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Federal Financial Exposure to Natural Catastrophe Risk

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Federal Financial Exposure to Natural Catastrophe Risk

Abstract

The objective of this paper is to estimate the expected annual costs to taxpayers of federal disaster-related expenditures to provide guidance to federal policymakers in budgeting and formulating disaster relief policy. Our estimates take into account recent trends in the generosity of federal disaster policy as well as statistical data on the frequency and severity of losses from natural catastrophes. Our estimates of the costs of disasters are based on two sources: (1) simulation analysis by Applied Insurance Research, a leading catastrophe modeling firm, and (2) historical data on insured catastrophe losses from Property Claims Services, an insurance industry statistical firm. We estimate the average expected federal expenditures for disaster assistance related to hurricanes, earthquakes, thunderstorms, and winter storms to be about $20 billion a year. In a "bad" year, corresponding to a catastrophic event of severity expected only once every century, the bill could exceed $100 billion. Given the current approach to disaster relief funding, we project an "unfunded" liability for disaster assistance over the next 75 years comparable to that of Social Security. The magnitude of the projected liability strongly suggests that government should adopt a proactive, ex ante approach to disaster relief policy rather than the current ad hoc reactive approach.

Federal Financial Exposure to Natural Catastrophe Risk

I. Introduction

In the aftermath of the terrorist attacks of September 11, 2001, Congress passed supplemental appropriations of over $26 billion for redevelopment, clean-up, and aid to attack victims and their families. By the standards of the time, the nature and extent of the expenditures were unprecedented. However the new standard would be broken only a few years later, when Congress appropriated emergency funds for over $80 billion in disaster assistance in the aftermath of Hurricane Katrina and three other hurricanes which all occurred in one four month period.

Viewed in the context of federal disaster policy over the last century, the responses to September 11 and Hurricane Katrina fit well with a long-term trend of a continuously increasing federal role in disaster assistance (e.g., Moss (1999), (2002)). Over twenty years ago, Kunreuther and Miller (1985) observed:

> The role of the federal government with respect to hazards has been changing … there has also been a realization that government has been viewed as the protector of risks in ways that would have been unthinkable 50 years ago. Even 30 years ago there was a reluctance by local communities to rely on federal relief for recovery purposes.

Reactions to more recent disasters have revealed a telling shift in political sentiments at the state and local level. The response of Missouri Governor Mel Carnahan to calls for fiscal restraint in the aftermath of the Mississippi River flooding in 1993[1] ("This is not the time for debating the fine points of long-term policy!") seems more representative of local opinion today. Moreover, development has been steadily increasing in catastrophe-prone areas, so the property at risk is far greater now than at any time in the past.[2] Indeed, the subsidization of high-risk areas embedded in federal disaster policy has almost certainly encouraged development in those areas, thereby increasing federal exposure.[3]

The combination of rising standards for federal assistance and the growing private exposure suggests that the "stealth entitlement" of federal disaster assistance has grown large enough to merit a deeper assessment. Following Governor Carnahan's exhortation, we make no attempt in this paper to dissect the "finer points" of public disaster policy. Instead, we set ourselves the more concrete objective of assessing the federal exposure. In other words, if we take as given the current generosity of federal disaster policy and the current state of development in catastrophe-prone areas, what is the taxpayer's expected annual bill for disaster-related expenditures? And what could the bill be in a "bad" year?

The numbers we estimate in answering the foregoing questions are significant. Based on the historical relationship between catastrophe damages and federal expenditures, together with prospective assessments of future catastrophe damages from 1) a leading catastrophe modeling

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[1] Cited by Moss (1999), page 259.

[2] For example, the amount of property exposed to hurricane losses grew by 27% to $2.5 trillion between 2004 and 2007. See Hartwig (2008).

[3] This is an important moral hazard issue that is beyond the scope of the present paper. It would be useful to explore the link between federal disaster policy and development in future research.

firm, Applied Insurance Research (AIR) and 2) the projection of historical catastrophe loss data from Property Claims Services (PCS), we estimate the average expected bill for disaster assistance related to hurricanes, earthquakes, thunderstorms, and winter storms to be about $20 billion a year. In a "bad" year, corresponding to a catastrophic event of severity expected only once every century, the bill could exceed $100 billion. Conservative methods guide both estimates, so more liberal assumptions (e.g., extrapolating recent growth in federal generosity to the future, instead of assuming no change) would yield considerably higher estimates.

To get a sense of the significance of these figures in relation to other, more familiar obligations of the federal government, we take the expected annual expense over the next 75 years and compute a net present value (NPV) of this "unfunded liability". Doing so yields a figure between $1.2 and $7.1 trillion, depending on assumptions of growth and discount rates. For comparison, the trustees of Social Security project a shortfall with an NPV of $4.9 trillion over this same horizon.

Even the conservative estimate of $20 billion a year is far higher than the Federal Emergency Management Agency (FEMA) regular budget for disaster relief. Regular appropriations for the Disaster Relief Fund (the main vehicle for federal relief) averaged about $1 billion over the fiscal years 2001-2005, while supplemental appropriations to the Disaster Relief Fund averaged $16.5 billion over the same period.[4] Our estimate of future relief spending is accurate enough to allow budgeting for disasters in the regular appropriation process.

The rest of this paper is organized as follows. Section II offers background, including details on federal disaster policy. Section III discusses the methodology used for 1) assessing the relationship between federal disaster relief and catastrophe damages and 2) estimating the prospective distribution of aggregate catastrophe losses for the United States. Section IV discusses the results, including the effects of modifying assumptions. Section V concludes with a discussion of the policy implications of our findings.

II. Background

The federal government's financial exposure to catastrophic risk stems mainly from *ad hoc* disaster relief distributed to individuals, business, and communities; direct exposure of government facilities and service provision operations to disasters; and government insurance programs such as the National Flood Insurance Program (NFIP) and the Terrorism Risk Insurance Program (TRIP). We discuss each of these sources below.

Disaster Relief

Historically, disaster relief expenditures have been the most significant component of federal catastrophe exposure. One consequence of the seemingly *ad hoc* nature of the relief is that only a small portion of anticipated relief expenditures is contained in the budget. However, although the full extent of the federal obligation to assist may not be explicitly enumerated by legislation, history suggests that federal action is inevitable after major disasters: Indeed, assistance seems discretionary in name only. In the words of Moss (1997, p. 334):

[4] GAO Report 07-139: "Budget Issues: FEMA Needs Adequate Data, Plans, and Systems to Effectively Manage Resources for Day-to-Day Operations."

> Disaster spending has become a political sacred cow. … Again and again in the aftermath of disasters, representatives from the affected states have insisted that their constituents deserve no less than what other victims received and that the particular nature of their disaster might justify even more. Federal catastrophe coverage has thus been subject to a ratcheting-up process …

The Stafford Emergency Assistance and Disaster Relief Act of 1988, and its antecedents beginning with the Disaster Relief Act of 1950, guide the process for federal relief in the aftermath of catastrophes. The act formally requires the federal government to offer aid when state and local resources are overwhelmed by a major catastrophe. The Stafford Act designates FEMA to give declaration recommendations to the President after a disaster and the Homeland Security Presidential Directive (HSPD)-5 makes the Secretary of Homeland Security "responsible for coordinating Federal resources within the United States to prepare for, respond to, and recover from terrorist attacks, major disasters, and other emergencies" (DHS 2006).

If the President makes a declaration, then FEMA is charged with overseeing the response both directly and by administering funds to other federal agencies. The money comes from the Disaster Relief Fund (DRF), a "no-year" account (i.e., any dollars appropriated remain available until expended) which receives annual appropriations, though is largely reliant on supplemental appropriations from Congress in the event of major catastrophes.

The other sources of significant federal spending on disasters are the Small Business Administration (SBA), which makes subsidized disaster loans to households and businesses, and the U.S. Department of Agriculture (USDA) which dispenses disaster loss funds to farmers. Most funding for the SBA is provided through its annual appropriations from Congress. The President may make a Major Disaster declaration or an Emergency declaration. The latter is less significant and aims for federal costs not to exceed $5 million. If the President makes a more substantial Major Disaster declaration, some types of available federal aid actually have Stafford Act mandated *floors* on the federal share of expenditures. These mandated floors include 75% of eligible costs for "Essential assistance" and "Debris Removal" and 100% of "Housing assistance."[5]

Exposures to Federal Facilities and Operations

Federal government property, such as military bases or VA hospitals, can be susceptible to direct physical damage from catastrophes. The federal government is also bound to provide certain everyday public services, including providing Social Security and Medicare benefits, and running federal law and order institutions. The prompt resumption of these services post-disaster can entail significantly higher than normal operational costs.[6]

Insurance Programs

The U.S. federal government plays significant roles in disaster insurance markets. In particular, it essentially acts as the major underwriter of residential flood insurance (through the NFIP, administered by FEMA); it also effectively acts as the country's largest reinsurer of terrorism

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[5] Bea, Keith. "Federal Stafford Act Disaster Assistance: Presidential Declarations, Eligible Activities, and Funding." *CRS Report for Congress*. Order Code RL33053. April 28, 2006.
[6] "Hurricane Katrina: What Government is Doing." Department of Homeland Security. Sept. 24, 2006.

risk through the TRIP.

The maximum government exposure under TRIP is laid out by statute. For 2009-2014, the federal government is technically liable for up to $61.625 billion of terrorism losses, of which some fraction may be recouped from the industry.[7] To date, no losses have been paid under TRIP. Of course, it is likely that the government's exposure to terrorism losses is significantly larger than the limits laid out in TRIP. The government paid out approximately $16 billion through the September 11 Victims' Compensation Fund of 2001,[8] and pressures for ad hoc payments are likely to develop if a terrorist event larger than the $100 billion maximum under TRIP were to occur.

The NFIP boasts about $1.1 trillion in exposures nationally.[9] Although it is described as a "self financing" program, the NFIP has borrowing rights at the Treasury when losses exceed its resources. This borrowing authority was increased dramatically to $20.8 billion to cover claims following Hurricane Katrina. In reality, NFIP is not self supporting and has been criticized for leaving a high proportion of flood exposed properties uninsured and not operating on sound actuarial principles (Cummins 2006, Jenkins 2006).[10] Hence, in its present form, NFIP creates more financial exposure for the federal treasury than was envisioned when the program was established.

Other federal insurance programs are also exposed to catastrophe losses. Notably, the U.S. Department of Agriculture insured $50 billion of crop value in 2006 through the Federal Crop Insurance Corporation.[11]

Additional Sources of Exposure

The aftermath of a major catastrophe will entail significant economic disruption for the affected region, and potentially for entire national industries. Lost jobs, reduced wages, and lower output will all result in a lower tax base. This means less federal revenue at a time of increased federal spending. Government post-disaster aid will contribute to rebuilding the tax base, and thus over the long run, will lessen the size of indirect exposure created by lost tax revenues.

Next we describe our collection and analysis of data on federal disaster expenditures and catastrophe losses.

III. Data and Methodology

As noted above, *ad hoc* disaster assistance has historically been the most important source of

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[7] The figure of $61.625 billion is obtained by multiplying the federal coinsurance share for 2007-2014 (85%) by $72.5 billion (calculated as the maximum insured loss amount of $100 billion less the aggregate industry retention of $27.5 billion). See Dunham and Dembeck (2008).

[8] Victims' compensation is not explicitly part of TRIP, which primarily provides reinsurance for property-casualty insurance coverages. Data on September 11 victims' compensation are from the following website: http://www.usdoj.gov/archive/victimcompensation/payments_deceased.html.

[9] See http://www.fema.gov/business/nfip/statistics/cy2007cov.shtm.

[10] The net deficit of losses paid over premiums collected spiked at $4.9 trillion following Katrina but had declined to about $556 million by 2007. See http://www.fema.gov/business/nfip/statistics/statscal.shtm.

[11] Source: Federal Crop Insurance Corporation *Summary of Business Report for 2004 through 2007* (as of 1-29-07).

direct federal financial exposure to catastrophes. Hence, the remainder of the paper focuses on that component of exposure. We use data on disaster damages and disaster assistance to project the distribution of expected federal disaster relief expenditures.

There are three basic steps to this analysis. The first step is to document the relation between catastrophe damages and federal relief expenditures over the period 1989 to 2008 to estimate the amount of federal relief expenditures likely to be "produced" by catastrophe losses. The second step is to develop a prospective annual catastrophe loss distribution for the United States. The third and final step, performed in the results section, is to apply the estimated ratio of federal relief expenditures to catastrophe damages (obtained in the first step) to the estimated catastrophe damage distribution (obtained in the second step) to produce an estimated annual federal disaster expenditure distribution for the United States. In this step, we also calculate the net present value of the implicit government liability arising from catastrophe losses.

