Analysis of a Deductible/Credit Formula for FEMA Post-Disaster Public Assistance

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Final Report to the Federal Emergency Management Agency

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November 11, 2016

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Preface

A team of researchers affiliated with the Center for Risk and Economic Analysis of Terrorism Events (CREATE) was asked by the Federal Emergency Management Agency (FEMA) to develop a formula for implementing a Deductible/Credit System for the Agency's Public Assistance (PA) Program. This FEMA Program provides post-disaster financial relief for losses incurred by state, tribal, and local governments for property damage and for various emergency expenditures to protect health and safety and to continue critical government operations in the aftermath of events that meet the current threshold of Presidential Disaster Declarations. On average, over the last 10 years, FEMA has covered approximately 77.5% of the losses included in grant applications for PA.

The trend for disaster losses is expected to increase, owing primarily to the expanding built environment, and possible new threats (e.g. terrorist attacks) and more extreme natural forces (e.g., hurricanes, flooding). This will necessitate increased PA expenditures at a time of increased concern over federal spending. However, the conflict between growing needs and tighter fiscal management is true at all levels of government, not just the federal level.

One approach to relieving the budgetary strain, and, more importantly, the losses incurred by disasters, is for non-federal government entities to implement disaster loss reduction strategies, including mitigation, post-disaster actions to promote government continuity and recovery, insurance, and the establishment of relief funds. The existence of the PA Program, however, undercuts the incentives to implement these loss reduction measures because the federal government is covering a large portion of disaster losses. The situation is an example of *moral hazard*, where one party does not exercise due diligence because it is not fully responsible for the cost of its actions (or inactions). Just as automobile insurance policies have a deductible against claims in order to promote more responsibility among drivers, a Disaster Deductible is intended likewise to increase the accountability of state governments for disaster losses. A program that consists only of a Disaster Deductible provides some incentives, but it would also make states worse off in the near term because of the need to incur expenses to cover a larger share of disaster losses. However, the incentive system can be strengthened and the imposition on state budgets relieved considerably if a Credit against the Deductible can be established for state government expenditures on risk reduction. As risk reduction accumulates, there can potentially be a win-win outcome in the longer-term, whereby both federal and state government disaster expenditures will be reduced.

This report provides an analysis of the Deductible/Credit System in this context. The research team followed an established policy analysis framework. It begins by orienting the research to the goal, or objective, of the proposed policy -- the reduction of disaster losses. It identifies alternative strategies and tactics to achieve this objective -- mitigation, resilience, insurance, and relief funds. It estimates the cost and effectiveness of the strategies and tactics to achieving the objective as reflected in benefit-cost ratios. It factors in constraints on this achievement of the objective -- the reality that not all types of losses can be reduced. It also includes policy levers that can be fine-tuned -- the Credits against the Deductible. Another aspect of policy analysis is the design of policy instruments to achieve various objectives. An incentive-based system, like a Disaster Deductible and/or Credit, in contrast to direct regulation, is an established and increasingly popular and effective policy instrument approach, but it needs to be refined to take account of the conditions and realities of the case in point, including the reaction to the policy by those who must carry it out. At the same time, the best policy instruments are those that incorporate some flexibility for improvement over time as contextual conditions, conceptual understanding, data availability, and technology and institutions change.

This report begins by providing a foundation for the estimation of the Disaster Deductible itself. This initial Base Deductible is calculated using historical PA expenditures as a proxy for disaster losses. We then adjust the Base Deductible for important characteristics that differ across states by the application of a Fiscal Capacity Index, which reflects the financial ability of each state to respond to disasters, and by the application of a Risk Index, which differentiates the expected value of disaster losses across states. We develop a Mathematical Programming (MP) Model to analyze the potential response of states. The MP Model includes all of the important features of the policy analysis framework, and its optimal solution yields the mix of loss reduction strategies and tactics that can achieve alternative goals of risk reduction and credit attainment at the least cost. In addition, we perform a Burden Analysis (BA), which analyzes the impact of the Deductible/Credit system and the state's response on both federal and state budgets.

The MP and BA analyses have also generated methodologies by which FEMA and the states can analyze all elements of the Deductible/Credit system. We have developed spreadsheet programs that readily calculate the Base Deductible, the various indices, and the Adjusted Deductible. We have also developed a visualization tool that displays the implications of various configurations of the Deductible/Credit System on a map of the United States.

The basic Disaster Deductible Formula (DDF) derived in Part I of this Report and the extended versions developed in Part II are evaluated in relation to several criteria, such as: technical and fiscal ability to achieve FEMA's goals, stability, economic efficiency, equity (fairness), flexibility, transparency, and political feasibility. No single formulation is superior to all others according to these criteria, so policy-makers must make judgments about the relative priorities (weight) among these evaluative criteria.

The report also examines various alternative assumptions and parameters that can be considered in the formulation of the DDF. Moreover, sensitivity tests are undertaken to determine implication of variations in assumption/parameters on the bottom-line costs, on federal/state expenditure shares, and on various other evaluative criteria.

This Report is divided into two parts. In Part I, we construct what we refer to as the Basic Deductible/Credit System (DDF1), which conforms to assumptions and parameters suggested in a FEMA White Paper on the Disaster Deductible/Credit System. In Part II, we explore important refinements of DDF1 under the heading of what we refer to as DDF2. We examine each major assumption and parameter of DDF1 and evaluate the implications of alternatives. We do not limit this analysis to the current delineation of the PA Program. Instead, we take a broader and longer-term view. We emphasize at the outset that several of the refinements that we examine could not be implemented in the near term, because of the absence of a firm conceptual base for them or lack of data by which to gauge their implications. In addition, the reader should not view DDF2 as a fixed combination of assumption/parameters, but rather as a menu of possible refinements for the corresponding aspect of DDF1.

The major refinements explored in DDF2 include a Fiscal Capacity Index based on alternative combinations of indicators than those employed in DDF1, a Risk Index that can include forecasts of some changing conditions that can cause future increases in risk, a broader risk framework that offers more insight into state government motivations and also provides a capability to fine-tune the federal-state share, a DDF that goes beyond a focus on property damage to include life-saving and reduction of government interruption, and the addition of post-disaster resilience tactics as a means to both reduce risk and to obtain credits against the deductible.

The authors acknowledge valuable guidance, input, and feedback by FEMA staff, primarily Jotham Allen, Colt Hagmeier, and James Ruger, as well as Marc Fuller and Julie Waters. We also thank our colleague Ali Abbas for his comments on an earlier draft, as well as Philip Schneider and Carolyn Kousky, who served as external reviewers. Noah Miller, Joshua Banks, Lillian Anderson, Phuong Nguyen, and Krystian Palmero served as able research assistants. The authors are, however, solely responsible for any remaining errors and omissions.

Part I. Basic Analysis of a Disaster Deductible/Credit System

Executive Summary for Part I

Part I of this report develops a basic Disaster Deductible/Credit Formula (DDF1) to incentivize state governments to increase their capabilities to withstand disasters. It parallels on-going efforts by the Federal Emergency Management Agency to design such a policy (see, e.g., FEMA, 2016a).

Currently, following a Presidential Disaster Declaration, FEMA provides approximately three-quarters of the funds needed for intergovernmental disaster relief through its Public Assistance (PA) Program, while non-federal levels of government cover the remaining non-federal share. The DDF is intended to encourage states to build fiscal capacity to fund their post-disaster assistance needs, to provide incentives to engage in mitigation, and to purchase insurance to reduce expected losses. All of these responses will lessen the need for future federal disaster assistance.

The DDF establishes a Base Deductible chosen using a simple equal-share rule, whereby it is the same dollar value for each state. The Base Deductible is adjusted for each state's Fiscal Capacity and underlying Risk Exposure, extreme values are capped, and then the final adjusted deductible is normalized (proportionally shifted so that the mean value is consistent with the original base). By itself, a deductible shifts the responsibility of funding the first dollar of public assistance to the states, and away from FEMA. When combined with Credits offsetting the Deductible that come from spending on mitigation and other disaster-reduction activities, each state can reduce both its total cost of disasters and its need for PA compared to a Deductible alone.

A Mathematical Programming model is used to determine the least-cost combination of the state response to the Deductible choosing among mitigation, insurance, and relief fund expenditures to achieve specified risk-reduction or deductible-reduction goals. While mitigation measures are generally preferred because they offer higher benefit-cost ratios (BCRs), the optimal solution for some states is to choose a mix of mitigation and insurance, often depending on the particular threats the state faces. In Part I, the BCRs for mitigation projects have been adjusted to focus on property damage reduction only, which vary depending on the type of threat.

The results are then analyzed in a Burden Analysis -- a simple technique to measure the fiscal impacts of the response on the states and FEMA. This analysis, reported for selected states, reveals the following impacts:

1. Compared to the current situation (the status quo), the Deductible by itself shifts a portion of the burden of funding public assistance from FEMA to the states.

2. The Deductible alone offers little or no incentive for states to undertake risk-reduction tactics, since the state share of public assistance is otherwise still the status quo of approximately 25%. In many cases, any risk reduction benefits are offset by state spending on risk reduction.

3. Offering credit for mitigation and other disaster risk-reduction activities provides a strong incentive for states to engage in these activities, and thereby significantly reduces the negative fiscal impact of the deductible alone. Simulations indicate that in the first few years, states are still not better off than under the current (no deductible) situation. However, over time, the cumulative risk reduction does make states better off in terms of their risk exposure and their expected payoff. Over time, as states respond through increased mitigation, expected losses decrease, and, with a constant deductible, the states become better off than they are currently. Reducing the Deductible to zero makes them no worse off than currently, but reducing expected losses makes them better off at some point in the near future.

Sensitivity analyses demonstrated that the general results are quite robust. That is, the basic conclusions hold, even with moderate changes in key assumptions and parameter values relating to caps on the deductible, relative weights given to the fiscal capacity and risk adjustments, benefit-cost ratios, and credit multipliers. The optimal mix of risk reduction responses is affected by variations in benefit-cost ratios for individual types of responses, but the optimal mix of responses to attain a given credit level against the deductible is affected only to a limited extent.

There are two major contributions of Part I of this report: the development of an initial Disaster Deductible Formula, and the development of tools to analyze the impact of the policy change. The first formula meets all of FEMA's requirements, and the application of the analytical tools offers insights into its strengths and weaknesses. The tools also provide means for FEMA to determine how to adjust the Deductible formula parameters to meet some specific goals with respect to risk reduction, efficiency, and equity. However, not all goals are likely to be met simultaneously, as some of them involve tradeoffs.

I. Introduction

A. Objectives

The research contained in this report is aimed at informing FEMA's stated major objective to "develop a state level capability measure which will be used to support the possible incorporation of a state-funded deductible into the structure of federal disaster assistance in a manner that will incentivize state, tribal, territorial, and local governments to take the actions necessary to increase their capabilities to withstand disasters" (FEMA, 2015a; p.2). This report presents the development of an initial Disaster Deductible Formula (DDF) to meet this objective. The DDF is based on indicators recommended for consideration by FEMA, and assumptions and parameters consistent with real world considerations and consensus by FEMA and the research team. A second report will explore alternative DDF formulations.

The proposed DDF is intended to encourage behavior that leads state governments[1] to decrease vulnerability and hence losses from disasters. The goal has multiple facets: to reduce moral hazard,[2] to encourage states to purchase hazard insurance, increase fiscal capacity for disaster recovery, and to reduce losses through mitigation and resilience.

The current FEMA PA Program provides funding for emergency and permanent work in communities in relation to public facilities following a Presidential Disaster Declaration. This Declaration is triggered if the expected losses exceed the threshold value as determined by simply multiplying a $1.41 factor to the state's population from the last census. The actual eligible PA costs are split between FEMA and the state at a nominal 75:25, but the FEMA share can increase to 90%, or even 100%. Based on PA data from 2005 to 2015 the average FEMA share nationally was 77.5%.

Under the proposed Disaster Deductible Formula (DDF) program, disasters will still be declared using the current system. However, a Deductible, composed of a base level for all states and then adjusted state by state, according to state fiscal capacity and state risk, is proposed. Individual states would pay for those disaster losses, eligible to be covered by PA, up to the level of their Adjusted Deductible minus credits they earn for qualifying expenditures on risk reduction through mitigation, insurance, relief funds, and resilience in the previous year. For declared disasters, the Net Deductible (Deductible less credits) would be applied beginning January 1 on an annual, rather than on an event, basis. Once the Net Deductible is met from state spending, the remaining public assistance spending would be split between FEMA and the state along the lines of the current system.

FEMA's White Paper on Disaster Deductibles (FEMA, 2015b; p. 5) prioritizes the following "guiding principles" to drive design and implementation of the DDF concept:

- Ensure the supplemental nature of FEMA support by eliminating "first-dollar" assistance;

[1] Henceforth, we will use the term "state" to cover state, territorial, and local governments. We acknowledge that the roles of these various jurisdictions differ and there is important interplay between some of them, but these aspects are beyond the scope of this study.
[2] Moral hazard is the lack of incentive to guard against risk where one is shielded from its consequences, e.g., by disaster assistance.

- Incentivize proactive fiscal planning by states for disasters and establish mechanisms to better assess state fiscal capacity to respond to disasters; and

- Encourage and incentivize risk-informed mitigation strategies on a broad scale.

The DDF is not just an end in itself, even though promoting risk reduction is a positive outcome. It is a broader instrument to improve federal disaster relief policy. Thus, some objectives of this broader policy include:

1. Provide financial assistance to states impacted by disasters. It should be kept in mind that most FEMA disaster relief comes from its Public Assistance (PA) program, and that the proposal calls for examining only this program. This assistance provides funds to:

- Restore operation of non-federal governments;

- Restore operation of infrastructure for their populations;

- Restore operation of their economies and orderly functioning of their communities (including non-profit organizations); and

- Decrease vulnerability to future disasters.

2. Both the public and the private sector are concerned with what economists call economic efficiency. This is the concept of achieving the greatest benefit from a given expenditure, or equivalently, spending the least resources to achieve a given objective. If the goal is to reduce losses from disasters, everyone in society has a desire to do so without wasting resources unnecessarily. With a clear objective, the DDF can be designed to choose the combination of deductible, and credits that lead to mitigation and other disaster-related activities with the least cost.

3. An additional consideration that has received accelerating attention in recent years, in part because of the increased frequency and magnitude of major disasters, is setting the FEMA criteria for evaluating state and local response and recovery capability. One of FEMA's charges in stipulating the goals of this research states: "In practice, the formula would identify a baseline level of capability based on identified measures, below which a requesting state would be entirely responsible for the costs, and above which the PA Program would provide contributions" (FEMA, 2015a; p. 2). While a DDF would not directly affect the criterion (or trigger) for a state to receive a major disaster declaration, it would address much of the broader input FEMA has received from Congress, the GAO (2012), and the DHS Office of the Inspector General, by establishing a sound baseline in the form of the Disaster Deductible for each state, thereby incentivizing each state to better plan for smaller disaster relief, and yet maintain all the elements of the current federal assistance program for larger disasters. The proposed formula would thus alter the amount of federal government assistance from its current level. This report analyzes how the DDF will affect both total federal and state funding for disaster relief.

4. The DDF would also affect the distribution of federal assistance dollars across states, and hence would affect the distribution of state spending on disaster relief. Most definitions of equity are altruistic, though efforts have been made to come up with objective alternatives (e.g., absence of envy),

but even these are fraught with value judgments. Altruistic definitions essentially focus on the "neediest" in society. However, there are many subtleties here in defining the neediest. Is it neediest states, or groups within each state? Should need be based on baseline conditions at the state level (e.g., per capita income or overall income inequality), vulnerability, or losses for each disaster? Should these "reference bases" be anchored to current conditions, cumulative historical conditions, or future projections?

This report explores the many subtleties of the research questions. However, our major focus will be to address the main issues head-on:

- What are the "essential" elements of a DDF? We establish a sound foundation for a Base Deductible with Fiscal Capacity and Risk Adjustments. We weight the adjustments and impose caps on the DDF to control for potentially extreme levels applicable to some states.

- How would a Deductible Credit mechanism work? The Credit mechanism provides a way that states can offset the Deductible through risk reduction efforts such as mitigation, insurance, and relief funds. The state response would depend on the state target (e.g., risk reduction vs. deductible reduction), benefit-cost ratios for these risk reduction efforts, and the amount of credit they receive for expenditures on them. FEMA could use various "policy levers", including the base deductible, deductible caps, adjustment weights, credit multipliers, and timing of credits, to promote various disaster related goals.

- Would a Deductible and Credit formula provide incentives to undertake additional disaster loss reduction activities, and would states even be better off than they are currently? We simulate the potential response of states to specific risk reduction and credit attainment targets. The analysis indicates that each state is better off with Deductible Credits for disaster loss reduction than under the Deductible alone, but does incur more post-disaster expenditures than the status quo (no Deductible). However, over time, the cumulative risk reduction does make states better off in terms of their risk exposure and their expected payoff.

- What is the cross-state fairness of various DDFs? The Base Deductible is the same for each state. However, the Fiscal Capacity and Risk Adjustments render it somewhat unequal across states in relation to state per capita GDP, and this inequality is increased slightly following the states' risk-reduction response.

B. Overview

This report offers the following contributions to formulating and analyzing a Disaster Deductible Formula (DDF):

- Establishes a Base Deductible for all states

- Develops and computes formula adjustments for state Fiscal Capacity and Risk

- Calculates an Adjusted DDF for all states
- Analyzes the incentives to reduce risk and obtain credits against the Deductible
- Develops a Mathematical Programming model to optimize state strategies to achieve fixed targets of risk reduction and credit attainment
- Conducts a Burden Analysis for sample states of the implications of the DDF
- Develops a Burden Analysis spreadsheet capability
- Simulates the time-path of the implications of the DDF
- Analyzes the equity implications of the DDF
- Provides an assessment of the assumptions and parameters underlying the analysis
- Evaluates the advantages and disadvantages of the first DDF

In Part II of this study, we further analyze the Disaster Deductible/Credit System. This includes a critical appraisal of many of the assumptions and parameters underlying the first DDF Formula (DDF1) presented below. It includes consideration of alternative indicators by which to adjust the Base Deductible, consideration of a broader set of risks and risk reduction strategies, and additional sensitivity tests. It also includes an analysis of policy implementation issues.

II. The Base Deductible

The particular deductible charged to a state should be a function of the expected disaster losses a state faces, but also must consider the ability of a state to fund that deductible, as well as its share of public assistance as it does under the current program. Currently a state pays nominally 25% of public assistance on declared disasters, although the President can adjust the federal share up from 75% to 90%, or even 100%. As a result, the average state share for declared disasters over the past ten years has been 22.5%. To implement a Disaster Deductible Formula, we first establish a Base Deductible upon which state disaster risk and fiscal capacity adjustments are made to create a final adjusted state-specific deductible.

Although there are a number of candidates for a Base Deductible, the simplest approach is to begin with an equal share basis, whereby it is the same dollar value for each state.[3] We set the Base Deductible at $22.2 million, which is the median value of annual average PA across each of the states.[4] Without further adjustments for risk and fiscal capacity, this would result in one-half of states receiving public

[3] We considered alternative base deductibles, such as various equal percentage or equal absolute amount of base deductibles. We also considered setting the deductible so that it offsets a given level of PA in the absence of credits (e.g., 50% of total PA divided by 51 would mean that the deductible program would offset 50% of total PA).
[4] The annual average PA for each state is calculated as the sum of PA between 1999 and 2015 divided by 17 years. The Base Deductible is the median of these annual values across the 50 states.

assistance and one-half of states not receiving public assistance if all states experience their average disaster-year. Note also that the median annual average PA value is substantially lower than the mean annual average PA value ($88 million). This indicates that, in the absence of mitigation and credits against the deductible, the baseline deductible would reduce FEMA expenditure by approximately 25%.[5]

In the following two sections we develop a State Fiscal Capacity Index and State Risk Disaster Index. These are applied to the Base Deductible to arrive at an Adjusted Disaster Deductible Formula (DDF):

Adjusted Deductible = Base Deductible * 75% x Risk Index + 25% x Fiscal Capacity Index)

III. Fiscal Capacity Index

The Base Deductible is adjusted by a Fiscal Capacity Index not only because it is one of FEMA's guiding principles for the Disaster Deductible (FEMA, 2015b), but more fundamentally because it reflects a state's ability to build disaster response capacity, and to plan for disasters (GAO, 2012). It is only when a state's ability to fund disaster assistance is overwhelmed that FEMA should become involved.

A. The Meaning of Fiscal Capacity

Over the last ten years, states spent an average of $1.2 billion each year on disaster public assistance out of a total average spending on public assistance of almost $5.5 billion. To provide some perspective, average annual state public assistance represents less than one-tenth of 1% of total state spending of $1,500 billion. However, there are many competing demands on state budgets. All states have some form of balanced budget requirement, and there is constant political pressure for lower taxes. Although a state government can expect some amount of disaster spending to occur every year, the exact amount is unpredictable, and not easily incorporated into a budget. Even with the current relatively generous level of assistance provided by the federal government for declared disasters, states are often hard pressed to fund the levels of public assistance required when large disasters strike. Through the DDF, FEMA is attempting to make states more fiscally responsible for anticipated losses while providing incentives to reduce the need for public assistance, as well as increase the capacity to fund that public assistance. Fiscal capacity potentially has two components which differ in the extent they can be planned: a reserve fund committed to disaster related assistance, and a general ability to appropriate funds to cover the actual costs of public assistance post-disaster.

The most general measures of fiscal capacity would be potential revenue and actual revenue. As reported by FEMA (2014; p.28) median state actual revenue was $26 billion in 2012, while potential revenue, as measured by Total Taxable Resources (TTR) was almost ten times that amount. According to the Department of the Treasury, states only capture 10% of their potential revenue. However, history and political realities limit actual revenue collection, and reflect how each state's citizenry values state-provided public goods and activities and the relative importance of spending on such things as education, public safety, transportation, and social services. The current potential or actual revenues available to a state are not the only measures of fiscal capacity, as many states have reserves and access

[5] $22M / $88M x 100 = 25.28%

to financial markets to borrow money. These sources may be as important as politically contentious taxes and fees in determining the ability of a state to fund disaster assistance.

