant under a one-sided test but not under a two-sided test.
6. The number of annual tornadoes decreased from 1640 in 2011 to 938 in 2012, or by 43 percent. NOAA records indicate that there was no change in tornado reporting between 2011 and 2012.
7. Category 5 has damage from \$50,000 to \$500,000, while category 9 has damage of \$500 million and over.
8. The t -ratio of the acceleration coefficient is 0.4, far below the level required for statistical significance.
9. The year 2011 was unusual in the number of billion-dollar tornado disasters, five including the two identified earlier in the chapter. All five incurred at least \$2.0 billion in estimated financial costs. The 498 deaths from the April and May 2011 tornado outbreaks accounted for 58 percent of all deaths caused by the 19 billion-dollar tornado disasters.
10. See <https://www.fema.gov/safe-room-funding> (accessed July 15, 2016).
11. See <https://www.ready.gov/tornadoes> (accessed July 15, 2016).

7

Drought and Other Risks to Agriculture

Agricultural producers face numerous, often simultaneous, sources of risk: volatility in product and input prices, macroeconomic disturbances affecting agricultural markets, outbreaks and spread of highly contagious diseases damaging to livestock, and adverse weather events. With diverse risks in agriculture, the responses required to manage them need to be different. Agricultural producers can directly manage variation in production, prices, and predictable weather with standard business strategy. Marketable risk can be handled through market instruments, such as insurance and futures markets, or through cooperative arrangements among agricultural producers.

Infrequent but catastrophic events that affect many agricultural producers over a wide area and for a sustained period of time require a different approach. Catastrophic risk strains the coping capacities of agricultural producers. One example of a catastrophic risk is severe and widespread drought. Losses associated with catastrophic risk affect the willingness of private insurers to provide coverage against certain hazards. If the private insurance market fails to provide coverage for catastrophic risk, then government intervention is required. Programs that address both marketable and catastrophic risk are discussed in Chapter 3.

Unlike the risks associated with hurricanes and floods, those associated with drought are less well understood. The World Meteorological Organization defines drought as a natural hazard that occurs due to natural climatic variability.¹ Chapter 1 introduces the declaration classification used by FEMA: major disaster declarations, emergency declarations, and fire management assistance declarations. The FEMA incident descriptions do not directly identify drought as a descriptor in these declarations. While drought often contributes to the severity of wildland fires, these fires are described as having lightning and nonlightning causes. The agency uses the descriptors floods, hail, severe storms, and winter freezes when declaring incidents that affect agricultural production. Drought is not an explicit category of either major disaster

or emergency declarations. This classification may reflect an important contrast between the onset and duration of drought compared to other adverse weather-related events whose onset and duration span just one or a few days. Drought, in contrast, extends over several months or even years, and drought-related agricultural and other economic losses also accumulate over longer periods.

The first section of this chapter introduces terminology that is relevant to the discussion of drought. Four types of drought are introduced: meteorological, hydrological, agricultural, and socioeconomic. Meteorological drought is a climatic phenomenon rather than a hazard; it only becomes hazardous when it is translated into hydrological or agricultural drought (UNISDR 2011). The regression analysis in this section examines the severity of drought in the United States from 1950 to 2012 using state-level data from NOAA.² We utilize OLS estimation to draw inferences that can provide useful background information for increasing our understanding of droughts. Note that this estimation technique does not imply a causal relationship; it only shows an association between the variables of interest. More sophisticated statistical methods are appropriate to use with a larger and richer data set, particularly if the focus of the investigation is at the substate level. Our regression analysis finds that while drought is closely related to annual temperature and precipitation, annual precipitation has a more important effect in explaining year-to-year variation in drought severity. The geographic scope of droughts is also explored, with drought being more frequent in states in the interior of the nation and less frequent in states along the coasts.

The second section of this chapter examines the agricultural drought experience of the Dust Bowl of the 1930s and places it into a wider historical context by comparing data from the 1930s with two recent multiyear periods. The third section examines the role of insurance in covering marketable risk, which can be handled through market instruments, such as federal crop insurance. The experience of federal crop insurance over time is examined with a regression analysis. The final section provides concluding comments.

DROUGHT, MEASUREMENT, DETERMINANTS, AND COSTS

Past research and practice have proposed more than 100 definitions of drought. The National Drought Mitigation Center at the University of Nebraska classifies drought into four categories using a taxonomy originally developed by Wilhite and Grantz (1985). These four categories of drought are meteorological, hydrological, agricultural, and socioeconomic. The first three categories deal with ways to measure drought as a physical phenomenon; the last deals with drought in terms of supply and demand, tracking the effects of a shortfall in water as it is transmitted through socioeconomic arrangements.

Each category of drought merits a brief discussion. Meteorological drought assesses the degree of dryness and the duration of the dry period. It is usually defined as deficiencies in rainfall, with periods ranging from a few months to several years or even decades. Since average precipitation varies widely across local geographic areas, the measurement of meteorological drought involves a comparison of current dryness conditions with the long-run average for the area. Long droughts often change in intensity over time and may affect different areas.

Hydrological drought assesses the effects of precipitation shortfalls over a period on surface and subsurface water supply. Agricultural drought links meteorological and/or hydrological drought to its impact on agriculture. During a period of agricultural drought, demand for water for agricultural uses exceeds the supply. Here, supply encompasses groundwater and reservoir water stocks as well as precipitation. Agricultural drought considers the demand-supply water balance at all stages of crop development from planting to maturity. Socioeconomic drought considers not only agriculture but also the broader balance between water demand and supply in society; for example, power generation, household use, industrial use, and social and environmental impacts.

The measurement of meteorological drought is well characterized, but the measurement of hydrological and agricultural drought remains a challenge. The World Meteorological Organization (2010) advocates that agricultural drought be measured using composite indices that consider rainfall, soil moisture, temperature, soil and crop type,

stream flow, groundwater, and snow pack, as well as historical records of drought impacts.

Meteorological drought severity is often measured with the Palmer Drought Severity Index (PDSI), which considers the duration and intensity of drought-inducing weather patterns. Long-term drought is cumulative, and the PDSI uses weather information from the current month and several recent months. The PDSI is measured as an index with values that can range from 6.0 (wettest conditions) to -6.0 (driest conditions). In actual use, PDSI values of 4.0 and above signal extremely wet conditions, while values of -4.0 and below signal extreme drought.

A second drought severity index is the Palmer Hydrological Drought Index (PHDI), which measures the hydrological effect of drought; for example, water-related indicators such as reservoir levels and groundwater levels. It is also measured as an index that can range between 6.0 and -6.0 . The PHDI responds more slowly to changing weather conditions than the PDSI since the hydrological effects of drought take longer to develop and longer to recover when compared to meteorological drought indices such as the PDSI.

At the statewide level, both the PDSI and PHDI are closely related to annual temperature and precipitation. Drought severity in the United States is examined with regression analysis using state-level annual data for the period 1951–2012.

The determinants of drought severity in the analysis are current and lagged annual values of average temperature and annual precipitation. The regression results for 48 states showed that both weather variables are statistically significant, but annual precipitation had a more important effect, particularly in explaining year-to-year variation in the PHDI.³

Table 7.1 summarizes the results of a regression analysis using both drought indices. Each entry is a simple average of statistics across 48 state-level regressions.⁴ Five observations from these results seem most pertinent to the analysis. First, the regression results explain most of the variation in both drought indices. The average adjusted R^2 is 0.810 in the PDSI regression analysis and 0.823 in the PHDI regressions. Second, the vast majority of slope coefficients for current and lagged temperature and precipitation have expected signs; that is, negative for temperature and positive for precipitation. Third, precipitation has a more statistically significant effect on drought severity than temperature; the

Table 7.1 Regression Analysis of Drought Severity, 1951–2012

	PDSI		PHDI	
	Avg. coefficient and <i>t</i> -ratio	Significant <i>t</i> -ratios ^a	Avg. coefficient and <i>t</i> -ratios	Significant <i>t</i> -ratios ^a
Regression coefficients				
Constant	11.79 (1.81)	23	10.05 (1.59)	18
Current temperature	-0.333 (3.41)	43	-0.310 (3.02)	40
Lagged temperature	-0.157 (1.70)	18	-0.176 (1.96)	23
Current precipitation	0.305 (13.08)	48	0.300 (12.12)	48
Lagged precipitation	0.180 (6.59)	48	0.258 (9.54)	48
Summary statistics				
Adjusted <i>R</i> ²	0.810		0.823	
Standard error	0.827		0.886	
Average index	0.125		0.332	

^aThe *t*-ratio is 2.0 or larger and the coefficients have expected signs, that is, negative for temperature and positive for precipitation.

SOURCE: The regression analysis uses data from 1950 to 2012 for 48 states available from the National Centers for Environmental Information (NCEI) of NOAA. Beside each coefficient in parentheses is the absolute value of the *t*-ratio; the result is statistically significant if the *t*-ratio is 2.0 or larger. Coefficients and summary statistics are simple averages across 48 states with no weighting for state size.

t-ratios for the precipitation coefficients are four to five times the size of the *t*-ratios for the temperature coefficients for both indices. Fourth, current-year effects on drought severity are clearly larger than the one-year lagged effects. The coefficients on the current-year variables for both average temperature and annual precipitation display noticeably higher averages than their one-year lagged counterparts. While lagged effects are important in the analysis, particularly for precipitation, current-year effects are generally more significant. Fifth, lagged effects are relatively larger and have greater statistical significance in the PHDI regression analysis than in the PDSI regressions. The lagged-to-current ratios are 0.471 ($= -0.157 \div -0.333$) and 0.568 ($= -0.176 \div -0.310$) for the average temperature coefficients; for the annual precipitation coefficients, they are 0.590 ($= 0.180 \div 0.305$) and 0.860 ($= 0.258 \div 0.300$). These results imply that not only does the start of adverse hydrological conditions take longer to develop when compared to meteorological conditions, but they also take longer to end.

To summarize these results, most of the annual variation in both drought indices at the state level is explained by yearly variation in average temperature and annual precipitation. In annual data the effects of both climate variables on drought in the current year are larger than their one-year lagged effects.

In contrast to the incident descriptions used by FEMA in its declaration, the NOAA data of billion-dollar disasters that extend back to 1980 do include drought as a disaster-related event. NOAA records show 21 drought-related billion-dollar disasters between 1980 and 2013 incurring cumulative costs of \$278.2 billion (in 2013 dollars), or an average of \$13.2 billion for each disaster. Of the seven types of disasters discussed in Chapter 2, droughts and hurricanes are the two most costly per-occurrence catastrophes. Also noted in Chapter 2 are three drought-related disasters since 1980 that resulted in financial costs in excess of \$25 billion (the droughts of 1980, 1988, and 2012).

Drought is a widespread, multistate phenomenon. For 9 of the 21 drought-related billion-dollar disasters, the NOAA data identify the affected states. The other 12 simply identify the region(s) and indicate that several states were affected.⁵ Of all the states, 40 experienced at least one period of drought during the nine years that NOAA provided details for individual states. The states with no recorded drought events were the six New England states plus New Jersey, Delaware, D.C., Alaska, and Hawaii. At the other extreme, the 14 states with four or more periods of drought during these nine years were states in the interior: Illinois, Indiana, Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, South Dakota, Arkansas, Oklahoma, Texas, Arizona, and New Mexico.

From these nine episodes it is clear that drought was experienced more frequently by states in the interior of the United States and less frequently by states along the coasts. Of the 23 states that front one of the three coasts (Atlantic, Gulf, and Pacific), drought was experienced 33 times for an average of 1.4 per state. Among the 28 interior states drought was experienced 91 times for an average of 3.2 per state. Since 1980 the economic losses from drought have not been randomly distributed across the individual states.

PRECIPITATION IN THE WEST

The most widely recognized period of drought in the United States was the Dust Bowl of the 1930s, when residents of Oklahoma and adjacent states experienced severe hardship caused by several years of below-average precipitation. We recognize that the catastrophic experience of the Dust Bowl is more complicated than simply several years of below-average precipitation. The environmental catastrophe was due not only to government land policies at the time, but also to the intense cultivation of inappropriate crops (see, for example, Egan [2006] and Hornbeck [2012]).

In the current terminology of the UNISDR (2009, p. 27), the origin of the Dust Bowl would be classified as a socionatural hazard: circumstances where human activity increases the occurrence of certain hazards beyond their natural probabilities. Socionatural hazards can be reduced, and even avoided, through effective management of land and environmental resources. To help the agricultural sector recover from the combined effects of the Great Depression and the Dust Bowl, Congress passed the Federal Crop Insurance Act, which established the federal crop insurance program, as discussed in Chapter 3.