Data on the Relation between Catastrophe Loss and Federal Disaster Relief

We combine loss estimates for recent catastrophes with figures for emergency supplemental appropriations to assess the generosity of post-disaster federal aid.

We restrict our attention to catastrophes with at least $1 billion in total damages (in nominal terms) between 1989 and 2008. The main source for total damage estimates is data from the National Oceanic and Atmospheric Administration's (NOAA) National Climactic Data Center (NCDC) and Munich Re (2008, 2009). For each catastrophe, we also identify insured losses using the Insurance Services Office's (ISO) Property Claims Services (PCS) estimates of privately insured losses and the National Flood Insurance Program (NFIP) payouts for flood losses under NFIP. Our selection criterion yields 65 events, with the majority being hurricanes and tropical storms. Also included are the Loma Prieta, Northridge and Nisqually earthquakes,[12] the Oklahoma City and September 11th terrorist attacks,[13] and various significant floods, storms, and wildfires.[14] As the NOAA relates, unlike with private and NFIP insured losses, where every dollar paid out in claims is recorded, there is no federal agency tasked with keeping track of total losses resulting from catastrophes in the US.

NOAA bases their estimates on compilations of statistics from "Storm Data (NCDC publication), the National Weather Service, the Federal Emergency Management Agency, other U.S. government agencies, individual state emergency management agencies, state and regional

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[12] Total losses for Loma Prieta and Northridge earthquakes, described as overall losses in the entire affected region, come from "Megacities – Megarisks: Trends and challenges for insurance and risk management." Munich Re. 2005. Total losses for the Nisqually Earthquake come from Meszaros and Fiegener. "Effects of the 2001 Nisqually Earthquake on Small Businesses in Washington State." U.S. Dept. of Commerce Economic Development Administration. Oct. 2002.

[13] Oklahoma City Bombing total damage from "Governor, Finance Director Release Bomb Damage Estimates." Press Release from the Office of Governor Frank Keating. http://www.state.ok.us/osfdocs/nr5-18.html September 11th total damage figure from Bram, Orr and Rapaport. "Measuring the Effects of The September 11 Attack on NYC." FRBNY Economic Policy Review. November 2002. (New York City) and Nanto, Dick K. "9/11 Terrorism: Global Economic Costs" CRS Report for Congress. RS21937. Oct. 5, 2004. (Pentagon)

[14] NOAA damage estimates are used for all events except the three earthquakes, the Oklahoma City bombing, and the September 11th terrorist attacks.

climate centers, and insurance industry estimates."[15] The figures from the NOAA and the others we use for total damages always encompass insured and uninsured property damages. For longer duration events, like the 1993 Mississippi Flood, droughts, and the earthquakes in our sample, our total loss figures include additional economic costs, such as reduced agricultural output. In the case of September 11th, our total loss figure explicitly includes economic costs associated with labor losses. The catastrophes, with the associated estimates of total and insured losses, are summarized in Figures 1a and 1b, where Figure 1a presents nominal losses and Figure 1b presents exposure and price-adjusted losses.

The gap between insured and total losses is, of course, significant. In the case of earthquakes, this can be attributed partly to low rates of earthquake insurance purchase; similarly, in the case of hurricanes and tropical storms, significant amounts of damage can result from flood---and many households are either uninsured or only partially insured against flood. Deductibles, coinsurance, and uninsured damages (e.g., certain "economic costs" described above) further contribute to insured losses being substantially below our estimate of total losses. For the entire sample of 65 events, the insured to total loss ratio averages less than 50%.

For federal expenditures, we only use figures for emergency supplemental appropriations for disaster assistance. This is legislation outside of the regular annual budgeting process. By our estimates, it accounts for about 80% of all federal disaster spending over the period, as we discuss below. The money can go to any agency involved in relief, but the majority is provided through FEMA's Disaster Relief Fund. The appropriations include funds for "disaster relief, repair of federal facilities, and hazard mitigation activities directed towards reducing the affects of future disasters." Not included are funds for "counterterrorism, law enforcement, and national security (Murray 2006)."

It should be noted that the narrow focus on supplemental appropriations ignores some elements of federal financial exposure to disasters. We do not include the budgeted portion of federal disaster spending, which covers annual appropriations to FEMA's disaster relief fund, much of the Small Business Administration's subsidized disaster loans program, and reconstruction projects which take place long after the fact. Also not included are farm and economic supplemental appropriations through the USDA for specifically agricultural disasters, like droughts. Total USDA spending on farm disaster aid totaled $54.4 billion over this time horizon.[16] We also treat NFIP losses as insurance payments and thus exclude them from the expenditure data. Of course, a case could be made for including them: While the program was close to being self-financing through 2004 (at which point, the NFIP had aggregated only a $200 million deficit), the picture looked far different after record flood losses of the 2005 hurricane season, when the cumulative deficit of losses over premiums was $4.9 billion. Although the deficit was reduced to $556 million by 2007, the program is unlikely to be self-supporting in the

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[15] The National Oceanic & Atmospheric Administration (NOAA) describes their estimates of total costs as "the costs in terms of dollars and lives that would not have been incurred had the event not taken place. Insured and uninsured losses are included in damage estimates. Economic costs are included for wide-scale, long-lasting events such as drought." The estimates are from Lott and Ross. "Tracking and Evaluating U.S. Billion Dollar Weather Disasters, 1980-2005." *NOAA's National Climactic Data Center, Asheville, North Carolina*. 2006. Updated estimates (1/22/2007) obtained http://www.ncdc.noaa.gov/oa/reports/billionz.html.

[16] Chite, Ralph M. "Emergency Funding for Agriculture: A Brief History of Supplemental Appropriations, FY1989-FY2006." CRS Report for Congress. Apr. 3, 2006. See also Murray and Lindsay (2008).

long-run and is badly in need of reform.[17]

Other special items are also excluded: For example, in the case of the 2001 terrorist attacks, we have not included the billions in indemnification distributed through the Victims' Compensation Fund. In summary, our figures for total federal disaster expenditures capture a significant portion, but not all, of the non-budgeted federal exposure to disaster risk; furthermore, we do not attempt to capture exposures that are already reflected in the budget.

We draw on the Congressional Research Service analysis of appropriations, the text of the aid legislation, and date of catastrophe occurrence to assign aid to catastrophes.[18] The appropriation legislation for disasters is usually part of larger bills, and often money is earmarked for multiple recent disasters. This fact, combined with the large number of hurricanes in the sample, make drawing inferences by catastrophe type difficult. Instead we focus on all the events together.

Figure 2 shows the ratio of federal expenditures to total losses. The ratio of aid to total losses has a mean of 33% and a median of 30%, and the ratio of aid to uninsured losses has a mean of 101% and a median of 64%. In aggregate, the 65 events, in values adjusted to 2008 exposure and price levels, comprise about $1.1 trillion in total losses, $450 billion in insured losses, and $375 billion in emergency spending. These aggregated figures are summarized in Table 1b.

While there is significant volatility in the aid ratios across the sample, there is some evidence of an increase in generosity over time: Emergency federal aid/total losses for 9/11 and surrounding natural disasters was 62%, even though federal aid did not breach 50% of total loss for any of the previous events in the sample. Beginning in the 2005 hurricane season and continuing through 2008, federal aid averaged 69% of total losses.[19]

To obtain a more comprehensive picture of federal government spending on disaster aid, we tabulate annual total federal disaster spending and compare it to annual catastrophe losses for fiscal years 1989-2008. The data are presented in Table 1 and Figure 3. In addition to the emergency supplemental appropriations discussed above, we include regular annual appropriations to FEMA's disaster relief fund, USDA emergency funding for agriculture disasters,[20] and the subsidization cost of SBA disaster loans.[21] Annual catastrophe losses are comprised of NOAA's billion dollar weather events, the Loma Prieta, Northridge, and Nisqually earthquakes, and the Oklahoma City and September 11th terrorist attacks. Over this span, in values adjusted to 2008 exposure and price levels, we observe $512 billion in total disaster

[17] Data are from the FEMA website: http://www.fema.gov/business/nfip/statistics/statscal.shtm, and represent cumulative premiums minus cumulative losses from 1978-2007. Statements about FEMA being self-supporting are usually based on a comparison of premiums and loss payments. However, this comparison is misleading because it ignores program expenses. Hence, even during periods when premiums exceed loss payments, it is not necessarily the case that the program is truly self-supporting.

[18] Appropriation legislation is sometimes explicit in assigning particular dollars to a particular catastrophe or set of catastrophes, in which case the allocation is straightforward. In other cases, legislation appropriates funds for unspecified catastrophes in the future, in which case the date of occurrence is relevant for assignment.

[19] It is difficult to distinguish the level of funding for the specific events during this period because the Congressional acts authorizing the payments tended to lump together funding for several events rather than distinguishing specific funding per event.

[20] Funding for "market loss payments to compensate for low farm commodity prices" is excluded.

[21] Emergency supplemental figures are adjusted to avoid double counting for some SBA disaster loan subsidies and DRF original appropriations.

spending and $1.1 trillion in catastrophe losses,[22] for a coverage ratio of 45%. It should be noted that the annual coverage ratios in Figure 3 are partially misleading as spending on a major disaster typically is spread over more than one year.

We now proceed to discuss projections of the catastrophe loss distribution for the entire United States, which will form the other half of the estimate of the federal government's catastrophe loss exposure.

Data on the Aggregate Catastrophe Loss Distribution for the United States

The prospective catastrophe loss distribution for the United States is obviously difficult to estimate precisely, but a rough sense of its character is essential for our exercise. We use two methods to project the distribution.

The first method starts with the prospective distribution of catastrophe losses from a leading catastrophe modeling firm, Applied Insurance Research (AIR). We make adjustments to AIR's distribution to account for uninsured losses (e.g., such as flood losses incurred in hurricanes).

The second method starts with ISO's Property Claims Services database, which contains data on insured losses from U.S. catastrophes spanning more than five decades. We then adjust the historical figures to account for changes in property exposure and price levels. We also make adjustments to account for insurance penetration rates and uninsured losses. The methodology for these adjustments is described below.

In both methods, we restrict our attention to natural catastrophes, such as hurricanes and earthquakes. This leads to a conservative estimate (in the sense of being smaller than what is likely) of catastrophe exposure in two respects. First, we omit man-made catastrophes such as terrorist attacks, oil spills, oil platform fires and explosions, and nuclear power accidents. Second, our methodology almost certainly neglects to fully reflect catastrophe exposure from flooding, since our data sources are focused on privately insured losses. While we have made adjustments to events in the data to reflect the presence of uninsured flood losses, these adjustments are applied only to events that produced significant insured losses (such as a tropical storm). Such a methodology understates flood exposure by failing to account for events with significant flooding but insignificant wind involvement.

Aggregate Catastrophe Loss Distribution based on the AIR Model

Catastrophe modeling is recognized globally as the standard technique for risk assessment and management. It is utilized by insurers and other firms exposed to catastrophic risk in pricing, risk selection and underwriting, loss mitigation, reinsurance decision making, and overall portfolio management. AIR Worldwide, which provided the catastrophic loss estimates discussed here, is one of the three global leaders in catastrophe modeling. Although catastrophe modeling began in the 1980s, the development of the technology accelerated following Hurricane Andrew in 1992 and the Northridge earthquake in 1994.

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[22] The main distinction between the catastrophe losses used in this calculation relative to those used previously relates to the inclusion of drought losses. This augmentation is necessary due to the inclusion of the USDA expenditures.

The AIR model is a stochastic simulation model that incorporates mathematical representations of the natural occurrence patterns and characteristics of hurricanes, earthquakes, and other catastrophes.[23] The model incorporates meteorological and seismological data, actuarial loss data, and information on property values, construction types, and occupancy classes (classifications that indicate what the structure is being used for, such as residential, retail, etc.). In most major geographical areas, the AIR model maps insurer exposure to catastrophic losses to the level of the individual building structure. Incorporated in the model are property characteristics and insurance coverage parameters. Thus, the model provides simulated loss distributions for individual insurers in finely divided geographical areas.

The structure of the AIR model is shown in Figure 4a. The simulations begin with event generation, which entails random generation of events in terms of their location, frequency of occurrence, and severity. The simulations incorporate probability distributions based on historical data for each variable that defines the events. By sampling from these distributions, a large stochastic catalogue of simulated event scenarios is generated. This process is represented schematically in Figure 4b for the simulation of hurricanes.

To estimate the damage potential of natural hazards, the model estimates their physical parameters not only at the source, but also at the sites of the affected building inventory. The local intensity part of the model's hazard module is designed to capture how intensity changes as the simulated catastrophe propagates or travels over the affected area. Detailed scientific and geophysical data and algorithms are employed to model the local effects of each simulated event.