Our analysis not only introduces alternative sources of fiscal capacity, but will allow FEMA to adjust the relative role each plays in funding disaster assistance through the mechanism of the credit given each source against the deductible.

B. Fiscal Indicators

The FEMA (2015b) White Paper lists several fiscal capacity indices, as well as specific US government accounts for some of them. In creating the Fiscal Capacity Index we consider the following measures:

i. Total actual revenue (TAR)
ii. State gross domestic product (GDP)
iii. Potential revenue as measured by Total Taxable Resources (TTR)*
iv. State surplus/deficit*
v. State reserve funds*
vi. State bond rating*

We found most of these indicators to be highly correlated, as noted in Table I-1. Therefore, we utilized only the indicators listed above that are denoted by an asterisk.[6] Compared with TAR, both TTR and GDP are more widely used measures of state fiscal capacity that are not affected by the jurisdiction's fiscal choices. The major reason that we choose TTR over GDP is that the former excludes some components in GDP, such as employer and employee contributions to social insurance and federal indirect business taxes, which are not susceptible to taxation by the state government, and thus cannot be utilized to increase the state fiscal capacity to fund disaster assistance. On the other hand, TTR includes some state income sources such as dividend income, monetary interest from assets its residents hold in other jurisdictions, and labor income received by commuter residents that is potentially subject to state taxation (U.S. Department of Treasury, 2002; GAO, 2012). In sub-section D below, we discuss how we combine the four indicators to compute a Fiscal Capacity Index for the purpose at hand

Table I-1. Correlations Between Some Capacity Indicators

	Population	TAR	GDP	TTR	Surplus/Deficit	Reserve Funds	Bond Rating
Population	1.000						
TAR	0.958	1.000					
GDP	0.986	0.980	1.000				
TTR	0.987	0.981	0.998	1.000			
Surplus/Deficit	0.752	0.708	0.724	0.717	1.000		
Reserve Funds	0.221	0.204	0.236	0.222	0.351	1.000	
Bond Rating	-0.217	-0.306	-0.257	-0.251	0.018	0.057	1.000

[6] For example, in its assessment of FEMA's PA allocation criteria, GAO (2012) strongly recommended the use of Total Taxable Resources (TTR) to reflect fiscal capacity.

C. Data

Appendix I-A presents the basic data we used to calculate the various fiscal capacity indices. For each fiscal indicator, we collected data for the most recent 10 years of available data, and computed the 10-year average values. Major data sources include the following:

2003-2012 state Total Taxable Resources: U.S. Department of Treasury (2014) http://www.treasury.gov/resource-center/economic-policy/taxable-resources/Pages/Total-Taxable-Resources.aspx;

2005-2014 GSP: U.S. Department of Commerce (2015a) http://www.bea.gov/regional/;

2005-2014 state Total Actual Revenue: Department of Commerce (2015b) https://www.census.gov/govs/state/;

2005-2014 data on state Reserve Funds:

National Association of State Budget Officers (2015) http://www.nasbo.org/publications-data/fiscal-survey-of-the-states/archives;

Office of the Chief Financial Officer, Washington, DC. 2015. Annual Financial Reports, http://cfo.dc.gov/page/annual-financial-report-cafr;

Department of Finance and Administration. 2013. "Official Forecast of General Revenues for the Fiscal Year Ending June 30, 2014," State of Arkansas. http://www.dfa.arkansas.gov/offices/budget/Documents/fy14_gr_forecast.pdf (Change the number in the URL to access other years);

Wisconsin State Assembly. 2012. "Rainy Day Fund receives its largest deposit in Wisconsin's History," http://legis.wisconsin.gov/assembly/thiesfeldt/pressreleases/Pages/Rainy%20Day.aspx.

2004-2013 data on state Surplus/Deficit are (calculated as the difference between state total actual revenue and state total expenditures): Department of Commerce (2015b) https://www.census.gov/govs/state/.

2005-2014 S&P state Bond Ratings: Pew Charitable Trusts (2015) http://www.pewtrusts.org/en/research-and-analysis/blogs/stateline/2014/06/09/sp-ratings-2014.

D. Fiscal Capacity Index

Four fiscal capacity indices are first computed based on the following four indictors: Total Taxable Resources, State Surplus/Deficit, State Reserve Funds, and State Bond Rating. The formulas used to construct the indices are:

1. Per Capita TTR Index

$$Per\ Capita\ TTR_i = \frac{TTR_i}{Population_i} \quad (1)$$

$$Per\ Capita\ TTR\ Index_i = \frac{Per\ Capita\ TTR_i}{Median\ Per\ Capita\ TTR} \quad (2)$$

2. Per Capita Surplus/Deficit Index

$$Per\ Capita\ Surplus/Deficit_i = \frac{Surplus/Deficit_i}{Population_i} \quad (3)$$

$$Per\ Capita\ Surplus/Deficit\ Index_i = \frac{Per\ Capita\ Surplus/Deficit_i}{Median\ Per\ Capita\ Surplus/Deficit} \quad (4)$$

3. Per Capita Reserve Fund Index

$$Per\ Capita\ Reserve\ Fund_i = \frac{Reserve\ Fund_i}{Population_i} \quad (5)$$

$$Per\ Capita\ Reserve\ Fund\ Index_i = \frac{Per\ Capita\ Reserve\ Fund_i}{Median\ Per\ Capita\ Reserve\ Fund} \quad (6)$$

4. Bond Rating Index

$$Bond\ Rating\ Index_i = \frac{Bond\ Rating_i}{Median\ Bond\ Rating} \quad (7)$$

The first four numerical columns in Table I-2 present the values of the four alternative fiscal capacity indices for the 50 states and DC. In Column 5, we computed the simple average of the four indices, which implies an application of equal weights in integrating the four fiscal capacity indices into one overall index.[7] The overall fiscal capacity index ranges from 0.52 in Kentucky to 61.47 in Alaska (mainly due to its high per capita reserve funds index).

The last row of Table I-2 presents the standard deviations of the indices. The Bond Rating Index has the lowest standard deviation (0.13), followed by the Per Capita TTR Index (0.23). The Per Capita Reserve Funds Index has the highest standard deviation (32.49), due to a couple of outlier states, such as Alaska and Wyoming, which hold substantially higher reserve funds compared with the other states (primarily due to their taxation of the extraction of natural resources within their borders). The standard deviation of the Average Index is 8.48. A discussion of attempts to control for the influence of outliers in this measure appears later in the report.

[7] We adjust these weights in the sensitivity analysis below.

Table I-2. Fiscal Capacity Indices

	State	Per Capita TTR Index	Per Capita Surplus/Deficit Index	Per Capita State Reserve Funds Index	Bond Rating Index	Average of Four Indices
1	Alabama	0.82	0.38	0.70	0.96	0.71
2	Alaska	1.42	10.30	233.12	1.05	61.47
3	Arizona	0.85	0.68	0.81	0.90	0.81
4	Arkansas	0.82	1.79	0.02	0.96	0.90
5	California	1.12	0.52	0.86	0.60	0.77
6	Colorado	1.05	0.91	0.81	0.92	0.92
7	Connecticut	1.56	0.69	3.67	0.96	1.72
8	Delaware	1.34	3.16	3.66	0.69	2.21
9	DC	1.97	2.95	12.43	1.19	4.64
10	Florida	0.93	0.88	0.73	1.18	0.93
11	Georgia	0.90	0.45	1.17	1.19	0.93
12	Hawaii	1.03	1.95	0.67	0.92	1.14
13	Idaho	0.78	2.49	1.00	0.99	1.31
14	Illinois	1.15	0.26	0.25	0.80	0.61
15	Indiana	0.95	0.84	1.02	1.12	0.98
16	Iowa	1.01	1.78	3.03	1.15	1.74
17	Kansas	1.00	1.00	0.00*	1.07	0.77
18	Kentucky	0.83	0.03	0.40	0.84	0.52
19	Louisiana	1.00	0.50	2.24	0.78	1.13
20	Maine	0.89	2.58	0.82	0.93	1.31
21	Maryland	1.28	0.29	2.37	1.19	1.28
22	Massachusetts	1.32	0.37	4.44	0.97	1.77
23	Michigan	0.92	0.47	0.23	0.88	0.63
24	Minnesota	1.09	0.95	2.41	1.17	1.41
25	Mississippi	0.72	1.28	0.97	0.96	0.98
26	Missouri	0.95	1.38	0.81	1.19	1.08
27	Montana	0.82	3.71	0.00*	0.91	1.36
28	Nebraska	1.05	2.54	4.38	1.11	2.27
29	Nevada	1.02	2.09	0.58	1.01	1.18
30	New Hampshire	1.16	2.41	0.47	0.96	1.25
31	New Jersey	1.36	0.00	0.46	0.91	0.68
32	New Mexico	0.88	0.77	5.51	1.07	2.06
33	New York	1.33	0.68	1.12	0.96	1.02
34	North Carolina	0.90	1.06	0.92	1.19	1.02
35	North Dakota	0.99	7.20	7.98	1.01	4.30
36	Ohio	0.97	1.27	0.95	1.07	1.07
37	Oklahoma	0.88	1.61	2.44	1.03	1.49
38	Oregon	1.00	1.65	0.62	0.96	1.06
39	Pennsylvania	1.03	0.03	0.47	0.96	0.62

40	Rhode Island	1.12	3.02	2.12	0.94	1.80
41	South Carolina	0.77	0.16	0.92	1.09	0.73
42	South Dakota	1.02	4.30	2.76	1.00	2.27
43	Tennessee	0.86	0.64	1.25	1.05	0.95
44	Texas	0.97	0.65	2.92	1.03	1.39
45	Utah	0.85	1.31	1.98	1.19	1.33
46	Vermont	0.99	5.14	1.76	1.07	2.24
47	Virginia	1.15	0.71	1.55	1.19	1.15
48	Washington	1.11	0.47	0.40	1.04	0.75
49	West Virginia	0.78	2.98	5.96	0.90	2.66
50	Wisconsin	0.99	0.94	0.13	0.91	0.74
51	Wyoming	1.44	9.40	17.70	1.06	7.40
	Standard Deviation	**0.23**	**2.16**	**32.49**	**0.13**	**8.48**

Sources: U.S. Department of Treasury (2014); Department of Commerce (2015b); National Association of State Budget Officers (2015); Pew Charitable Trusts (2015).

*According to the National Association of State Budget Officers (2015), Kansas and Montana have no reserve fund.

To better compare the indices, we plotted the four alternative indices in Figure I-1. The final fiscal capacity index, which again is the average of per capita TTR index, per capita budget surplus/deficit index, per capita state reserves index, and bond rating index, is plotted in Figure I-2.

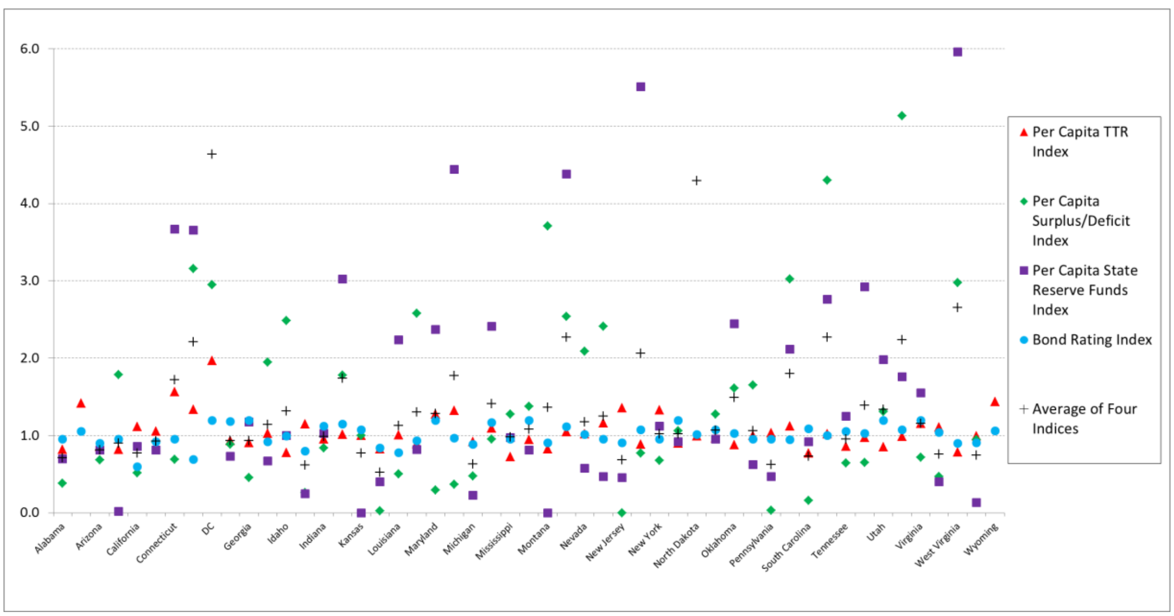

Figure I-1. Comparison of Alternative Fiscal Capacity Indices

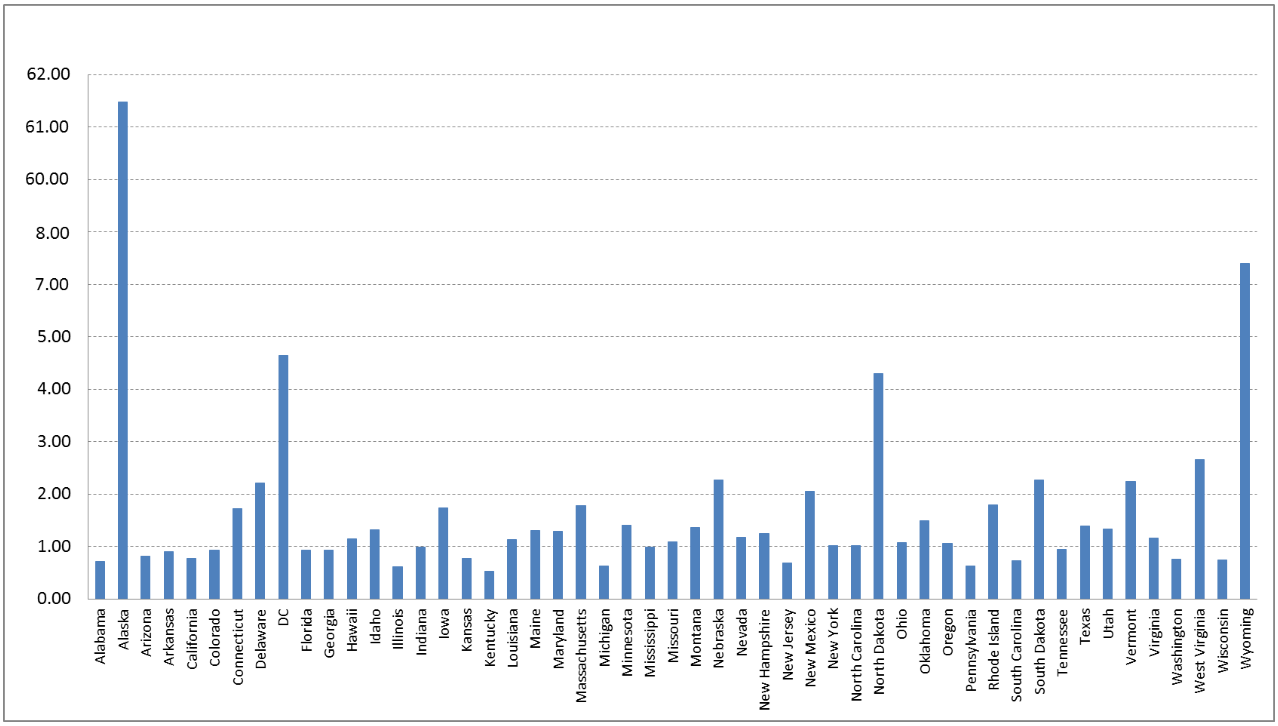

Figure I-2. Fiscal Capacity Index

IV. Disaster Risk Index

A. Risk Framework

One of the dimensions that FEMA has identified for state deductible adjustment is disaster risk. States with higher risks will have higher PA payments, shared by FEMA and the state entities. As is the case in all risk-based insurance, those with higher risks pay higher premiums. Although the PA program is not a premium-based insurance program, it remains both efficient and fair for higher risk states to expect to pay higher PA, and as part of that, a higher deductible. A higher deductible also provides a state with greater incentive to mitigate, and otherwise offset the deductible and expected PA through credits. As a result, increasing the deductible as risk increases leads to larger reductions in expected public assistance needs.

While there are many functional forms that could relate deductibles to risk, one approach is to adjust based on the ratio of a state's risk to the average or median risk across all states. This is a parsimonious approach that results in the relationship between states' deductibles equaling the relationship between states' risk, all else equal. A state that has twice as much risk as the average or median state will have a deductible that is twice as high as the deductible of the average or median state.

In theory, a state's risk should be calculated by multiplying the probability that it experiences a disaster by its public assistance needs in the event of a disaster, and summing over all potential disasters. After considering both the magnitude of disasters, as well as the disaster type, however, there is a continuum of disasters that should be considered in computing state risk. Estimating the "true" risk facing each state would therefore require knowledge of the probability of a disaster of every magnitude occurring, as well as the PA needs resulting from such a disaster.

B. AAL Risk Index

The first state-level risk index is constructed using the Average Annualized Loss (AAL) values obtained using HAZUS loss modeling results. (FEMA, 2016b; CBO, 2016; Jaiswal, 2015) These loss estimates for various threats (flood, hurricane, and earthquake) are used to construct a measure of each state's relative risk. Unfortunately, the AAL estimates are for the total amount of the loss caused by the hazard, which includes losses by individuals and businesses as well as public sector losses. They also differ in terms of drivers and the treatment of insured vs. uninsured losses. Consequently, the AAL losses do not offer a necessarily accurate measure of Public Assistance losses covered by FEMA under the current program. If, however, the relationship between total losses and PA losses were constant, or are assumed to be constant, across hazards and across states, the AAL can be used to construct the relative risk index.

Since the HAZUS loss modeling approach uses science-based estimates of loss exposure and physical inventory, the estimates are not directly related to actual observed losses, as opposed to the alternative risk index model using actual PA losses over a nearly 20-year period. However, since actual losses depend heavily on actual events, many lower probability events which haven't been observed in the past 20 years, such as 100-year floods, or severe earthquakes, can be modeled by HAZUS and thus appear in the AAL risk measure, but not in the alternative PA risk measure.

The AAL based risk index produces risk measures for hazards in states that may not have experienced such a disaster in recent times. The science-based models predict threats and consequent losses for events that might occur over a time period of hundreds, or even thousands of years. Consequently, while California is often considered at greatest risk from an extreme earthquake, HAZUS models predict larger annual losses from flooding.

The strengths of using the AAL risk measure include:

1. Based on a common HAZUS modeling approach

2. All threats, including those not recently experienced, are included in the measure

The weaknesses are:

1. There is no direct link between total losses and PA losses across hazards, states or time

2. It includes events that are extremely unlikely to occur within social or political decision-making time frames

C. PA-BASED RISK INDEX (PARI)

We also calculate an alternative measure of PA risk using historical data on PA between 1999 and 2015, inclusive. This approach provides a Risk Index (RI) that is relatively close to historical average PA but can provide some smoothing of major disaster events.

A Risk Index that is based on PA is attractive because it closely mirrors FEMA's historical "exposure" to risk in terms of financial assistance it has provided. Because large deductibles provide greater incentive to mitigate than small deductibles, tying the Risk Index to PA means that states that receive large amounts of FEMA PA will receive the highest deductibles and therefore have the greatest incentive to mitigate. The downside to this approach is that it only reflects risk if a state experienced declared disaster events that occurred between 1999 and 2015. Although, for example, California has substantial earthquake risk, that is not reflected because no earthquakes resulting in substantial PA occurred in California between 1999 and 2015.

A state's expected annual PA depends on the number of disasters that occur each year and on the amount of PA needed when a disaster occurs. We assume that both the frequency and magnitude of disasters are distributed as random variables. This simultaneously takes into account the frequency and magnitude of disaster events, as well as state characteristics such as infrastructure that would affect PA needs.

We assume that the number of disasters that occur each year is a Poisson random variable.[8] Similarly, we assume that the magnitude of PA needs for a disaster is a log-normal random variable.[9] For each state we calculate the number of disasters that have received PA in each year between 1999 and 2015. We then estimate the parameters of the Poisson distribution that most accurately fit the observed data on the number of disasters in each year. Similarly, for each state we estimate the parameters of the log-normal distribution that most closely fits the state's historical PA receipts.

We then compute the mean number of disaster events per year and the mean PA per event based on the fitted parameters of the distributions. The average PA per year for each state is calculated by multiplying the mean number of disaster events per year by the mean PA per event. We calculate the Risk Index for each state by dividing the state's expected PA per year by the median level of expected PA per year across each of the 50 states. Figure I-3 shows the PARI across the 50 states and, for comparison, the Risk Index based on average annual PA, i.e. a state's average annual PA divided by the median average annual PA across all states. The PARI tracks relatively closely to the historical average PA Risk Index. Note that states that had one or two extremely damaging events, like Louisiana, have lower PARI risk than average annual risk. States that have frequent, moderately damaging disasters, such as California, have higher PARI risk than average annual risk.

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[8] A Poisson random variable takes on positive integer values, including zero. This is the most common distributions to model the number of relatively rare events occurring in a given time period.

[9] A log-normal random variable is strictly positive and is not restricted to integers. The log-normal distribution is commonly used for variables that have a long right-hand tail (i.e., an over-representation of large events compared with more symmetric distributions.