Table 7.2 places the precipitation experience of the 1930s into a wider historical context by comparing long-run state-level precipitation data with data from the 1930s and from two recent multiyear periods.⁶ It displays precipitation averages for 15 western states and the average annual precipitation for the 48 states of the United States. Precipitation for each year is expressed as a ratio to the 1901–2000 average, and the ratios were then averaged for the indicated periods. The table shows the averages for three multiyear periods (1930–1939, 2000–2006, and 2007–2013) and for the 100 years from 1901 to 2000.

For the 15 western states and the United States, column (1) shows the 100-year average precipitation, while columns (2)–(4) show ratios to the long-run average precipitation for the three multiyear periods. Based on 48 states, national data precipitation in the 1930s averaged 6 percent below the 100-year average. In contrast, the national ratios for 2000–2006 and 2007–2013 match the long-run national average. From an aggregate national perspective the 1930s were dry years while the years since 2000 have experienced average precipitation.

Table 7.2 Average Precipitation by State, the 1930s and 2000s

Geographic areas	100-year average, 1901–2000 (1)	Ratio to 100-year average, 1930–1939 (2)	Ratio to 100-year average, 2000–2006 (3)	Ratio to 100-year average 2007–2013 (4)
Oklahoma	33.8	0.89	0.99	1.02
Kansas	27.1	0.83	1.00	1.07
Nebraska	22.6	0.85	0.95	1.09
Texas	27.1	0.96	1.06	0.98
Arizona	12.6	1.00	0.92	0.92
Colorado	18.1	0.90	0.82	0.85
Idaho	23.9	0.88	0.73	0.76
Montana	18.7	0.87	0.75	0.88
Nevada	10.3	0.96	0.85	0.79
New Mexico	14.0	0.99	0.96	0.88
Utah	13.6	0.92	0.86	0.84
Wyoming	15.9	0.92	0.70	0.82
California	22.4	0.93	0.98	0.79
Oregon	32.2	0.89	0.79	0.81
Washington	42.0	0.97	0.86	0.92
United States	29.9	0.94	0.99	1.00
Average 15 states	22.3	0.92	0.88	0.89
Average 4 Plains	27.7	0.88	1.00	1.04
Average 8 Mountain	15.9	0.93	0.82	0.84
Average 3 Pacific	32.2	0.93	0.87	0.84

SOURCE: Annual precipitation data from NOAA. Column (1) shows 100-year averages. Columns (2)–(4) show average ratios of annual precipitation to the 100-year average for the indicated multiyear periods.

The state-level ratios and the multi-state averages at the bottom of Table 7.2 show a clear pattern of below-average precipitation in all three periods. Of the 15 individual states, the average precipitation ratio for 14 falls below 1.00 during 1930–1939, for 14 again during 2000–2006, and for 12 during 2007–2013. Average precipitation ratios across the 15 western states are generally below 1.0, and the average precipitation ratios for both 2000–2006 and 2007–2013 are actually lower than dur-

ing the 1930s (the 15-state average ratios are 0.88 and 0.89 compared to 0.92 in the 1930s, respectively).

While the Dust Bowl in Oklahoma has received major attention, note that the average precipitation ratios for Kansas and Nebraska during the 1930s were both lower than that in Oklahoma (0.83 and 0.85, respectively, compared to 0.89). Note also for the two post-2000 periods that the four plains states experienced precipitation averages that matched and even exceeded their long-run 1901–2000 averages.

For the eight states in the Mountain division and the three in the Pacific division, both recent multiyear periods have been even drier than during the 1930s.⁷ For these 11 states, all but 1 (Arizona in the 1930s) of the 33 state-level precipitation ratios in Table 7.2 fall below 1.0. Note also that 20 of 22 ratios during the 2000–2006 and 2007–2013 periods were lower than during the 1930s. For these states in the Mountain and Pacific census divisions, the shortfall of annual precipitation below the 100-year average has been larger since 2000 than during the 1930s. The average ratios at the bottom of Table 7.2 reinforce this point. The precipitation shortfall during 2007–2013 averaged 16 percent for both the Mountain and the Pacific states.

ECONOMIC LOSSES AND INSURANCE

Adverse weather-related risks for agricultural producers include drought, flooding, hail, high winds, and winter freezes. Drought is paramount because of its geographic scope, the timing of its onset and duration, and the scale of the potential losses. Drought typically affects multistate areas and, unlike other weather-related disasters, is measured in terms of months and seasons of the year rather than days.

As noted in Chapter 1, agricultural producers face multiple, often simultaneous, sources of weather-related and other risks that result in frequent losses. These marketable risks can be handled through insurance programs to help mitigate the losses associated with them. The federal crop insurance program is discussed in Chapter 3. Recall that participation in the federal crop insurance program is voluntary, and insurance policies only cover losses associated with the unavoidable risks of adverse weather and weather-related plant diseases and insect

infestations. The USDA determines which commodity to insure on a crop-by-crop and county-by-county basis. The Risk Management Agency of the USDA has overall responsibility for supervising the federal crop insurance program, which it administers in partnership with the private sector.

A number of factors make the federal crop insurance program the foundation of financial and risk management plans for many agricultural producers (see Rain and Hail Insurance Society [2015]). First, the program is flexible. The diversity of coverage and product levels provide agricultural producers with the opportunity to obtain the coverage that best fits their own risk-management needs. The agricultural producer selects both the percentage of yield to be covered (that is, 50–75 percent; 85 percent coverage is available for limited crops and in limited counties) and the percentage of the commodity price (55–100 percent). Second, the program is affordable. Because the government shares in the risk and administrative premium costs, agricultural producers can purchase crop insurance at more affordable premium prices. The result is affordable protection for agricultural producers and manageable costs for taxpayers. The third important factor is availability. Private sector delivery provides localized service for agricultural producers who purchase crop insurance from the local agent of their choice. Fourth, crop insurance is predictable. Agricultural producers and their lenders know what their protection is before they plant their crop because the producers pay a significant portion of the cost themselves. In this section, the performance of the federal crop insurance program is examined with regression analysis.

A number of legislative changes have modified the federal crop insurance program since its establishment. Legislative changes were introduced in 1980, 1994, 2000, 2008, and 2014. The Federal Crop Insurance Act of 1980 encouraged participation in the program by authorizing a subsidy for premiums. It also added coverage for additional crops and regions of the country. The Federal Crop Insurance Reform Act of 1994 further expanded program participation by increasing subsidies and made coverage mandatory for certain benefits that were previously offered for free. The Risk Management Agency was created in 1996 to operate and manage the Federal Crop Insurance Corporation and the requirement for mandatory enrollment was lifted. The Agriculture Risk Protection Act of 2000 added \$8.2 billion in new federal spending over

a five-year period, primarily through more generous premium subsidies to help make the program more affordable to agricultural producers. The objective was to enhance participation levels and reduce the need for ad hoc emergency disaster payments. The Food, Conservation, and Energy Act of 2008 modified the legislation to reduce the overall cost and create a permanent disaster assistance program. The most recent modification was with the Agricultural Act of 2014, which covers a greater share of agricultural losses and makes other modifications that broaden policy coverage.

Agricultural crop insurance currently covers more than 80 percent of insurable farmland, and most producers select 70 percent of crop yield to be covered. Note that the federal crop insurance policy is a contract between the insured agricultural producer and the insurance company, not the federal government. For the agricultural producer to receive the federal subsidy attached to the program, the private insurance policy is required to follow federal standards and rates. Because the policy is private, all premiums are owed to and guaranteed by the insurance providers. Table 7.3 summarizes agricultural insurance coverage with emphasis on regional and time series aspects of developments since the mid-1990s.

Columns (1) and (2), respectively, show total farmland acreage and prime acreage in the nine census divisions of the so-called lower 48 states, that is, excluding Alaska and Hawaii. Total farmland acreage is 920.1, just below a billion acres, while prime farm acreage was 271 million in 2002, or 0.295 of total acreage. Column (5) shows prime farmland acreage as a share of total acreage by Census Bureau division. The lowest share is observed in the Mountain division (0.036); below-average shares are also present in the New England and Pacific divisions (both slightly below 0.200). The highest prime farmland share is observed in the states of the East North Central division (0.668), with proportions ranging between 0.332 and 0.405 across four other divisions.

The growth in agricultural insurance coverage is vividly illustrated in columns (3) and (4), which show absolute coverage estimates for 1994 and 2013, and in columns (6) and (7), which show shares of insurable farmland acreage for the same two years. Between 1994 and 2013, insured acreage increased by 2.6 times, from 88.8 to 231.2 million acres, or from 0.327 to 0.855 of prime farmland acreage. Insured acreage grew substantially in all regions, increasing by more than 0.450 in

Table 7.3 Federal Crop Insurance Acreage, 1994 and 2013

Region	Acreage in farms, 2007 (1)	Prime farmland acreage, 2002 (2)	Insured acres, 1994 (3)	Insured acres, 2013 (4)	Prime farmland share, = (2) ÷ (1) (5)	Insured farmland share, 1994 = (3) ÷ (2) (6)	Insured farmland share, 2012 = (4) ÷ (2) (7)
New England	4.0	0.8	0.1	0.6	0.191	0.077	0.788
Middle Atlantic	15.7	5.6	0.3	3.1	0.354	0.048	0.547
South Atlantic	47.1	13.1	3.6	10.9	0.278	0.273	0.829
E. South Central	45.5	18.4	3.7	16.4	0.405	0.200	0.888
W. South Central	187.5	62.3	21.9	50.8	0.332	0.352	0.815
E. North Central	80.7	53.9	11.8	43.5	0.668	0.219	0.807
W. North Central	261.9	99.4	44.3	92.7	0.380	0.445	0.933
Mountain	221.0	7.9	1.4	5.5	0.036	0.181	0.695
Pacific ^a	56.7	10.1	1.8	8.7	0.177	0.182	0.866
United States ^a	920.1	271.5	88.8	232.1	0.295	0.327	0.855

^aExcludes Alaska and Hawaii.

SOURCE: Data in columns (1)–(4) from USDA. Acreage in millions. Columns (5)–(7) derived from columns (1)–(4).

all nine Census Bureau divisions and by more than 0.680 in the New England, East South Central, and Pacific divisions. By 2013 more than 65 percent of prime farmland acreage was insured in eight of nine Census Bureau divisions (all but the Middle Atlantic division). Nationwide more than 80 percent of prime farmland acreage was insured.

The loss protection provided by federal crop insurance has also increased substantially. Three factors have contributed to the increase in insurance indemnity payments to agricultural producers. The first is increased insurance coverage, as illustrated in Table 7.3. The second factor is the increase in the crop loss replacement rate. Glauber (2012) notes that in 1998 only 9 percent of insured acres were enrolled at coverage levels above 70 percent of loss replacement, whereas 70 percent of insured acres were enrolled at loss replacement levels above 70 percent in 2011. Recall that the Agriculture Risk Protection Act of 2000 added \$8.2 billion in new federal spending over a five-year period to the program primarily through more generous premium subsidies. Thus, the legislation encouraged the increase in loss replacement and raised the subsidy levels for buy-up policies, which provided insurance protection against decreases in crop prices.

The third factor that has contributed to the increase in crop insurance protection is a substantial increase in the market prices of most major crops. During 2010–2013, for example, the average price received by farmers for crops was 94 percent higher than the average price during 1990–1993. For the same period the total GDP deflator increased by 49 percent, or about half the increase in crop prices.⁸ Illustrative of the growth in crop insurance protection, total program liabilities grew from \$13.6 billion in 1994 to \$123.6 billion in 2013 (Rain and Hail Insurance Society 2015, p. 4). This ninefold increase in potential liabilities provides a vivid indication of recent growth in crop insurance protection.

While the scope of federal crop insurance has expanded in the past 20 years, agricultural producers have continued to receive substantial disaster assistance payments to compensate for crop losses. Glauber (2012, p. 484) estimates that disaster-related costs were nearly \$10.0 billion during the nine fiscal years from 2001 to 2009. Table 7.4 provides a summary of the experience with federal crop insurance between 1990 and 2013. The data were mainly derived from the survey article by Glauber (2012, Table 2), but updated with data from the Rain and Hail Insurance Society (2015).

Table 7.4 Federal Crop Insurance Financial Flows, 1990–2013 (\$ billions)

	Indemnity payments (1)	Crop loss insurance premiums			Farmer net indemnity = (1) – (3) (5)	Administrative costs (6)	Total insurance outlays = (5) + (6) (7)
		Total = (3) + (4) (2)	Farmer-paid (3)	Government subsidy (4)			
1990–1993	4,563	3,088	2,285	803	2,278	1,020	3,299
1994–1997	4,656	6,106	3,076	3,030	1,578	2,402	3,980
1998–2001	9,668	9,688	4,623	5,065	5,044	3,719	8,763
2002–2005	12,905	14,482	5,878	8,604	7,026	5,071	12,097
2006–2009	20,960	29,944	12,321	17,623	8,639	11,703	20,342
2010–2013	44,202	42,435	16,019	26,416	28,183	13,834	42,017
1990–2013	96,954	105,745	44,202	61,541	52,748	37,749	90,498

SOURCE: Glauber (2012, Table 2) and Rain and Hail Insurance Society (2015). The authors estimate administrative costs in 2012 and 2013.