The damage estimation, or vulnerability, component of the model superimposes the local intensities of each simulated event onto a database of exposed properties and estimates the expected level of damage to buildings and their contents. Loss estimates are based on region-specific damage functions for many different construction types and occupancies. Total damage estimates can be generated for the entire insurance industry, individual insurer policy portfolios, or for individual buildings.

In the final component of the model, insured losses are calculated by applying specific insurance policy conditions to the total damage estimates. Policy conditions include deductibles by coverage, coverage limits and sublimits, coinsurance, and other policy conditions. The output of the model is an estimated loss distribution for a specific insurance portfolio and location, often presented as an exceedence probability curve which plots the probability of exceeding various loss amounts.

For purposes of the present study, AIR provided expected average losses and the higher percentiles, in aggregate and by occurrence, for hurricane, earthquake, winter storm, and severe thunderstorm. For all perils except earthquake, the estimates project insured losses, while the earthquake projection addresses insurable losses. As a result, AIR estimates of insured losses for perils other than earthquake will differ from total losses because of deductibles, policy limits, and uninsured losses. Accordingly, we adjust losses for the hurricane, thunderstorm, and winter storm perils upward to account for the historical relation between insured losses and total property losses observed in our sample of catastrophes. The intention is, to the extent possible, to adjust the AIR output to a basis consistent with the total loss estimates used in the previous

[23] The discussion of the AIR model is based on Clark (2004).

section. However, we do not attempt to adjust the earthquake losses to reflect uninsured economic costs absent from the AIR calculations. As a result, the loss estimates should be lower than those that would be fully consistent with the "total losses" used in the previous section. Hence, our ultimate projections of total loss exposure from the AIR model will be conservative in the sense of yielding estimates of federal exposure that are probably on the low side.

Table 2 summarizes the average annual aggregate and occurrence losses produced by adjusting the AIR losses as described. In addition, we list the 99th percentile for all cases---the amount of loss corresponding to that expected with a frequency of once per century.[24] The estimates show an annual aggregate expected average total loss of $35-$43 billion. The higher figure uses a shorter historical time series of hurricanes to account for the recent trend of more frequent and severe hurricanes. For All Perils, there is a one percent chance of an annual loss of at least $273-282 billion dollars (without attempting the adjustment to hurricane and thunderstorm losses described above).[25]

Aggregate Catastrophe Loss Distribution based on PCS Data

In this section, we discuss the estimation of catastrophe loss distributions using the PCS data on insured catastrophe losses. PCS reports losses at the state level, beginning in 1949, for various types of catastrophes. We adjust the data for changing exposure levels, as explained below, to provide estimates of the losses that would have resulted from the historical catastrophes recorded by PCS if today's property values had existed at the time of the events. Maximum likelihood estimation is used to fit the adjusted losses to underlying parametric loss distributions. In this fashion, we can project expected losses and various percentiles to compare with the figures provided by AIR.

Data Considerations

Property Claims Services (PCS), a division of the Insurance Services Office (ISO), compiles data on insured losses from catastrophes. Currently, PCS defines a catastrophe as an event that causes $25 million or more in damages and affects a significant number of policyholders.[26] The PCS loss estimates are for personal and commercial property along with vehicle losses covered by comprehensive coverage.[27] The data are collected by canvassing the insurance industry following major loss events and conducting supplemental field research in some instances.[28]

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[24] Note that the figures for the percentiles for the All Perils category do not contain adjustments for the historical relation between insured losses and total property losses, as we do not have detailed information on the composition of the All Perils distribution. The average, however, does reflect the adjustment.

[25] This figure represents the 99th percentile of the distribution of the sum of insured losses for all perils except Earthquake, and insurable losses for Earthquake. Since we do not have the composition of the All Perils distribution, we cannot make the referenced adjustments without making further assumptions. In the case of the average, however, the adjustments yielded an increase of about 50%; a similar impact on the 99th percentile would suggest a figure above $400 billion.

[26] The monetary threshold used by PCS to define a catastrophe has been adjusted over time. From 1949 to 1981, the dollar threshold was $1 million; from 1982 to 1996, the threshold was $5 million; and since 1997 the threshold has been $25 million.

[27] Auto losses generally represent 10% or less of total losses from catastrophes (email from Gary Kearny of PCS).

[28] PCS generally combines two methods to develop the best estimate of insured catastrophe losses. First, PCS conducts confidential surveys of insurers, agents, adjusters, public officials, and others to gather data on claim volumes and amounts. PCS analyzes the data and combines it with trend factors to determine a loss estimate. PCS

PCS maintains data from 1949 through the present, broken down by state and by type of event. The PCS analysis in this paper focuses on the period 1950 through 2006.

In this study, we develop models based on fitting probability distributions to the PCS data. We then estimate the loss quantiles to measure exposure to loss from various perils.

Prior to fitting probability distributions, it is important to adjust the PCS loss data for changes in the value of property exposed to loss. The reason for this adjustment is that the value of property exposed to loss in the United States has expanded dramatically during the period 1949 through 2006, both from growth in the housing stock and price appreciation. Consequently, events from prior decades would be likely to cause much greater damages if they occurred today. To adjust the data for changes in property values, we created an exposure index for each state using the U.S. Census Bureau's decennial census data on housing values.[29] Values for years between the decades are calculated based on logarithmic interpolation; values for 2001-2006 are calculated based on the annual growth rate that prevailed from 1990 to 2000. This series gives the aggregate value of owner-occupied homes for each state in nominal dollars, so an increase in these figures over time represents both more houses being built and increases in the price level. The index is computed simply as the ratio of the 2006 value in a given state to the value in a past year:

$$ExposureIndex_{state}^{year} = \frac{AggregateHomeValue_{state}^{2006}}{AggregateHomeValue_{state}^{year}}$$

Then the nominal loss value reported by PCS for a given catastrophe in a given year and state is multiplied by the value of the exposure index for that year and state. This is an estimate of the losses a past catastrophe would cause if it occurred today, considering present price levels and the size of exposed infrastructure.[30]

Because PCS focuses on insured losses from catastrophic events, we also adjust the PCS data to estimate the total (insured and uninsured) losses from each event. These adjustments differ by peril because the proportion of property covered by insurance varies significantly by peril. For example, earthquake insurance take-up rates in California are substantially smaller than

---

also maintains a database containing information on the number and types of structures for every U.S. state. Using that information, PCS can estimate the number of insurable risks in a specific geographic area. Combined with survey information, the structure data forms the basis for the PCS damage estimates. For large or unusual events, PCS resurveys the affected insurers to obtain updated information. PCS estimation methodology is described in more detail in Property Claims Services (2006).

[29] The series used is: H024. AGGREGATE VALUE - Universe: Specified owner-occupied housing units, defined by the Census Bureau as the "Total number of owner occupied housing units described as either a one family home detached from any other house or a one family house attached to one or more houses on less than 10 acres with no business on the property. The data for "specified" units exclude mobile homes, houses with a business or medical office, houses on 10 or more acres, and housing units in multi-unit buildings."

[30] The use of a housing value index implicitly assumes that the value of commercial property and automobiles exposed to loss has expanded at the same rate as the value of residential property. Because population growth in a geographical region is likely to be accompanied by corresponding growth in commercial activity and the number of automobiles, this is likely to be a reasonable assumption. The use of housing values that the value of land as a proportion of total housing value remains more or less constant over time. This assumption is potentially important because storm damages are to structures and other property rather than to land, whereas the value of land is incorporated in the value of the housing stock.

homeowners insurance take-up rates in the Southeast. These adjustments are described in detail below.

For a hurricane/tropical storm, thunderstorm, and winter storm loss, we scale up the losses by a constant factor, the inverse of the insured-to-total loss ratio for the corresponding peril in our federal expenditure sample (with NFIP losses not included in the insured figure).

Similarly for earthquakes, we use known take-up rates for earthquake insurance since 1996 for California (available from the California Department of Insurance), and project earlier take-up rates based on the relationship between annual California earthquake premium data (also from the California Department of Insurance), California aggregate housing value, and the known take-up rates since 1996.[31] We apply the inverse of these known and estimated take-up rates to the PCS insured earthquake loss for the year it occurs to get a total loss figure.

Statistical Methodology

To estimate an aggregate annual claims distribution, we use a Fast Fourier Transform (FFT) inversion method. The approach requires separate estimates of the severity of loss and annual frequency of occurrence distributions for each specific peril. We then compound these estimates to produce distributions of aggregate annual claims by peril and for all catastrophes.

Thus, the estimation has five phases[32]:

(1) Estimate the severity of loss and annual frequency distributions separately for each of the major catastrophe perils using maximum likelihood estimation.

(2) Discretize the severity distribution, by dividing the full range of possible loss into equal segments, and placing all the probability within a segment at its midpoint.

(3) Apply the FFT to the discretized severity distribution to obtain its characteristic function.

(4) Transform this characteristic function using the estimated frequency distribution, yielding the characteristic function of the aggregate annual claims distribution.

(5) Apply an inverse FFT to recover the aggregate annual claims distribution functions.[33]

[31] Take-up rates since 1996 are from the California Department of Insurance: http://www.insurance.ca.gov/0250-insurers/0600-data-reports/0100-earthquake-cov-exp/. Annual earthquake premium data was obtained by fax from Richard Roth Jr. at the California Department of Insurance.

[32] The reason for applying the Fast Fourier Transform (FFT) approach is that the total claims distribution cannot be computed by convoluting the severity random variables and then compounding the convolutions with the frequency distribution for most realistic frequency and severity distributions. However, the total claims distribution can be recovered by computing and then inverting the characteristic function. The Fourier transform approach is discussed in Klugman, Panjer, and Willmot (2004). The severity distributions are discretized using the rounding method on 4,096 segments of $100 million of loss. Any further tail probability, corresponding to losses exceeding $409.6 billion (Number of segments * loss per segment), is placed on the last point of the discretized severity pdf.

[33] This implicitly assumes that losses from catastrophe perils such as hurricanes, tornadoes, and earthquakes are statistically independent. The calculation utilizes the result that the characteristic function of the sum of independent random variables is the product of the characteristic functions of the individual random variables in the sum.

For fitting the severity of loss data, three different distributions are used, which have been shown to provide good models of loss distributions in prior research (e.g., Cummins, Lewis, and Phillips, 1999). The distributions – the lognormal, the Pareto, and the Burr 12 – are specified as follows:

The lognormal: $$f(x) = \frac{1}{x\sigma\sqrt{2\pi}} e^{-\frac{1}{2}(\frac{\ln(x)-\mu}{\sigma})^2} \quad , x > 0$$

The Pareto: $$f(x) = \alpha\lambda^{\alpha}(\lambda + x)^{-\alpha-1} \quad , \; x > 0$$

The Burr 12: $$f(x) = |a| \, q \, x^{a-1} b^{-a} [1 + (\frac{x}{b})^a]^{-q-1}$$

We use the Poisson distribution, specified below, to fit the annual occurrences of a given peril over our sample period, 1950-2005:

The Poisson: $$f(x) = e^{-\lambda} \frac{\lambda^x}{x!} \quad , \; x = 0, 1, 2\ldots$$

Results

Summary statistics on catastrophe losses are presented in Table 3, which have been adjusted for changes in housing exposures, both from growth in the housing stock and price level increases (but not to account for differences between insured losses and total losses). All data are from PCS. Hurricanes have the highest average and median loss severity at \$8.8 billion and \$1.2 billion, respectively. Hurricanes also have the highest standard deviation of loss. As expected, the observed losses are highly skewed for all perils.

The trends in the total number of catastrophic events and the total insured losses are shown in Figure 5. The loss amounts have been adjusted to 2006 property values, and catastrophes that would not have caused at least \$25 million in losses at 2006 property value levels have been deleted for purposes of preparing this figure. Even though Hurricane Katrina was the largest loss event recorded during the sample period in nominal dollars, based on the housing value-adjusted loss data there were five previous events of approximately equal or greater magnitude. In 1950, a major wind and thunderstorm event caused substantial property losses from Maryland to Maine. If a similar event occurred at present, the estimated losses would be greater than \$227 billion. In 1954, Hurricane Carol caused major damage ranging from New Jersey to Maine with particularly large losses in Massachusetts and New York. The same year, Hurricane Hazel caused devastating losses ranging from South Carolina to New York. If those storms occurred today, it is estimated that Carol and Hazel would cause losses of \$132 billion and \$125 billion, respectively. A storm of the magnitude of Hurricane Gloria, which struck several Northeastern states in 1985, would cause estimated losses of \$65 billion if it occurred today. By contrast, insured losses from Hurricane Katrina were "only" \$44 billion.