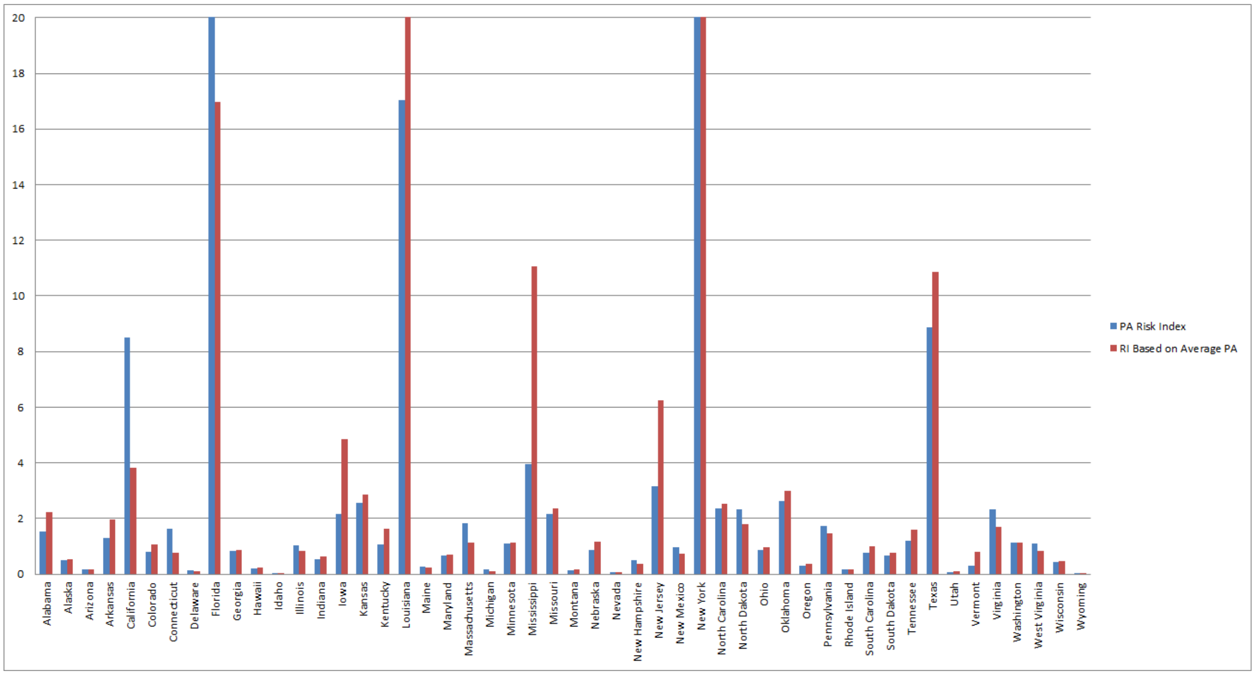

Figure I-3. PA-Based Risk Index

To summarize, the strengths of this approach are:

1. Based on PA risk
2. PA data are based on estimates of disaster losses for actual events. The estimates have been made at the "ground" (state and local) level and have been vetted individually by FEMA.
3. Takes into account the full set of available PA data
4. Easy to update

The weaknesses are:

1. Does not distinguish threat types
2. Omits risk for threats for which no disaster event took place between 1999 and 2015.
3. Disaster damage estimates may be poor for states with few disaster events

D. Risk Index

Risk indices are calculated based on the ratio of a state's risk relative to the risk of the median state. For the AALRI, the measure of risk is based on AAL losses, while for the PARI the measure of risk is based on average annual PA. A state that has risk twice as high as the median state's risk would be assigned a risk index of 2.0, while a state that has risk that is half of the median risk would have a risk index of 0.5. Risk indices are presented in Figure I-4.

Risk indices range from 0.09 in Wyoming to 24.48 in Florida under the AALRI and from 0.03 in Wyoming to 22.37 in Florida for the PARI approach. The mean and standard deviation are 2.16 and 4.10 for the AALRI approach and 2.70 and 5.53 for the PARI approach. PARI values are higher for states that have

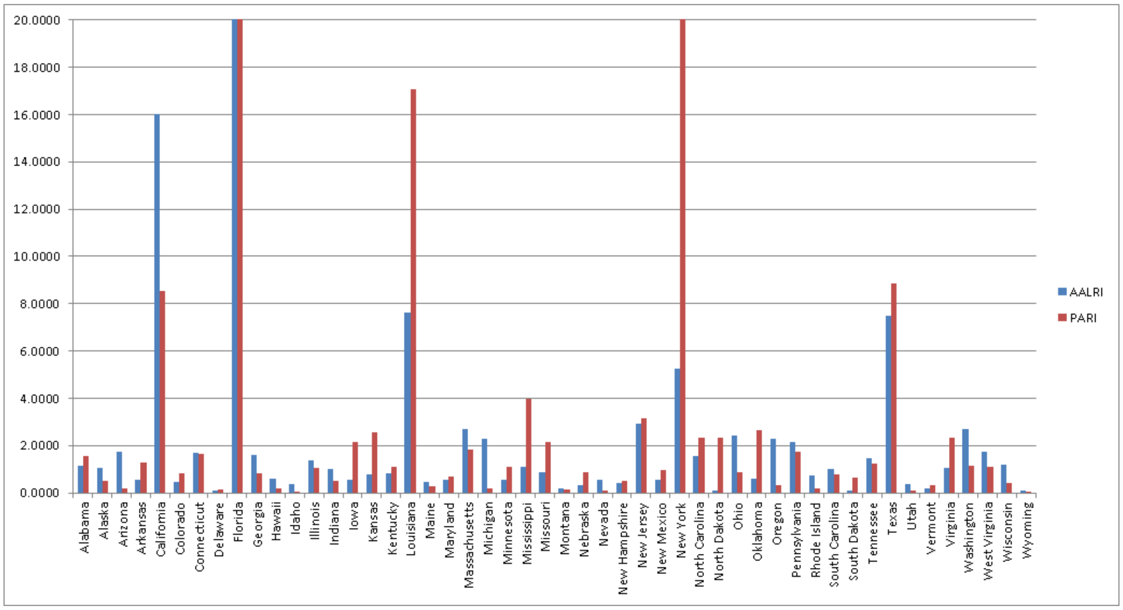

Figure I-4. State Risk Indices

experienced major disasters since 1999, while AALRI values are higher for states that are relatively highly exposed to floods, hurricanes, and earthquakes. The majority of states have Risk Indices that fall between 0.5 and 2 for both the PARI and AALRI approaches. The Risk Indices are substantially higher for Florida, Louisiana, New York, and Texas, while the lowest values occur in Delaware, Idaho, Montana and Wyoming.

V. Disaster Deductible Formula

A. Combined Index

Following the construction of the Risk and Fiscal Capacity Indices, it is necessary to combine the two adjustments into a single index that can be applied to a Baseline Deductible. There are a large number of ways that the Risk and Fiscal Capacity Indices can be combined, but we place 75% of the weight on the Risk Index and 25% of the weight on the Fiscal Capacity index.[10] Further, we place caps on both the Risk Index and on the elements of the Fiscal Capacity Index to prevent extremely large values from resulting in unduly large deductibles. We place a cap of 15 on the Risk Index and a cap of 5 on the elements of the Fiscal Capacity Index. We further normalize the Combined Index by dividing each state's Combined Index by the median Combined Index across all of the 50 states.

The Combined Index for each state is presented in Figure I-5 for both the AALI and PARI. With the exception of Alaska, the Combined Indices fall below 5.0, and most fall below 2.0. The Combined Index is particularly high for states like Alaska, North Dakota, and Wyoming because of their high fiscal

[10] See sensitivity tests on alternative weighting schemes in Section VIIIB.

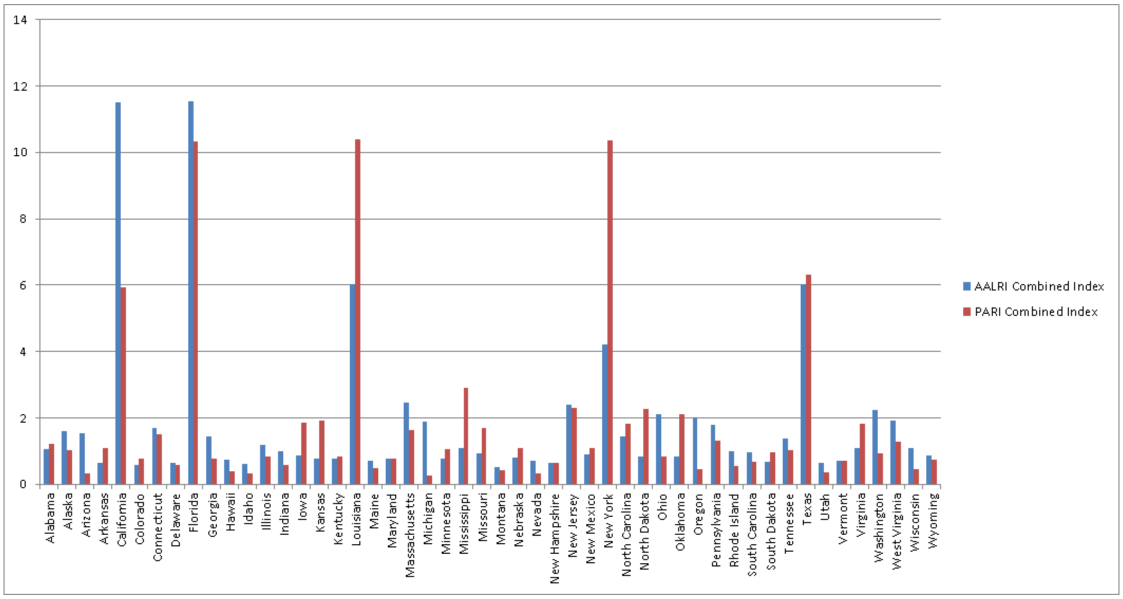

Figure I-5. State Combined Indices

capacity due to their taxation of natural resource extraction. On the other hand, the Combined Index is high for states like Louisiana and Texas because of high risk exposure.

B. DDF

Following the calculation of the Risk and Fiscal Capacity Indices, the baseline deductible must be adjusted to reflect these concerns. The Risk and Fiscal Capacity Indices were constructed to reflect a state's risk or fiscal capacity relative to other states. The Combined Index for a given state is therefore relative to other states as well. As a result, the Combined Index can simply be multiplied by the Base Deductible to scale it up or down to reflect a state's risk and fiscal capacity.

The Adjusted Deductible is:

$$Adjusted\ Deductible = Baseline\ Deductible * (Risk\ Index * 0.75 + Fiscal\ Capacity\ Index * 0.25)$$

Finally, we normalize these Deductibles to ensure that the Average Deductible equals the Baseline Deductible. Without this normalization, the former will exceed the latter, leading to potential political problems in implementation.[11] The normalization is achieved by multiplying each state's Deductible by the ratio of the Baseline Deductible to the Average Deductible to scale down each state's Deductible down to the Baseline Deductible value.

[11] The average deductible exceeds the baseline deductible because the Risk and Fiscal Capacity Indices are calculated relative to the corresponding median values, rather than mean values.

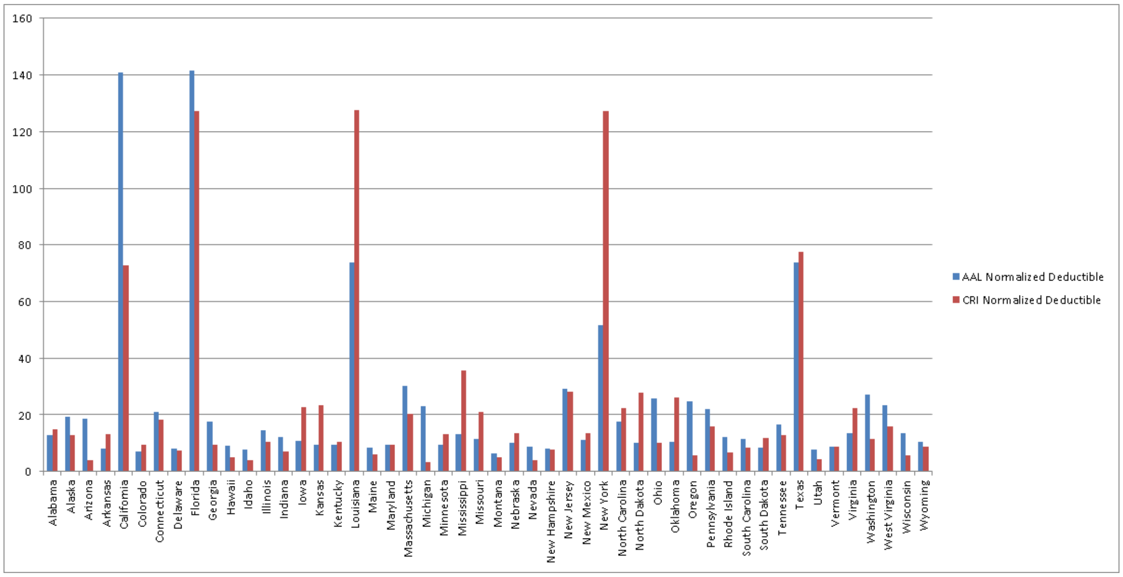

Figure I-6. State Normalized Deductibles

Normalized Deductibles are presented in Figure I-6. Normalized Deductibles generally fall between $15 million and $40 million. Under both the AALRI and PARI approaches, Florida has the highest Normalized Deductible, $141.5 million for AALRI and $127.2 million for PARI. Using the AALRI approach, Montana has the lowest Normalized Deductible at $6.2 million, while the PARI approach results in Idaho having the lowest Normalized Deductible at $3.9 million.

In Section VIII-B, we perform the following three sensitivity analyses on the calculation of the DDF:

1. Change weighting for Risk Index and Fiscal Capacity to 25/75 or 50/50

2. Set credit multipliers equal to mitigation BCR multipliers

3. Use alternative mitigation BCRs

VI. Incentivization Formula

A. Analytical Framework

Charging states a disaster deductible, by itself, would have no impact on expected disaster losses and simply represent a transfer of fiscal responsibility from FEMA to the states. States currently share this responsibility for declared disaster public assistance though the nominal 25% non-federal share, which can be adjusted to 10% or even less. The average non-federal share, based on the past ten years, is 22.5%. Imposing a deductible alone will increase state spending for declared disasters.

The primary goal of the DDF is to provide states with an incentive to mitigate or otherwise undertake actions both pre- and post-disaster that reduce the total loss and associated need for public assistance.

Consequently, a key to this analysis is creating a mechanism to incentivize mitigation. In its simplest form, the relationship between the disaster losses, the deductible, and mitigation credits is defined by the equation:

Expected state spending per year = Adjusted deductible – Mitigation Credits + State non-Federal share

Each element is expanded upon in the illustration below:

1. Adjusted Deductible = Base Deductible * (75% x Risk Index + 25% x Fiscal Capacity Index)*(Base Deductible/ avg (Base Deductible * (75% x Risk Index + 25% x Fiscal Capacity Index)))

1.1. Base Deductible = median of 17-yr avg annual Fed PA

1.2. Risk Index = sum (flood, hurricane, severe storm exposure) / median exposure

1.3. Fiscal Capacity Index = [(TTR/pop)/median(TTR/pop) + (Budget surplus/pop)/median(Budget surplus/pop) + (Reserves/pop)/median(Reserves/pop) + (Bond rating)/median(Bond rating)] / 4

2. Mitigation Spending: for example set to 75% of the risk or Deductible.

2.1. Mitigation Multiplier (reduction in loss) = Mitigation Spending * 3.18

2.2. Deductible Credit = Mitigation Spending * 3

3. Non-Federal Share = .225 * [Total PA – (Adjusted Deductible – Credits)]

The DDF, and the resulting fund and offsetting expenditures reflect both the interest of the state to contribute to disaster relief, and the need for FEMA to establish a vested interest for states in reducing disaster damage.

B. Credits for Mitigation, Relief Fund, Insurance Incentives

A state has many options for responding to disasters and the resultant need for public assistance. Mitigation covers a broad range of activities, most of which are undertaken pre-disaster (even post-disaster mitigation is primarily intended to use the restoration and reconstruction phase to reduce losses in the future). We use mitigation as a general term to also include some resilience tactics, actions taken to reduce losses from the present disaster, either in preparation for the disaster (e.g., purchasing portable generators) or once the disaster has struck (such as debris removal). Measures to improve resilience are likely to have shorter temporal impact than mitigation measures, but may also have more immediate and obvious benefits than mitigation. Also, most resilience tactics are intended to reduce business (or) government interruption, rather than property damage (Rose, 2009).

As an alternative to mitigation, which as a general category of actions reduces the probability or the size of damage and loss, insurance and relief funds provide a source of compensation for those losses once they occur. For a relatively modest premium a public building can be insured against damage.[12] In fact, FEMA's Recovery Policy FP 206-086-1 requires those receiving federal public assistance to insure the property against future loss by purchasing individual or multi-hazard insurance, or self-insuring via a FEMA approved plan. Establishing a relief fund not only represents a commitment by the state to funding expected public assistance needs, but also ensures that necessary public assistance is available when, inevitably, disasters occur.

It can be shown, with the examples below, that simply charging the states a deductible will not provide a significant incentive for states to mitigate. The mechanism by which FEMA can encourage states to mitigate is through credits against the disaster deductible. Even if states are currently engaged in disaster loss reduction activities, further reductions can be achieved by additional mitigation, by insuring public assets against disaster-related damage, and by establishing relief funds. As is shown in Section VIF below, charging states a deductible alone does not guarantee an incentive for states to undertake any of these activities. However, the deductible credit does, and FEMA can use the credits to incentivize loss reduction and risk spreading. The relevant parameters in the DDF are the credit rates applied to expenditures on each type of activity. For example, with regard to establishing and funding a disaster relief fund (DRF), states may receive a one-time lump sum credit for establishing a DRF, and then each year receive a dollar-for-dollar credit for state budget allocations made to the DRF.

C. Incentivization Mathematical Programming Model

1. Overview

We have developed a formal mathematical programming (MP) model[13] to analyze the state government response to the Disaster Deductible.[14] The model is a stylized approach to the problem, based on several key assumptions and parameters, aimed at both making the analysis realistic but also imposing some simplifications to make it manageable. Results do not yield pinpoint accurate results, but are intended to be indicative of potential outcomes. The MP Model will be structured so that it will represent a user-friendly software tool that FEMA can employ for analysis similar to those presented below.

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[12] Although in any year, for any particular insured building, the premium represents only a fraction of the total loss if the disaster strikes, the insurance premiums will be set at least equal to the actually fair—expected value of loss—amount. Hence, over the long run, and across many insured properties, the premium cost will be equal to the expected loss, plus administrative costs and insurance company profits.

[13] Mathematical programming models use computational methods to solve optimization problems. The typical formation of such problems is a linear or nonlinear function of a number of variables (objective function) to be optimized subject to a number of constraints in the form of linear or nonlinear equalities or inequalities (constraint functions).

[14] The MP Model is currently run in a linear programming format using the General Algebraic Modeling System (GAMS). This model can be generalized to include non-linearities and can be run in GAMS as well. Corresponding to the MP Model, the optimization decision can be expressed as a standard economic optimization problem. This has been programmed in *R* and yields equivalent results.

The MP model is set up to optimize an objective function subject to various constraints relating to physical conditions and policy variables. There are two variants according to the following objective functions:

- Minimize state expenditure subject to a target risk reduction
- Minimize state expenditure subject to a target credit against the deductible[15]

The major parameters of the model include: risk reduction per dollar of expenditure on risk reduction strategies (loss reduction multipliers) and credits per dollar of expenditure on risk reduction strategies (credit multipliers). Major constraints other than the targets noted above are individual limits on the extent of these mitigation and policy limits on the use of various strategies.

2. Model Specification

The MP Model is specified below, beginning with following definitions of terms:

X_{ij} : expenditure on risk reduction (credit attainment) for threat, *i* by tactic, *j*, where i = 1 . . . 5 (flood, hurricane, severe storm, earthquake, other); where *j* = 1 . . . 3 (mitigation, relief fund, insurance)

a_{ij} : risk reduction in dollar values per dollar expenditure on risk reduction for threat, *i*, by tactic, *j*

r_i : maximum risk (expected annual loss) for each threat type, *i*

R_s : overall risk reduction target for state, *s*, where *s* = 1 . . . 51

d_j : deductible credit per dollar expenditure on risk reduction tactic, *j*

c_i : maximum deductible credit for each threat type, *i*

C_s : overall deductible credit attainment target for state, *s*, where *s* = 1 . . . 51

Y_s : fiscal capacity in each state, *s*

MP Problem #1: Minimize cost (expenditure on various risk reduction tactics) to achieve a Risk Reduction Target

Objective function:

Minimize $\sum_i \sum_j X_{ij} = X$ *[minimize total expenditure on risk reduction]*

[15] We model state responses to their expected annual amount of PA so in our models each state requires PA each year. As a result, states respond to the deductible amount and total PA, but not to the probability that the deductible is paid (the probability of a disaster).

Subject to:

$\sum_j a_{ij} X_{ij} \leq r_i$ *[risk reduction for each threat should not exceed the maximum annual risk of that threat]*

$\sum_i r_i = R_s$ *[total risk reduction obtained from risk reduction of each threat meets the state risk reduction goal (e.g., 25%, 50%, or 75% of state total risk, which is capped by the state adjusted deductible)]*

$a_{i,mitigation} \times X_{i,mitigation} \leq 50\% \times r_i$ *[risk reduction from mitigation for each threat should not exceed 50% of the maximum annual risk of that threat]*

$a_{i,insurance} \times X_{i,insurance} \leq 50\% \times r_i$ *[risk reduction from insurance for each threat should not exceed 50% of the maximum annual risk of that threat]*

$a_{i,relief\ fund} \times X_{i,relief\ fund} \leq 50\% \times r_i$ *[risk reduction from relief funds for each threat should not exceed 50% of the maximum annual risk of that threat]*

$\sum_i \sum_j X_{ij} \leq Y_s$ *[state expenditure constraint; will integrate it later]*

MP Problem #2: Minimize cost (expenditure on various risk reduction tactics) to achieve a Deductible Credit Attainment Target:

Objective function:

Minimize $\sum_i \sum_j X_{ij} = X$ *[minimize total expenditure on deductible credit attainment]*

Subject to:

$\sum_j a_{ij} X_{ij} \leq r_i$ *[risk reduction for each threat not exceeding the maximum annual risk of that threat]*

$\sum_j \left[d_j \left(\sum_i X_{ij} \right) \right] = C_s$ *[total deductible credit obtained should meet the state credit attainment goal (e.g., 25%, 50%, and 75% of state adjusted deductible)]*

$a_{i,m} \times X_{i,m} \leq 50\% \times r_i$ *[risk reduction from mitigation, m, for each threat should not exceed 50% of the maximum annual risk of that threat]*

$a_{i,n} \times X_{i,n} \leq 50\% \times r_i$ *[risk reduction from insurance, n, for each threat should not exceed 50% of the maximum annual risk of that threat]*

$a_{i,f} \times X_{i,f} \leq 50\% \times r_i$ *[risk reduction from relief funds, f, for each threat should not exceed 50% of the maximum annual risk of that threat]*

$d_n \times X_{i,n} \leq 50\% \times c_i$ *[deductible credit obtained from insurance for threat i should not exceed 50% of the credit limit for that threat]*

$d_f \times X_{i,f} \leq 50\% \times c_i$ *[deductible credit obtained from relief funds for threat i should not exceed 50% of the credit limit for that threat]*

$\sum_i \sum_j X_{ij} \leq Y_s$ *[state expenditure constraint; will integrate it later]*

Appendix I-B presents an example of one of the mathematical programming (MP) problems, organized in what is known as *activity analysis* form, which clearly displays all of the parameter values within the structure of the model.