The data are arranged into six four-year periods between 1990 and 2013. One striking feature of Table 7.4 is the growth of indemnity payments to agricultural producers, increasing from \$4.563 billion during 1990–1993 to \$44.202 billion during 2010–2013. Indemnity payments across the 24 years totaled \$96.95 billion. As a percent of agricultural GDP, indemnity payments increased from 1.5 percent in 1990–1993 to 6.8 percent in 2010–2013.

Columns (2)–(4) provide details of the insurance premiums that support the federal crop insurance program. Of the total \$105.7 billion, agricultural producers paid \$44.2 billion, while \$61.5 billion (58 percent) was covered by government subsidies. The table also shows that government subsidies have grown relative to premiums paid by agricultural producers. Government subsidies represented only 26 percent of premiums during 1990–1993 but 62 percent during 2010–2013. The final three columns of Table 7.4 provide other financial details of federal crop insurance. The net farmer indemnity (indemnity payments less farmer premium payments) totaled \$52.7 billion during these 24 years. Total administrative costs incurred by the insurance carriers were \$37.3 billion, or 39 percent of indemnity payments. Total insurance costs (farmer net indemnity payments plus administrative costs, shown in column [7]), totaled \$90.5 billion. Note also that total insurance costs increased sharply during 2010–2013, driven mainly by the large increase in indemnity payments. The presence of serious drought conditions affecting many farming areas during 2010–2013 significantly contributed to the increase in payments.

Further regression analysis examined the association between drought and crop insurance indemnification from 1990 to 2013. Recall that the NOAA data record 22 droughts that resulted in billion-dollar losses between 1980 and 2013. Five droughts occurred between 1980 and 1989, and 17 after 1990. The results show that crop indemnification payments are closely linked to agricultural output.⁹ Between 1990 and 2013, each \$1.00 of agricultural output was associated with about \$0.10 of indemnification. Also, crop loss indemnification has increased substantially relative to crop losses in recent years. Aggregate crop insurance payments have definitely added to the financial security of U.S. crop farmers. Between 1990 and 2013, crop insurance payments became much more important in stabilizing farm income.

CONCLUSIONS

The severity of drought is closely related to both annual temperature and precipitation. Annual precipitation, however, has a more important effect in explaining year-to-year variation. The increase in global temperatures can significantly increase the probability of heavy precipitation and high heat extremes throughout the world. The results of our analysis in Chapter 2 show that there is a statistically significant association between major disaster declarations and increasing temperatures and precipitation in the United States. The increase in the occurrence of adverse weather-related events requires ever-increasing taxpayer dollars to finance the agencies responsible for improving our capability to mitigate them.

From the nine billion-dollar drought-related episodes with state-level detail explored in this chapter, it is clear that drought was experienced more frequently by states in the interior of the United States and less frequently by states along the coasts. Hence, economic losses from drought have not been randomly distributed across the individual states.

The federal crop insurance program is an example of a proactive measure undertaken by private and public stakeholders working together for effective prevention. As Chapter 3 illustrates, private delivery of federal assistance is not unprecedented, as other federal programs are structured in similar ways. The federal crop insurance program is unique in that private companies use a federally designed insurance policy to enter into a private contract with agricultural producers. Both the federal government and the insurance providers share in the underwriting performance of the contract. The USDA provides easily accessible information about the likely risks of adverse-weather hazards on a crop-by-crop and county-by-county basis. Agricultural producers translate the information into risk-related commodity valuations. The crop insurance market guides agricultural producers and their decisions about which prevention measures to take, and the institutional framework of the federal crop insurance program ensures public involvement and oversight that facilitates collective action.

Our regression analysis of the federal crop insurance program does not cover the most recent modification, the Agricultural Act of 2014. The legislation expands the scope of the program by covering a greater

share of agricultural losses, and makes other modifications that broaden policy coverage. It makes major changes to commodity programs, adds new crop insurance options, and expands programs for specialty crops, organic farmers, bioenergy, and rural development. Based on our results of the program between 1990 and 2013, which showed that federal crop insurance has become more important in stabilizing farm income, the most recent legislation is expected to be even more significant.

Forecasting, early warning, and compensatory measures such as insurance are critical elements of drought risk management. To address the underlying factors of drought risk, however, private and public stakeholders need to consider other policies, particularly land planning and water management.

Notes

1. In recent years, concern has grown worldwide that drought may be increasing in frequency due to climate change. See World Meteorological Organization (n.d.).
2. The data are from the NCDC.
3. Data are not available for Alaska, D.C., and Hawaii for the full 1950–2012 period.
4. The individual state-level regression results are available from the authors.
5. The nine years are 1991, 1998, 2005, 2006, 2007, 2009, 2011, 2012, and 2013.
6. This analysis emphasizes annual precipitation for multiyear periods. Similar results are obtained when either of the drought indices (PDSI or PHDI) is examined.
7. The two exceptions are Montana during 2007–2013 and California during 2000–2006.
8. The GDP deflator is a measure of the aggregate price level. Price changes in the current year are compared to those in a base year for all goods and services produced within the economy. The rate of change in the GDP deflator is the most comprehensive measure of inflation.
9. The regression results are available from the authors. While it would be preferable to examine indemnity payments relative to crop output, removing such elements as livestock production in agricultural GDP, the available data in the National Income and Product Accounts do not provide such a breakdown.

8

Wildfires

The National Interagency Fire Center (NIFC) defines a wildfire as the unplanned ignition of a wildland fire (caused by lightning, volcanoes, or unauthorized or accidental human-caused fires) and escaped prescribed fires.¹ As of September 2015, wildfires had burned 9.0 million acres nationwide, far above the 2003–2012 annual average of 6.2 million acres. At that time, above-normal temperatures and below-normal precipitation in the Northwest, accompanied by the long-term drought in Southern California, led to above-normal fire potential throughout the region.

Wildfires have always been an integral and natural part of forest ecosystems. Two main factors, however, are changing these ecosystems. First, climate change is contributing to an increased risk of wildfires in the United States. The most recent national climate assessment conducted by the U.S. Global Change Research Program (Joyce et al. 2014) concludes that large and intense fires will occur more frequently due to climate change and increasingly affect western forests in the United States. As global temperatures rise, there is an increased likelihood that wildfires will not only be more frequent but also more severe (see Joyce et al. [2014]). Moreover, climatic conditions are changing the scale of wildfires and the length of the fire season. Second, human development is intensifying in wildfire-prone areas. As more people build homes in and near wildfire-prone areas, individuals and families are exposed to greater risks from wildfires. As a result, fire suppression and recovery costs increase.

The first section of this chapter presents an overview of wildfires using statistical information. Information on the incidence and frequency of wildfires can help stakeholders assess the risk from wildfires and further a discussion of the mitigation practices landowners can use. The second section examines the direct costs of wildfires. Fire management expenditures include the costs associated with preparedness ahead of the fire season, suppression or firefighting during the fire season, measures to reduce vegetation fuel (either through removal or prescribed

burns), and postfire rehabilitation. The frequency of large wildfires is examined in the third section, and geographic patterns are discussed. The fourth section considers wildfire management in the federal budget. The final section provides concluding comments. Information on the costs of wildfires, particularly the frequency of large wildfires, can help shape the organization of fire suppression in the federal government, as well as state and federal funding for wildland fire management.

STATISTICS ON WILDFIRES

According to statistics published by the NIFC, which began in 1960, more than 60,000 wildfires occur in the United States each year. More than 3.0 million acres have burned every year since 1999, and the acreage burned each year is increasing. Wildland acreage nationwide has been relatively constant since 1910: it decreases whenever population growth expands urban development and increases whenever former farmland reverts to wildland.² Although the annual number of wildfires has not been increasing in recent years, the acres burned per fire have been trending upward strongly since about 1990.

Annual NIFC data show that the United States experienced 5.6 million wildfires between 1960 and 2013.³ During these 54 years, the burned area totaled 235.8 million acres, or 362,849 square miles. The cumulative acreage burned between 1960 and 2013 is 9.6 percent of the total land area of the nation (3.8 million square miles).

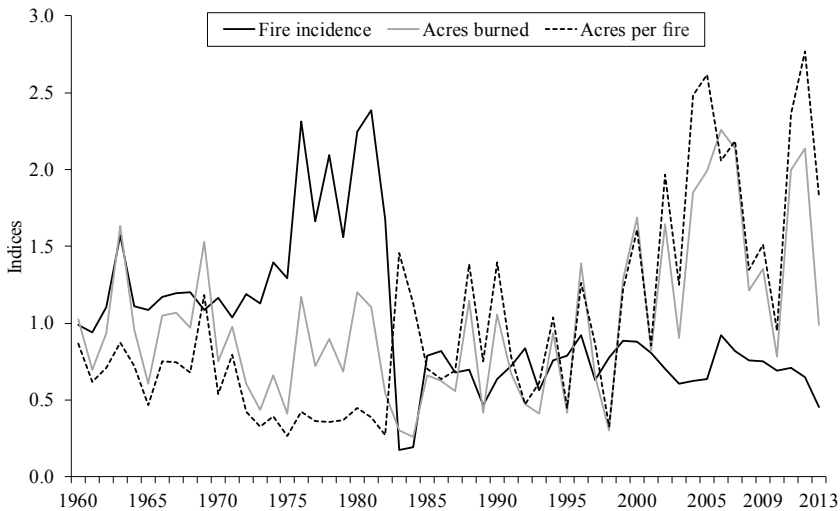
Each year fires are deliberately set by the various agencies responsible for forest and wildfire management. Federal and state agencies work together through the National Cohesive Wildland Fire Management Strategy. The main federal agencies are the USDA, specifically the Forest Service, and the U.S. Department of the Interior (DOI).⁴ On nonfederal lands, states also manage forests and fight wildfires together with county and local jurisdictions.⁵ While state foresters are responsible for managing wildfires, they pay for only a modest share of fire-fighting costs.

The primary cause of nonprescribed wildfires is human activity: leaving campfires unattended, burning debris, negligently discarding cigarettes, and arson (see Theobald and Romme [2007]). The main

natural cause of wildfires is lightning: between 2002 and 2012, it was responsible for 14 percent of the 823,032 wildfires. Lightning-caused fires, however, are much larger on average than nonlightning fires; they are responsible for 62 percent of total acres burned during the same 11 years.⁶ Prescribed fires (also called controlled burns) that escape their boundaries constitute 18 percent of all wildfires in the United States and 25 percent of acres burned from 2002 to 2012.⁷

Figure 8.1 displays data from 1960 to 2013 for three indices: the incidence of wildfires, total acres burned, and the average acreage per fire.⁸ Each series shows the ratio of annual data to its respective 1960–2013 average. Three important trends are evident over these 54 years. First, the incidence of wildfires has not increased over time. In fact, it is lower from the mid-1980s through 2013 than from the 1960s through the mid-1980s. The index of fire incidence has been below 1.00 since 1983, while all but two pre-1983 indices exceed 1.00. Wildfire occurrences were especially numerous between 1976 and 1982. Second, both total acres burned and average acres per fire have increased since the early to mid-1990s. Recently the indices for both measures have often

Figure 8.1 Indices of Wildfires, 1960–2013



SOURCE: NIFC data.

exceeded 2.00; that is, twice the 54-year average. Third, the annual data for all three series vary sharply year to year. The coefficient of variation for each series is approximately 0.50 or larger, indicating a high degree of variability from one year to the next.⁹

The underlying trends become more obvious when multiyear averages are calculated.¹⁰ Using a regression analysis with an equation that introduces a linear trend starting in 1990, we find that the pre-1990 average acreage per wildland fire was 32.8 acres. The 1990-trend coefficient for the regression is 3.162; that is, an increase of 3.162 acres per fire a year. Based on this linear trend, the projected acreage per wildfire increased from 32.2 acres in 1989 to 108.1 acres in 2013, or more than three times the 1989 level. This single explanatory variable (the 1990 trend) explains more than half the variation in average acreage per wildfire from 1960 to 2013. The implications for societal costs and other consequences of fires are clear.

Wildfires display an obvious geographic pattern. Most occur west of the Mississippi River in states with low annual rainfall. On average, these states are larger than their eastern counterparts, accounting for approximately 75 percent of the nation's land area. From 2002 to 2013, 55 percent of wildfires occurred in western states, but those fires accounted for 93 percent of the acres burned. Table 8.1 summarizes the distribution of wildfires by U.S. Census Bureau divisions during 2002–2013. The six data columns show, respectively, for each division its land area, the number of fires, acres burned, average acreage per fire, and average annual precipitation (from 1951 to 2000).