Parameter estimates for the various distributions and perils are shown in Table 4, along with log likelihood function values. Estimates are shown both for insured and total losses. The last column of the table shows the best fitting distribution based on an approximate likelihood ratio test.[34] The Pareto provides the best fit for all perils except Earthquake.

As an example of one of the estimated distributions, the severity distribution of total losses from hurricanes and tropical storms is shown in Figure 6. The likelihood ratio results show that the Pareto provides the best fit to this set of data but not at a high level of statistical significance. The graph bears this out but suggests that all three distributions fit the data reasonably well, with the Pareto and Burr12 perhaps overestimating the probability in the tail of the distribution. In Figure 7 we present the annual aggregate claims distribution of total losses for all perils. These distributions are not directly estimated from the data. They are derived by compounding the separately estimated severity and frequency distributions for each individual peril through the FFT method described above. Due to computational limitations, all three distributions are capped at $409.6 billion, leading to underestimation of probability in the tail of the distribution.

Table 5 presents the means and upper percentiles of the estimated severity of loss distributions for the models whose parameters are shown in Table 4. The percentiles shown are the 50th, the 75th, the 90th, the 95th, the 99th, and the 99.9th. The latter three percentiles would correspond to event "return periods" of 20, 100, and 1000 years, respectively.

Focusing on the 99th percentile, the best fitting severity distribution for hurricanes (the Pareto) shows that a once in 100 year event would cause insured losses of $942 billion and total losses of $1,975 billion.

In Table 6 we present annual aggregate losses by peril and for all perils (hurricanes, earthquakes, wind and thunderstorm, and winter storm) combined. For all perils, we project an expected annual insured loss range of $24-$35 billion and a total loss range of $39-$48 billion. The 99th percentiles of the insured and total loss distributions are $181-$310 billion and $272-$337 billion, respectively. These estimates suggest very large exposure to catastrophic losses for both the government and the insurance industry.

IV. Estimated Annual Losses and Projected Liabilities

The AIR model projects expected annual catastrophe total losses of $35 to $43 billion; this is roughly comparable to the projections from the PCS data, which indicate annual average losses of $39 to $48 billion. For the 99th percentile, the AIR model indicates insurable loss of $273 to $282 billion, which is again comparable to the total loss figures from the PCS methods---which indicate a range from $272 billion to $337 billion, depending on the distribution chosen.

Reasonable estimates of the recent relation between federal aid and losses, based on the analysis presented, range from 30% to 50%---with figures at the higher end of the range supported by generosity observed in recent events such as the 2005 hurricanes, and by the aggregated ratios of aid to losses over the period. It is true that the aggregates are skewed to some degree by the larger events that have happened in recent years, but even a straight average, by event, of the

[34] The likelihood ratio test results are only approximate because the distributions estimated are not nested in the sense that they can be obtained by imposing parameter restrictions on the distribution with the largest number of parameters. The significance tests are based on a Chi-square distribution with 1 degree of freedom. The likelihood test statistic is 2*[log(L:distribution 1) – log(L: distribution 2)], for pairwise tests of the distributions.

ratio of aid to loss yields a figure in excess of 30%.
Thus, our analysis suggests an expected annual federal exposure in the neighborhood of $10 billion to $25 billion, with the exposure in a bad year (once in a century) in the neighborhood of $80 billion to about $170 billion.[35]

These figures have two significant aspects. First, even the low end of our expected estimate is substantially higher than current regular appropriations. Second, the projections are accurate enough to be used for determining the size of regular appropriations. As Holtz-Eakins (2005) states, "many analysts believe that current federal budget procedures can lead to inappropriate evaluations of the trade-offs involved in providing assistance and can reduce incentives for mitigation and recovery efforts by state and local governments." He continues that one option, instead of relying so heavily on emergency supplemental appropriations, is to, "appropriate money for disaster programs in regular appropriations bills in amounts equal to the expected funding need for each program." One way of realizing this would be to simply require that the midpoint of our estimate range be budgeted in advance for disaster relief. Then going forward, projections can be updated fairly easily each year, to encompass improvements in catastrophe modeling, revised assumptions about disaster frequency and severity, or changes in expected relief generosity. By aligning policymaker incentives and allowing proper comparison of competing spending priorities, implementing such a system would reduce the substantial future costs of disaster relief.[36]

Assuming our current system of disaster relief is left unreformed, we can compute the net present value of the liability to the federal government of disaster spending over a given time horizon (for purposes of comparison with the unfunded liability associated with other social programs). We take the midpoint of our estimate of expected annual spending, $17.5 billion. We assume growth in exposure equal to the long term trend (1950-2006) annual growth rate in the value of the US housing stock index, 9%. Currently about $2 billion is set aside for disaster aid each year, and we assume this grows with nominal GDP based on the same 1950-2006 span which is 7.1%. Using a 5% discount rate, the net present value (NPV) of the liability over a 75-year horizon is $7.1 trillion. If we assume everything grows at the 5% discount rate, the NPV is $1.2 trillion. Over this same horizon, the trustees of Social Security project a shortfall with a NPV of $4.9 trillion.[37]

V. Concluding Remarks

The tremendous growth in federal disaster spending observed over the 20th century has continued in more recent years. The $82 billion in emergency federal spending on Katrina and other proximate hurricanes in 2005 exceeded the FY2005 budget of all but 5 government agencies as

[35] These ranges are rounded figures computed by multiplying the lower bound of our estimates of expected annual catastrophe losses by the lower bound of observed federal aid ratios, 30%, and the higher bound of our estimates by the higher bound of observed federal aid ratios, 50%.
[36] Of course, challenges arise when shifting to explicit recognition of expected disaster relief in the budget. In particular, bureaucratic motivations to overspend on particular disasters would have to be addressed. On the other hand, it is debatable whether an official budgetary acknowledgment of this entitlement, based on current levels of generosity, would encourage or restrain further growth in generosity.
[37] "The present value of future tax income minus cost, plus starting trust fund assets, minus the present value of the ending target trust fund amounts to -$4.9 trillion for the OASDI program." The 2006 OASDI Trustees Report. Section IV. Actuarial Estimates. May 1, 2006. http://www.ssa.gov/OACT/TR/TR06/

well as the total amount appropriated for the much maligned congressional earmarks.[38] Our analysis shows that the expected annual expenditure on disaster assistance – an estimated $10 to $25 billion – is quite significant and could be even higher if more aggressive assumptions, that put a greater weight on recent trends, are used. While this estimate is obviously not precise, different assumptions or methods seem unlikely to alter the basic inferences about the significance of the annual cost.

The cost is indeed significant: Given the current approach to disaster relief funding---we project an "unfunded" liability for disaster assistance over the next 75 years comparable to that of Social Security. FEMA's current annual budget falls far short of expected annual federal disaster assistance, most of which is financed through supplemental appropriations on an "as needed" basis. Over the period FY1989-FY2006, FEMA's Disaster Relief Fund received original appropriations for less than $15 billion, while experiencing outlays of over $58 billion.[39]

This budgetary treatment may not be unusual, but the lack of transparency with respect to acknowledging the commitment and accounting for its size is unfortunate in at least two respects. First, the costs and benefits of the disaster assistance program currently cannot be weighed against other national priorities. Second, federal disaster policy itself cannot be optimized without understanding the commitment and the dollars involved. For example, if a scaling back of the federal disaster assistance program is not politically realistic, federal subsidization of state and local mitigation expenditures may be in the taxpayer's interest---at least in the short run. Our projections make explicitly incorporating expected relief spending in the regular budgeting process a real possibility. Doing so would force the informed decision making that will optimize relief, although such incorporation would have to be combined with careful consideration of spending authority and bureaucratic incentives to insure that spending is ultimately restrained.

In designing disaster relief policy, there are many important considerations that we do not attempt to analyze. Notably, many have observed that disaster assistance embodies a "Samaritan's Dilemma" in the sense of its presence encouraging development in high-risk areas. Implicit in our approach is the notion that, prior to probing the deeper implications of the economic incentives embedded in disaster relief policy, it makes sense to first ask how extensive it is. Thus, we have attempted to measure and document the financial extent of current policy, with the belief that reform and management must be informed by measurement.

We document that disaster assistance is a large and continuous liability to the federal government, which increases with the value of infrastructure exposed to catastrophes. Though we are accustomed to think of catastrophes as unpredictable, our analysis demonstrates that it is possible to forecast expected future costs for disaster assistance. Knowing the magnitude of these figures can inform both the budgeting process and, ultimately, the design of disaster relief policy.

[38] The agencies were HHS (Medicare), Social Security, Defense, Treasury (Debt Interest), and Agriculture (CRS RL33228). FY2005 earmarks totaled approximately $50 billion. CRS Appropriations Team. "Earmarks in Appropriation Acts: FY1994, FY1996, FY1998, FY2000, FY2002, FY2004, FY2005." *Congressional Research Service Memorandum*. January 29, 2006.

[39] Bea, Keith. "Federal Stafford Act Disaster Assistance: Presidential Declarations, Eligible Activities, and Funding." *CRS Report for Congress*. Order Code RL33053. April 28, 2006.

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Figure 1a
Sample of Major Disasters: 1989-1998