3. Assumptions

- Loss Reduction Multipliers. This refers to the benefit-cost ratios (BCRs) associated with risk reduction strategies.
  - Mitigation: We rely upon the Benefit-Cost ratios (BCRs) derived in the *Mitigation Saves* Report to Congress (MMC, 2005; referred to as the *MS* Study). These BCRs include a range of benefits categorized broadly as property damage, casualty, historical and environmental, and business interruption. Mitigation projects for various threats tend to emphasize some benefits more than others. For example, the *MS* Study found that casualty reduction was the largest benefit in wind-related mitigation projects, while property damage reduction was the largest benefit for flood-related projects. Since FEMA Public Assistance focuses on property damage rather than casualties or business interruption, which are, in part, covered by other programs or from other sources, we have adjusted the BCRs from the *MS* Study to reflect only property damage. The Study only identified three threat types: Wind, Flood, and Earthquake. For the other two threat types, the Property Damage Only BCRs are calculated as the property damage share of benefits of the entire costs, resulting lower adjusted BCRs. The resulting adjusted BCRs are: earthquakes, 28% *1.5 = .42; hurricanes, 13% *3.9 = 0.51; flood: 96% * 5.0 = 4.75. The overall BCR is a weighted average of the component BCRs using cost as the weights and changes from 4.0 to 3.18. This BCR is also used for the remaining categories of severe storm and "other".

  - - Floods— 4.75:1
    - Hurricanes— 0.51:1
    - Earthquakes— 0.42:1
    - Severe storms— 3.18:1
    - Other— 3.18:1

  -- Relief Funds: assume the "loss reduction" is 1:1. While this strategy applies to all threats, it can only be applied to specific losses that take place in a given year; hence, it is threat specific in the model. Most importantly, it is not actually a reduction in risk but simply a shift in the risk from the federal government to the state.

--Insurance: assume the "loss reduction" is 1:1, representing the actuarial value of insurance. We assume that this strategy is threat-specific (i.e., states would buy separate insurances against each threat, and the coverage would be bundled such that the premiums would reflect the actuarial value of the individual threats). And again, it is not actually a reduction in risk but simply a shift in the risk, this time to the private sector.

--In our incentivization analysis, we will place the following limits on risk reduction strategies:

- Mitigation: 50% of risk (because not all risks can be mitigated)
- Relief Fund: 50% (because this is only risk spreading and not actually risk reduction)
- Insurance: 50% (because this is only risk spreading and not actually risk reduction)

- Credit Multipliers.[16] In order to incentivize risk reduction behavior, we assume that FEMA would provide credits for state implementation of various strategies. The credit multipliers are:
  - Mitigation—3:1[17]
  - Relief funds—1:1[18]
  - Insurance—2:1[19]

4. Simulation Results

a. AAL Risk Case

We selected three states, CA, MS, and OH, as the example states to run the MP analysis. The simulation results of the MP analysis are presented in Tables I-3, I-4, I-5, I-6, I-7, and I-8. Summary tables that present the basic data and parameters used in the MP analysis are presented in Appendix I-C1. Note that because Insurance and Relief Funds were not part of the optimal solution in most cases, we have suppressed their entries in the tables of those cases to conserve space.

MP Problem #1

California: The total state risk is $1,334.33 million. The state adjusted deductible is $141.03 million. The maximum risk any state would choose to reduce in response to the policy proposal is

[16] The question of when credit will be applied is relevant for our analysis of the DDF program over a period of years. Since credits must be applied ex post, the credit for Year 1 mitigation will be applied to the anticipated deductible in Year 2. However, since the deductible is a virtual (budgeted) expenditure and is only realized at the end of the year, it is possible to align both the calculation of the credit, and the actual expenditures by the state on mitigation (and other credit activities) and public assistance. Given that many states have two-year budgets, and that annual variation in the deductible is likely to be politically unappealing, the assessment of the deductible and credits can be aligned with relative ease.
[17] Applicable to the year in which the expenditure is made.
[18] Applicable only in year the Relief Fund is initiated, or year in which any subsequent increases to it are made.
[19] Applied to annual insurance premium. Since the premium is a small fraction of the actual damage coverage, the multiplier of 2 is used to provide sufficient incentive, and differentiate it from the direct dollar nature of the relief fund.

limited by its deductible. Moreover, we assume that any given sate will not fully respond to the incentive, and we limit the response to 75%. For the 75% reduction case (which is the Base Case of our analysis), the risk reduction target is $105.77 million for CA. We also perform sensitivity tests for the 50% and 25% reduction cases, where the risk reduction target is $70.51 million and $35.26 million, respectively.

For all three cases, the risk reduction target is achieved by mitigation of floods, which has the highest BCR (4.75) among all the mitigation strategies. Since the PA risk of flood adjusted from AAL-based flood risk for California is $866.67 million, the constraint that mitigation can only achieve up to 50% reduction of the maximum risk of floods is not binding for any of the three cases. The total expenditures in the 75%, 50%, and 25% risk reduction cases are $22.27, $14.85, and $7.42 million, respectively.

Mississippi: The total state risk is $99.34 million. The state adjusted deductible is $13.32 million. Since we limit the state maximum risk by the deductible, for the 75% reduction case, the risk reduction target is $9.99 million, and for the 50% and 25% reduction cases, the risk reduction target is $6.66 million and $3.33 million, respectively.

As in the case of California, for all of the three alternative risk reduction targets, the optimal risk reduction mix will only include flood mitigation. The PA risk of flood adjusted from AAL-based flood risk for Mississippi is $58.82 million. Therefore, the constraint that mitigation of floods cannot reduce more than 50% of the maximum risk of flood in the state is not binding for any of the three cases. The total expenditures in the 75%, 50%, and 25% risk reduction cases are $2.10, $1.40, and $0.70 million, respectively.

Ohio: The total state risk is $210.91 million. The state adjusted deductible is $25.86 million. Since we limit the state maximum risk by the deductible, for the 75% reduction case, the risk reduction target is $19.40 million, and for the 50% and 25% reduction cases, the risk reduction target is $12.93 million and $6.47 million, respectively.

As for the cases of California and Mississippi, Ohio will choose to achieve the three alternative risk reduction targets by mitigation of flood alone. The PA risk of flood adjusted from AAL-based flood risk for Ohio is $187.22 million. Therefore, the constraint that mitigation of floods cannot reduce more than 50% of the maximum risk of flood in the state is not binding for any of the three cases. The total expenditures in the 75%, 50%, and 25% risk reduction cases are $4.08, $2.72, and $1.36 million, respectively.

TABLE I-3. Minimization of Risk Reduction Expenditure for Target Risk Reduction – California AALRI Case
(in million dollars)

	Expenditure			Risk Reduction Attained		
	Reduce 75% of State Risk*	Reduce 50% of State Risk*	Reduce 25% of State Risk*	Reduce 75% of State Risk*	Reduce 50% of State Risk*	Reduce 25% of State Risk*
Mitigation						
Hurricanes						
Floods	22.27	14.85	7.42	105.77	70.51	35.26
Severe Storms						
Earthquakes						
Other						
Total	22.27	14.85	7.42	105.77	70.51	35.26

* We limit the state risk by the state adjusted deductible (which is 141.03 for CA).

TABLE I-4. Minimization of Risk Reduction Expenditure for Target Risk Reduction– Mississippi AALRI Case
(in million dollars)

	Expenditure			Risk Reduction Attained		
	Reduce 75% of State Risk*	Reduce 50% of State Risk*	Reduce 25% of State Risk*	Reduce 75% of State Risk*	Reduce 50% of State Risk*	Reduce 25% of State Risk*
Mitigation						
Hurricanes						
Floods	2.10	1.40	0.70	9.99	6.66	3.33
Severe Storms						
Earthquakes						
Other						
Total	2.10	1.40	0.70	9.99	6.66	3.33

* We limit the state risk by the state adjusted deductible (which is 13.32 for MS).

TABLE I-5. Minimization of Risk Reduction Expenditure for Target Risk Reduction – Ohio AALRI Case
(in million dollars)

	Expenditure			Risk Reduction Attained		
	Reduce 75% of State Risk*	Reduce 50% of State Risk*	Reduce 25% of State Risk*	Reduce 75% of State Risk*	Reduce 50% of State Risk*	Reduce 25% of State Risk*
<u>Mitigation</u>						
Hurricanes						
Floods	4.08	2.72	1.36	19.40	12.93	6.47
Severe Storms						
Earthquakes						
Other						
Total	4.08	2.72	1.36	19.40	12.93	6.47

* We limit the state risk by the state adjusted deductible (which is 25.86 for OH).

<u>MP Problem #2</u>

<u>California</u>: The state adjusted deductible is $141.03 million. So the targeted credit level is $105.77 million for the 75% deductible credit attainment case (Base Case), $70.51 million for 50% deductible case, and $35.26 million for the 25% deductible case.

For all of the three cases, the model chooses mitigation of floods alone to achieve the credit attainment target. The total expenditures are $35.26, $23.50, and $11.75 million, respectively, for the 75%, 50%, and 25% credit attainment cases.

<u>Mississippi</u>: The state adjusted deductible is $13.32 million. So for the 75% deductible Base Case, the credit attainment target is $9.99 million and for 50% and 25% deductible cases, the credit attainment target is $6.66 million and $3.33 million, respectively.

For all of the three cases, the model chooses mitigation of Hurricanes alone to achieve the credit attainment target. The total expenditures are $2.10, $1.40, and $0.70 million, respectively, for the 75%, 50%, and 25% credit attainment cases.

<u>Ohio</u>: The state adjusted deductible is $25.86 million. So for the 75% deductible Base Case, the credit attainment target is $19.40 million and for 50% and 25% deductible cases, the credit attainment target is $12.93 million and $6.47 million, respectively.

As in the case of California, the optimal solution includes mitigation of Floods alone. The total expenditures are $6.47, $4.31, and $2.16 million, respectively, for the 75%, 50%, and 25% credit attainment cases.

Note that for all three cases in all three states, the optimal solutions presented in the tables are not unique. This is because the credit multiplier for mitigation on the various threat types is the same at 3.0. So from the expenditure (cost) minimization point of view, to achieve the same deductible credit attainment target, there is no difference in investing in mitigation among the various threat types, as long as the risk reduction for each threat type from mitigation does not exceed 50% of the maximum risk of that threat. The reason that the model chooses mitigation of hurricanes for Mississippi over the other mitigation strategies is that "hurricanes" is entered into the model before the other strategies, and thus becomes the first one examined by the optimization algorithm in the model. As for California and Ohio, since the two states have zero risk of hurricanes, the model optimization algorithm chooses the second threat type, floods, that is entered into the model.

TABLE I-6. Minimization of Risk Reduction Expenditure for Target Credit – California AALRI Case

(in million dollars)

	Expenditure			Deductible Credit Attained		
	75% Deductible Credit	50% Deductible Credit	25% Deductible Credit	75% Deductible Credit	50% Deductible Credit	25% Deductible Credit
Mitigation						
Hurricanes						
Floods	35.26	23.50	11.75	105.77	70.51	35.26
Severe Storms						
Earthquakes						
Other						
Total	35.26	23.50	11.75	105.77	70.51	35.26

TABLE I-7. Minimization of Risk Reduction Expenditure for Target Credit – Mississippi AALRI Case

(in million dollars)

	Expenditure			Deductible Credit Attained		
	75% Deductible Credit	50% Deductible Credit	25% Deductible Credit	75% Deductible Credit	50% Deductible Credit	25% Deductible Credit
Mitigation						
Hurricanes	3.33	2.22	1.11	9.99	6.66	3.33
Floods						
Severe Storms						
Earthquakes						
Other						
Total	3.33	2.22	1.11	9.99	6.66	3.33

TABLE I-8. Minimization of Risk Reduction Expenditure for Target Credit – Ohio AALRI Case
(in million dollars)

	Expenditure			Deductible Credit Attained		
	75% Deductible Credit	50% Deductible Credit	25% Deductible Credit	75% Deductible Credit	50% Deductible Credit	25% Deductible Credit
Mitigation						
Hurricanes						
Floods	6.47	4.31	2.16	19.40	12.93	6.47
Severe Storms						
Earthquakes						
Other						
Total	6.47	4.31	2.16	19.40	12.93	6.47

b. PA Risk Case

The simulation results of the MP analysis for the PA Risk Case are presented in Tables I-9, I-10, I-11, I-12, I-13, and I-14. Summary tables that present the basic data and parameters used in the MP analysis are presented in Appendix I-C2.

MP Problem #1

California: The total state risk is $224.98 million. The state adjusted deductible is $72.89 million. Since we limit the state maximum risk by the deductible, for the 75% reduction case, the risk reduction target is $54.66 million, and for the 50% and 25% reduction cases, the risk reduction target is $36.44 million and $18.22 million, respectively.

For the Base Case—reducing 75% of state risk:

1. Total minimized expenditure is $16.66 million
2. The risk reduction target of $54.66 million (75% of deductible) is achieved
3. The constraint that mitigation can only achieve up to 75% reduction of the maximum risk is binding for floods and severe storms
4. The model then chose expenditure on mitigation for “other” threat to meet the remaining risk reduction target

For the Sensitivity Cases—reducing 25% or 50% of state risk:

1. Total minimized expenditure is $5.20 million and $10.93 million, respectively
2. The risk reduction target of $18.22 million or $36.44 million are achieved

3. The constraint that mitigation can only achieve up to 50% reduction of the maximum risk is only binding for floods
4. The model then chose expenditure on mitigation for severe storms to meet the remaining risk reduction target

Note for all of the three cases, the optimal solutions presented in the tables are not unique. This is because, while mitigation of floods has the highest BCR of 4.75 (which is why it is always chosen by the model as the first risk reduction strategy to implement and is always fully utilized before the model chooses the strategy that has the next highest BCR), both mitigation of severe storms and "other" have the next highest BCR of 3.18.[20] So from the expenditure (cost) minimization point of view, to achieve the risk reduction goal, there is no difference in investing between mitigation of severe storms and "other", as long as the risk reduction for these two threat types from mitigation does not exceed 50% of the maximum risk of the threat.

Mississippi: The total state risk is $104.91 million. The state adjusted deductible is $35.73 million. Since we limit the state maximum risk by the deductible, for the 75% reduction case, the risk reduction target is $26.80 million, and for the 50% and 25% reduction cases, the risk reduction target is $17.87 million and $8.93 million, respectively.

For the Base Case—reducing 75% of state risk:

1. Total minimized expenditure is $24.77 million
2. The risk reduction target of $26.80 million (75% of deductible) is achieved
3. The constraints that mitigation can only achieve up to 50% reduction of the maximum risk are binding for floods, severe storms, and other
4. According to the modeled risk, MS does not have risks associated with earthquake. Since the BCR of mitigating risk from hurricanes is 0.51, which is lower than the BCR for insurance or relief fund, the remaining amount of risk reduction target is met by insurance or relief fund expenditures on "hurricanes". Note that both insurance and relief fund have a BCR of 1. Therefore, there is no difference in choosing between insurance and relief fund in the MP optimal solution. In addition, the BCRs for insurance and relief funds of different threat types are all the same at 1 as well. The reason that "hurricanes" is chosen over the other threat types is because "hurricanes" is entered into the model before other threat types, and thus the model chooses it first when the strategies with BCRs higher than 1 have been used up.

For the Sensitivity Cases—reducing 25% or 50% of state risk:

1. Total minimized expenditure is $6.91 million and $15.84 million, respectively
2. The risk reduction target of $8.93 million or $17.87 million is achieved

[20] In the DDF Visualization Interface, the BCR is adjustable, as is the rate at which BCRs decline as high-risk projects are selected first.

3. The constraint that mitigation can only achieve up to 50% reduction of the maximum risk is binding for floods, severe storms, and “other”
4. The model then chose expenditure on insurance for “hurricanes” to meet the remaining risk reduction target
5. The MP solutions for the 25% and 50% cases are not unique as well. This is for the same reasons stated above -- the BCRs for insurance against the various threat types and for relief fund are all the same at 1.0. Therefore, the choice between insurance for different threat types and relief fund does not affect the optimal solution.

Ohio: The total state risk is $23.13 million. The state adjusted deductible is $10.26 million. Since we limit the state maximum risk by the deductible, for the 75% reduction case, the risk reduction target is $7.70 million, and for the 50% and 25% reduction cases, the risk reduction target is $5.13 million and $2.57 million, respectively.

For the three cases – reducing 75%, 50%, or 25% of state risk:

1. Total minimized expenditure is $2.42, $1.61, and $0.81 million, respectively
2. The risk reduction target of $7.70 million (75% of deductible), $5.13 million (50% of deductible), or $2.57 million (25% of deductible) is achieved
3. The only mitigation spending category in the optimal solution is severe storms
4. The constraints that mitigation can only achieve up to 50% reduction of the maximum risk is not binding for severe storms
5. The optimal solutions for any of the three cases are not unique. This is again because both mitigation of severe storms and “other” have a BCR of 3.18. So from the expenditure (cost) minimization point of view, to achieve the risk reduction goal, there is no difference in investing between mitigation of severe storms and “other”.

TABLE I-9. Minimization of Risk Reduction Expenditure for Target Risk Reduction – California PARI Case

(in million dollars)

	Expenditure			Risk Reduction Attained		
	Reduce 75% of State Risk*	Reduce 50% of State Risk*	Reduce 25% of State Risk*	Reduce 75% of State Risk*	Reduce 50% of State Risk*	Reduce 25% of State Risk*
Mitigation						
Hurricanes						
Floods	1.08	1.08	1.08	5.12	5.12	5.12
Severe Storms	11.42	9.85	4.12	36.31	31.33	13.11
Earthquakes						
Other	4.17			13.24		
Total	16.66	10.93	5.20	54.66	36.44	18.22

* We limit the state risk by the state adjusted deductible (which is 72.89 for CA).

TABLE I-10. Minimization of Risk Reduction Expenditure for Target Risk Reduction– Mississippi PARI Case

(in million dollars)

	Expenditure			Risk Reduction Attained		
	Reduce 75% of State Risk*	Reduce 50% of State Risk*	Reduce 25% of State Risk*	Reduce 75% of State Risk*	Reduce 50% of State Risk*	Reduce 25% of State Risk*
Mitigation						
Hurricanes						
Floods	0.02	0.02	0.02	0.10	0.10	0.10
Severe Storms	0.84	0.84	0.84	2.69	2.69	2.69
Earthquakes						
Other	0.05	0.05	0.05	0.16	0.16	0.16
Insurance or Relief Funds						
Hurricanes	23.86	14.93	5.99	23.86	14.93	5.99
Floods						
Severe Storms						
Earthquakes						
Other						
Total	24.77	15.84	6.91	26.80	17.87	8.93

* We limit the state risk by the state adjusted deductible (which is 35.73 for MS).

TABLE I-11. Minimization of Risk Reduction Expenditure for Target Risk Reduction – Ohio PARI Case

(in million dollars)

	Expenditure			Risk Reduction Attained		
	Reduce 75% of State Risk*	Reduce 50% of State Risk*	Reduce 25% of State Risk*	Reduce 75% of State Risk*	Reduce 50% of State Risk*	Reduce 25% of State Risk*
Mitigation						
Hurricanes						
Floods						
Severe Storms	2.42	1.61	0.81	7.70	5.13	2.57
Earthquakes						
Other						
Total	2.42	1.61	0.81	7.70	5.13	2.57

* We limit the state risk by the state adjusted deductible (which is 10.26 for OH).

MP Problem #2

California: The state adjusted deductible is $72.89 million. So the targeted credit level is $54.67 million for the 75% deductible credit attainment case, $36.44 million for 50% deductible case, and $18.22 million for the 25% deductible case.

For the Base Case—attaining credit = 75% deductible:

1. Total minimized expenditure is $18.22 million
2. The credit attainment target of $54.67 million (75% of deductible) is achieved
3. The constraint that mitigation can only achieve up to 50% reduction of the maximum risk is only binding for floods and severe storms
4. The model then chose expenditure on mitigation of earthquake to meet the remaining credit attainment target

For the Sensitivity Case—attaining credit = 25% deductible:

1. Total minimized expenditure is $6.07 million
2. The credit attainment target of $18.22 million (25% of deductible) is achieved
3. The constraint that mitigation can only achieve up to 50% reduction of the maximum risk is only binding for floods
4. The model then chose expenditure on mitigation of severe storms to meet the remaining credit attainment target

For the Sensitivity Case—attaining credit = 50% deductible:

1. Total minimized expenditure is $12.15 million
2. The credit attainment target of $36.44 million (50% of deductible) is achieved
3. The constraint that mitigation can only achieve up to 50% reduction of the maximum risk is binding for floods
4. The model then chose expenditure on mitigation of severe storms to meet the remaining credit attainment target

Mississippi: The state adjusted deductible is $35.73 million. So for the 75% deductible case, the credit attainment target is $26.80 million and for 50% and 25% deductible cases, the credit attainment target is $17.87 million and $8.93 million, respectively.