Chapter 1 notes that we use the classification of the U.S. Census Bureau in our presentation of geographic patterns throughout the book. The United States is divided into four regions: Northeast, Midwest, West, and South. Each of the four census regions is divided into two or more census divisions. The former three regions have two census divisions while the South region has three. The two divisions in the Northeast region are the New England division and the Middle Atlantic division; the East North Central division and the West North Central division form the Midwest region; and the two divisions in the West region are the Mountain division and the Pacific division. The South Atlantic division, the East South Central division and the West South Central division comprise the South region.

Table 8.1 Wildfires by Census Bureau Division, 2002–2013

Census Bureau division	Land area, square miles (000s) (1)	Number of fires (2)	Fires per 1,000 square miles (3)	Total area burned, square miles (000s) (4)	Average acres per fire (5)	Annual precipitation (inches) (6)
New England	72	36,548	0.512	42.1	1.15	42.88
Middle Atlantic	109	23,468	0.215	113.7	4.84	41.22
South Atlantic	293	209,259	0.714	4,154.0	19.85	49.07
East South Central	183	84,146	0.459	1,515.5	18.01	53.60
West South Central	444	130,043	0.293	9,740.4	74.90	34.87
East North Central	301	38,022	0.126	227.6	5.99	35.19
West North Central	520	67,356	0.129	3,172.9	47.11	26.67
Mountain	864	133,256	0.154	30,781.0	230.99	13.66
Pacific	1,009	143,044	0.142	34,370.9	240.28	25.95
United States	3,796	865,142	0.228	84,118.1	97.23	28.91

NOTE: Annual precipitation is from 1951 to 2000. Divisional precipitation averages are based on the statewide average weighted by the land area of the state

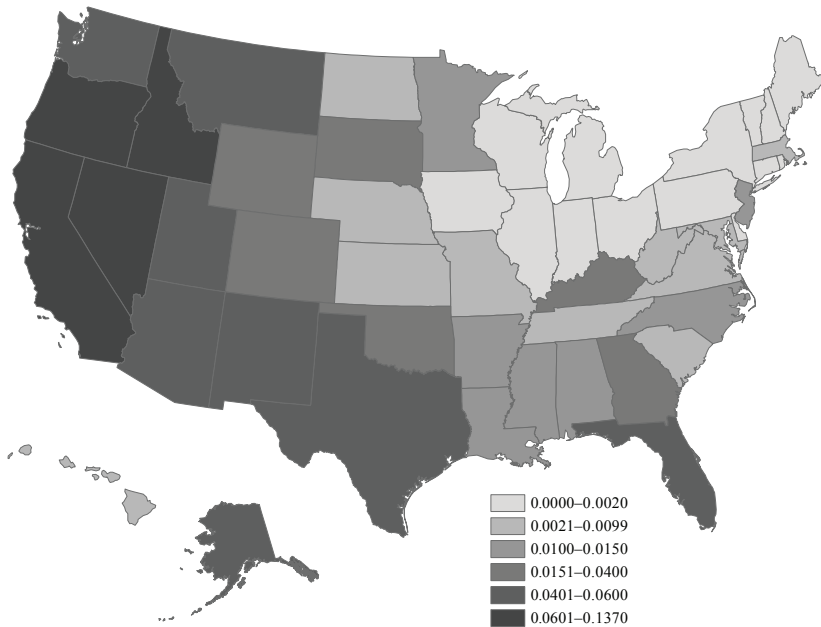
SOURCE: Land area from the Census Bureau; number of wildfires and acres burned from the NIFC; annual precipitation from NOAA.

In addition to expected relationships, Table 8.1 displays some unexpected patterns. For example, the four western Census Bureau divisions have the largest land areas: the West South Central, West North Central, Mountain, and Pacific divisions each exceed 400,000 square miles. The largest number of wildfires (209,259), however, occurs in the South Atlantic division, which has a fire incidence rate of 0.714 per 1,000 square miles, approximately three times the national average of 0.228 per 1,000 square miles. Especially high fire incidence rates occurred in four of the five largest states of this division (Florida, Georgia, North Carolina, and South Carolina), all 0.50 per 1,000 square miles.¹¹ In contrast, both North Central divisions and the Mountain and Pacific divisions have average occurrence rates between 0.126 and 0.154.¹²

Furthermore, precipitation among the South Atlantic states averages nearly 50 inches a year, the second highest divisional average and 70 percent above the national average. This observation raises questions about why a geographic area with so much rainfall has such a high wildfire incidence rate.

Wildfire severity, as gauged by the average acres burned per fire, shows an expected association with precipitation. Mountain division states have the second-highest average acres burned per fire (231) and the lowest annual rainfall (14 inches, less than half the national average). In contrast, the four divisions where the average annual rainfall is above 40 inches all have an average acreage of 20 or fewer acres burned per wildfire. In a simple cross-section regression analysis, the association between average acreage burned per fire (during 2002–2013 for the 48 contiguous states) and annual precipitation is negative and statistically significant.¹³ At the state level, however, the results are more varied: only about half the interstate variation is associated with differences in annual rainfall.

Figure 8.2 vividly illustrates the geographic variability of wildfires. Between 2002 and 2013, total acreage burned by wildfires represented 3.5 percent of the total acreage of the 50 states plus D.C. In 26 states, the acreage burned was less than 1 percent of total acreage; 20 of these 26 states were east of the Mississippi River. Acreage burned in eastern states exceeded 1.5 percent of total acreage in just Kentucky, Georgia, and Florida. In contrast, all 4 states where burned acreage was above 6.0 percent, and 11 of the 12 states where burned acreage was above 4.0 percent were western states.

Figure 8.2 Share of State Area Burned by Wildfires, 2002–2013

SOURCE: NIFC data on acres burned by state, 2002–2013 measured as a proportion of total state acreage.

THE DIRECT COSTS OF WILDFIRES

The many wildfires and the acreage they burn entail substantial costs. In fire management expenditures, Bracmort (2013) include the costs associated with preparedness ahead of the fire season, suppression or firefighting during the fire season, measures to reduce vegetation fuel (either through removal or prescribed burns), and postfire rehabilitation.

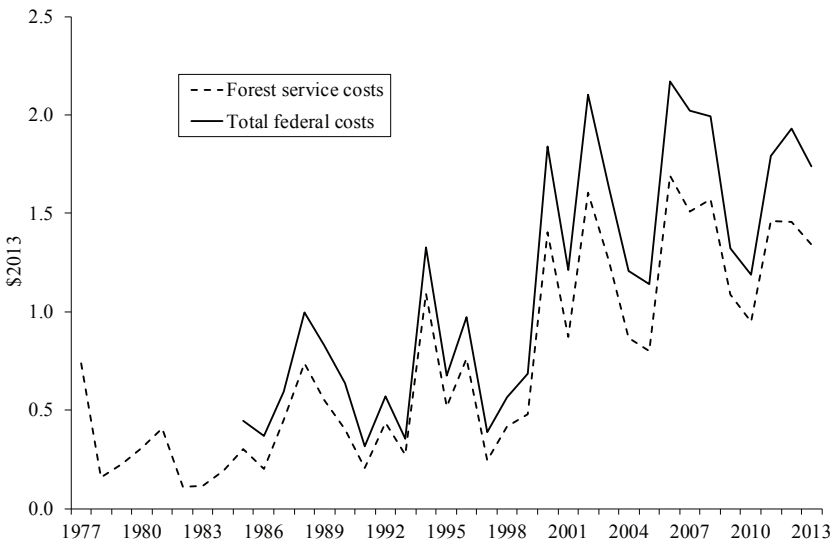
The NIFC has published estimates of annual fire suppression costs incurred by federal agencies since 1985. Federal fire suppression costs averaged \$371 million a year during 1985–1989 but \$1,548 million a year during 2009–2013. Of the total federal costs in 2013, the Forest Service was responsible for almost 77 percent; the DOI was responsible

for the remaining 23 percent. Most of the fourfold increase in cost was the result of increased acreage burned and inflation. The real cost per acre in prices of 2009 purchasing power increased 17 percent, from \$222 in 1985–1989 to \$260 in 2009–2013. Though federal firefighting costs have increased, the increase in real terms is mainly the result of an increase in acreage burned since the late 1980s.

Figure 8.3 summarizes the annual costs of fire suppression for the two lead federal agencies in real terms. Fire suppression costs for the Forest Service are displayed from 1977, while the total costs for the Forest Service and DOI are shown from 1985. Two patterns are obvious: the large increase in fire suppression costs since 2000 and the wide year-to-year variability. Note also that total federal costs exceeded \$1.5 billion in 9 of the 14 years since 2000 but not once in the years before 2000.

A second component of total firefighting costs is expenditure incurred by state agencies. These costs are less easily estimated because of the large number of state and local agencies with wildfire suppression responsibilities. A recent analysis by the Union of Concerned Scientists,

Figure 8.3 Federal Fire Suppression Costs, 1977–2013 (billions of 2013 dollars)



SOURCE: NIFC and Bracmort (2013, Figure 2).

however, shows that state spending on fire management nearly matched federal spending on fire suppression in 1998, 2002, 2004, 2006, and 2008 (the five years covered in our analysis).¹⁴ Because assembling state-level data is a major undertaking, it is not obvious how state spending compares to federal spending over the long run. Also, since the states receive substantial reimbursements from the federal partner for firefighting costs, estimating net state-financed firefighting costs are challenging. The federal share of total fire suppression costs exceeds 50 percent, but it may or may not reach 60 percent.

THE FREQUENCY OF LARGE WILDFIRES

While there is no universal definition of what constitutes a large wildfire, at least three data series could be useful: one from FEMA and two from the NIFC. Chapter 1 notes that FEMA makes fire management assistance declarations after a state submits a request because a single fire (or a group of fires) is large enough to pose a “threat of major disaster.” The agency responds to these requests expeditiously; a decision is often rendered within hours of the appeal. The Fire Management Assistance Grant Program provides a federal cost-share of 75 percent of the allowable costs of firefighting. Allowable costs include the costs of field camps; equipment use, repair and replacement; tools, materials, and supplies; and mobilization and demobilization activities.

The FEMA data on fire management assistance declarations commenced in 1970. Between 1970 and 2013, FEMA made 1,049 fire management assistance declarations. These declarations fall into two broad periods. Between 1970 and 1993, FEMA consistently made fewer than 10 declarations a year. Starting in 1994, the agency averaged 48 declarations a year. These declarations refer to major fire events that involve large costs of suppression and other factors, such as the value of lost timber and crops. The agency does not, however, estimate the total costs of its fire-related declarations.

On occasion, a wildfire grows and becomes large enough for FEMA to make a major disaster declaration. Between 1970 and 2013, FEMA declared 35 wildfires as major disasters. In addition, FEMA classified 15 wildfires as emergency declarations, which are smaller than major

disasters but of sufficient scale that states are reimbursed for certain fire suppression costs. These declarations can be considered large fires. Note that the 1,099 FEMA declarations between 1970 and 2013 represent 0.025 percent of the 4,443,165 wildfires reported by NIFC over the same period.

Two measures of large wildfires are available from NIFC data. Between 1950 and 2013, there were 52 “historically significant wildland fires;” only 4 occurred before 1970. Among historically significant fires, 9 resulted in major disaster declarations and 15 as fire management assistance declarations by FEMA. The NIFC also identified 154 wildfires since 1997 that burned 100,000 or more acres. Of that group, 58 had burned more than 200,000 acres.

The three groupings of large fires show similar patterns in both their timing and their geographic locus. Table 8.2 reinforces points made earlier, but now with specific reference to *large* wildfires as recorded by both FEMA and the NIFC for the years from 1970–2013. Two patterns, both discussed earlier, are obvious in Table 8.2. First, large wildfires became more frequent after 1989. There were from three to six times as many large wildfires during 1990–1999 than during 1980–1989. In addition, there were more large wildfires from 2010 to 2013 than during the 1970s and 1980s combined. More than likely, drought conditions will only add to the frequency of wildfires and increase the associated costs of fire suppression and recovery. Second, wildfires are mainly a western phenomenon; the incidence of large fires is higher in both the Mountain and Pacific divisions. This pattern is related to the low precipitation received by sizable areas of the states in these divisions, increasing the risk of large acreage burned per fire.

As noted in the introduction, more people have built or are building homes in and near wildfire-prone areas. As a consequence, they are exposed to higher risks from fires and greater recovery costs. Radeloff et al. (2005) and Theobald and Romme (2007) find that, in the past 50 years, development near wildland areas has expanded significantly. Population growth, housing preferences, and the increasing number of vacation homes are contributing to these development trends. The intersection of wildlands and urban environments is known as the wildland-urban interface (WUI). According to Botts et al. (2013), in 2008 approximately 40 percent of the 115 million single-family homes in the United States were in the WUI. Housing development in and

Table 8.2 Geographic Locus of Large Fires by Decade and Area, 1970–2013

	Fire management assistance and other declarations	Historically significant wildland fires	Wildland fires that burned 100,000 or more acres
Large fires by decade			
1970–1979	41	4	n/a
1980–1989	38	5	n/a
1990–1999	231	16	n/a
2000–2009	571	11	103
2010–2013	218	12	40
Large fires by Census Bureau division			
East	115	4	5
West North Central	38	2	1
West South Central	332	2	12
Mountain	310	25	59
Pacific	304	15	66

NOTE: n/a = not available.