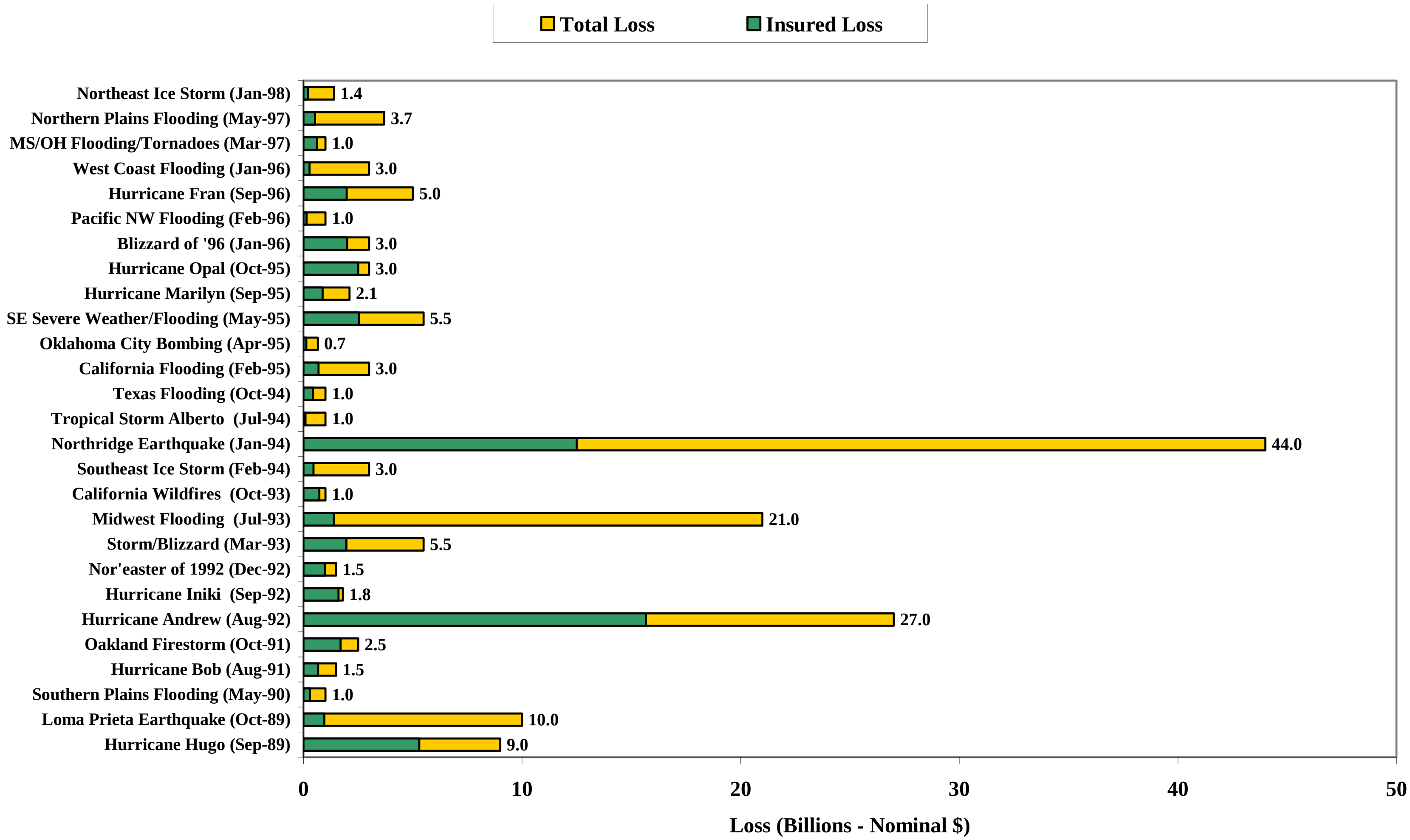


Figure 1a - Continued
Sample of Major Disasters: 1999-2008

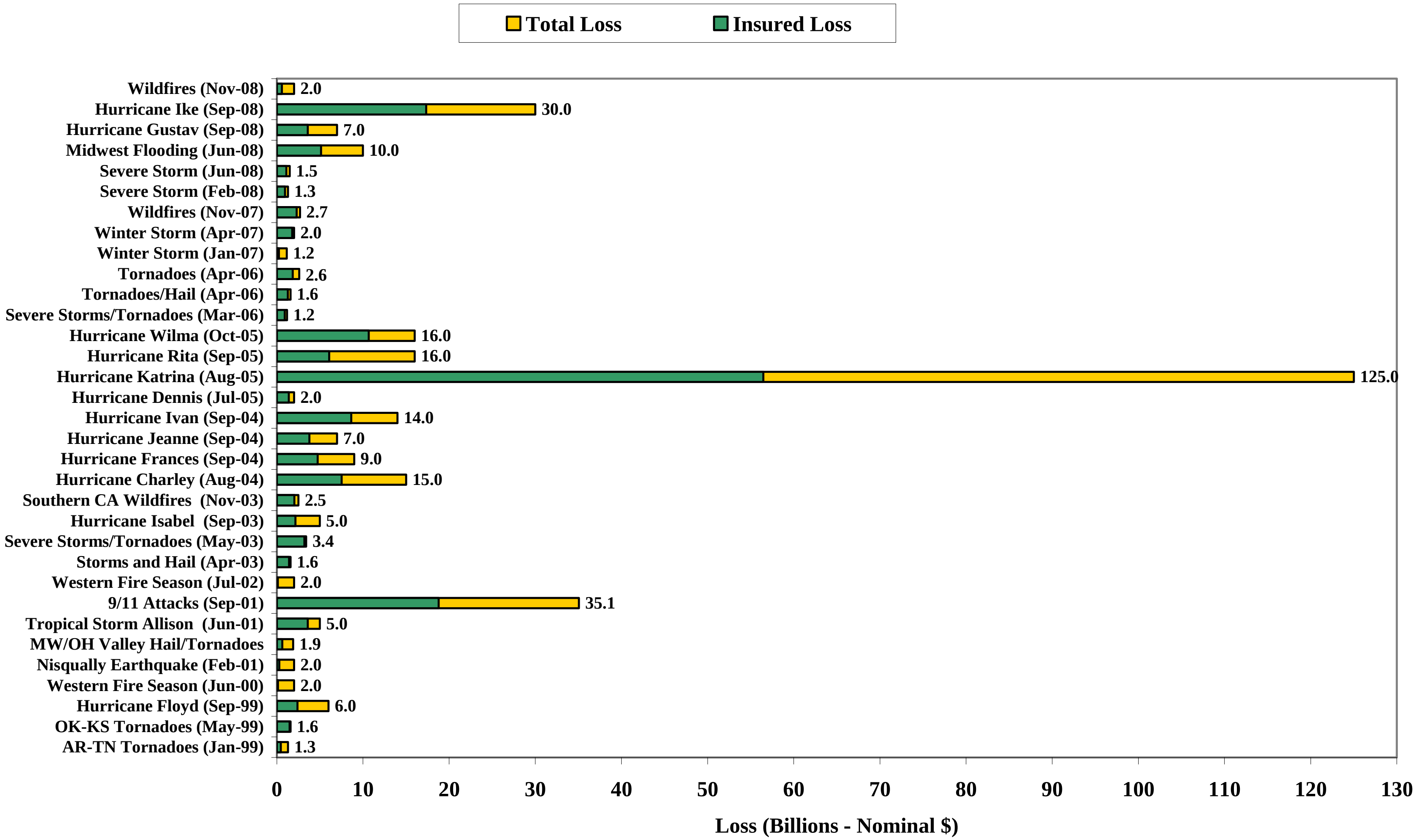
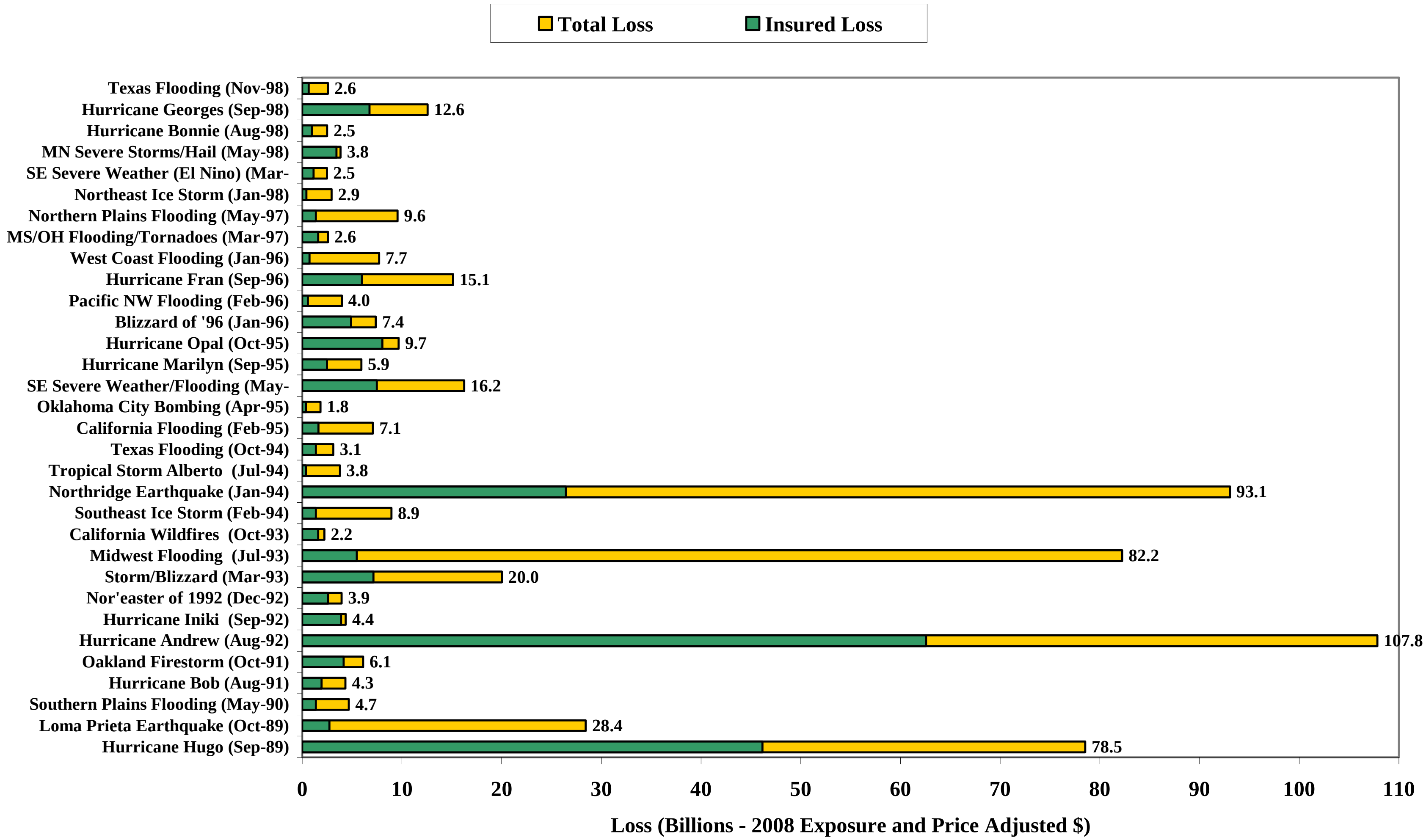
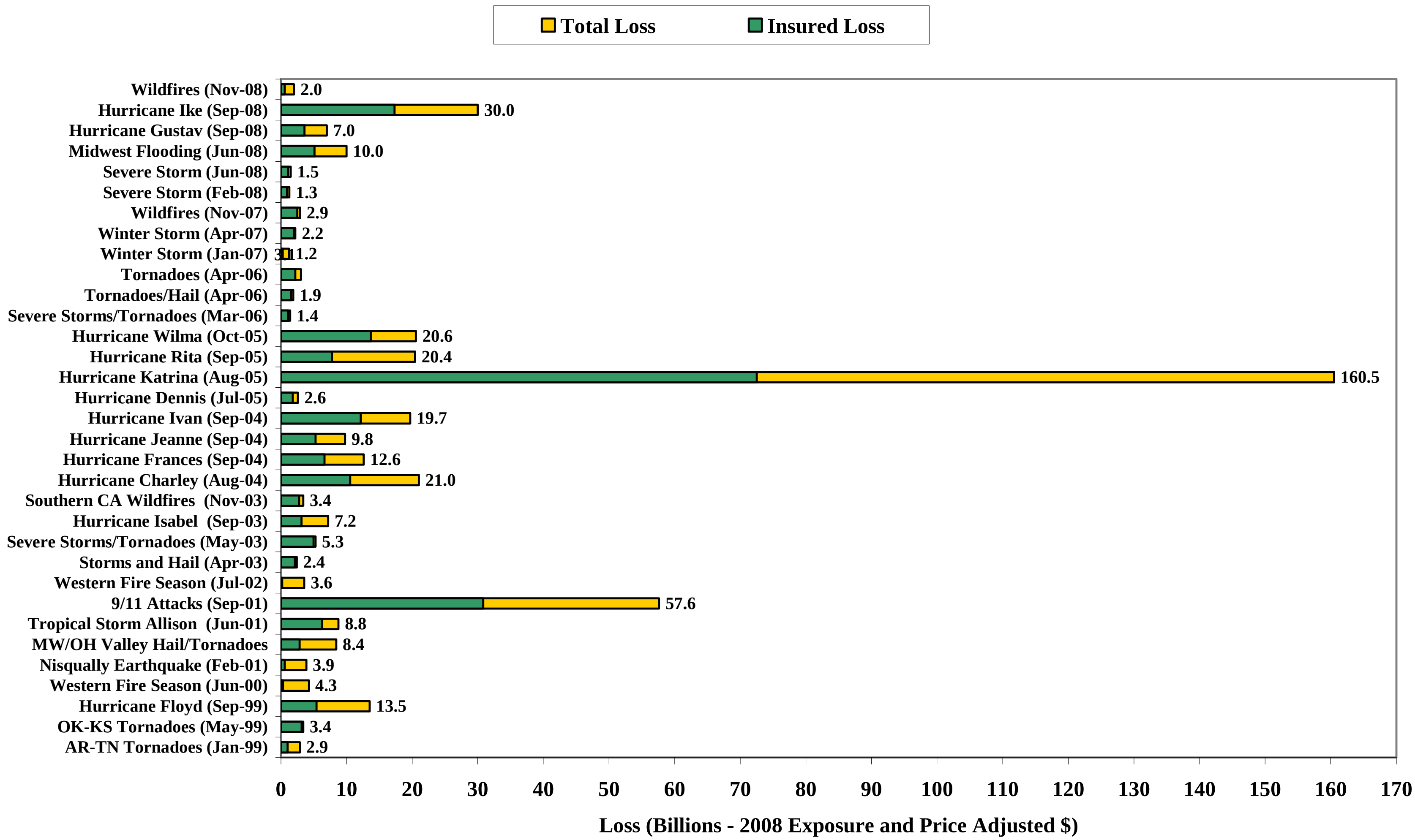