For the Base Case—attaining credit = 75% deductible:

1. Total minimized expenditure is $8.93 million
2. The credit attainment target of $26.80 million (75% of deductible) is achieved
3. The model chose expenditure on mitigation of hurricanes to meet the credit attainment target

4. The constraints that mitigation can only achieve up to 50% reduction of the maximum risk is not binding for any threat type

For the Sensitivity Cases—obtaining credit = 25% or 50% deductible:

1. Total minimized expenditure is $2.98 million or $5.96 million, respectively
2. The credit attainment target of $8.93 million (25% of deductible) or $17.87 million (50% of deductible) is achieved
3. The model chose expenditure on mitigation of hurricanes to meet the credit attainment target
4. The constraints that mitigation can only achieve up to 50% reduction of the maximum risk is not binding for any threat type

Ohio: The state adjusted deductible is $10.26 million. So for the 75% deductible case, the credit attainment target is $7.70 million and for 50% and 25% deductible cases, the credit attainment target is $5.13 million and $2.57 million, respectively.

For the Base Case—attaining credit = 75% deductible:

1. Total minimized expenditure is $2.57 million
2. The credit attainment target of $7.70 million (75% of deductible) is achieved
3. The model choses expenditure on mitigation of hurricanes and severe storms to meet the credit attainment target
4. The constraints that mitigation can only achieve up to 50% reduction of the maximum risk is binding for hurricanes

For the Sensitivity Case—attaining credit = 25% deductible:

1. Total minimized expenditure is $0.86 million
2. The credit attainment target of $2.57 million (25% of deductible) is achieved
3. The model choses expenditure on mitigation of hurricanes to meet the credit attainment target
4. The constraints that mitigation can only achieve up to 50% reduction of the maximum risk is not binding for hurricanes

For the Sensitivity Case—obtaining credit = 50% deductible:

1. Total minimized expenditure is $1.71 million
2. The credit attainment target of $5.13 million is achieved
3. The model chose expenditure on mitigation of hurricanes and severe storms to meet the credit attainment target
4. The constraints that mitigation can only achieve up to 50% reduction of the maximum risk is binding for hurricanes

Note that for all three cases in all three states, the optimal solutions presented in the tables are not unique. This is because the credit multiplier for mitigation on the various threat types is the same at 3.0. So from the expenditure (cost) minimization point of view, to achieve the same deductible credit attainment target, there is no difference in investing in mitigation among the various threat types, as long as the risk reduction for each threat type from mitigation does not exceed 50% of the maximum risk of that threat.

TABLE I-12. Minimization of Risk Reduction Expenditure for Target Credit – California PARI Case

(in million dollars)

	Expenditure			Deductible Credit Attained		
	75% Deductible Credit	50% Deductible Credit	25% Deductible Credit	75% Deductible Credit	50% Deductible Credit	25% Deductible Credit
<u>Mitigation</u>						
Hurricanes						
Floods	1.08	1.08	1.08	3.23	3.23	3.23
Severe Storms	11.42	11.07	5.00	34.25	33.21	14.99
Earthquakes	5.73			17.18		
Other						
Total	18.22	12.15	6.07	54.67	36.44	18.22

TABLE I-13. Minimization of Risk Reduction Expenditure for Target Credit – Mississippi PARI Case

(in million dollars)

	Expenditure			Deductible Credit Attained		
	75% Deductible Credit	50% Deductible Credit	25% Deductible Credit	75% Deductible Credit	50% Deductible Credit	25% Deductible Credit
<u>Mitigation</u>						
Hurricanes	8.93	5.96	2.98	26.80	17.87	8.93
Floods						
Severe Storms						
Earthquakes						
Other						
Total	8.93	5.96	2.98	26.80	17.87	8.93

TABLE I-14. Minimization of Risk Reduction Expenditure for Target Credit – Ohio PARI Case

(in million dollars)

	Expenditure			Deductible Credit Attained		
	75% Deductible Credit	50% Deductible Credit	25% Deductible Credit	75% Deductible Credit	50% Deductible Credit	25% Deductible Credit
<u>Mitigation</u>						
Hurricanes	0.99	0.99	0.86	2.97	2.97	2.57
Floods						
Severe Storms	1.58	0.72		4.73	2.16	
Earthquakes						
Other						
Total	2.57	1.71	0.86	7.70	5.13	2.57

Comparing the MP results for the AALRI Case and the PARI Case, we have the following findings:

- For California and Ohio, the adjusted deductibles in the AALRI Case are higher than in the PARI Case. Since we limit the state maximum risk by the deductible in the risk reduction target MP analysis, total expenditures to achieve a specified level of risk reduction are lower in the PARI Case than in the AALRI Case for the two states. Less total expenditures are also incurred to achieve a specified level of deductible credit in the PARI case because of the lower total adjusted deductible in this case compared to the AALRI Case.
- In contrast, for Mississippi, since the adjusted deductible in the AALRI Case is lower than in the PARI Case, less expenditure is incurred for the state in both the risk reduction and credit attainment simulations for the AALRI Case than in the corresponding simulations for the PARI Case.
- In most cases, the optimal solution for the AALRI Case only includes mitigation of floods. This is largely because of the high risk level of floods based on the AAL estimates even after adjusting by 0.1 for the PA risk. Since flood mitigation has the highest BCR, all three states can achieve the risk reduction target by using flood mitigation alone without reaching the 50% risk reduction constraint for this mitigation strategy.

Note that the simulations presented above do not illustrate the full capability of the MP Model. As we've already noted, the results change and become more general (in terms of additional strategies being part of the optimal solution) as the constraints are adjusted. Also, the constant parameter values and the overall linear character of the model resulted in "corner" solutions, meaning that the Model will choose extreme values for the strategies, rather than a mix of them in the non-linear case, which would imply substitutability between strategies. The non-linearities would realistically stem from the fact that the mitigation multiplier, for example, would decline as additional mitigation options were implemented (one would begin with the highest return on investment and work down the mitigation investment schedule). The various individual constraints might be tightened or loosened, or credit multiplier values changed, depending on policy considerations relating to FEMA's preferences for individual strategies (recall that insurance and relief funds do not actually reduce risk but simply spread it).

In Section VIIIB, we perform MP analysis for the following two sensitivity cases:

1. Set credit multipliers equal to mitigation BCR multipliers

2. Use alternative mitigation BCRs

D. Burden Analysis

In general, an economic "burden analysis" shows how better off, or worse off, both the state government and the federal government are under alternative scenarios. We use this tool to analyze the impact of the DDF on states. Not only can we identify if the state will be better or worse off under the DDF program, we can measure the size of the impact in terms of dollar expenditures. In this section, sample burden analyses are presented for three states: California, Mississippi, and Ohio. These were chosen because California and Mississippi suffer significant disaster losses on an annual basis and one is a large, wealthy state, while the other is a relatively small, poorer state. Ohio has lower expected losses and represents many states for which disasters are not common, but when they do occur such states are often unprepared for them. The burden analysis can, and will be, conducted on all states, however, at a later date.

The analysis is based on the following relationships:

1. Adjusted Deductible = Base Deductible * (75% x Risk Index + 25% x Fiscal Capacity Index) *(Base Deductible/ avg (Base Deductible * (75% x Risk Index + 25% x Fiscal Capacity Index)))

  2. Base Deductible = median of 17-yr avg annual Fed PA across states

  3. Risk Index = sum (flood, hurricane, severe storm exposure) / median exposure

  4. Fiscal Capacity Index = avg (TTR/pop, Budget surplus/pop, Reserves/pop, Bond rating)

5. Mitigation Spending: set to 75% of the risk or the Deductible

  6. Loss Reduction = Mitigation Spending * Mitigation Multiplier

  7. Deductible Credit = Mitigation, or other, Spending * Credit Multiplier

8. Expected State Spending = Adjusted Deductible – Credits + Non-Fed share

  9. Non-Fed Share = .225 * [Total PA – (Adjusted Deductible – Credits)]

From an accounting perspective, the deductible is set at the beginning of the fiscal year, while actual spending on disasters and credits against the deductible are calculated at the end of the fiscal year. For example, the state will be charged its deductible and state share at the end of the fiscal year by FEMA, once actual losses and actual mitigation spending is known. This timing makes for a relatively simple implementation of the DDF.[21] The parameters used in the examples are described in Section VIC3.

1. Burden Analysis of AALRI based deductible.

Two sample Burden Analyses are provided below when the Deductible is calculated using the AALRI. This is done for the three states. The first burden table reflects a mitigation goal to reduce risk by 75%, and the second table reflects the goal of achieving a 75% reduction in the deductible via credits.

In all burden tables the status quo reflects the current situation in which states pay an average share of 22.5% of all public assistance related losses per year, while FEMA pays the remaining. This is shown in Section A Status Quo of Table I-15.

The impact of charging the state a deductible is shown in Section B of the same table. Compared to the status quo base-case, the deductible represents a significant increase in the state's disaster burden. There is a corresponding decrease (same magnitude) in federal spending on disaster public assistance as the deductible alone represents a simple transfer of cost from FEMA to the state.

Section C of Table I-9 shows the effect of the DDF where a state can offset the deductible through credits for spending on mitigation. Mitigation efforts by the state lower the expected total loss and associated public assistance, thereby reducing the state's expected share. Spending on mitigation is credited with a multiplier against the deductible, thereby reducing the state's deductible burden. Under the DDF program, states benefit two ways from spending on mitigation: mitigation lowers total losses and lowers the deductible. However, the funds spent on mitigation do offset some of these benefits. FEMA also benefits from state mitigation spending since it pays the larger share of total public assistance. As the example above shows, each state still spends more on disaster related activities (mitigation and post-disaster public assistance) compared to the current system. However, compared to the deductible only scenario, each state spends less. As was the case with the deductible only, FEMA spends less than the current system when credit against the deductible is given for mitigation spending.

Another sample burden analysis is provided below, where the goal for mitigation is achieving a 75% reduction in the deductible via credits.

[21] Since mitigation is done in advance of a disaster, credit should be given when the mitigation spending occurs. But as soon as the mitigation is in place, it reduces expected losses, and actual losses when they occur. All dollars in the DDF are anticipated, and only realized throughout the year as actual disasters occur. Actual spending on disasters occurs in real time. Accounting of the DDF can be done at the end of the period (one or two years, depending on state budget cycle). If the state "overspends" on disasters, FEMA can issue a rebate, or carry over the credit to the following year.

Table I-15.
Burden Analysis for DDF1 – AALRI case
California, Mississippi, Ohio
(75% risk reduction)

	Expenditures ($millions)		
	CA	**MS**	**OH**
A. Status Quo			
Total expected Public Assistance (PA)	1334.33	99.34	210.91
State share of PA	300.22	22.35	47.46
Federal PA	1034.10	76.99	163.46
B. Deductible only			
Total expected Public Assistance (PA)	1334.33	99.34	210.91
State deductible	141.03	13.32	25.86
PA after state pays deductible	1193.30	86.02	185.05
State share of remaining PA	268.49	19.35	41.64
State total spending (deduct. + state share)	409.52	32.68	67.50
Federal PA	924.81	66.67	143.41
Change in State burden	109.29	10.33	20.05
Change in Federal burden	-109.29	-10.33	-20.05
C. Mitigation with DDF credit			
Total expected Public Assistance (PA)	1334.33	99.34	210.91
Spending on mitigation	22.27	2.10	4.08
Insurance coverage	0.00	0.00	0.00
Additions to relief fund	0.00	0.00	0.00
Reduction in PA from expenditures	105.77	9.99	19.40
Total actual PA	1228.56	89.35	191.52
State deductible less credits	74.22	7.01	13.61
PA less deductible	1154.33	82.34	177.90
State share of remaining PA	259.73	18.53	40.03
State total spending (mitigation + deduct. + share)	356.22	27.64	57.72
Federal PA	894.61	63.81	137.88
Change in State burden from status quo	55.99	5.29	10.27
Change in State burden rel. to deductible only	-53.30	-5.04	-9.78
Change in Federal burden from status quo	-139.50	-13.18	-25.58
Change in Federal burden rel. to deductible only	-30.20	-2.85	-5.54

Table I-16.
Burden Analysis for DDF1 – AALRI case
California, Mississippi, Ohio
(75% reduction in deductible)

	Expenditures ($millions)		
	CA	**MS**	**OH**
A. Status Quo			
Total expected Public Assistance (PA)	1334.33	99.34	210.91
State share of PA	300.22	22.35	47.46
Federal PA	1034.10	76.99	163.46
B. Deductible only			
Total expected Public Assistance (PA)	1334.33	99.34	210.91
State deductible	141.03	13.32	25.86
PA after state pays deductible	1193.30	86.02	185.05
State share of remaining PA	268.49	19.35	41.64
State total spending (deduct. + state share)	409.52	32.68	67.50
Federal PA	924.81	66.67	143.41
Change in State burden	109.29	10.33	20.05
Change in Federal burden	-109.29	-10.33	-20.05
C. Mitigation with DDF credit			
Total expected Public Assistance (PA)	1334.33	99.34	210.91
Spending on mitigation	35.26	3.33	6.47
Insurance coverage	0.00	0.00	0.00
Additions to relief fund	0.00	0.00	0.00
Reduction in PA from expenditures	105.77	9.99	19.40
Total actual PA	1228.56	89.35	191.52
State deductible less credits	35.26	3.33	6.47
PA less deductible	1193.30	86.02	185.05
State share of remaining PA	268.49	19.35	41.64
State total spending (mitigation + deduct. + share)	339.01	26.02	54.57
Federal PA	924.81	66.67	143.41
Change in State burden from status quo	38.78	3.66	7.11
Change in State burden rel. to deductible only	-70.51	-6.66	-12.93
Change in Federal burden from status quo	-109.30	-10.32	-20.05
Change in Federal burden rel. to deductible only	0.00	0.00	0.00

Sections A and B of Table I-16 are the same as the previous table. Because mitigation spending is designed to reduce the deductible by 75% through the credit, the portfolio of mitigation activities can differ from that intended to reduce the risk by 75%. Section C of Table I-12 shows this slightly different effect of the DDF where a state can offset the deductible through credits for spending on mitigation. Mitigation spending rises slightly for each of the states. Total state spending falls compared to the status quo. Similar results hold for the comparison of the DDF to the deductible only scenario. Overall the differences are relatively small between the two goals of reducing risk by 75% and reducing the deductible by 75%.

2. Burden Analysis of PARI based deductible

Two sample burden analyses are provided below when the deductible is calculated using the PARI to calculate the deductible. This is done for the three states. The first burden table reflects a mitigation goal to reduce risk by 75%, and the second table reflects the goal of achieving a 75% reduction in the deductible via credits.

In all burden tables the status quo reflects the current situation in which states pay an average share of 22.5% of all public assistance related losses per year, while FEMA pays the remaining. This is shown in Section A Status Quo of Table I-17. Expected PA losses are significantly lower in the PARI case than in the AALRI case.

The impact of charging the state a deductible is shown in Section B of the same table. Compared to the status quo Base-Case, the deductible represents a significant increase in the state's disaster burden. There is a corresponding decrease (same magnitude) in federal spending on disaster public assistance as the deductible alone represents a simple transfer of cost from FEMA to the state.
Section C of Table I-17 shows the effect of the DDF where a state can offset the deductible through credits for spending on mitigation and other activities such as insurance. Mitigation efforts by the state lower the expected total loss and associated public assistance, thereby reducing the state's expected share. Spending on mitigation is credited with a multiplier against the deductible, as are insurance credits but not with a multiplier, thereby reducing the state's deductible burden. As the example above shows, each state still spends more on disaster-related activities (mitigation and post-disaster public assistance) compared to the current system. Compared to the case based on the AAL Risk Index, both California and Ohio continue to spend on mitigation only, but at a lower level, whereas Mississippi moves to spending on insurance, which causes a large increase in the relative burden of the DDF compared to the status quo for that state. The relative burdens for the other two states fall considerably, due mainly to the mitigation choices revealed in the MP analysis.

Another sample burden analysis is provided below, where the goal for mitigation is achieving a 75% reduction in the deductible via credits.

Sections A and B of Table I-18 are the same as the previous table. Because mitigation spending is designed to reduce the deductible by 75% through the credit, the portfolio of mitigation activities can differ from that intended to reduce the risk by 75%. Section C of Table I-14 shows this slightly different effect of the DDF where a state can offset the deductible through credits for spending on mitigation. Mitigation spending changes slightly for California and Ohio, but Mississippi moves away from insurance to a higher level of mitigation spending. Total state spending falls compared to the status quo. Overall the differences are relatively small between the two goals of reducing risk by 75% and reducing the deductible by 75% except for Mississippi—again a result driven by the response of the state to the particular threats faced.

Table I-17.
Burden Analysis for DDF1 – PARI case
California, Mississippi, Ohio
(75% risk reduction)

	Expenditures ($millions)		
	CA	**MS**	**OH**
A. Status Quo			
Total expected Public Assistance (PA)	224.98	104.91	23.13
State share of PA	50.62	23.60	5.20
Federal PA	174.36	81.30	17.92
B. Deductible only			
Total expected Public Assistance (PA)	224.98	104.91	23.13
State deductible	72.89	35.73	10.26
PA after state pays deductible	152.09	69.17	12.86
State share of remaining PA	34.22	15.56	2.89
State total spending (deduct. + state share)	107.11	51.30	13.16
Federal PA	117.87	53.61	9.97
Change in State burden	56.49	27.69	7.95
Change in Federal burden	-56.49	-27.69	-7.95
C. Mitigation with DDF credit			
Total expected Public Assistance (PA)	224.98	104.91	23.13
Spending on mitigation	16.66	0.87	2.42
Insurance coverage	0.00	23.86	0.00
Additions to relief fund	0.00	0.00	0.00
Reduction in PA from expenditures	54.66	26.80	7.70
Total actual PA	170.32	78.11	15.43
State deductible less credits	22.91	9.28	3.00
PA less deductible	147.41	68.83	12.43
State share of remaining PA	33.17	15.49	2.80
State total spending (mitigation + deduct. + share)	72.73	49.49	8.22
Federal PA	114.24	53.34	9.63
Change in State burden from status quo	22.11	25.89	3.01
Change in State burden rel. to deductible only	-34.37	-1.81	-4.94
Change in Federal burden from status quo	-60.12	-27.96	-8.29
Change in Federal burden rel. to deductible only	-3.63	-0.27	-0.34

Table I-18.
Burden Analysis for DDF1 – PARI case
California, Mississippi, Ohio
(75% reduction in deductible)

	Expenditures ($millions)		
	CA	**MS**	**OH**
A. Status Quo			
Total expected Public Assistance (PA)	224.98	104.91	23.13
State share of PA	50.62	23.60	5.20
Federal PA	174.36	81.30	17.92
B. Deductible only			
Total expected Public Assistance (PA)	224.98	104.91	23.13
State deductible	72.89	35.73	10.26
PA after state pays deductible	152.09	69.17	12.86
State share of remaining PA	34.22	15.56	2.89
State total spending (deduct. + state share)	107.11	51.30	13.16
Federal PA	117.87	53.61	9.97
Change in State burden	56.49	27.69	7.95
Change in Federal burden	-56.49	-27.69	-7.95
C. Mitigation with DDF credit			
Total expected Public Assistance (PA)	224.98	104.91	23.13
Spending on mitigation	18.22	8.93	2.57
Insurance coverage	0.00	0.00	0.00
Additions to relief fund	0.00	0.00	0.00
Reduction in PA from expenditures	54.66	26.80	7.70
Total actual PA	170.32	78.11	15.43
State deductible less credits	18.22	8.93	2.57
PA less deductible	152.10	69.17	12.86
State share of remaining PA	34.22	15.56	2.89
State total spending (mitigation + deduct. + share)	70.66	33.43	8.03
Federal PA	117.87	53.61	9.97
Change in State burden from status quo	20.04	9.83	2.82
Change in State burden rel. to deductible only	-36.44	-17.87	-5.13
Change in Federal burden from status quo	-56.48	-27.69	-7.96
Change in Federal burden rel. to deductible only	0.00	0.00	0.00

Table I-19 shows the effect of the DDF on state expenditure for a sample of eight states. States are assumed to spend on mitigation to reduce their deductible by 75%. Mitigation results in reduction in Expected PA. Note, for example, that California's pre-mitigation expected PA was originally $1334.2 million, while its post-mitigation PA (shown in line 4 of the table) is $1,228.4 million in the AALRI scenario.[22] Total state expenditure with mitigation is shown in line 7, where total expenditure is the sum of mitigation expenditure plus the deductible plus the remaining state-share. Finally, line 8 shows

[22] California's expected PA can be calculated by dividing its non-federal share PA in Column 1, by the state share of 0.225. Values may not line up perfectly due to rounding in the table.

the difference between state's expenditure under the DDF with mitigation relative to the status quo, in which they pay only the 22.5% share.

Table I-20 shows the impacts for eight states under the PARI case. Expenditure on risk reduction is higher for every state under the DDF than under the status quo. Expenditure increases are highest for states that have relatively high expected PA, such as Florida, Louisiana, and New York. Expenditure increases are relatively small for states that face relatively smaller risk.

In Section VIIIB, we perform burden analysis under alternative mitigation BCRs.

Table I-19. Summary of Incentivization Response
Spending Set to Reduce Deductible by 75% - AALRI

	States							
Component of DDF:	**AK***	**CA**	**DE***	**FL**	**IA**	**LA**	**NY**	**OH**
1. Current State Share	20.14	300.2	2.3	437.8	33.1	133.5	194.8	47.5
2. Deductible + Share	35.2	409.5	8.5	547.5	41.3	190.8	234.8	67.5
3. Mitigation Spending	3.0	22.0	2.9	22.1	2.8	11.5	8.1	4.0
4. Expected PA w. Mitigation	74.9	1228.6	4.1	1839.6	138.9	537.9	826.9	191.6
5. Deductible – Credit	10.3	74.9	4.0	75.2	5.6	39.3	27.5	13.7
6. State Share w. Mitigation	14.5	259.6	0.9	397.0	30.0	112.2	179.9	40.0
7. Total State Spending (= 3 + 5 + 6)	27.9	356.5	9.2	494.3	37.3	163.0	215.4	57.8
8. Change from Current (= 7 – 1)	7.8	56.3	5.5	56.5	4.2	29.5	20.6	10.3

* This state's deductible is larger than its expected PA. The entry is MIN (deductible + share, expected PA). This has no effect on the overall DDF impact because there will still be years in which the state's PA exceeds the deductible. It only matter s for presentation.