SOURCE: Fire management assistance and other declarations data from FEMA; other data from the NIFC.

near wildfire-prone forested areas raises the exposure to both the risks of wildfires and their costs, and it requires spending more resources on fire suppression.

Theobald and Romme (2007) assert that nearly 90 percent of the developed areas located in or near forests are privately owned, and nearly two-thirds of this land area is at high risk for wildfires. Development in and near the WUI has increased the costs for federal agencies that help provide financial and technical assistance to state and local agencies for wildfire protection.

The costs associated with wildfires are substantial. Two main factors affect these costs: the size of a wildfire and how much private property is damaged. Direct fire suppression costs, however, significantly underestimate the total costs of a wildfire. Other fire-related costs, such as presuppression costs, disaster relief expenditures, timber losses, tourism-related losses, human health effects, and damage to ecosystems can greatly exceed the direct costs of fire suppression. Butry et al.

(2001) find that in some cases these other categories of costs may not be fully evident until years after the suppression of a fire.

Wildfire protection efforts are weighted toward fire suppression, which take up a major share of agency budgets. While the protection of natural resources and property is important, the overarching priority in wildfire management is human safety. According to the Office of the Inspector General (2006, p. ii), an audit of Forest Service expenditures found that the majority of the costs of putting out large fires are “directly linked to protecting private property in the WUI.” Moreover, one response to the worsening wildfire situation has been a shift of financial resources from investment in long-term forest management and forest health that would lower the risk of future wildfires to fire suppression. With the cost of fire suppression often exceeding actual budget allocations in the severe wildfire seasons of recent years, the Forest Service has borrowed from nonsuppression or even nonfire management budget lines (see Tidwell [2013]). In addition, budget constraints have delayed the acquisition of lands for conservation purposes and reduced the expenditure on other maintenance programs. The reallocation of resources to fire suppression activities from other intended uses is commonly termed “fire borrowing.”

Another response to the worsening wildfire situation has been an increased reliance on supplemental emergency appropriations from Congress. Cleetus and Mulik (2014) report that in 2012 and 2013 the Obama administration removed more than \$1.0 billion from other program accounts and transferred the funds to fire suppression. Recent legislative proposals, as well as the administration’s 2014 budget, would change the way federal wildfire costs are funded and create a separate emergency fund dedicated to fire suppression. In 2013, Senators Ron Wyden and Mike Crapo proposed legislation to increase funding for fire suppression (S. 1875, or the Wildfire Disaster Funding Act of 2013) and Senators John McCain, John Barrasso, and Jeff Flake proposed similar legislation in 2014 (S. 2593, the FLAME Act Amendments of 2014). In an environment of tight budgets, however, rising wildfire costs will continue to pose a major fiscal challenge.

WILDFIRE MANAGEMENT IN THE FEDERAL BUDGET

Table 8.3 summarizes federal appropriations for wildfire management spanning fiscal years 2008 to 2013. The table divides activities into five subaccounts. The data are derived from a relatively recent report by Bracmort (2013) that separates the details for both Forest Service and DOI wildfire activities. The subaccounts for preparedness and hazardous fuels encompass various activities designed to prevent and limit the scope of wildfires, such as firefighter training, equipment acquisition, reducing fuel loads in fire-prone areas, and rehabilitation of fire-damaged areas. Their combined appropriations exceeded that for the suppression subaccount (\$9.436 billion versus \$6.860 billion) over the six years examined. Emergency and other ad hoc budget increments for fire suppression during these years, however, totaled fully half of the original amounts budgeted for suppression costs.

“Fire borrowing” transfers financial resources from the preparedness and hazardous fuels subaccounts for use in fire suppression. This practice effectively reduces activities related to forest management, forest restoration, and land acquisition. Both the 2013 Wyden-Crapo proposal (S. 1875) and the 2014 McCain-Barrasso-Flake proposal (S. 2593) would provide explicit and enhanced funds for fire suppression,

Table 8.3 Federal Wildfire Management Appropriations, Fiscal Years 2008–2013

	Total appropriation (\$ billions)	Budget shares
Preparedness	6.394	0.308
Hazardous fuels	3.043	0.147
Suppression	6.860	0.033
Emergency and other suppression costs ^a	3.453	0.166
All other costs	1.009	0.049
Total	20.759	1.000

^aEmergency appropriations and Federal Land Assistance, Management and Enhancement (FLAME) Wildfire Suppression Reserve Fund appropriations net of recessions and use of prior year funds.

SOURCE: Bracmort (2013, Table 5).

protect the other subaccounts, and end fire borrowing. Neither bill has been enacted.

CONCLUSIONS

Private local development complicates decisions about how to manage our wildland in many ways. Urban development not only eliminates some trees and forests, but it also increases population density, human activities, and urban infrastructure. State and local zoning policies continue to allow development in the WUI. The fact that most of the firefighting costs are borne by the federal government, while local authorities and developers decide where and how much to build in wildfire-prone areas, creates a misalignment of incentives. Indeed, local zoning policies may encourage development in high-risk areas, reduce the incentive for homeowners to fireproof their homes and properties, increase firefighting costs, and exacerbate the physical risk to firefighters. As a result, federal taxpayer funds are not being used effectively to manage wildlands and build resilience to wildfires because they are heavily directed at fire suppression.

Risk is defined as the probability of an adverse event (or hazard) occurring that causes physical harm or financial losses. In the context of wildfires, risk is increasing in part because of changing climatic conditions. The risk is compounded by a moral hazard problem: local decision makers (governments and homeowners) may make choices that result in a greater exposure to risk because they do not pay the full costs of those choices. For example, decisions to permit development in wildfire-prone areas are made by local zoning authorities. This development, however, can result in greater firefighting costs, most of which are paid by federal taxpayers.

A key element in reducing threats to the WUI and restoring fire to its natural role in the environment is community education and involvement. Mitigating the risks from wildfires requires a combination of active measures, which include actions that reduce the risk itself (such as limiting the chances of wildfire damage through fuels management and fireproofing measures in homes and communities), limit exposure to risk (such as limiting development in wildfire-prone areas and buy-

ing insurance protection), and provide financial resources to help people recover from fires (such as disaster assistance or insurance payouts).

Homeowners share responsibility for protecting themselves and their property. In many states, however, this responsibility is voluntary and not enforced by statewide law or insurance company practices. California is one of the few states with strict statewide building codes and fire codes that apply to communities in wildfire-prone areas.

Why encourage mitigation in building regulations? Adherence to model building codes can mean the difference between life and death or whether homes remain standing or are completely destroyed by fire. The evidence that mitigation can save lives and reduce costs is more than anecdotal. Model building codes can offer enhanced protection against the threats of disasters to make communities more resilient, sustainable, and livable for generations to come (see Vaughan and Turner [2013]). Such codes lower the price of mitigation for building owners. Other states, particularly western states, should follow California's lead.

Notes

1. A wildland is defined as land that is not cultivated or not suitable for cultivation. Wildlands include forests, shrublands, grasslands, and other types of natural ecosystems. A prescribed fire is a wildland fire originating from a planned ignition to meet the objectives specified in a preapproved, written prescribed fire plan.
2. Forest area has been relatively stable since 1910, although the population has more than tripled since then. See Oswalt and Smith (2014).
3. "Total Wildland Fires and Acres" (1960–2015) https://www.nifc.gov/fireInfo/fireInfo_stats_totalFires.html (accessed July 20, 2016).
4. To be specific, five federal agencies manage and have primary fire program responsibilities: 1) the Bureau of Land Management, 2) the National Park Service, 3) the U.S. Fish and Wildlife Service, 4) the Bureau of Indian Affairs in the U.S. Department of the Interior; and 5) the Forest Service in the USDA.
5. The U.S. Fire Administration works with county and local fire departments; the National Association of State Foresters represents the states. The state, county, and local jurisdictions provide primary fire protection on nonfederal public and private lands across all 50 states.
6. The NIFC recently changed its nomenclature; what was previously termed *human-caused fires* is now *nonlightning* fires.
7. Statistical information on prescribed fires in the United States has only been published since 2002 by the NIFC.
8. The National Interagency Coordination Center at the NIFC compiles annual wild-

land fire statistics for federal and state agencies. As the statistics before 1983 were not derived from the current reporting process, information before 1983 should not be compared to subsequent data.

9. The coefficient of variation is the ratio of the standard deviation to the mean.
10. For example, acres per fire averaged 39.8 during 1980–1989 but 96.6 during 2002–2013.
11. The states in the South Atlantic Division are Delaware, D.C., Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, and West Virginia.
12. The states in the East North Central division are Illinois, Indiana, Michigan, Ohio, and Wisconsin; in the West North Central division are Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, and South Dakota. The states in the Mountain division are Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, and Wyoming; and the Pacific division are Alaska, California, Hawaii, Oregon, and Washington.
13. Alaska, D.C., and Hawaii were not included in the analysis due to lack of long-term average precipitation data.
14. Expressed in 2013 dollars, state spending totaled \$7.7 billion while federal spending totaled \$8.0 billion. See Cleetus and Mulik (2014, Figure 7).

9

Geological and Man-Made Disasters

The two least common categories of disaster-related declarations used by FEMA are geological and man-made. This classification is somewhat different from the terminology used by the UNISDR, which aims to promote common usage of disaster risk reduction concepts in order to assist in the disaster risk reduction efforts of stakeholders. Both FEMA and the UNISDR classify geological processes or phenomena in the same way; they include internal earth processes, such as earthquakes, volcanic activity, and emissions, and related geophysical processes, such as landslides, rockslides, and surface collapses. Instead of *man-made*, the UNISDR uses *technological*; that is, a disaster originating from technological or industrial conditions, including accidents, dangerous procedures, infrastructure failures, or specific human activities. Examples of technological hazards include chemical spills, dam failures, fires, factory explosions, industrial pollution, nuclear radiation, transport accidents, and toxic wastes.

Under man-made disasters, FEMA lists chemical/biological, dam/levee breaks, explosions, radiation leaks, technological, terrorism, and virus threats. Nationwide, there were 38 geological and 22 man-made major disasters between 1953 and 2014. Combined, they averaged about one occurrence each year during these six decades. Humans cannot usually predict geological disasters, but man-made disasters can be avoided and prevented.

While geological and man-made disasters have been infrequent, the associated DUA weeks compensated for three of them ranked in the top 15 of the disasters that occurred between 1983 and 2014. As noted in Chapter 3, information on DUA only commences in 1983. One of these three top-ranked events was the civil unrest that erupted on April 29, 1992, in Los Angeles. This event is classified by FEMA as *California Fire During a Period of Civil Unrest* (DR-942), with an incident period from April 29, 1992, to May 28, 1992. The major disaster declaration was made on May 2, 1992. Fifty-two people lost their lives when violent mobs stormed through the city of Los Angeles. When the rioting

was over, approximately 2,500 people were injured and an estimated \$1.0 billion in property was damaged.¹

The second event was the *California Northridge Earthquake* (DR-1008). The incident period was January 17, 1994, to November 30, 1994, with the major disaster declaration made on January 17, 1994. The third event was the *New York Terrorist Attack* (DR-1391). The incident period was September 11, 2001, with a major disaster declared the same day.

This chapter begins by considering the 38 major disasters based on three geological hazards between 1953 and 2014: earthquakes, volcanic eruptions, and tsunamis. The focus of the discussion is on these specific geological hazards and does not consider the related geophysical processes, which would include disasters associated with landslides, mudslides, meteorology, and oceanography. The second section examines the 22 man-made major disasters between 1953 and 2014. The economic losses associated with these disasters are outlined in this section together with the weeks compensated under the DUA program. Generally, nearly all the man-made disasters have resulted in modest financial losses compared to catastrophic natural disasters. The third section examines the role of private insurance in covering geological risk. In California, for example, about 20 private insurance carriers sell and service earthquake insurance policies. Similarly, the provision of insurance against man-made risks has remained within the domain of private insurance, discussed in the fourth section of the chapter. In contrast, terrorism insurance arrangements since the September 11, 2001, attacks have seen the addition of a major element of government participation. The chapter then looks at the provision of terrorism insurance and the legislation associated with its delivery, and ends with concluding comments.

GEOLOGICAL DISASTERS

Three types of geological hazards—earthquakes, volcanic eruptions, and tsunamis—resulted in 38 major disaster declarations since 1953, with earthquakes accounting for 27 of them. As stated above, the discussion in this section focuses on geological events.² The vast major-

ity (32 of 38) of these events occurred in the five states in the Pacific division, with California and Hawaii accounting for 14 and 10 events, respectively.