Figure 1b
Sample of Major Disasters: 1989-1998



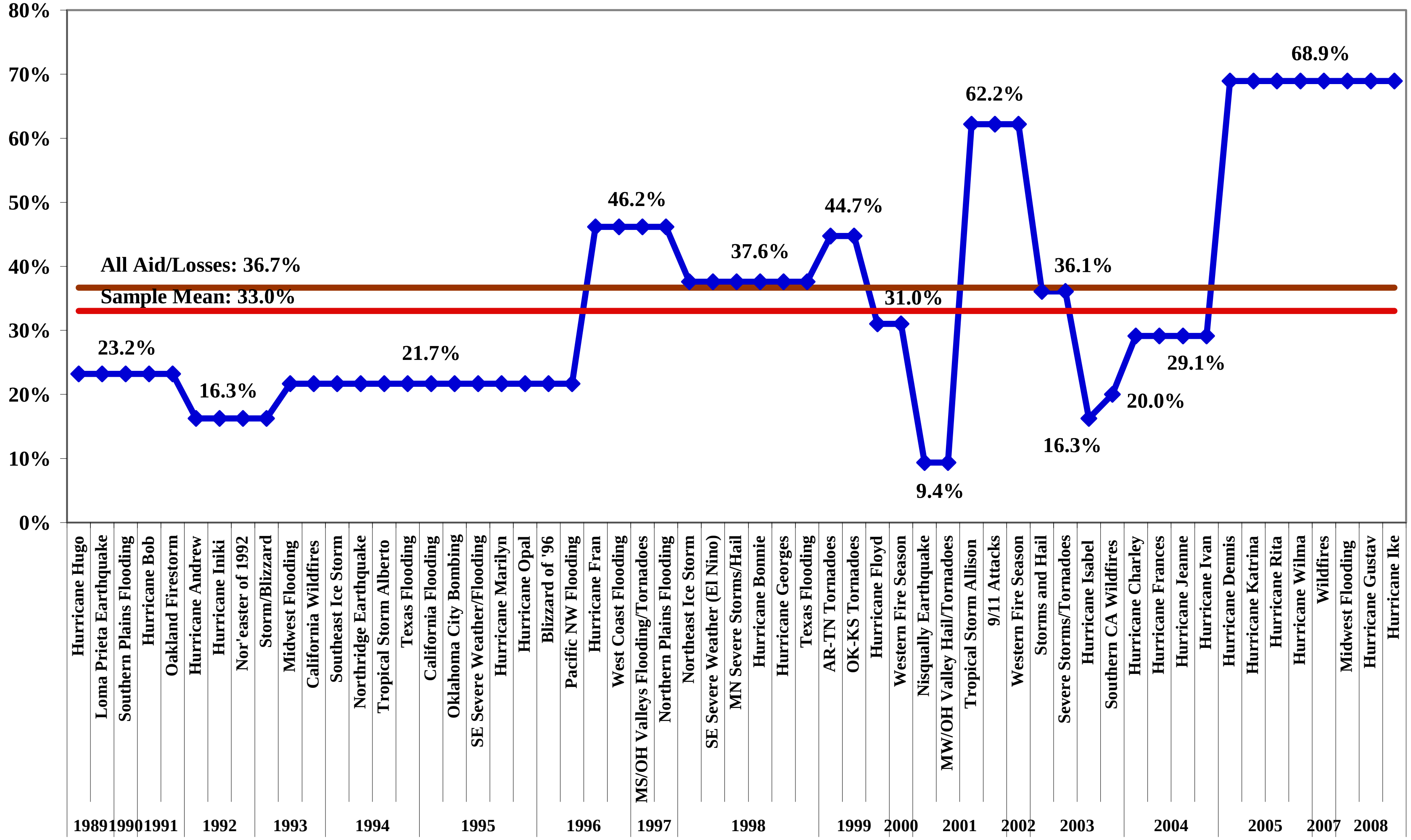
Note: Insured and total loss figures are adjusted at the state level by our 2008 exposure index. This index captures both price level changes and changes in the size of the housing stock. The intent is to estimate the losses a past disaster would cause if it occurred today.

Figure 1b - Continued
Sample of Major Disasters: 1999-2008



Note: Insured and total loss figures are adjusted at the state level by our 2008 exposure index. This index captures both price level changes and changes in the size of the housing stock. The intent is to estimate the losses a past disaster would cause if it occurred today.

Figure 2
Federal Aid Ratios: 1989-2008



Note: Each data point represents a specific disaster in our sample, with labels for the most significant disasters. The "All Aid/Losses" ratio is computed after adjusting loss and aid figures by our 2008 exposure index. This index captures both price level changes and changes in the size of the housing stock. This yields a ratio which is not over-weighted by recent disasters.

Table 1a
Summary of Catastrophe Loss and Federal Aid

1989-2008

Values in Billions - Nominal $

Emergency Supplemental Appropriations

Aggregate		By Event	Mean	Median
Number of Events	65			
Total Loss	510.0	**Aid to Total Loss**	33.0%	30.1%
Insured Loss (including NFIP)	235.9	**Insured Loss to Total**	45.7%	44.6%
NFIP	27.2	**Aid to Uninsured Loss**	101.4%	63.8%
Federal Aid	240.6			
Aid to Total Loss	47.2%			
Insured Loss to Total	46.3%			
Aid to Uninsured Loss	87.8%			

Total Federal Disaster Spending

Aggregate		By Year	Mean	Median
Number of Years	20			
Total Loss	542.1	**Aid to Total Loss**	62.0%	55.7%
NFIP	32.9			
Federal Aid	285.7			
Aid to Total Loss	52.7%			

Table 1b
Summary of Catastrophe Loss and Federal Aid

1989-2008

Values in Billions - 2008 Exposure and Price Adjusted $

Emergency Supplemental Appropriations

Aggregate		By Event	Mean	Median
Number of Events	65			
Total Loss	1,021.9	**Aid to Total Loss**	33.0%	30.1%
Insured Loss (including NFIP)	449.9	**Insured Loss to Total**	45.7%	44.6%
NFIP	44.2	**Aid to Uninsured Loss**	101.4%	63.8%
Federal Aid	374.7			
Aid to Total Loss	36.7%			
Insured Loss to Total	44.0%			
Aid to Uninsured Loss	65.5%			

Total Federal Disaster Spending

Aggregate		By Year	Mean	Median
Number of Years	20			
Total Loss	1,136.6	**Aid to Total Loss**	62.0%	55.7%
NFIP	59.8			
Federal Aid	511.8			
Aid to Total Loss	45.0%			

Note: In Table 1b, loss figures are adjusted at the state level by our 2008 exposure index. This index captures both price level changes and changes in the size of the housing stock. The intent is to estimate the losses a past disaster would cause if it occurred today. Federal disaster spending is also adjusted using the same index, which yields an aggregate aid ratio which is not over-weighted by recent disasters.

Figure 3a
Total Federal Disaster Spending: FY1989-FY2008

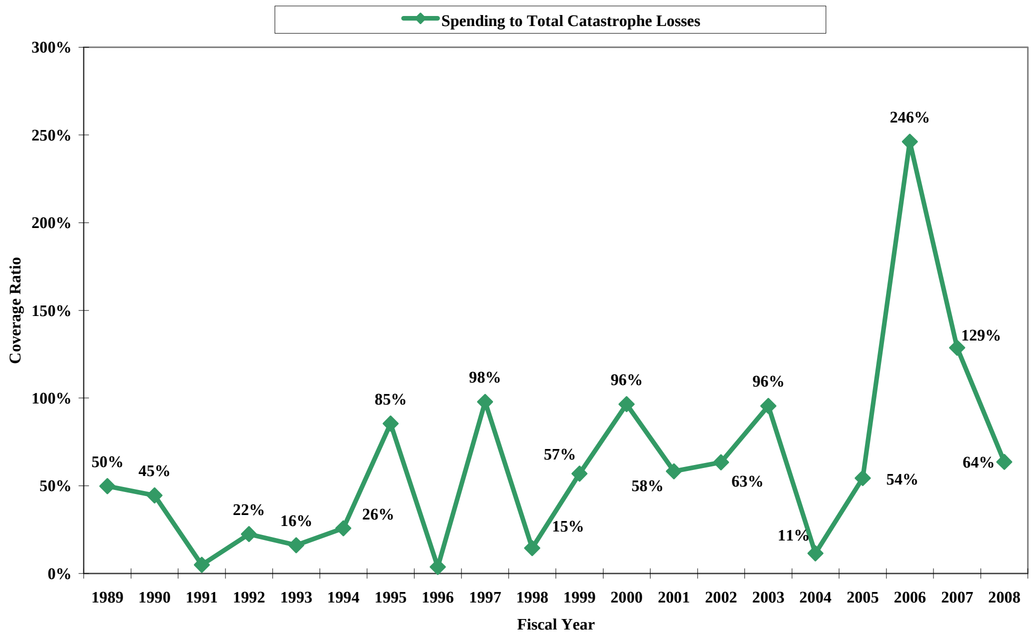
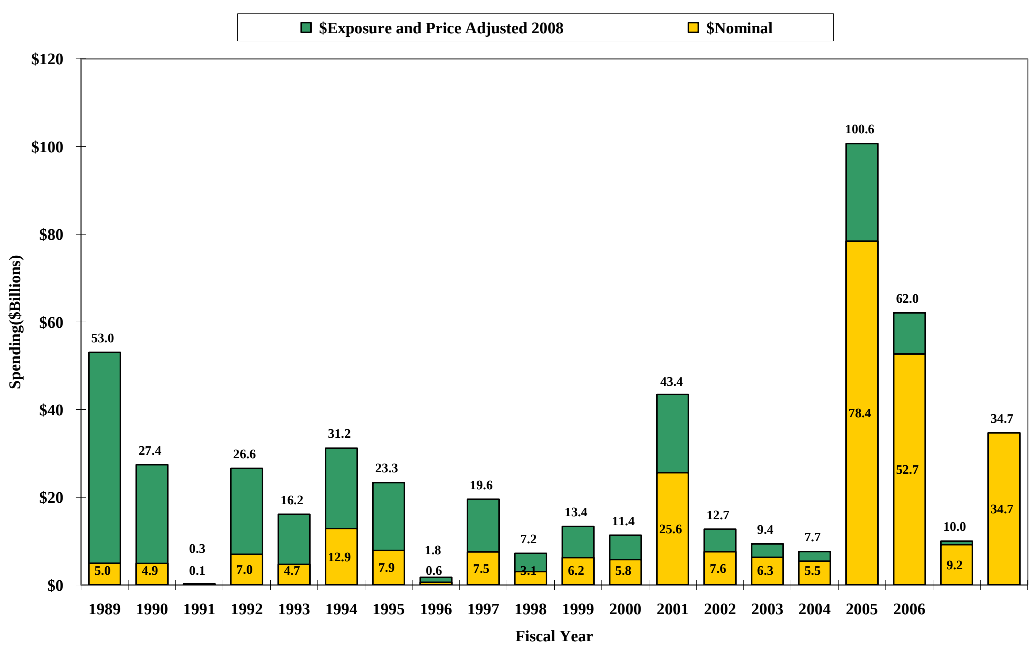


Figure 3b
Total Federal Disaster Spending: FY1989-FY2008



Note: In figure 3b, values are adjusted at the state level by our 2008 exposure index. This index captures both price level changes and changes in the size of the housing stock. The intent is to estimate the spending that would have resulted if a past disaster occurred today.

Figure 4a: The Structure of the AIR Simulation Model

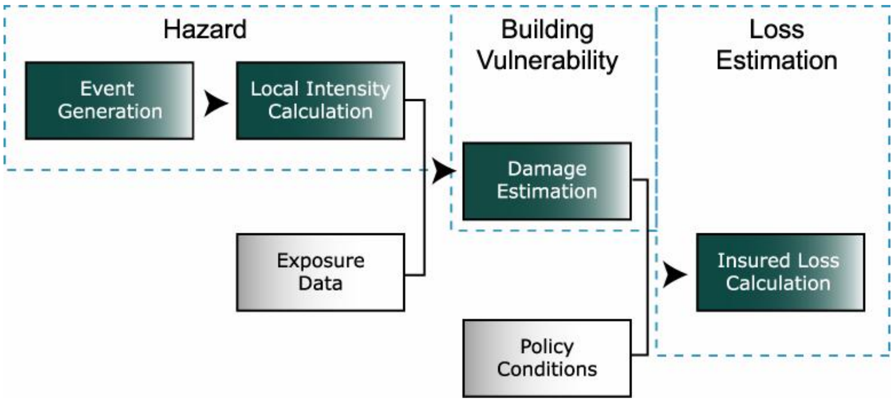


Figure 4b: Simulating a Stochastic Catalogue of Storm Events

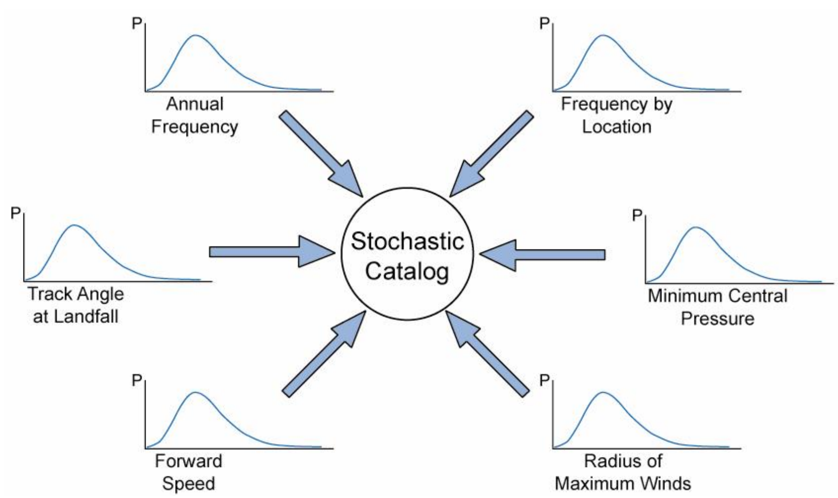


Table 2

AIR based projections of US catastrophe loss exposure

Perils include hurricane, earthquake, winter storm, severe thunderstorm, and implicitly, flood.
Hurricane expected average loss scaled by 47.7% insured to total loss ratio.
Severe Thunderstorm expected average loss scaled by 74.3% insured to total loss ratio.
Winter Storm expected average loss scaled by 55.6% insured to total loss ratio.
Amounts in $billions

All Perils (Standard Hurricane Model)

	Aggregate	**Occurrence**
Expected Average Loss	35.2	21.6
99th Percentile	272.6	234.6

All Perils (Near Term Hurricane Sensitivity) [a]

	Aggregate	**Occurrence**
Expected Average Loss	43.1	27.7
99th Percentile	281.6	240.3

Hurricane (Standard Model)

	Aggregate	**Occurrence**
Expected Average Loss	19.9	16.8
99th Percentile	109.0	97.4

Hurricane (Near Term Sensitivity)

	Aggregate	**Occurrence**
Expected Average Loss	27.8	22.9
99th Percentile	138.7	122.0

Earthquake

	Aggregate	**Occurrence**
Expected Average Loss	16.3	14.7
99th Percentile	238.2	213.8

Winter Storm

	Aggregate	**Occurrence**
Expected Average Loss	4.1	2.0
99th Percentile	8.8	5.5

Severe Thunderstorm

	Aggregate	**Occurrence**
Expected Average Loss	11.2	2.8
99th Percentile	19.7	10.3

[a] Near term hurricane sensitivity uses a shorter historical time series of hurricanes to account for the recent trend of more frequent and severe hurricanes.