Table I-20. Summary of Incentivization Response
Spending Set to Reduce Deductible by 75% - PARI

	States							
Component of DDF:	**AK***	**CA**	**DE***	**FL**	**IA**	**LA**	**NY**	**OH**
1. Current State Share	2.9	50.6	0.8	133.0	12.8	101.3	174.1	5.2
2. Deductible + Share	12.8	107.1	3.4	231.5	30.6	200.3	272.9	13.2
3. Mitigation Spending	5.8	16.6	2.1	69.0	5.2	94.7	29.9	2.4
4. Expected PA w. Mitigation	3.5	170.2	0.8	495.5	40.0	354.6	678.4	15.5
5. Deductible – Credit	0	22.9	0.8	0	7.1	0	37.8	3.0
6. State Share w. Mitigation	0.7	33.1	0	111.5	7.4	114.9	144.1	2.8
7. Total State Spending (= 3 + 5 + 6)	3.6	72.3	3.0	180.5	19.7	209.6	211.8	8.2
8. Change from Current (= 7 – 1)	0.7	22.1	2.2	56.5	6.9	108.3	37.7	3.0

E. Time-Path of DDF Implications

Figures I-7 to I-10 show the effect of the DDF on PA and on state expenditure for California and Mississippi over a twenty-year time horizon. States obtain credits for seventy five percent of their normalized deductible. In early years, states obtain credits through mitigation expenditure on disaster types that have a benefit-cost ratio that exceeds 1:1, focusing on the mitigation behaviors that have high BCRs. For example, in year 1, California offsets its deductible by mitigating floods (the highest BCR) and severe storms (the second highest BCR). Because California has mitigated its expected flood PA by half in year 1, in year 2 it offsets its deductible by mitigating against severe storms and "other" (whose BCR is equal to that of severe storms). By year 4, California has mitigated its severe storm and "other" expected PA by one-half and then obtains insurance to offset its deductible. Note that even though California could mitigate against earthquakes, it chooses to obtain insurance because earthquake mitigation has a BCR below 1:1 (the BCR for insurance). The time path horizon suggests similar results if the deductible is calculated using the AALRI. While AALRI suggests substantially higher PA than PARI, giving California the ability to mitigate more before it reaches the 50% constraint on mitigation, California's deductible increases as well. As a result, California's risk reduction target is higher than the PARI case and California increases its expenditure on mitigation. The general order of behavior is unchanged. California first mitigates against floods, and then against severe storms and other threats. After risk from floods, severe storms, and other threats has been reduced by one half, California purchases insurance rather than mitigate against earthquakes, which have a BCR below 1:1.

In Mississippi, by contrast, most PA is due to hurricanes, which have a BCR below 1:1. As a result, Mississippi performs relatively little mitigation before switching to insurance. This mitigation is for flood threats, and Mississippi is projected to reduce its flood PA by half before even the first year's credit is offset. This is the case in both the PARI and AALRI formulations of the Risk Index.

Note that in California expected PA after mitigation is declining over time. This occurs because the benefits of mitigation are cumulative. The changes in the slope of the total PA after mitigation curve occur when there is a switch between the types of disasters that are being mitigated. In states that have relatively high BCR disasters, such as floods and severe storms, it is possible to have many years of mitigation expenditure, and substantial reductions in expected PA. In both California and Mississippi, expected expenditure falls relative to the baseline under the assumption of AALRI risk. This occurs because AALRI assumes higher flood risk than PARI, thus increasing the amount of possible mitigation. Further, because flood mitigation has the highest BCR among all possible mitigation strategies, this results in more mitigation at a lower cost.

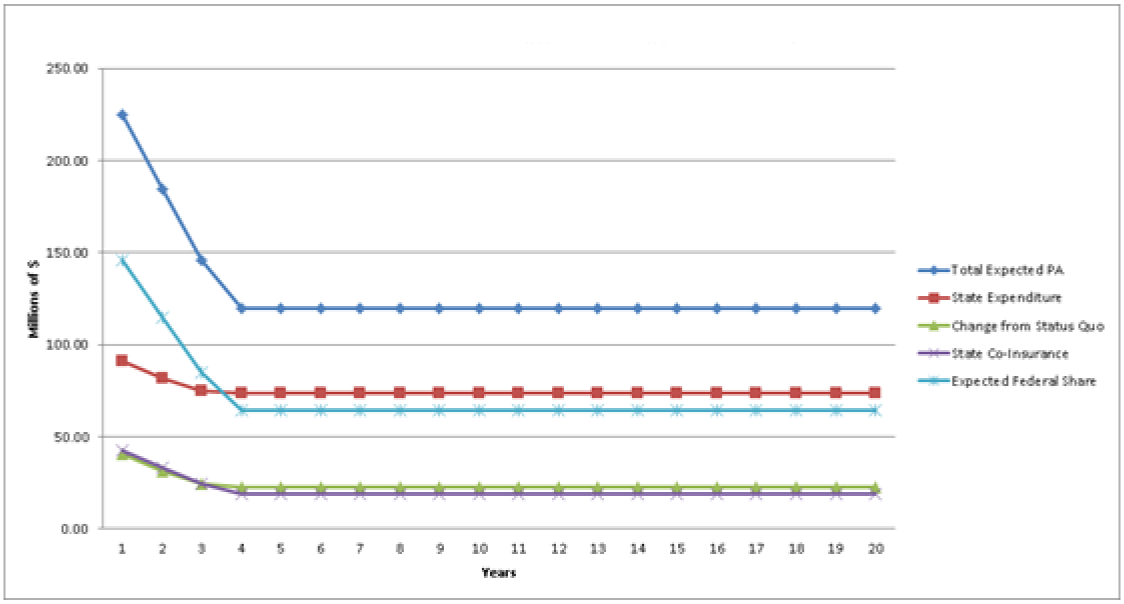

Figure I-7. Effect of DDF on California Over Time – PARI

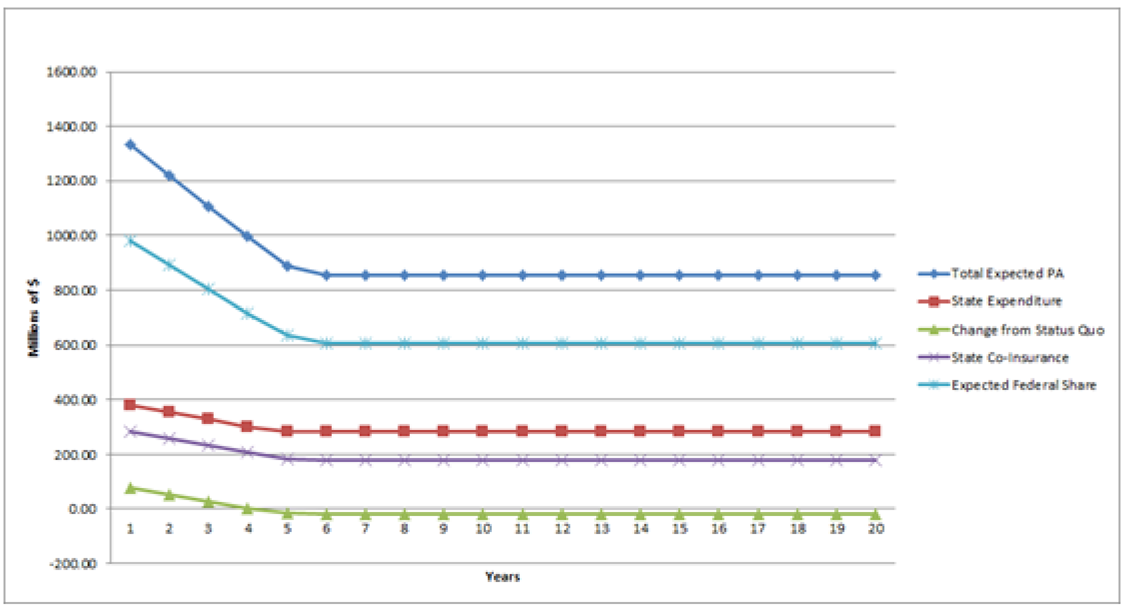

Figure I-8. Effect of DDF on California Over Time – AALRI

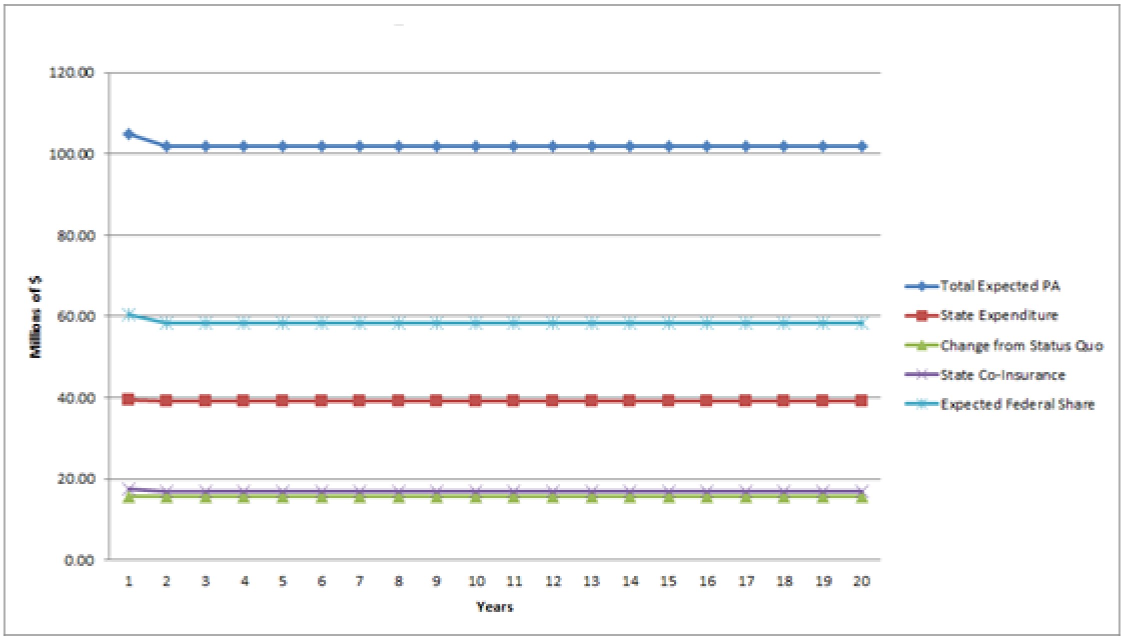

Figure I-9. Effect of DDF on Mississippi Over Time - PARI

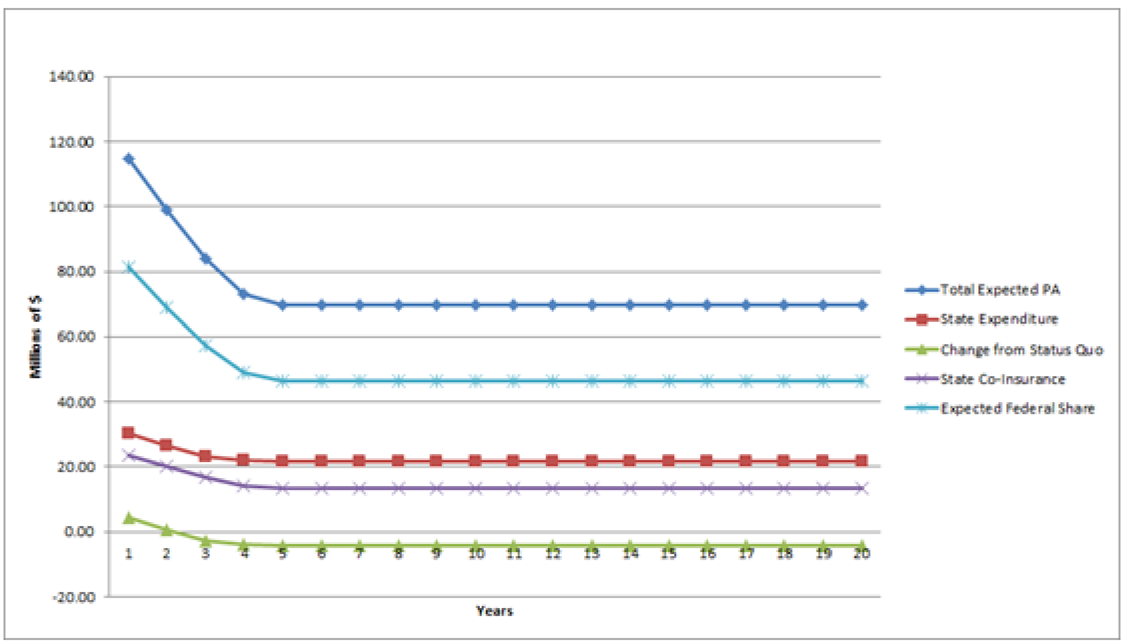

Figure I-10. Effect of DDF on Mississippi Over Time - AALRI

VII. Equity Issues

A. Overview

All public policies have equity implications whether intended or not. The motivation for disaster assistance is to a great extent to help survivors of a random occurrence. Those entities affected by a disaster, whether a political jurisdiction or the individuals who reside within its boundaries, suffer a loss of economic well-being, and are therefore deemed worthy of assistance either with regard to their absolute or relative status. Like most equity motivations, this one is altruistic.[23]

We will approach the equity of the FEMA Disaster Deductible from two perspectives. First is a "bottom-up" approach, where we will examine the equity implications of the DDF whose parameters are specified in this Report. This involves applying standard measures of inequality, such as the Gini Coefficient and Atkinson Index, to the Disaster deductible itself across states.

Second is a "top-down" approach, where an equity principle is chosen at the outset, and the Disaster Deductible levels across states are devised to conform to it. Equity principles are numerous, and there is no consensus on the best one to apply in general, and typically not in particular instances either. Some standard equity principles in cases such as this include Ability to Pay, Horizontal Equity (having the initial allocation or outcome be equal across entities), and Egalitarian (equal per capita allocation or outcome). For example, FEMA's threshold for the disaster declaration of equal per capita losses (currently at $1.41) is an example of this equity principle. Application of this top-down perspective would require an explicit policy decision about equity on the part of FEMA.

In addition, we will examine the "bottom-up" results in relation to the equity principles that they most closely approximate. This will provide further insight as to whether the equity outcome of the DDF formula specified above is desirable. As with other aspects of our methodology, it can be generalized to other DDFs.

B. Bottom-Up Analysis

Here we analyze the equity implications of the Disaster Deductible itself in terms of common measures of inequality. Figure I-11 and Figure I-12 presents the Lorenz Curve associated with the Disaster deductibles across states in the Base Case for the AALRI Case and the PARI Case, respectively. The Lorenz curve plots the cumulative Disaster Deductible on the vertical axis in relation to individual state allocations with respect to per capita GSP on the horizontal axis (the states are ordered from lowest to highest in terms of per capita GSP deductibles). The 45° line represents perfect equality. In this case, the perfect equality condition represents proportional relationship between state deductibles and state per capita GSP (i.e., state that has twice per capita GSP of another state should also have twice deductibles). The difference between the curve and the 45° line is the extent of inequality. The Gini Coefficient measures this by the ratio of the area between the curve and the 45° line in relation to the triangle

[23] Not all equity principles are altruistic, as will be discussed later. Also, disaster assistance has motivations beyond equity. One perspective is that the region hit by the disaster will be an economic drag on its state or even national economy, and therefore post-disaster assistance is intended to promote overall economic efficiency.

delineated by the 45° line and horizontal and vertical axes. Gini Coefficient values range between 0 and 1, with higher levels indicating higher levels of inequality

In Figure I-11, the Gini Coefficient value is .4888 for the AALRI Case, indicating a modest amount of inequality across states in terms of the Disaster Deductible itself.[24] The Gini Coefficient value for the PARI Case shown in Figure I-12 is .5493, indicating a higher amount of inequality across states.

One way to evaluate which equity principle best reflects the DDFs calculated in this report is correlation analysis. We calculated correlations for both the AALRI Case and PARI Case with the following results:

Adjusted State Deductibles (AALRI Case) and State Populations: 0.8085

Adjusted State Deductibles (AALRI Case) and GSPs: 0.7692

Adjusted State Deductibles (AALRI Case) and per capita GSPs: 0.0974

Adjusted State Deductibles (PARI Case) and State Populations: 0.5894

Adjusted State Deductibles (PARI Case) and GSPs: 0.5937

Adjusted State Deductibles (PARI Case) and per capita GSPs: 0.1627

Potentially the Ability to Pay principle would be relevant to the Deductible, while the Vertical Equity principle would be relevant to the Burden, the reason being that the former is an allocation-based principle, while the latter is outcome-based. The Egalitarian Principle would be relevant to both.

For the Adjusted Deductible, the correlations for Population and GSP are higher in the AALRI Case than in the PARI Case. Since Egalitarian principle in general would favor states with large populations, high correlations between Adjusted Deductibles and Population indicate that this equity principle is not operative in both cases. If we focus on the correlation between the Adjusted State Deductible and per capita GSP, the correlation of 0.0974 for the AALRI Case and 0.1627 for the PARI Case are both very low, which indicate that the Ability to Pay principle is not applicable here as well. We can also make assessments regarding other equity principles. By inspection of the poorest states, we can also note that the Rawlsian Maximin principle[25] does not apply. We also know by inspection that the Deductible does not reflect Horizontal Equity. In fact, it appears that the state Deductibles are rather random with respect to GSP, the reference base by which most equity principles are measured. However, since most equity measures use income, or wealth, as the basis for comparison, some of the adjustments for individual states can create unanticipated results. For example,

[24] The Gini coefficient for total GSP itself across states is 0.5330.
[25] This principle calls for favoring the bottom tier of least well-off states.

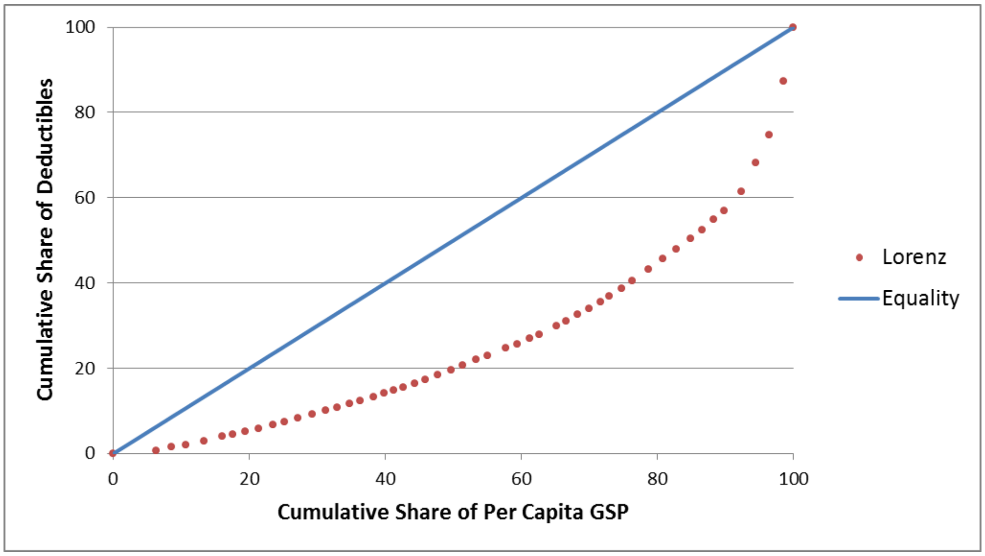

Figure I-11. Lorenz Curve of State Adjusted Deductibles for AALRI Case (states are ordered by per capita GSP adjusted deductibles)

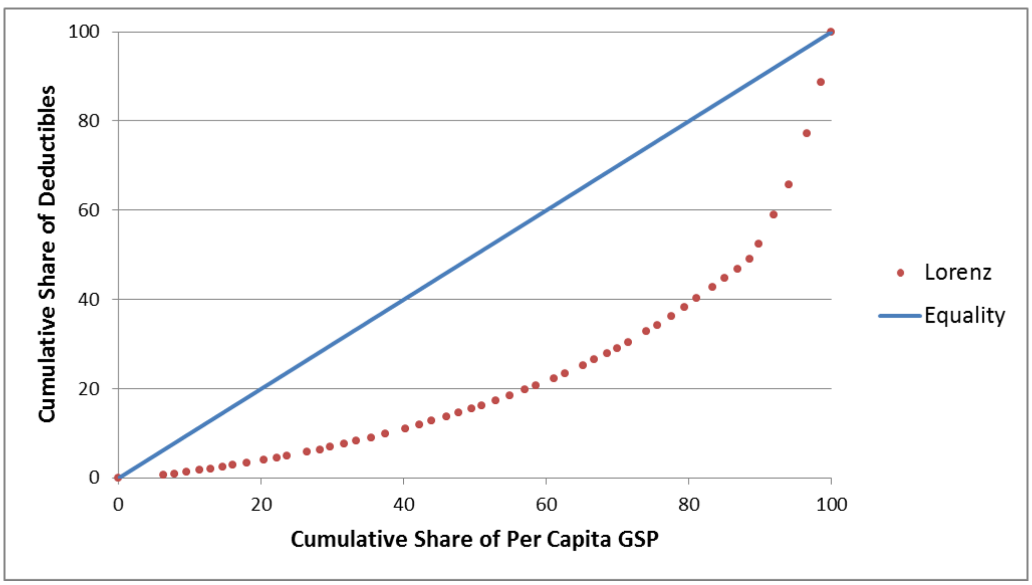

Figure I-12. Lorenz Curve of State Adjusted Deductibles for PARI Case (states are ordered by per capita GSP adjusted deductibles)

although wealthier states may suffer greater loss for a given hazard, hazards tend to be distributed randomly with regard to wealth.[26]

C. Top-Down Analysis

For this second approach, we will utilize the framework for equity analysis developed by Rose and applied in other major public policy contexts (Rose et al., 1998; Rose and Zhang, 2002; Rose, 2013). The framework involves the following steps:

a. Specifying equity principles, or criteria, applicable to the issue at hand

b. Mapping equity principles into reference bases, or metrics, by which to gauge them

c. Analyzing the implications of alternative policy designs on equity, and analyzing the broader implications (e.g., efficiency, political feasibility) of alternative in principle/reference base combinations (equity formulas)

d. Designing and implementing a DDF that conforms to a desired equity principle

This brief introduction provides a summary of some major aspects of the analysis of FEMA disaster assistance with and without the DDF.