- 1) Earthquakes. Three major disasters due to a geological hazard occurred east of the Mississippi River, and all three were earthquakes.³ One was the *New York Earthquake* (DR-1415), with the incident occurring on April 20, 2002, and the major disaster declaration made on May 16, 2002. The second and third declarations were made for the same earthquake event. The incident period for the *Virginia Earthquake* (DR-4042) was from August 23, 2011, to October 25, 2011, with the major disaster declaration made on November 04, 2011. The third was the *District of Columbia (DC) Earthquake* (DR-4044), with an incident period of August 23, 2011, to August 28, 2011; the major disaster declaration was made on November 08, 2011.
- 2) Volcanic eruptions. Three of the five volcanic eruptions occurred in Hawaii, but the Mount St. Helens eruption of 1980 resulted in major disaster declarations in two states, Idaho and Washington. The incident period of the *Washington Volcanic Eruption, Mt. St. Helens* (DR-623) was May 21, 1980, and its major disaster declaration was made on May 21; the *Idaho Volcanic Eruption, Mt. St. Helens* (DR-624) has an incident period of May 22, 1980, and a major disaster declaration on May 22.
- 3) Tsunamis. A tsunami is a great sea wave that originates from a submarine earth movement or volcanic eruption. The six tsunami-related declarations were declared for Hawaii (three in the state), California (two), and Alaska (one).

Thus, all three types of geological hazards that led to disaster declarations were concentrated in the five states that border the Pacific Ocean. To date, the post-1953 disasters originating from geological hazards have been of modest scale in terms of their effects on economic output. Not one of these events incurred more than \$1.0 billion in estimated costs as measured by the NOAA billion-dollar disasters between 1980 and 2013. The two most serious events from available data on DUA weeks compensated were the *California Loma Prieta Earthquake* (DR-845) and the *California Northridge Earthquake* (DR-1008). The

Loma Prieta earthquake had an incident period of October 17, 1989, to December 18, 1989, with 16,262 weeks compensated in the DUA program. The Northridge earthquake had an incident period of January 17, 1994, to November 30, 1994, with DUA weeks compensated of 81,405. Since the DUA data on weeks compensated are available only since 1983, it is possible that the Mount St. Helens volcanic eruption of 1980 or some other pre-1983 disaster may have caused a larger number of DUA weeks compensated and/or had estimated costs of more than \$1.0 billion. From the available data, however, it is clear that the disasters originating from geological hazards of the past six decades have had relatively smaller consequences compared to other disasters, such as hurricanes and drought.

MAN-MADE DISASTERS

While geological disasters fall into obvious categories, man-made disasters take a wider variety of forms. As stated above, FEMA lists chemical/biological, dam/levee breaks, explosions, radiation leaks, technological, terrorism, and virus threats as possible man-made disasters. Our discussion of 22 major disasters since 1953 identifies four categories: flooding from dam and levee failures (10 events), large industrial accidents (3 events), large urban fires (including domestic disturbances, 5 events) and terrorist acts (4 counts). The four terrorist acts were the *New York World Trade Center Explosion* (DR-984) on February 26, 1993, with the major disaster declaration on April 02, 1993; the *Oklahoma Explosion at Federal Courthouse in Oklahoma City* (DR-1048) on April 19, 1995, with the major disaster declaration on April 26, 1995; and the simultaneous major disaster declarations on September 11, 2001, for the *New York Terrorist Attack* (DR-1391) and the *Virginia Terrorist Attack* (DR-1392).

The two September 11, 2001, major disasters incurred more than \$200 billion in financial costs.⁴ The estimated costs of the other two events fell below the \$1.0 billion threshold used by NOAA in their classification of billion-dollar disasters. It should also be noted that FEMA classified the Boston Marathon bombing of April 2013 as an emergency

declaration and not as a major disaster: *Massachusetts Explosions* (EM-3362), emergency declaration declared on April 17, 2013.

Nearly all the man-made disaster declarations in the FEMA historical record have relatively modest estimated financial costs. Eight of the 22 events occurred after DUA compensation data for individual major disasters became available in 1983. The two major disaster events on September 11, 2001, caused 74,857 DUA weeks compensated (ranking 11th in DUA weeks compensated) and \$13.9 million in DUA payments.⁵ The Los Angeles civil disturbances and fires (DR-942) of 1992 caused 69,584 DUA weeks compensated and \$6.0 million in DUA payments. The total estimated cost of this event may or may not have been less than \$1.0 billion. Since the NOAA loss estimates are measured in terms of 2013 dollars, the inflation factor would be 1.66 times the actual costs measured in 1992 prices. Regardless of the estimate from this 1992 event, it is obvious that the costs of the September 11, 2001, disaster events were very large, larger even than those arising from Hurricane Katrina, which NOAA estimated to be \$149 billion (2013 dollars). The single disaster on September 11, 2001, resulted in estimated costs of between one-fourth and one-fifth of all the billion-dollar natural disasters between 1980 and 2013.

Terrorist acts in the United States between 1953 and 2014 have been limited to the four incidents previously noted. Two other potential types of man-made major disasters, however, can also be identified: nuclear, biological, chemical, and radiological (NBCR); and cyber. Accidents or deliberate acts in any of these NBCR risk areas could potentially trigger a major disaster. To date, the partial meltdown of the nuclear power plant at Three Mile Island, Pennsylvania, in 1979 has been the most serious nuclear power incident on record in the United States. While this man-made disaster was not classified by FEMA as a major disaster, there was a major evacuation in the area around Three Mile Island and the plant was eventually closed. There have been other domestic incidents involving nuclear power plants that could have had more disastrous outcomes.⁶

An analysis of the potential hazards associated with the storage of chemicals in six midwestern states was recently completed by the Center for Effective Government (2015). An explosion at a fertilizer plant in West, Texas, in 2013 that killed 10 first responders prompted

increased awareness of chemical hazards. In its report, the Center for Effective Government identified more than 3,000 sites in the six mid-western states with large volumes of stored chemicals and included several recommendations to assure greater safety of stored chemicals.

An increase in measles cases linked to an amusement park in California in 2015 is the most recent example of disease-related risks in the United States. Although the Centers for Disease Control and Prevention (CDC) does not identify the source, the outbreak probably originated with a person who became infected with measles while overseas and then visited the amusement park while contagious. That year, 189 people from 24 states and D.C. were reported to have measles. Since the CDC announced measles elimination in 2000, the largest number of cases was in 2014, with 667 cases in 27 states.⁷

In April 2016 the CDC reported 358 cases of travel-associated Zika virus in the 50 states and D.C., but the number of locally acquired vector-borne cases is zero.⁸ In American Samoa, Puerto Rico, and the U.S. Virgin Islands the CDC reported 475 Zika virus cases: 4 travel-associated cases and 471 locally acquired vector-borne cases.

Earlier examples of disease-related risks include the Spanish flu pandemic of 1918, the polio epidemic of the early 1950s, and the HIV/AIDS epidemic in the 1980s. In short, biological risks are always potentially present as pathogens evolve, develop immunities to vaccines, and hinder public health interventions.

A technology company's experience in 2014 offers a vivid example of cyber risks. A group calling itself the Guardians of Peace hacked its way into Sony Pictures, taking valuable insider information and leaving the Sony network inoperable for days. As the U.S. economy evolves toward increased reliance on information technology and the Internet, these risks seem slated to grow in the foreseeable future. More broadly, avoidance of NBCR risks will become increasingly important as the U.S. economy continues to evolve. Insuring against geological and man-made disasters will undoubtedly constitute an important element in our defense against these various risks.

INSURANCE AGAINST GEOLOGICAL DISASTERS

Private markets exist for the purchase of insurance against geological risks. In California, for example, about 20 private insurance carriers sell and service earthquake insurance policies, which are sold as add-ons to basic homeowners insurance policies. Premium rates vary by geographic area within the state.

Oversight of earthquake insurance is the responsibility of the California Earthquake Authority (CEA), a public, not-for-profit entity established with private funding in 1996 following the Northridge earthquake of 1994. The CEA has a five-person governing board with three voting members (the governor, the state treasurer, and the insurance commissioner), and two nonvoting members (the speaker of the assembly, and the chair of the Senate Rules Committee). Policies can be purchased through CEA or with private carriers. About three-quarters of the approximately 800,000 insured Californian homeowners have coverage through CEA policies. The authority also educates and encourages homeowners to increase preparedness for future earthquakes. Thus, its mission encompasses education and other measures to promote resiliency as well as property-loss protection.

Insurance protection against most types of man-made disasters can also be secured through private insurance carriers. The federal government, however, oversees insurance against terrorist acts. Terrorism insurance is discussed in later in this chapter.

INSURANCE AGAINST MAN-MADE DISASTERS

As noted above, man-made disasters can result from deliberate acts such as a terrorist bombing or from an accident. Only five notable incidents of successful terrorist acts have occurred in the United States since 1993.⁹ It should also be observed that the distinction between geological and man-made disasters is somewhat artificial. Thirty-four nuclear reactors in the United States are located downstream from a large dam (see Lochbaum, Lyman, and Strahan [2014]). For example, three reactors of the Oconee Nuclear Power Plant in South Carolina are down-

stream from the Jocassee Dam on the Keowee River. If an earthquake were to breach the dam and flood the power facility, then the cause of the disaster would have both geological and man-made elements.

Catastrophic losses from geological disasters, such as earthquakes, and man-made disasters, such as nuclear radiation and terrorism, have affected the willingness of private insurers to provide coverage against these perils. Insurance arrangements currently exist for two types of man-made disasters identified previously: NBCR risks, including nuclear accidents and cyber attacks. All providers of nuclear power are required to purchase accident insurance from private carriers. Insurance coverage of the other components of NBCR risks can be purchased through private carriers who quote rates for the separate NBCR risks. Insurance against cyber attacks can be purchased as part of a commercial property insurance policy. The extent of coverage is not fully known, but it is believed to exceed half of all companies with a higher coverage rate among larger firms.

Because the historical experience of losses from NBCR and cyber incidents has been limited, and losses have not been “large,” provision of insurance against these risks has remained within the domain of private insurance. In contrast, since September 11, terrorism insurance arrangements have changed, with the addition of a major element of government participation.

TERRORISM INSURANCE

Prior to the 2001 attacks, private insurance carriers provided insurance against terrorist acts as part of standard commercial property insurance policies. The cost of coverage for this specific risk was not explicitly shown in these policies. The attacks resulted in \$44 billion of insured losses for insurance carriers and their reinsurers.¹⁰ Following these attacks, carriers started to exclude terrorist acts from coverage, which exerted a negative influence on new commercial and real estate investments.

Against this background, the U.S. Congress passed and the president signed into law the Terrorism Risk Insurance Act (TRIA). There were two main provisions in the legislation. First, carriers were man-

dated to offer terrorism coverage in their commercial insurance policies and on the same terms as other insurance risks. Second, the legislation established a loss-sharing arrangement among three parties: companies, insurance carriers, and the federal government.

The legislation was planned as a short-run “fix” to assure coverage of businesses and to provide time for the insurance industry to develop private coverage vehicles. These expected developments did not occur, and the original law was succeeded by extensions enacted in 2005, 2007, and 2015. The most recent legislation of January 2015 extended TRIA to the end of December 2020. Four important provisions of TRIA were amended. First, the primary administrative responsibility resides with the U.S. Treasury Department. Second, the composition of the three-person committee that makes the determination (certification) of whether an incident is a terrorist act replaced the secretary of state with the secretary of homeland security. The composition of the committee in the 2002 legislation was the secretary of the treasury, the attorney general, and the secretary of state.

Third, provisions in the legislation define a set of financial thresholds: a minimum threshold for what constitutes a terrorist act, a minimum threshold for federal participation in the compensation of survivors of the terrorist act, a deductible level covered by insurance carriers, and a government-carrier sharing formula for losses that exceed the deductible. The 2015 extension placed all these thresholds on a sliding scale so that their levels in 2020 are considerably higher than in 2015. The federal share above the deductible threshold is to gradually decline from 85 percent in 2015 to 80 percent in 2020. Finally, TRIA is intended to be budget neutral. Federal government compensation to claimants is to be recouped through later assessments on insurance carriers.

The provision of terrorist insurance faces multiple challenges. The infrequency of terrorist acts means potential losses are highly indeterminate, making it uncertain how to appropriately price terrorist insurance policies. In addition, coverage boundaries are not clear. Workers' compensation and fire insurance are probably liable for certain losses that arise from terrorist acts. A successful cyber attack might be covered by cyber insurance. Furthermore, basic information on terrorist insurance coverage, costs, and pricing is incomplete. The 2015 TRIA legislation mandates the Government Accountability Office to conduct studies to close these various information gaps.

It is currently estimated that TRIA covers about 60 percent of private employers. The Government Accountability Office (2014) finds that the price of terrorist insurance policies has stabilized since 2010, and premiums are relatively constant at about 2.0 percent of overall property insurance premiums. It appears that TRIA has stabilized in recent years.