Table 3

PCS Data 1950-2006

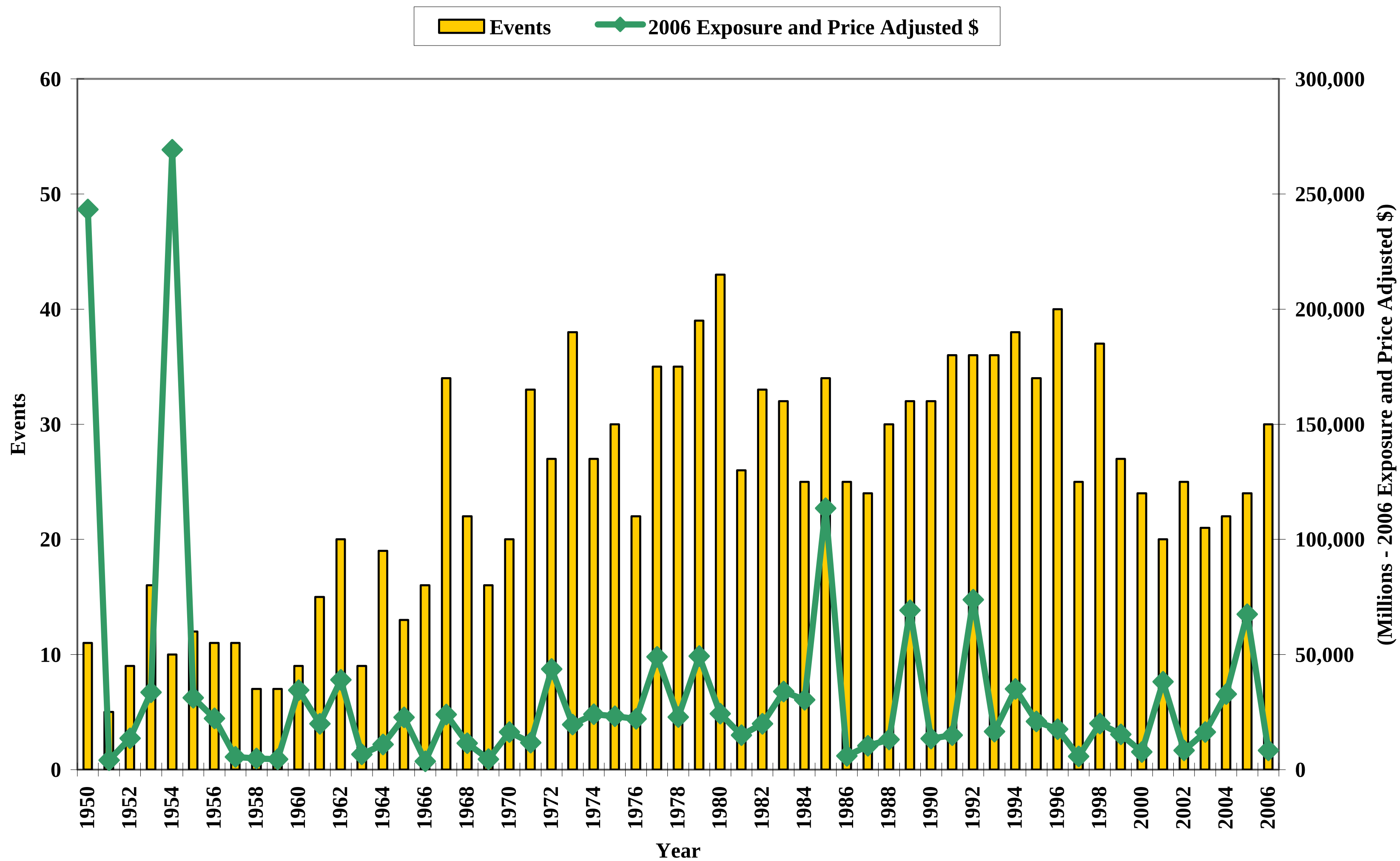
Summary Statistics - Exposure Adjusted Insured Loss

Values in Billions of 2006 Exposure and Price Adjusted $

Cat Type	**N**	**mean**	**median**	**SD**	**CV**	**skewness**	**min**	**max**	**P75**	**P90**	**P95**	**P99**
Wind and Thunderstorm Event	1,150	664	163	6,806	1,025.41	32.40	2	227,673	370	923	1,845	5,534
Winter Storm	128	1,382	312	2,908	210.44	3.92	17	18,619	1,147	3,437	6,180	16,383
Hurricane	85	8,830	1,220	22,158	250.93	4.23	11	132,032	5,435	29,601	44,357	132,032
Fire - Other	47	1,390	146	4,401	316.54	4.73	12	26,197	429	2,202	7,863	26,197
Wildland Fire	18	572	254	822	143.64	3.06	35	3,534	681	1,227	3,534	3,534
Earthquake	15	1,785	79	5,748	322.06	3.81	16	22,450	504	2,317	22,450	22,450
Tropical Storm	15	808	178	1,705	211.06	2.70	58	6,011	290	3,719	6,011	6,011
Riot	11	2,952	1,044	6,574	222.69	3.20	6	22,581	1,613	3,074	22,581	22,581
Utility Service Disruption	1	221	221				221	221	221	221	221	221
Volcanic Eruption	1	260	260				260	260	260	260	260	260
Water Damage	1	971	971				971	971	971	971	971	971

Note: Figures are adjusted at the state level by our 2006 exposure index. This index captures both price level changes and changes in the size of the housing stock. The intent is to estimate the losses a past disaster would cause if it occurred today.

Figure 5
PCS Aggregate Insured Loss - Threshold of $25 million by event



Note: Figures are adjusted at the state level by our 2006 exposure index. This index captures both price level changes and changes in the size of the housing stock. The intent is to estimate the losses a past disaster would cause if it occurred today.

Table 4
Maximum Likelihood Parameter Estimates and Log Likelihood Function Values: PCS Loss Data

			Severity					
			Lognormal			Pareto		
Cat Type	**Loss Type**	**N**	**mu**	**sigma**	**log(L)**	**alpha**	**lambda**	**log(L)**
Hurricane/Tropical Storm	Insured	100	6.870	2.112	-903.657	0.577	322.117	-905.820
	Total		7.610	2.112	-977.681	0.577	675.294	-979.844
Earthquake	Insured	15	4.869	1.988	-104.620	0.645	51.028	-103.840
	Total		7.354	1.749	-139.977	0.741	768.985	-139.416
Wind and Thunderstorm	Insured	1150	5.150	1.337	-7,888.080	1.696	335.761	-7,909.861
	Total		5.447	1.337	-8229.698	1.696	451.900	-8251.479
Winter Storm	Insured	128	5.983	1.535	-1,002.358	1.104	424.458	-1,005.737
	Total		6.570	1.535	-1,077.492	1.104	763.414	-1080.871

			Severity				Frequency	
			Burr12				Poisson	
Catastrophe Type	**Loss Type**	**N**	**a**	**b**	**q**	**log(L)**	**Lambda**	**log(L)**
Hurricane/Tropical Storm	Insured	100	1.526	1.40E+02	0.300	-905.113	1.768	-96.925
	Total		1.526	293.922	0.300	-979.136		
Earthquake	Insured	15	2.088	20.390	0.236	-102.292	0.268	-36.146
	Total		0.763	4,095.999	1.713	-141.08		
Wind and Thunderstorm	Insured	1150	1.554	1.16E+02	0.710	-7,868.334	20.089	-257.147
	Total		1.554	1.56E+02	0.710	-8209.952		
Winter Storm	Insured	128	1.738	1.35E+02	0.418	-1,001.830	2.214	-135.893
	Total		1.738	2.43E+02	0.418	-1076.965		

				Likelihood Ratio Tests				
Catastrophe Type	**Loss Type**	**N**	**Max -log(L)**	**LN - Pareto**	**Burr - LN**	**Burr - Pareto**	**Chi-Sq(5%,1)**	**Best Fit**
Hurricane/Tropical Storm	Insured	100	905.820	4.326	-2.912	1.414	3.84	Pareto
	Total		979.844	4.326	-2.910	1.416	3.84	Pareto
Earthquake	Insured	15	104.620	-1.560	4.656	3.096	3.84	LN
	Total		141.080	-1.122	-2.206	-3.328	3.84	Burr12
Wind and Thunderstorm	Insured	1150	7,909.861	43.562	39.492	83.054	3.84	Pareto**
	Total		8,251.479	43.562	39.492	83.054	3.84	Pareto**
Winter Storm	Insured	128	1,005.737	6.758	1.056	7.814	3.84	Pareto**
	Total		1,080.871	6.758	1.054	7.812	3.84	Pareto**

Note: ** indicates the distribution provides a significantly better fit than the other distributions based on an approximate Chi-square likelihood ratio test. LN = lognormal.

Table 5
Expected Loss and Upper Percentiles of PCS Severity Distributions

Values in $Billions

Lognormal Distribution			Percentiles						
Catastrophe Type	**Loss Type**	**mean**	**50.0**	**75.0**	**90.0**	**95.0**	**99.0**	**99.9**	**Best Fit**
Hurricane/Tropical Storm	Insured	9.0	1.0	4.0	14.4	31.1	131.0	657.8	Pareto
	Total	18.8	2.0	8.4	30.2	65.1	274.6	1,378.6	Pareto
Earthquake	Insured	0.9	0.1	0.5	1.7	3.4	13.3	60.6	LN
	Total	7.2	1.6	5.1	14.7	27.7	91.4	347.6	Burr12
Wind and Thunderstorm	Insured	0.4	0.2	0.4	1.0	1.6	3.9	10.7	Pareto**
	Total	0.6	0.2	0.6	1.3	2.1	5.2	14.5	Pareto**
Winter Storm	Insured	1.3	0.4	1.1	2.8	5.0	14.1	45.5	Pareto**
	Total	2.3	0.7	2.0	5.1	8.9	25.4	81.9	Pareto**

Pareto Distribution			Percentiles						
Catastrophe Type	**Loss Type**	**mean**	**50.0**	**75.0**	**90.0**	**95.0**	**99.0**	**99.9**	**Best Fit**
Hurricane/Tropical Storm	Insured	54.0 [a]	0.7	3.2	17.1	57.6	942.0	50,970.4	Pareto
	Total	113.2 [a]	1.6	6.8	35.9	120.8	1,974.9	106,855.5	Pareto
Earthquake	Insured	2.5 [a]	0.1	0.4	1.8	5.3	64.3	2,285.4	LN
	Total	10.0 [a]	1.2	4.2	16.4	43.1	383.8	8,599.3	Burr12
Wind and Thunderstorm	Insured	0.5	0.2	0.4	1.0	1.6	4.7	19.4	Pareto**
	Total	0.6	0.2	0.6	1.3	2.2	6.4	26.1	Pareto**
Winter Storm	Insured	4.1	0.4	1.1	3.0	6.0	27.1	221.0	Pareto**
	Total	7.3	0.7	1.9	5.4	10.8	48.7	397.5	Pareto**

Burr 12 Distribution			Percentiles						
Catastrophe Type	**Loss Type**	**mean**	**50.0**	**75.0**	**90.0**	**95.0**	**99.0**	**99.9**	**Best Fit**
Hurricane/Tropical Storm	Insured	510.9 [a]	0.6	2.9	21.4	97.4	3,277.2	501,031.6	Pareto
	Total	1,070.9 [a]	1.2	6.0	44.9	204.2	6,869.9	1,050,296.8	Pareto
Earthquake	Insured	25.7 [a]	0.1	0.3	2.2	8.9	233.4	24,973.2	LN
	Total	11.6	1.6	5.5	16.1	31.5	126.6	789.7	Burr12
Wind and Thunderstorm	Insured	1.2	0.2	0.4	0.9	1.7	7.5	60.7	Pareto**
	Total	1.6	0.2	0.5	1.2	2.3	10.1	81.6	Pareto**
Winter Storm	Insured	2.2 [a]	0.3	0.9	3.2	8.4	76.6	1,823.4	Pareto**
	Total	3.8 [a]	0.6	1.6	5.8	15.0	137.8	3,279.4	Pareto**

Note: ** indicates the distribution provides a significantly better fit than the other distributions based on an approximate Chi-square likelihood ratio test. LN = lognormal.