Current policy calls for a per capita disaster damage threshold for the designation of a presidential disaster declaration and as a guide to natural disaster aid, such as FEMA's Public Assistance (PA) program. In essence, this reflects Egalitarian equity, in this case, whereby every person in the US has an equal right to disaster assistance no matter where they are located. The reference base here is obviously population, though for other equity principles there may be several possible bases.[27] From the standpoint of fiscal capacity alone, the relevant equity principle is Ability to Pay, long a staple of the public finance literature. Here the choice of reference base becomes more complicated because there is no consensus on the best measure of this capacity. However, the proposed Total Taxable Resources (TTR), developed by the US Treasury Department, has several attractive features.

Going one step further to include vulnerability to hazards (the risk side) brings "need" into play, in contrast to Ability to Pay. Note, however, this does not invoke the Benefits principle of public finance, which requires that those who benefit from a public expenditure be the ones who pay for it. Attention to benefits in relation to the deductible is more a matter of altruism, though not necessarily Vertical Equity because of the relatively low correlation between the Deductible level and state GSP.

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[26] One possible exception, where there may be a strong positive correlation between wealth and disaster loss is when wealth accumulates in geographical areas that are more prone to disaster loss such as in coastal areas, mountainous or heavily wooded areas. Heavily populated commercial areas are also often located on coasts and more prone to storm surge or tsunami hazards.

[27] Even for the Egalitarian principle, the reference base is not automatic. Here we are implicitly considering the current population. However, one can invoke a dynamic reference base relating to the previous or future population.

If we combine the fiscal capacity and risk/vulnerability aspects of the DDF, this translates into a change in well-being in terms of fiscal expenditure minus loss. If the formula is structured in such a way as to equalize the DDF across states on this basis, it corresponds to the Horizontal Equity principle. If it favors relatively less well-off states, then it corresponds to a Vertical Equity principle.

Another way of looking at equity is in relation to cross-subsidization among states. Because we use the median for the Base Deductible, half of the states are above it and half are below, thus dampening this possibility somewhat, though this is offset by the fiscal capacity and risk adjustments. Of course, there are no direct transfers from state to state involved in the implementation of the deductible, so any such effect would be through the federal-state fiscal apparatus of taxation, public expenditures, and intergovernmental transfers. Given the complexity of this federal-state relationship, it is not clear that indirect cross-subsidization would take place. Instead, we have focused on the aspect that can be measured— the cross-state equity of the deductible itself and of the state response.

Equity is important in its own right, but also in relation to political feasibility (Rose et al., 1989). Previous attempts by FEMA to revise the criteria for the allocation of disaster assistance have involved an analysis of equity implications (S. 1960, 2014; H. R. 3925, 2014) and have been criticized on equity grounds (GAO, 2001).

Overall, the State Deductible does not strongly conform to any of the standard equity principles. While there is inequality across states, the inequality appears to be random in relation to fairness. FEMA can, however, alter the Deductible level across states to meet any of several established equity principles. Equity is a complex consideration. Unlike economic efficiency, for which there is a strong consensus on a best definition, there is no consensus on the best form of equity. Therefore, one must consider several alternative equity principles and decide on the set most appropriate for the case at hand. Even then, there can be conflicts among the leading candidates.

VIII. Disaster Deductible Formula Evaluation

A. Assumptions and Parameters

The specification of the DDF and the incentivization response presented above is based on several major assumptions and key parameters. In this section, we discuss each in greater detail and indicate some of the major implications, including the sensitivity of the DDF to changes in the values used.

- Deductible Base Level. Based on the median of states' 17-year (1999-15) average of total annual PA funding. This value is then divided by median of all states plus the District of Columbia to obtain individual state values. The result is a Base Deductible of $22.2 million per state. The advantage of this specification is that it represents a pure level without any initial bias according to state conditions. Of course, the state-specific conditions are important and are factored in through the Fiscal Capacity and Risk Indices.

- Fiscal Capacity Adjustment. Numerous indicators of fiscal capacity were considered, but many of them were highly correlated. We therefore chose the following based on their inherent strengths in the absence of high correlations between them.
  - Per capita Total Taxable Resource (TTR) index
  - Per capita budget surplus/deficit index
  - Per capita state reserves index
  - State bond rating index

  Each index for each state is computed by calculating the value for each state and dividing by the median value across states. Then an average value of the four indices is used as the adjustment factor (together with the Risk Index) applied to the Base Deductible.
- Risk Adjustments. We utilized two approaches to adjusting for state risk. In one, a statistical distribution was fitted to the 17-year (1999-15) history of annual PA receipts for each state. Based on the fitted distributions we calculate the average annual amount of PA for each state. This adjustment is applied to the Base Deductible by calculating the value for each state and dividing by the median value across states. This risk adjustment is referred to as the PARI, or Public Assistance Based Risk Index. The second approach uses annualized average loss (AAL) estimates from models developed using the HAZUS loss estimation tool for earthquake, flood, and hurricane threats. Rather than being based on a short historical period of actual events, the AAL risk estimates are based on models that predict losses by threat using science-based models of hazard probability and exposure of physical assets to damage. Again this adjustment is applied to the Base Deductible by calculating the value for each state and dividing by the median value across states. This risk adjustment is referred to as the AALRI, or Average Annualized Loss Risk Index.
- Adjusted Base Deductible. The Fiscal Capacity Index and Risk Index are applied with 25% weight and 75% weight, respectively. In addition, the result is normalized back to a $22.2 million state average to control for the type of "bracket creep" that arises with the application of the 2 adjustment indices.
- Deductible Cap. A cap of $138.6 million is applied to eliminate outliers. The $138.6 million is based on the 95th percentile of disaster damages, which is then normalized to $94.6 million.
- Loss Reduction Multipliers. This refers to the benefit-cost ratios (BCRs) associated with risk reduction strategies.

  -- For mitigation, these were derived from the *Mitigation Saves* Report to Congress (MMC, 2005) and only consider property damage benefits:
  - - Floods— 4.75:1
    - Hurricanes— 0.51:1
    - Earthquakes— 0.42:1
    - Severe storms— 3.18:1
    - Other— 3.18:1
  - The BCRs derived in the *Mitigation Saves* Report to Congress (MMC, 2005) include a range of benefits categorized broadly as property damage, casualty, historical and environmental, and business interruption. Mitigation projects for various threats tend to emphasize more

of some benefits than others. For example, the MS Study found that casualty reduction was the largest benefit in wind-related mitigation projects, while property damage reduction was the largest benefits for flood-related projects. Since federal Public Assistance focuses on property damages rather than casualties or business interruption, which are covered by other programs or from other sources, we have derived property-damage only BCRs from the *Mitigation Saves* Study. The Study only identified three threat types: Wind, Flood and Earthquake, whereas we have five types. The Property Damage Only BCRs are calculated as the property damage share of benefits over the entire costs, thereby creating lower BCRs. These are for earthquakes: 28% *1.5 = .42; hurricanes 13% *3.9 = 0.51; flood: 96% * 5.0 = 4.8. The overall BCR is a weighted average of the component BCRs using cost as the weights and changes from 4.0 to 3.18. This BCR is also used for the other categories of severe storm and other.

-- For relief funds, we assume the "loss reduction" is 1:1. Note that this strategy, however, applies to all threats (and is not just threat-specific). Most importantly, it is not actually a reduction in risk but simply a shift in the risk from the federal government to the state.

--For insurance, we assume the "loss reduction" is 1:1, representing the actuarial value of insurance. We assume that this strategy is threat-specific. And again, it is not actually a reduction in risk but simply a shift in the risk, this time to private sector.

--In our incentivization analysis, we will place the following limits on risk reduction strategies:

- Mitigation: 50% of risk (because not all risks can be mitigated)
- Relief fund: 50% (because this is only risk spreading and not actually risk reduction)
- Insurance: 50% (because this is only risk spreading and not actually risk reduction)

- Credit Multipliers. In order to incentivize risk reduction behavior, we assume that FEMA would provide credits for state implementation of various strategies. The credit multipliers are as follows:
  - Mitigation—3:1[28]
  - Relief funds—1:1[29]
  - Insurance—2:1[30]

  We assumed that all credits are applied the first year in which the expenditures made.[31]
- The useful life of mitigation projects is assumed to be 50 years. This reflects the useful life of most buildings and various other structures like bridges, levees and dams (MMC, 2005).

The aforementioned assumptions and parameters fall into 3 groups. First, we can identify objective values to which an accuracy test can be applied. This would include the BCRs and useful life of mitigation projects. A second category is more subjective and can have a test of "reasonableness"

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[28] Applicable to the year in which the expenditure is made.

[29] Applicable only in year the Relief Fund is initiated, or year in which any subsequent increases to it are made.

[30] Applied to annual insurance premium.

[31] In practice, the credit can be applied in the year following the state's expenditure. In this report, we analyze state burdens under the assumption that each state experiences their expected damages with certainty (i.e. there is no chance of not having a disaster). Under this framework, dynamic issues around timing of the credit are negligible.

applied, such as the decision to adjust the Base Deductible by Fiscal Capacity and Risk Indices. This also applies to the 3:1 credit for risk reduction expenditures and the application of this credit to only the first year. A final category pertains to equity or fairness considerations (to be discussed further below) with respect to the initial $22.2 million Base Deductible and the imposition of a cap on outliers. The Base Deductible level chosen is considered fair from the standpoint of applying an equal baseline deductible across states. Moreover, by selecting the median of average annual PA, we ensure that half of the states will expect PA that falls below the baseline deductible and one-half of states will expect PA that is above the deductible.

We acknowledge that our illustrative results of the application of the DDF are sensitive to the various assumptions and parameters. The implications of any of them are straightforward in that the adjustment factors are applied in a multiplicative fashion, as are the Deductible Credit Multiplier and Loss Reduction Multipliers (BCRs). Use of forecasts of risk are less transparent, because they would likely be based on differentials in population and economic growth rates across states, as well as potentially changing climatic conditions. However, we will perform sensitivity tests on this aspect as well as many of the assumptions and parameters disused above.

B. Sensitivity Analyses

We considered several sensitivity analyses. These sensitivity analyses involve changes to the assumptions of key parameters that affect how states will respond to the DDF (such as values of risk reduction multipliers and credit multipliers). We do not present all possible calculations for each sensitivity analysis; instead we highlight the calculation that is most directly affected by each. In one case, however, we compute all applicable DDF calculations, allowing a full comparison to the DDF assumptions in the Base Case.

1. Change in Weights for Risk Index and Fiscal Capacity Index

The Deductible in the Base Case assumed that the combined index was calculated by placing 75% of the weight on the Risk Index and 25% on Fiscal Capacity Index. In the sensitivity test, we calculate the combined index placing 25% of the weight on the Risk Index and 75% of the weight on the Fiscal Capacity Index, and by assuming a simple 50/50 weighting between the Risk Index and Fiscal Capacity Index. This reduces the relative impact of high risk states. In general, states that have high Fiscal Capacity experience a higher deductible than they would receive under the baseline. Wyoming, for example, receives a normalized deductible of $21 million and $35 million for the 50/50 and 25/75 PARI sensitivity analyses. Its normalized Deductible in the Base Case is $10 million. Figures I-13 and I-14 show the effect of these sensitivity analyses in the case of the PARI and AALRI risk indices, respectively.

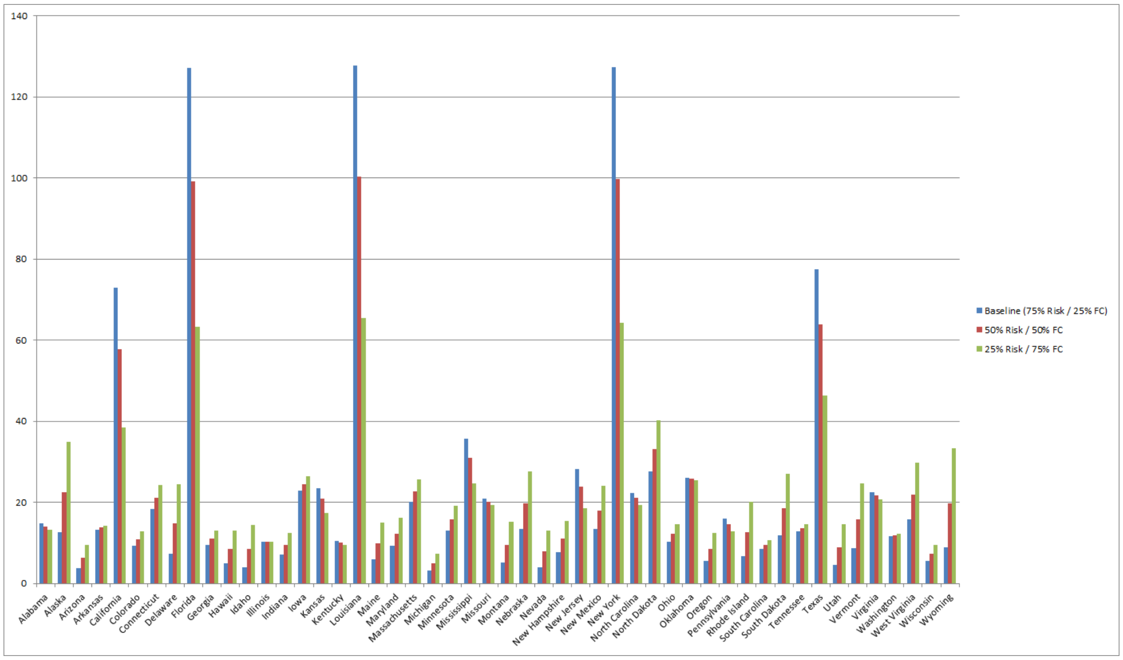

Figure I-13. Comparison of State Normalized Deductibles between the Base Case and Sensitivity Case - PARI

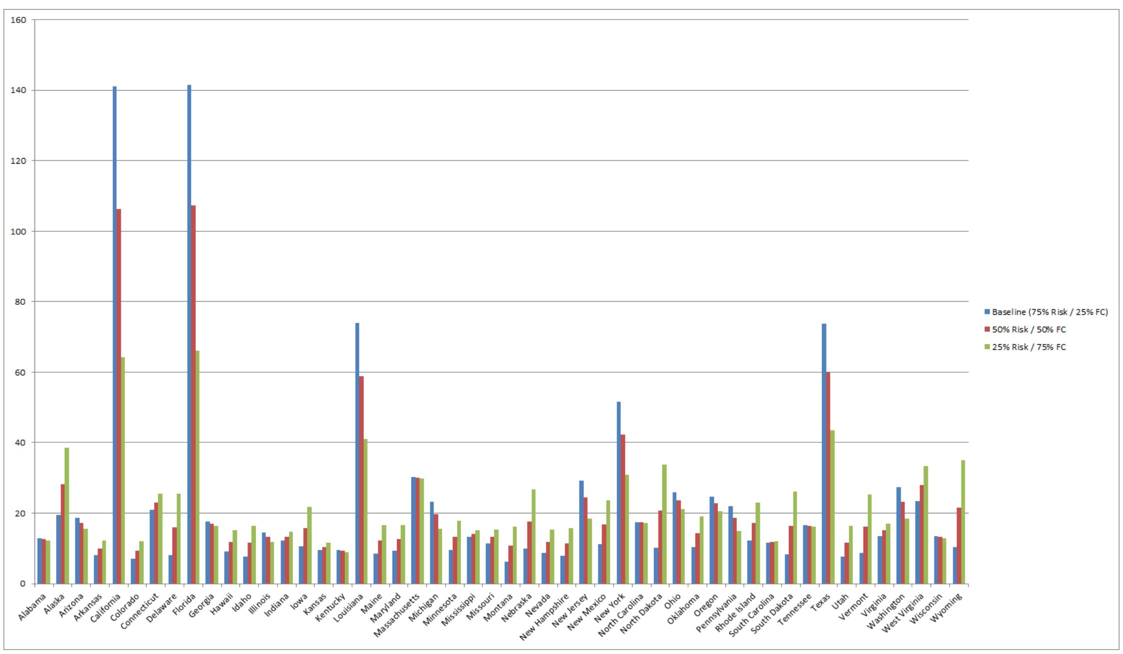

Figure I-14. Comparison of State Normalized Deductibles between the Base Case and Sensitivity Case – AALRI

2. Credit Multipliers Equal to Mitigation BCR Multipliers

We consider a sensitivity analysis in which the credit multiplier associated with mitigation expenditure is equal to the BCR of mitigation. This causes variation between disaster types, i.e., mitigation against floods receives more credits against the deductible than mitigation against earthquakes. This sensitivity analysis causes the mix of mitigation strategies to be the same regardless of whether the state is trying to achieve disaster reduction or trying to mitigate away a portion of its deductible. When all mitigation behavior receives the same amount of credit, a state focusing on obtaining deductible credits would be indifferent between the disaster types. By matching the credit multipliers to the BCR multipliers, states are incentivized to pursue the highest BCR mitigation options first, even when a state's objective is to obtain credits rather than to mitigate risk.

3. Alternative BCR Values

In this sensitivity analysis, we investigate the effect of using the overall BCRs from the *Mitigation Saves* study (MMC, 2005): rather than the property damage only BCRs used in the Base Case. The study BCRs include all benefits, not just those that would reduce public assistance. While the goal of FEMA's policy is to encourage mitigation of all types, the focus of the DDF has been on its impact on Public Assistance needs. The comparison presented here reveals the robustness of the DDF formula and the analytical tools we have developed because the results do not differ much between the Base Case and this sensitivity case. The full BCRs from the *Mitigation Saves* study are

- - Floods— 5.0:1
  - Hurricanes— 3.9:1
  - Earthquakes— 1.5:1
  - Severe storms— 4.0:1
  - Other— 4.0:1

AALRI Case

We only run the sensitivity analysis based on the 75% risk reduction or 75% credit attainment target (the Base Case). The MP analysis results for the AALRI Case are presented in Tables I-21 and I-22.

For the 75% risk reduction case, mitigation of floods will be the only strategy in the optimal solution for all three states. However, since the BCR of floods increases from 4.75 in the Base Case to 5.00 in the Full BCR Sensitivity Case, total expenditures decrease by about 5% for each state.

For the 75% credit attainment case, we got the exactly same results for California and Ohio. This is because in the credit attainment target simulation, the BCRs of different mitigation strategies do not matter as long as the credit multiplier for each mitigation strategy is the same at 3.0. As for Mississippi, the optimal solution in the sensitivity test includes both mitigation of Hurricanes and Earthquakes (compared to just mitigation of Hurricanes in the Base Case). This is because when the BCR of mitigation of Hurricanes increases from 0.51 to 3.90 in the Full BCR case, the constraint of 50% risk reduction from this threat type becomes binding. The model then chooses mitigation of Earthquakes to achieve the remaining credit attainment target. We note that the optimal solution is not unique in this sensitivity case. This is again because the credit multipliers for all the mitigation options are the same (3.0). From the expenditure minimization point of view, there is no difference in choosing among alternative mitigation options as long as the 50% risk reduction constraint is not binding for the individual mitigation options.

TABLE I-21. Minimization of Risk Reduction Expenditure for 75% Risk Reduction Target AALRI Case

(in million dollars)

	Expenditure			Risk Reduction Attained		
	CA	MS	OH	CA	MS	OH
Mitigation						
Hurricanes						
Floods	21.15	2.00	3.88	105.77	9.99	19.40
Severe Storms						
Earthquakes						
Other						
Total	21.15	2.00	3.88	105.77	9.99	19.40

TABLE I-22. Minimization of Risk Reduction Expenditure for 75% Credit Attainment Target AALRI Case

(in million dollars)

	Expenditure			Risk Reduction Attained		
	CA	MS	OH	CA	MS	OH
Mitigation						
Hurricanes		3.18			9.53	
Floods	35.26		6.47	105.77		19.40
Severe Storms						
Earthquakes		0.16			0.47	
Other						
Insurance or Relief Funds						
Hurricanes						
Floods						
Severe Storms						
Earthquakes						
Other						
Total	35.26	3.33	6.47	105.77	9.99	19.40

PARI Case

The MP analysis results for the PARI Case are presented in Tables I-23 and I-24.

For California, the results indicate that when the state seeks to achieve the risk reduction goal with minimized spending, it chooses the same set of risk reduction options (i.e., mitigating risk from floods, severe storms, and other) as in the Base Case simulation. However, the total risk reduction expenditures decrease by about 20%. This is because when the BCRs of the mitigation strategies increase in the sensitivity case, lower mitigation expenditures are needed to achieve the same level of risk reduction as in the Base Case. When the state's goal is to attain a 75% deductible credit with minimized spending, the total amount of risk reduction expenditures in the optimal solution remains the same as in the Base Case. However, the solution of this sensitivity case includes one additional mitigation strategy – mitigation of "other" threats, as well as slightly lower amounts of expenditure on mitigation of Floods, Severe Storms, and Earthquake. This is because in the sensitivity case, the BCRs for Floods, Severe Storms, and Earthquake increase from 4.75, 3.18, and 0.42 to 5.00, 4.00, and 1.50, respectively. Therefore, less can be spent on mitigating the risk of these threat types before the 50% risk reduction constraint becomes binding for the corresponding mitigation strategies. In addition, after the constraints for mitigating Floods, Severe Storms, and Earthquakes all become binding in the sensitivity analysis of the 75% credit attainment case, mitigation of Other threats becomes part of the optimal solution. However, for the same reason mentioned above, we note that the optimal solution is not unique in the sensitivity case.

For Mississippi, when the target is to achieve 75% risk reduction, the state does not need to spend on insurance in the sensitivity case as in the Base Case. This is because, in the sensitivity case, the BCR of mitigation of hurricanes increases from 0.51 to 3.90. Therefore, instead of choosing insurance after the constraint on mitigation becomes binding for Floods, Severe Storms, and Other as in the Base Case, the state will choose to mitigate Hurricanes to achieve the remaining risk reduction target in the sensitivity case. The total expenditures by MS decrease by 72%, because of the increased BCRs of the mitigation strategies relative to the Base Case. When the state target is credit attainment, the sensitivity analysis yields the exactly same results as in the base case. This is because in the credit attainment target simulation, the BCRs of different mitigation strategies do not matter as long as the credit multiplier for each mitigation strategy is the same at 3.0, and the constraint that risk reduction from mitigation cannot exceed 50% for each threat is not binding.