CONCLUSIONS

With guiding principles from the government, the insurance industry could provide insurance against the full range of geological and man-made disasters. The information presented here indicates that geological and man-made disasters are low-probability events; therefore, providing insurance for them is a particular challenge. Because decision-makers have limited experience with low-probability events, there is considerable uncertainty about the likelihood of their occurrence. There is a tendency to either ignore a potential disaster or overreact to a recent one. As a consequence, people and insurance providers tend to focus on the losses from a worst-case scenario without adequate reflection on the likelihood of the event occurring in the future.

If a private-public insurance program were to be provided then it would need to be linked with other initiatives. Given the reluctance of individuals to voluntarily purchase insurance against losses, regulations could require insurance coverage for all individuals who face similar risk. Insurance premiums would be risk based to provide appropriate price signals about the hazards individuals face and enable insurance providers to lower premiums for properties where mitigation is undertaken.

Chapter 10 discusses the provision of insurance for geological and man-made disasters. It outlines potential problems and offers suggestions for national disaster policies, such as proposals for legislation and administrative practices for improved planning and responses to disasters.

Notes

1. See http://www.lapdonline.org/history_of_the_lapd/content_basic_view/1132 (accessed July 21, 2016).
2. Given our focus in this chapter, geophysical processes such as the landslide in Oso, Washington, are not discussed. In the FEMA disaster-related declarations list this event is recorded as Washington Flooding and Mudslides (DR-4168), an incident period from March 22, 2014, to April 29, 2014, with a major disaster declaration on April 2, 2014.
3. The time period under discussion refers only to events since 1953. The earthquakes in New Madrid, Missouri, of 1811, and San Francisco of 1906 fall outside the scope of the discussion in this book.
4. See, for example, <http://www.iags.org/costof911.html>, from the Institute for the Analysis of Global Security (accessed July 21, 2016). The first 11 items of its 12-item list of loss categories total \$242 billion. No attempt has been made to compare the Institute's methodology for estimating losses with the NOAA methodology.
5. The benefits totaled \$13.7 million for New York and \$0.2 million for Virginia.
6. See Lochbaum, Lyman, and Strahan (2014). Chapters 9 and 10 in that volume provide details of other nuclear power incidents in the United States that could have had more serious consequences under differing circumstances. Chapter 12 describes the regulatory interface between the Nuclear Regulatory Commission and the nuclear power industry.
7. The number of measles cases reported to CDC is updated weekly at <http://www.cdc.gov/measles/cases-outbreaks.html> (accessed July 21, 2016).
8. <http://www.cdc.gov/zika/geo/united-states.html> (accessed April 18, 2016).
9. The New York World Trade Center Explosion (DR-984) in 1993; the Oklahoma Explosion at Federal Courthouse in Oklahoma City (DR-1048) in 1995; the two terrorist attacks on September 11, 2001 (DR-1391 and DR-1392); and the Massachusetts Explosions (EM-3362) in 2013.
10. See Kunreuther et al. (2014, section 1). Reinsurers paid for about two-thirds of the losses from the September 11, 2001, disaster.

10

Disasters and Compensation Systems

OVERVIEW OF DISASTERS

This volume explores the recent history of disasters in the United States using state-level data that extend back to the early 1950s. From 1953 through the end of 2013 the cumulative number of declarations made by FEMA was 2,046 major disasters, 355 emergency declarations, and 1,050 fire management declarations.¹ The results of analyzing state-level data in Chapter 2 show a strong upward trend in both major disaster and fire management assistance declarations. Between 1953 and 2013 the annual increase in major disasters was about one per year (shown by the annual trend coefficient of 0.885). The analysis also finds an acceleration in the occurrence of major disasters after 1995. Fire management assistance declarations in particular have become significantly more numerous since 1995.

Chapter 2 also documents the strong upward trend in the annual number of floods and tornadoes, which account for about three-quarters of all major disasters. Drawing on the findings of subsequent chapters, however, the increase in disasters is a broad-based phenomenon and is not limited to just one or two categories. In addition, Chapter 2 shows that the occurrence of disasters has far outpaced the growth in population since the early 1950s. A disaster incurs significant costs, including loss of life, reduced economic production, and damage to property and infrastructure. Generally speaking, fewer people are dying in disasters, but the financial costs associated with disasters are increasing.

Improved science and technology is a principal reason that fewer lives are lost when a disaster occurs. The forecasting of potential natural hazards has improved, and superior structures are being built to better withstand the effects of disasters due to these hazards. Even though property and infrastructure are more resistant to damage, the total dollar amount of destruction has been increasing, mainly because the number

of disaster-related events is rising. Stated simply, society now has a larger volume of valuable resources exposed to hazards. The increase in the occurrence of disasters also requires increasing taxpayer dollars to finance the various agencies responsible for managing the adverse effects of hazards and related disasters.

LABOR MARKET EFFECTS OF DISASTERS

Hurricanes stand out among the categories of major disasters for the scale of their destructive effects. The 33 hurricanes and tropical storms of the 1980–2013 period accounted for nearly half of the \$1.1 trillion of total costs from the 170 billion-dollar disasters as estimated by NOAA. Hurricanes also accounted for approximately two-thirds of DUA weeks compensated since 1983 and two-thirds of NFIP cash payments since 1978. Drought is the only other category of major disaster that is of comparable cost per event.

Chapters 4 and 5, which examine hurricanes and floods, establish that disasters have measurable effects in the labor market. Hurricane Katrina caused significant increases in the statewide unemployment rates of Louisiana and Mississippi in the fall of 2005. Associated with higher unemployment were significant increases in the number of UI beneficiaries in these two states, but not in Alabama. While Hurricane Sandy did not raise statewide unemployment rates in New York and New Jersey, it did cause significant increases in the number of UI beneficiaries in both states. In contrast, our analysis of Hurricanes Andrew and Ike and the four destructive hurricanes that impacted Florida during August–September 2004 does not find evidence of statewide increases in unemployment or UI beneficiaries.²

Our analysis of three major floods in the Midwest region also identifies significant labor market effects that followed the floods of 1993 and 1997, but not the flood of 2008. Unemployment rates in the affected states were higher and the number of UI beneficiaries increased significantly.³ In our analysis of tornadoes and drought, we also test for labor market effects due to these two categories of disasters, but do not find significant effects in statewide data.

These results lead us to conclude that finding state-level effects of major disasters is likely only if the disaster is of an extremely large scale and/or the state is comparatively small. The effects of Hurricanes Katrina and Sandy were discernible at the state level because of their large-scale destruction. We also infer that the effects of disasters on unemployment and UI reciprocity were of comparatively short duration, lasting from four to six months or fewer. A larger and richer data set, particularly with county-level data, could provide more information on disaster-related labor market effects.

The reporting of UI benefit payments does not separately identify payments due to disasters. We encourage a modification to the UI data reporting system to explicitly recognize disaster-related UI payments. This modification would allow policymakers and other stakeholders to more accurately assess the importance of major disasters as a cause for UI benefit payments. The need to know such information may grow in the future if the scale of the DUA program continues to decline, as documented in Chapter 3. Both UI and DUA benefits provide a cushion to vulnerable individuals not only during but after a disaster. These programs are already being delivered and can reach a sizable number of disaster-prone households. Our proposed modification requires relatively minor adaptations to the existing UI program with comparably low additional costs.

The current practice in state UI programs is to treat disaster-related UI benefit payments as noncharged benefits; that is, these payments are a common charge whose cost is spread across all covered employers and not assigned only to the individual employers who make the payments. In effect, current financing makes these benefit payments a shared financial responsibility of all employers in the state.

An argument can be advanced that disaster-related UI benefit payments are a federal rather than a state responsibility. To the extent that social insurance (as opposed to private insurance) compensates survivors, national funding of these benefits seems appropriate, analogous to the national funding of DUA benefits. A starting point for advancing this idea of national funding is to collect information on the current volume of disaster-related payments made by the UI programs. To obtain this information, a survey of the states is needed. Securing state cooperation in such a survey should not be a problem since the states would be transferring to the federal partner a part of the cost of benefits

currently financed by state-level UI taxes. After implementation, this approach to financing these benefit payments would be a national rather than state responsibility.

THE ROLE OF INSURANCE

Hazards, exposure, and vulnerability are characteristic of the relationship between people and risk. The UNISDR (2009) divides risk into two broad categories: extensive and intensive. An extensive risk is “associated with the exposure of dispersed populations to repeated or persistent hazard conditions of low or moderate intensity, often of a highly localized nature, which can lead to debilitating cumulative disaster impacts” (p. 15). An intensive risk, on the other hand, is “associated with the exposure of large concentrations of people and economic activities to intense hazard events, which can lead to potentially catastrophic disaster impacts involving high mortality and asset loss” (p. 18). A drought is an example of an extensive risk. Extensive risks are largely shaped by the underlying risk factors and can be relatively easily reduced. Flooding in large river basins and hurricanes are examples of an intensive risk. Intensive risks are largely determined by the location, severity, and frequency of the hazard, which means that there are limits as to how much risk can actually be reduced.

While the risks cannot be eliminated, the scale or severity of hazards can be substantially lessened in a way that can minimize the hazard to individuals and communities. If hazard severity and exposure cannot be reduced, then the main opportunities for reducing risk lie in reducing vulnerability. Vulnerability refers to the way a disaster will affect human life and property. The UNISDR (2015) considers three kinds of risk management strategies to reduce vulnerability: prospective risk management, corrective risk management, and compensatory risk management. Prospective risk management requires strategies to ensure that development does not introduce new risks to the stock of risk-prone assets. For example, building standards can be improved and enforced to reduce vulnerability in new construction, land-use planning can deter development from hazard-prone areas, and better water management can reduce drought risk. Corrective risk management removes risks

already present before they become a loss. For example, highly exposed and vulnerable structures could be relocated, obsolete infrastructure could be renovated, and degraded ecosystems could be restored.

Different risk management strategies are needed to reduce the two categories of risk defined above. Since extensive risks are largely shaped by the underlying risk factors, a greater understanding of these risk factors can reduce them. The more intensive risks need to be addressed through compensatory risk management, which can include risk transfer mechanisms, such as insurance and reinsurance, contingent financing, and social insurance and social protection programs. Insurance is a valuable tool for managing risk and handling vulnerability. When insurance functions as intended, it not only provides financial protection to individuals and communities, but also a profitable business model for insurance providers.

Private insurance policies can be devised for many hazards that have catastrophic consequences. There are three general requirements for insurability. First, the hazard and the associated losses need to occur with sufficient frequency that the insurance provider can develop an accurate estimate of the distribution of potential losses. Second, the act of insuring does not alter the distribution of the loss; that is, there is no moral hazard. Third, the parameters of the loss distribution (frequency and size of losses) are stable over time such that actuarially fair policies (including a profit for the insurer) can be devised.

Several hazards identified in this book satisfy these three conditions. Examples of anthropogenic hazards would include commercial airline crashes, construction collapses, maritime disasters, mine disasters, and train wrecks. Insurance policies can be devised and compensation provided to recipients who incur covered losses. For instance, commercial airlines can insure their equipment for the hazard of an air crash.

Chapter 3 presents the most common private insurance policy for homeowners in the United States: the Homeowner-3 (HO-3) policy. A standard HO-3 policy provides broad coverage for losses from hazards, such as explosions, fire, hail, lightning, smoke, storms, theft, tornadoes, vandalism, and wind. In some hailstorm-prone areas, there is a specific hail damage deductible. A deductible is the part of the claim that is not covered by the insurance company and will be borne by the insured homeowner. There are some restrictions in coverage for windstorm damage if one lives near the Atlantic or Gulf coasts because of the high

risk of damage from hurricanes. Similarly, if one lives in certain parts of the Midwest where tornadoes are common, windstorm damage is not usually covered.

Individuals choose how much prevention to undertake, how much insurance to purchase, and how much residual risk to bear through coping. Economic theory posits that individuals undertake prevention to the point where expected benefits (avoiding losses) exceed the costs, subject to a budget constraint. Survey findings show that individuals sometimes misperceive risks and may not always act in their own best interests. They tend to discount low-probability future losses and seem reluctant to invest in disaster risk management. A survey conducted by Viscusi and Zeckhauser (2006) finds that most respondents assess their risks as “below average.” Those in riskier areas who experience disasters estimate their risks to be higher, but not as high as they should statistically. These individuals appeared to underestimate risk even though the survey was conducted in 2006, shortly after Hurricane Katrina.

As Chapter 9 notes, earthquake insurance can be purchased for an additional premium under a standard HO-3 policy in all states except California. Earthquake coverage for residents in California can be purchased through the California Earthquake Authority, which is a state-run earthquake insurance program. Earthquake coverage for business firms in California is usually included in a commercial policy or can be purchased from private insurers as separate coverage.