[a] indicates true means do not exist due to skewness of distribution, these are simulated means computed as the mean from 0 to the 99.9th percentile + Loss(.999)*.001

Table 6

Expected Loss and Upper Percentiles of Aggregate Annual Claims Distributions

Values in $Billions

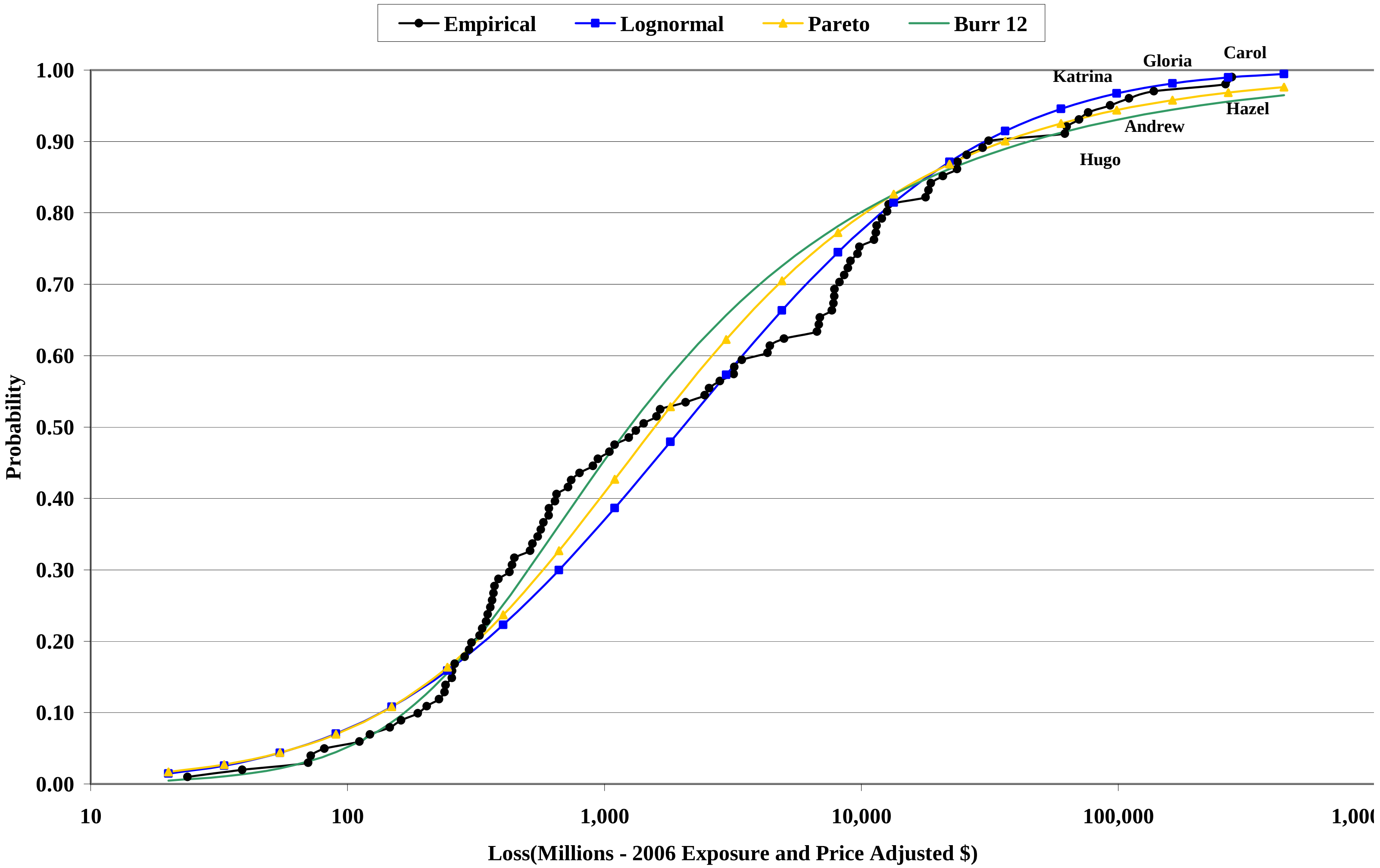
Lognormal			Percentiles					
Catastrophe Type	**Loss Type**	**mean**	**50.0**	**75.0**	**90.0**	**95.0**	**99.0**	**99.9**
Hurricane	Insured	12.5	2.0	9.3	29.6	56.7	175.8	391.5
	Total	22.2	4.3	19.2	58.8	108.1	275.2	409.4
Earthquake	Insured	0.2	0.0	0.0	0.1	0.7	4.5	26.7
	Total	1.8	0.0	0.0	2.5	7.4	36.1	165.6
Wind and Thunderstorm	Insured	8.4	7.4	10.2	13.7	16.4	24.0	41.1
	Total	11.4	10.0	13.8	18.5	22.2	32.4	55.4
Winter Storm	Insured	2.8	1.1	3.1	6.7	10.5	24.7	67.8
	Total	5.1	2.0	5.6	12.2	19.0	44.4	120.6
All Perils	Insured	23.6	14.4	23.7	43.9	70.0	180.6	355.8
	Total	39.4	23.5	41.7	81.7	128.4	271.8	388.4

Pareto			Percentiles					
Catastrophe Type	**Loss Type**	**mean**	**50.0**	**75.0**	**90.0**	**95.0**	**99.0**	**99.9**
Hurricane	Insured	16.7	1.5	7.7	34.1	84.4	324.3	409.4
	Total	24.5	3.1	15.1	60.9	134.4	383.7	409.4
Earthquake	Insured	0.8	0.0	0.0	0.1	0.5	8.1	246.1
	Total	3.0	0.0	0.0	1.9	6.5	60.2	409.4
Wind and Thunderstorm	Insured	9.5	7.6	10.9	15.7	20.3	39.1	117.6
	Total	12.8	10.3	14.7	21.2	27.4	52.5	152.4
Winter Storm	Insured	4.2	1.0	3.1	7.8	14.4	54.5	249.0
	Total	7.0	1.9	5.6	14.0	25.6	91.5	316.9
All Perils	Insured	28.3	14.4	25.4	55.5	101.7	268.6	390.1
	Total	42.2	22.8	42.3	92.3	155.4	315.2	397.9

Burr12			Percentiles					
Catastrophe Type	**Loss Type**	**mean**	**50.0**	**75.0**	**90.0**	**95.0**	**99.0**	**99.9**
Hurricane	Insured	18.9	1.1	6.9	38.4	104.1	388.9	409.4
	Total	25.8	2.4	13.2	64.4	152.8	409.4	409.4
Earthquake	Insured	1.5	0.0	0.0	0.0	0.5	15.1	409.4
	Total	2.2	0.0	0.0	2.7	8.0	41.6	254.2
Wind and Thunderstorm	Insured	13.0	7.8	12.5	22.2	34.9	104.7	306.1
	Total	17.0	10.5	16.9	29.8	46.4	132.2	330.5
Winter Storm	Insured	6.5	0.8	2.9	9.8	23.1	125.9	395.8
	Total	9.7	1.6	5.2	17.2	38.8	176.4	409.4
All Perils	Insured	34.5	15.3	31.5	78.5	142.1	309.7	397.3
	Total	47.8	24.1	49.6	114.4	187.1	337.1	401.1

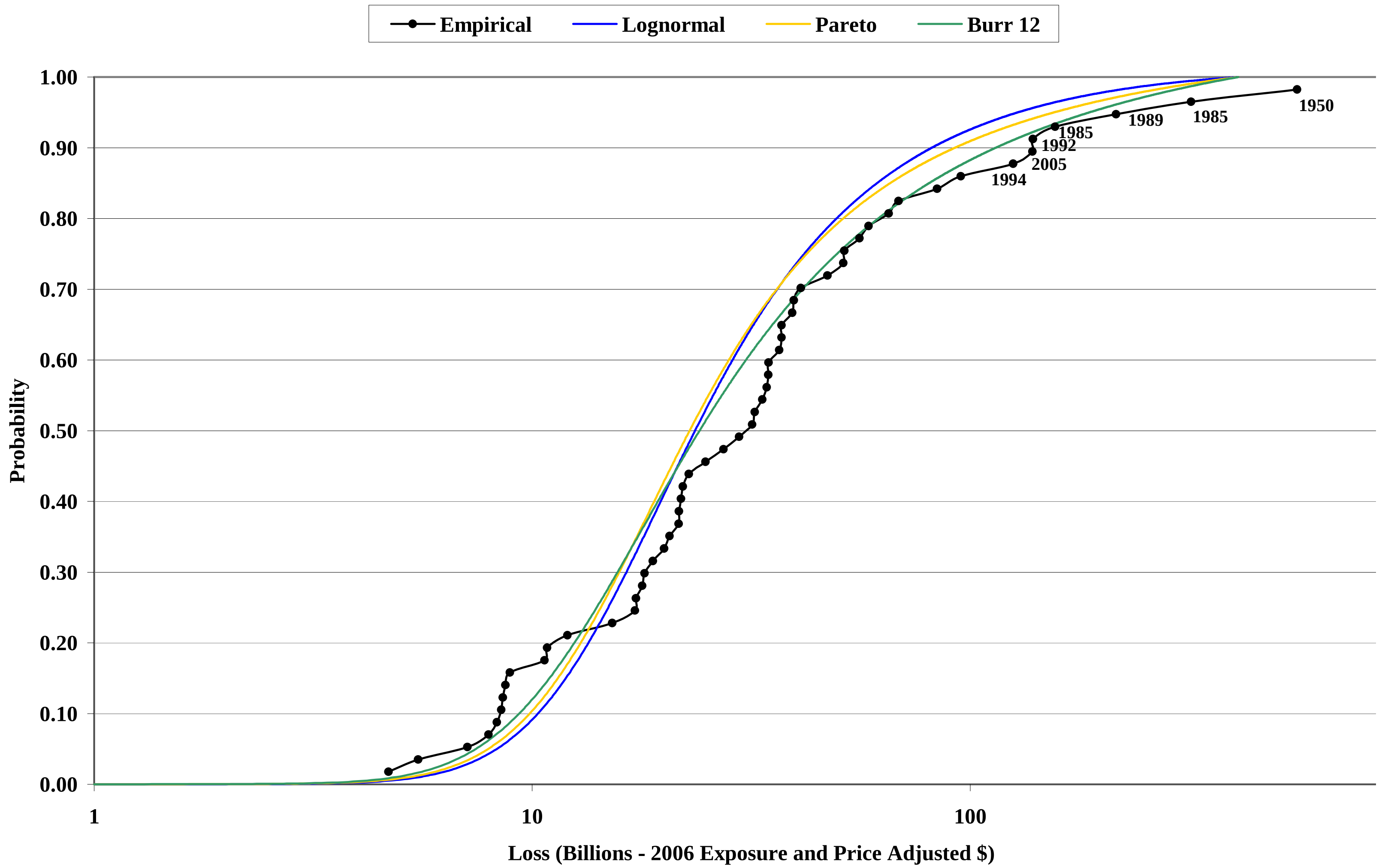
Figure 6

Hurricane/Tropical Storm Occurrence Severity - Total Loss



Note: The data used in this estimation were adjusted at the state level by our 2006 exposure index. This index captures both price level changes and changes in the size of the housing stock. The intent is to estimate the losses a past disaster would cause if it occurred today.

Figure 7
All Perils Annual Aggregate Claims - Total Loss



Note: The data used in this estimation were adjusted at the state level by our 2006 exposure index. This index captures both price level changes and changes in the size of the housing stock. The intent is to estimate the losses a past disaster would cause if it occurred today.