Other hazards with catastrophic consequences do not satisfy the three requirements for insurability. Examples include terrorist attacks, cyber attacks, nuclear power plant disasters, and biological catastrophes, such as plagues and epidemics. The likelihood of these hazards occurring is extremely rare, but the associated losses are devastating, making it difficult or impossible to assess. Hence, a catastrophic hazard is a low-probability, high-consequence (LP-HC) event.

Providing insurance for LP-HC events is a particular challenge for individuals at risk, insurance providers, and regulators. Individuals at risk have a tendency to ignore extremely rare events until after a disaster occurs. Many individuals do not voluntarily buy coverage against potential LP-HC events because they do not think a catastrophic loss will happen to them. Chapter 5 shows that people voluntarily buy insurance only after incurring a serious loss, but many cancel their policies if they do not experience a compensated loss in succeeding years. This

pattern leads us to conclude that many individuals do not view insurance as a protective measure. Rather, they consider insurance an investment and believe that the premium is wasted if they do not receive payment from an insurance claim.

Insurance providers do not behave optimally in the case of LP-HC events. After they suffer a severe loss, they may decide that the risk is completely uninsurable rather than increase the premium to cover the hazard. Chapters 3 and 5 note that private insurance companies provided flood insurance until the late 1920s. Following the heavy losses incurred by the insurance industry after the Mississippi floods in 1927, private flood insurance coverage was discontinued. Prior to the *New York Terrorist Attack* (DR-1391) on September 11, 2001, terrorist insurance was included (but not explicitly priced) in standard property loss policies providing coverage against damage to commercial property. Nearly all property loss policies written after September 2001 excluded terrorist attacks because insurance providers feared catastrophic losses from future attacks.

State regulators often limit insurance premiums in the case of LP-HC events because they are concerned about the affordability of insurance, especially to those who are at higher risk. Kunreuther and Michel-Kerjan (2011) outline how the state of Florida set up its own insurance company, Citizens Property Insurance Corporation, and heavily subsidized the policies of homeowners residing in hurricane-prone areas. These highly subsidized rates undercut the premiums of private insurers. Moreover, an inappropriate premium has adverse effects that are difficult to rectify later. For example, low premiums encouraged the construction of vacation homes in hazard-prone areas of Florida.

The behavior of at-risk individuals, insurance providers, and regulators outlined above defeats the objective of insurance. The main purpose of insurance is threefold: it needs to provide information about the severity of risk through setting appropriate premiums, it needs to motivate those at risk to undertake protection against LP-HC events, and it needs to offer incentives in the form of premium reductions to reward individuals and communities who invest in risk-reducing measures.

At least two insurance approaches can be suggested for LP-HC situations. First, the government can act as the insurer. Second, private insurers can write the basic policies but operate with back-up provided by reinsurance. As currently structured, terrorist insurance has an ele-

ment of the first approach in that the government insures against large open-ended liabilities. The private insurance industry participates with a sharing arrangement for what is in effect the deductible element of the insurance. Currently, the United States does not have an explicit insurance structure to insure against cyber attacks.

As Chapter 7 describes, the crop insurance program is a federal program that is delivered by private sector insurance providers, who use a federally designed insurance policy to enter into a private contract with agricultural producers. Both the federal government and the insurance providers share in the underwriting performance of the contract.

Government insurance programs now provide coverage for the hazards of both floods and terrorist attacks. Recall that floods were perceived to be uninsurable for three main reasons: adverse selection meant that only households and firms in flood-prone areas would purchase coverage; risk-based premiums were too costly for the average household; private insurers could not generate sufficient premiums to insure against a catastrophic flood event. Because private carriers effectively deemed potential losses too uncertain to price out and stopped providing coverage, the federal government has stepped in to provide it. Private carriers continue to participate in the administration of both the flood insurance and crop insurance, but the ultimate financial liability for losses resides with the federal government.

SOCIAL INSURANCE

An alternative approach for providing insurance protection against disaster risk is through social insurance. As noted in Chapter 3, social insurance can be viewed as a scheme that requires individuals to contribute in advance to a program that will help them in times of personal need, rather than rely on taxpayers when the need arises. All parties at risk pay actuarially fair premiums into a trust fund, which dispenses payments to those survivors who have coverage. Coverage can be mandatory as with UI and workers' compensation insurance. A potential advantage of social insurance is the mandatory feature of coverage so that the issues of adverse selection are avoided. Social insurance can also charge differential contribution rates that reflect risk; for exam-

ple, higher premium rates for residences and business establishments located adjacent to rivers, in floodplains, and in coastal areas. These same insurance-pricing features can also be provided through private insurance.

Social insurance does not reduce disaster risk in and of itself, but it can be part of strategic disaster risk management. Social insurance instruments can enhance the disaster resilience of individuals and households and protect household assets. Many of these instruments are already being delivered in the United States. They have the advantage of reaching large numbers of disaster-prone households and communities both during and after a disaster and can help compensate for income loss, medical expenses, and other expenses.

INCREASING PARTICIPATION IN THE NATIONAL FLOOD INSURANCE PROGRAM

NFIP coverage has been stable and even declining since 2006. As mentioned in Chapter 5, the program has difficulty maintaining coverage among insured homeowners who do not receive payments for losses in the years immediately after electing coverage. Three approaches hold promise for increasing coverage: the use of community ratings, multiyear policies, and increased enforcement of mandatory coverage.

Community ratings and multiyear policies differ from current NFIP policies that are sold annually to individual homeowners and business establishments. Community ratings would apply to an entire community where all households and businesses would participate and pay a community premium rate. These would be of particular relevance to communities where a substantial share of property is located in a 100-year floodplain.

Multiyear policies would be sold for multiyear periods, perhaps for the duration of a mortgage for property located in a 100-year floodplain. Such policies would encourage investment in preventive and protective measures with premiums reflecting risk over a longer time horizon than current annual insurance policies. Experience could determine if the price of multiyear insurance would be higher than single year coverage, but one advantage for individuals would be price stability. Regula-

tors would have to allow insurance providers to charge premiums that reflect risk.

Enforcement of mandatory participation in either approach, however, presents major administrative challenges. Pilot projects should test both ideas to assess their effectiveness and to help identify implementation problems. The point of both approaches would be to more effectively maintain flood insurance coverage compared to the present situation where annual attrition rates can be as high as 30 percent of covered properties.

A third approach to increasing coverage would be to aggressively enforce insurance coverage on properties located in 100-year floodplains. Estimates from the National Academy of Sciences (2015) suggest that half of all properties with mortgages in these locations avoid NFIP mandatory coverage. Enforcement could consider penalizing both the property owner and the mortgagor when noncovered properties are identified.

As noted in Chapter 5, NFIP coverage has not been increasing since about 2007 or even after the destruction caused by Sandy in late 2012. Unless coverage can be enhanced, the NFIP will decline and necessitate greater future reliance on emergency payments rather than insurance payments to the survivors of major floods.

CONCLUSIONS

As a nation, we can take measures to increase our resilience to disasters. These measures are generally long-term projects to enhance our awareness of hazards, improve our physical structures and infrastructure, and ensure that effective recovery procedures are in place when a disastrous event occurs. The Stafford Act instituted a first response to a disaster, introduced long-term recovery strategies, and established disaster assistance programs.

Managing disaster risks involves adaptation and mitigation from individuals, the private sector, and all levels of government. The UNISDR (2009, p. 19) defines mitigation as the “lessening or limitation of the adverse impacts of hazards and related disasters.” Mitigation measures include public awareness of hazards, dissemination of infor-

mation and timely warnings, hazard-resistant construction, and policies that incorporate disaster risk management. Individuals can respond to expected hazards and moderate their harmful effects. Local government and the private sector are critical players in reducing disaster risk, given their roles in managing risk information and financing. National governments can coordinate the efforts of local and state governments by providing information, establishing policy and legal frameworks, delivering financial support, and protecting vulnerable groups.

We need to continue investigating hazards so that we know how to prepare for and respond to them when they occur. Such observation usually involves monitoring natural hazards to identify any anomalous change that may lead to a more devastating event. As outlined in Chapter 4, hurricanes are known to pass through several stages of development: from tropical depression to tropical storm and then hurricane. Once a tropical depression is identified, meteorologists can monitor it to predict how long the development will take and identify the eventual path of the storm.

We can design and install early warning systems to alert us to hazards that may be about to occur. A people-centered early warning system would disseminate timely and meaningful warning information that would enable individuals and communities threatened by a hazard to prepare for and act appropriately with sufficient time to reduce the possibility of harm or loss. Together with early warning systems, we need to establish lines of communication and ensure that the public has an appropriate response to warnings. Warnings and evacuations need to be coordinated, and local capabilities must be able to respond to the warnings.

We can also develop and enforce building codes that require structures to withstand earthquakes or high winds. Building codes and regulations, construction styles, and zoning statutes are important elements in enhancing resilience to hazards. Climate data show that average temperatures and annual precipitation has increased in the United States. The increased temperature trend can lead to wildfire-induced degradation of ecosystems as well as property loss and mortality. Chapter 8 notes that forest managers and municipal planners are increasingly incorporating fire protection measures, such as prescribed burning, to support ecosystem adaptation. The U.S. Global Climate Change Program (Joyce et al. 2014) finds that adaptation in human settlements is

constrained by private property development in high-risk areas; adaptation could be encouraged by appropriate land-use planning.⁴ Chapter 5 indicates that extreme precipitation can result in floods in riverine and coastal areas that lead to property and infrastructure damage as well as environmental degradation. Older rainfall design standards are employed in some areas and need to be updated to reflect current climate conditions. The intensity of flood events could be reduced by conservation of wetlands and land-use planning.

While we do not discuss climate change in detail, we make references to the phenomenon throughout the book. Here we acknowledge that steps to increase resilience to climate change would significantly reduce exposure and vulnerability in densely populated areas and lead to successful prevention. The many disaster risks of climate change tend to be concentrated in urban areas. Improving housing and constructing resilient infrastructure systems are vital. The federal government has taken the lead in providing guidance, information, and support in planning for and implementing measures to adapt to climate change. The new federal climate adaptation initiatives and strategies developed in recent years are outlined in the U.S. Global Climate Change Program (Joyce et al. 2014).⁵ While all federal agencies are required to plan for adaptation, state/tribal governments, and local and regional governments are currently engaged in various stages of planning.

Risk-financing mechanisms in the private and public sector, such as insurance, can contribute to increasing resilience. As Chapter 10 shows, the design of insurance instruments is a continuing challenge; unintended consequences can lead to disincentives, market failure can result, and equity could be decreased. We can structure insurance policies to assist in the recovery from the damages incurred as well as providing compensation. Insurance providers and regulators need to educate at-risk households and businesses that insurance is a proactive way to reduce risk. In addition, insurance policies need to be transparent, understandable, and equitable. It is also important for insurance premiums to reflect risk so that policyholders accurately perceive the risk they face and become aware of the preventive or protective measures that reduce their vulnerability to potential losses. Insurance also needs to deal with the issues of affordability and equity. Any special treatment given to individuals at risk (for example, low-income uninsured or inadequately insured individuals) should be in the form of means-tested

financial support rather than insurance premium subsidies. Kunreuther and Michel-Kerjan (2011), Kunreuther, Pauly, and McMorro (2013) and Kunreuther (2015) suggest that the financial support should be means-tested insurance vouchers, financed by the federal government or at a state level through general taxes.

The United States uses a combination of private insurance, government insurance, disaster assistance, and other income support to manage the risk and vulnerability of disasters. The book examines selected aspects of these systems, as they provide support to survivors of catastrophic events. As a nation, we can take many steps to reduce the risk and vulnerability to hazards and to respond effectively when a disaster occurs. While these steps can be divided into several categories, it is important to note that there is no clear distinction among them: prevent preparedness, emergency responses immediately after extreme events occur, postevent recovery and reconstruction, and developing resilience in nondisaster times.

Preventing a disaster requires strategies that reduce exposure and vulnerability to contain damage and loss. Not all disasters, however, can be prevented. The impact of a disaster depends on how individuals and governments react and cope. Effective prevention requires a myriad of measures working harmoniously together. With enough public awareness, individuals, the private sector, and governments can undertake preventive measures, and the federal government can take the lead. The ultimate goal is to increase our resilience to hazards and avoid disasters. Our choices make us either more susceptible to disasters or more resilient.

Notes

1. Information on major disaster declarations is available from 1953; for emergency declarations from 1974; and fire management declarations from 1970.
2. The four hurricanes were Charley, Frances, Ivan, and Jeanne.
3. The nine Midwest states affected by the flooding in 1993 were Illinois, Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, South Dakota, and Wisconsin. The 1997 flood resulted in major disaster declarations in Minnesota, North Dakota, and South Dakota. The major disaster declarations in 2008 were in Iowa, Missouri, Nebraska, and South Dakota.
4. Bierbaum et al. (2014) find that adaptation by human settlements is also by limited household-level adaptive capacity.
5. See Note 4.

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