For Ohio, when the state target is risk reduction, the state will again choose mitigation of Severe Storms to achieve the 75% risk reduction goal as in the Base Case. However, since the BCR of Severe Storms increases from 3.18 in the Base Case to 4.00 in the Full BCR Sensitivity case, the total expenditure to achieve the same risk reduction goal is reduced by about 20%. For the 75% credit attainment case, the mix of mitigation strategies and the total expenditures remain the same as in the Base Case. However, less is spent on mitigation of Hurricanes and more is spent on Severe Storms. This is because when the BCR of Hurricanes increases from 0.51 to 3.90, less can be spent on this strategy before the constraint of a maximum of 50% risk reduction on this threat type is reached. However, we note again that the optimal solution is not unique in the sensitivity case.

TABLE I-23. Minimization of Risk Reduction Expenditure for 75% Risk Reduction Target PARI Case
(in million dollars)

	Expenditure			Risk Reduction Attained		
	CA	MS	OH	CA	MS	OH
Mitigation						
Hurricanes		6.12			23.86	
Floods	1.02	0.02		5.12	0.10	
Severe Storms	9.08	0.67	1.93	36.31	2.69	7.70
Earthquakes						
Other	3.31	0.04		13.24	0.16	
Insurance or Relief Funds						
Hurricanes						
Floods						
Severe Storms						
Earthquakes						
Other						
Total	13.41	6.85	1.93	54.66	26.80	7.70

TABLE I-24. Minimization of Risk Reduction Expenditure for 75% Credit Attainment Target PARI Case
(in million dollars)

	Expenditure			Risk Reduction Attained		
	CA	MS	OH	CA	MS	OH
Mitigation						
Hurricanes		8.93	0.13		26.80	0.39
Floods	1.02			3.07		
Severe Storms	9.08		2.44	27.23		7.31
Earthquakes	4.82			14.45		
Other	3.31			9.92		
Insurance or Relief Funds						
Hurricanes						
Floods						
Severe Storms						
Earthquakes						
Other						
Total	18.22	8.93	2.57	54.66	26.80	7.70

Following from the investigation of alternative BCR specification in the mathematical programing model, we use the results in a burden analysis to assess the impact on this analysis of the alternative assumptions for BCRs for both the AALRI (Table I-25) and PARI (Table I-26).

Table I-25.
Burden Analysis for DDF1 – AALRI
Three States (75% risk reduction)
Sensitivity Analysis – Full Benefit BCRs

	Expenditures ($millions)		
	California	**Mississippi**	**Ohio**
A. Status Quo			
Total expected Public Assistance (PA)	1334.33	99.34	210.91
State share of PA	300.22	22.35	47.46
Federal PA	1034.10	76.99	163.46
B. Deductible only			
Total expected Public Assistance (PA)	1334.33	99.34	210.91
State deductible	141.03	13.32	25.86
PA after state pays deductible	1193.30	86.02	185.05
State share of remaining PA	268.49	19.35	41.64
State total spending (deduct. + state share)	409.52	32.68	67.50
Federal PA	924.81	66.67	143.41
Change in State burden	109.29	10.33	20.05
Change in Federal burden	-109.29	-10.33	-20.05
C. Mitigation with DDF credit			
Total expected Public Assistance (PA)	1334.33	99.34	210.91
Mitigation spending	21.15	2.00	3.88
Insurance coverage	0.00	0.00	0.00
Relief fund	0.00	0.00	0.00
Reduction in PA from mitigation expenditures	70.51	6.66	12.93
Total actual PA	1263.81	92.68	197.98
State deductible less credit for mitigation	141.03	7.33	14.22
PA less deductible	1122.79	85.35	183.76
State share of remaining PA	252.63	19.20	41.35
State total spending (mitigation + deduct. + share)	393.65	28.53	59.45
Federal PA	870.16	66.15	142.41
Change in State burden from status quo	93.43	6.18	11.99
Change in State burden rel. to deductible only	-15.87	-4.15	-8.05
Change in Federal burden from status quo	-163.94	-10.84	-21.05
Change in Federal burden rel. to deductible only	-54.65	-0.52	-1.00

Table I-26. Burden Analysis for DDF1 – PARI Three States (75% risk reduction) Sensitivity Analysis – Full Benefit BCRs			
	Expenditures ($millions)		
	California	**Mississippi**	**Ohio**
A. Status Quo			
Total expected Public Assistance (PA)	224.98	104.91	23.13
State share of PA	50.62	23.60	5.20
Federal PA	174.36	81.30	17.92
B. Deductible only			
Total expected Public Assistance (PA)	224.98	104.91	23.13
State deductible	72.89	35.73	10.26
PA after state pays deductible	152.09	69.17	12.86
State share of remaining PA	34.22	15.56	2.89
State total spending (deduct. + state share)	107.11	51.30	13.16
Federal PA	117.87	53.61	9.97
Change in State burden	56.49	27.69	7.95
Change in Federal burden	-56.49	-27.69	-7.95
C. Mitigation with DDF credit			
Total expected Public Assistance (PA)	224.98	104.91	23.13
Mitigation spending	13.41	6.85	1.93
Insurance coverage	0.00	0.00	0.00
Relief fund	0.00	0.00	0.00
Reduction in PA from mitigation expenditures	36.44	17.87	5.13
Total actual PA	188.54	87.04	18.00
State deductible less credit for mitigation	32.66	15.19	4.49
PA less deductible	155.88	71.85	13.51
State share of remaining PA	35.07	16.17	3.04
State total spending (mitigation + deduct. + share)	81.14	38.20	9.45
Federal PA	120.81	55.68	10.47
Change in State burden from status quo	30.52	14.60	4.25
Change in State burden rel. to deductible only	-25.97	-13.09	-3.71
Change in Federal burden from status quo	-53.55	-25.62	-7.46
Change in Federal burden rel. to deductible only	2.94	2.07	0.50

Using the full impact BCRs does not have a significant impact on the goal of achieving a 75% reduction in the deductible through credits compared to the property damage only BCRs. Although the change in BCRs across threats in this sensitivity analysis changes the mitigation mix by threat type, it does not result in an appreciable effect on the burden analysis for either California or Ohio. This is because these two states will not swap the mix of mitigation strategies significantly. The only time this effect becomes significant is when the threat mix is such that those threats with low property damage BCRs are important, and a state moves away from mitigation to either insurance or building a relief fund. Since these activities have lower credit multipliers, states will have to spend more to achieve the credit goal. This effect results in a noticeable change in results for Mississippi, compared to using the property damage only BCRs. This is largely because of the particular threats the state faces. The optimal mix of mitigation and insurance favors insurance when using the property damage only BCR for hurricanes, which is lower than the all-benefit BCR. The Mathematical Program result has the state move away from mitigation and toward insurance to achieve the desired risk reduction.

There is no significant change in any state's outcome when the objective if a 75% reduction in deductible. This is because the credit multipliers do not change, and the goal of reducing the deductible by 75% is driven in this case by the credit multipliers.

The conclusion of this sensitivity analysis is that while the choice of BCRs affects the choice of optimal mitigation strategy mix, depending on the mix of threats each state faces, the choice of property damage only BCRs is driven more by concerns that we use BCRs that measure the appropriate benefits. The modeling approach is proven to be robust to alternative BCR values.

The sensitivity BCRs result in substantial changes in the time path figures, particularly in states that have high earthquake and hurricane PA. This large change occurs because under the baseline scenario, there is no mitigation against these threats, while under the alternative BCRs it is less costly to mitigate against these threats than to buy insurance. In California, the changes are relatively small under the PARI deductible because most of California's historical PA comes from severe storms, floods, and "other" disasters, all of which are mitigated against even under the baseline BCRs. This is shown in Figure I-15. Under the AALRI deductible which is shown in Figure I-16, however, expected earthquake damage is relatively high and the sensitivity BCRs result in several years of earthquake mitigation that does not take place under the baseline BCR assumption. The effect of the sensitivity parameters on Mississippi's expenditure depends on whether or not risk is modeled with PARI or AALRI. Under the PARI approach which is shown in Figure I-17, Mississippi's risks are dominated by hurricanes and switching from the baseline BCRs to the sensitivity BCRs results in greater potential mitigation. Under the AALRI assumptions shown in Figure I-18, on the other hand, Mississippi's risk is dominated by floods, which receive mitigation even under the baseline BCRs.

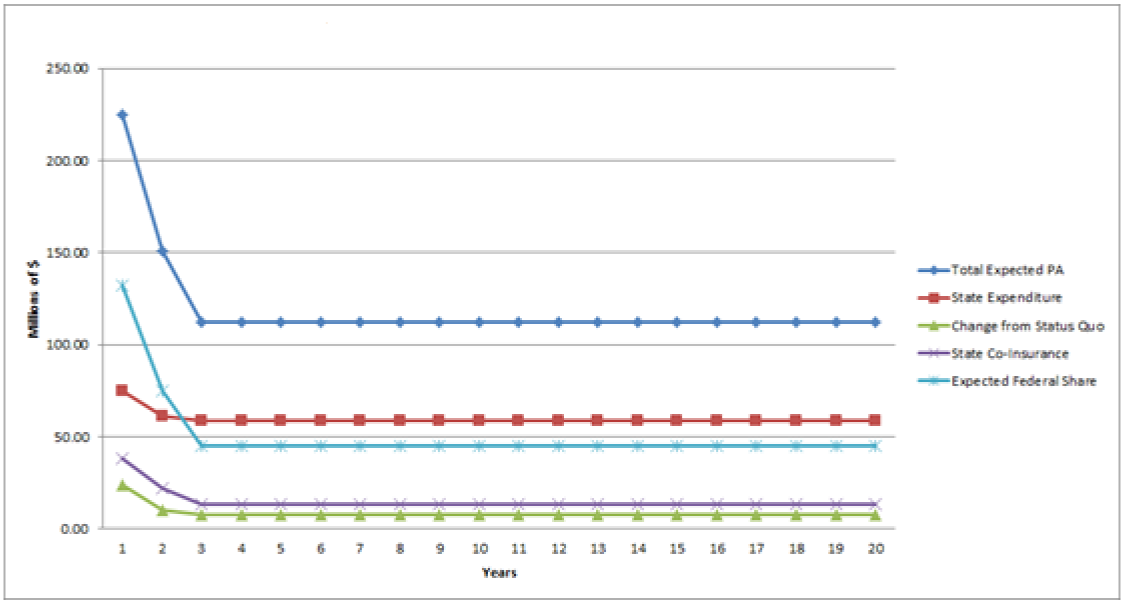

Figure I-15. The Effect of DDF on California over Time – PARI

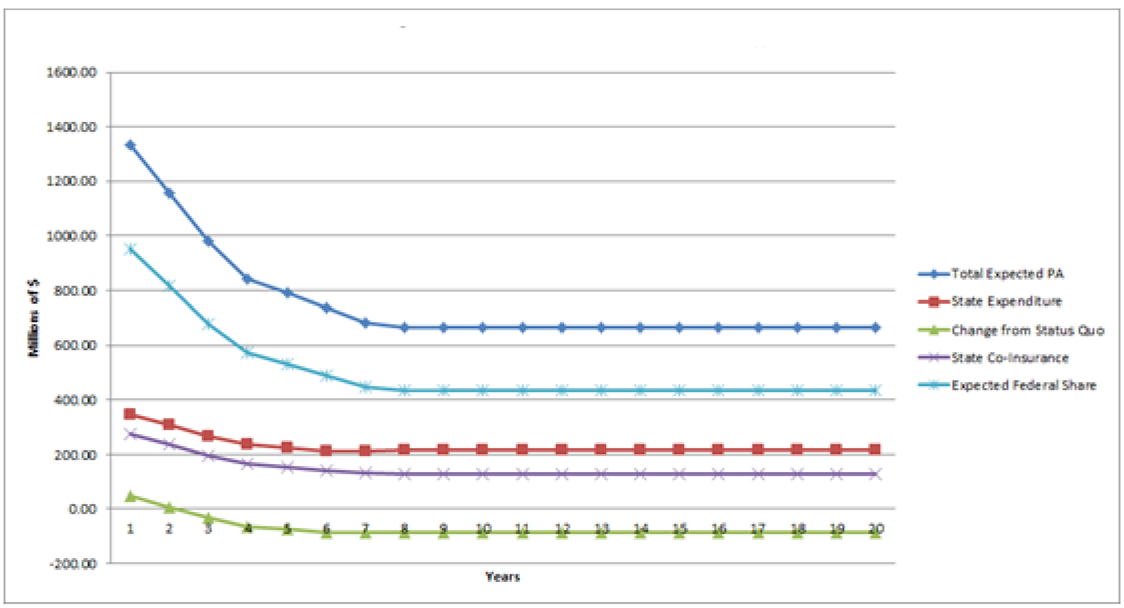

Figure I-16. The Effect of DDF on California over Time - AALRI

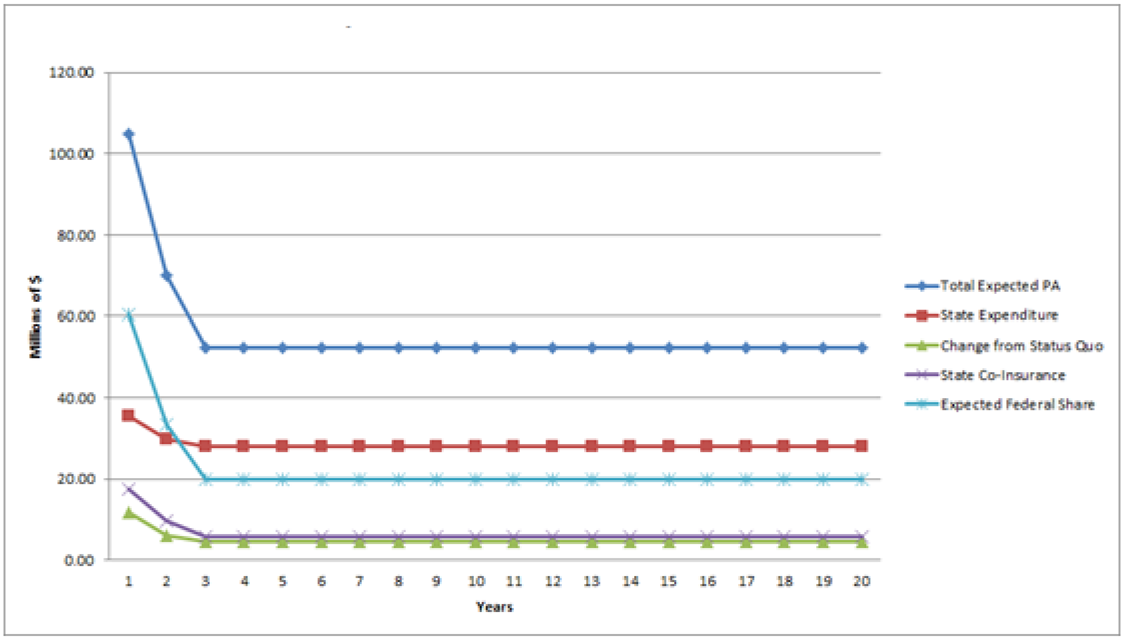

Figure I-17. The Effect of DDF on Mississippi over Time – PARI

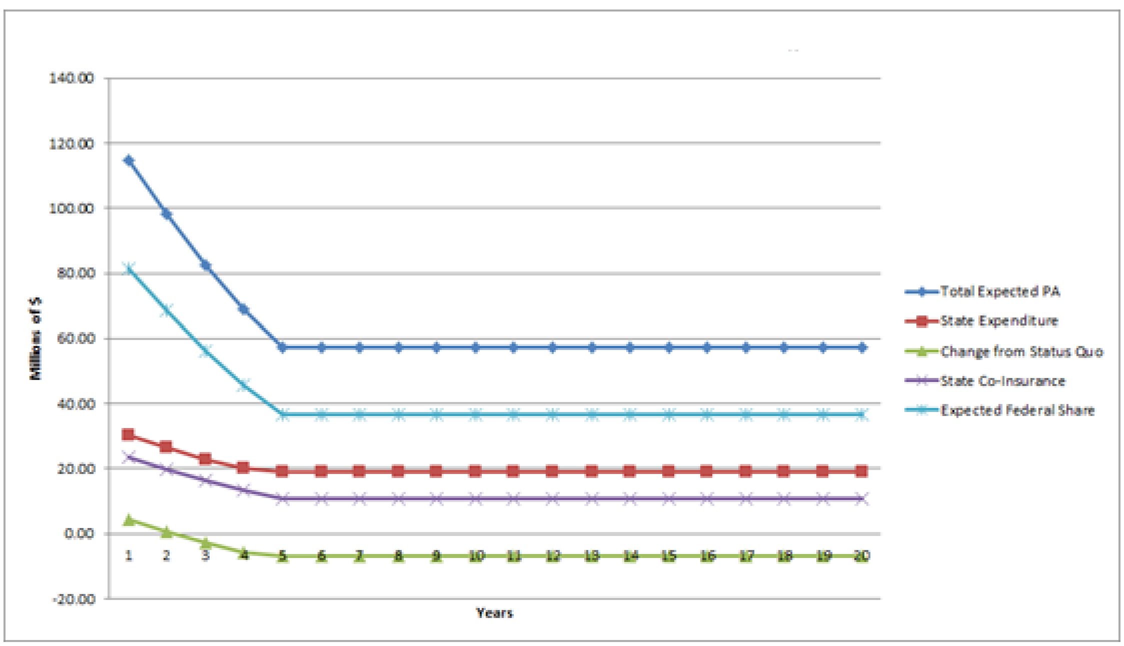

Figure I-18. The Effect of DDF on Mississippi over Time – AALRI

C. Assessment

The particular specification of the Disaster Deductible Formula presented here can be assessed against selected criteria. These criteria include:

- *Ability to achieve FEMA's goals*. The DDF shifts more responsibility for disaster risk to states and provides incentives for states to reduce this risk.
- *Stability.* The application of caps on deductibles prevents extreme outliers from having too much influence. This controls for both extreme values in the measures of fiscal capacity and the influence of extreme disasters.
- *Economic efficiency*. This is promoted by giving each state a choice in its risk reduction alternatives, so as to achieve a least-cost portfolio strategy.
- *Equity and fairness*. The Base Deductible satisfies some of the fundamental principles of equity. Each state starts off with the same deductible before adjustments are made for risk and fiscal capacity, which is consistent with Horizontal equity. Each state deductible is then adjusted for risk exposure, from all relevant hazards it faces, and adjusted for the fiscal capacity to fund both the deductible and the state's share of disaster public assistance, both of which relate to Ability to Pay equity.[32] Overall the adjustments address both Horizontal and Vertical equity objectives: similar states are treated similarly, but different states are treated differently.
- *Flexibility.* FEMA's choice of credit multipliers sets both the overall level of incentives for state disaster risk reduction expenditures and the relative reward for alternative tactics. Each type of mitigation can be credited differently, as can be the credit for purchasing insurance for public facilities and the credit for establishing a disaster relief fund. The credits can be set to affect the portfolio choice of disaster risk reduction response.
- *Transparency*. The DDF is predictable and easily calculated. This is attained by a relatively simple formula using publicly available data and with only a few parameters.
- *Political feasibility*. Allowing states to choose how to achieve a given reduction in their deductible via alternatives such as mitigation, insurance or establishing a relief fund empowers the states, and encourages participation in the program.

IX. Conclusion

This report has presented the results of developing an initial Disaster Deductible Formula (DDF) to incentivize state, tribal, territorial, and local governments to increase their capabilities to withstand disasters. The report specifies a DDF, deconstructs its operation, and analyzes the risk reduction and fiscal impact the DDF will have on all states using various economic methods to evaluate performance.

Currently, once a disaster declaration has been made, FEMA provides approximately three-quarters of the funds needed for public assistance, while non-federal levels of government cover the remaining non-federal share. The DDF is intended to encourage states to build fiscal capacity to fund their post-disaster assistance needs, to provide incentives to engage in mitigation and resilience, and to purchase

[32] Ability to Pay is indirectly affected by the need for covering losses.

insurance to reduce expected losses. All of these responses will lessen the need for federal disaster assistance.

The DDF establishes a Base Deductible chosen using a simple equal-share rule. The Base Deductible is adjusted for each state's Fiscal Capacity and underlying Risk Exposure with caps applied to prevent extreme values, and the final Adjusted Deductible is normalized (proportionally shifted so that the mean value is consistent with the original base). By itself, a deductible shifts the responsibility of funding the first dollar of Public Assistance to the states, and away from FEMA. When combined with Credits offsetting the Deductible for spending on mitigation and other disaster-reduction activities, each state can reduce both its total cost of disasters and reduce its need for PA compared to a deductible alone.

A Mathematical Programming Model is used to determine the least-cost combination of the state response to the Deductible through mitigation, insurance and relief fund expenditures to achieve specified risk-reduction or deductible-reduction goals.

The results are then analyzed in a Burden Analysis -- a simple technique to measure the fiscal impacts of the response on the states and FEMA. This analysis reported for selected states reveals the following impacts:

1. Compared to the status quo, a Deductible by itself shifts some of the burden of funding Public Assistance from FEMA to the states.

2. The Deductible alone offers little or no incentive for states to undertake risk-reduction tactics, since their Public Assistance share is approximately 25%, and any risk reduction is offset by the associated expenditures for many states.

3. Offering credit for mitigation and other disaster risk-reduction activities provides a strong incentive for states to engage in these activities, and thereby significantly reduces the negative fiscal impact of the Deductible alone. Simulations indicate that in the first few years, states are still not better off than under the current (no Deductible) situation. However, over time, the cumulative risk reduction does make states better off in terms of their risk exposure and their expected payoff.

Sensitivity analyses demonstrated that the general results are quite robust. That is, the basic conclusions hold, even with moderate changes in key assumptions and parameter values relating to caps on the Deductible, relative weights given to the fiscal capacity and risk adjustments, benefit-cost ratios and credit multipliers. The optimal mix of risk reduction responses is affected by variations in benefit-cost ratios for individual types of responses, but the optimal mix of responses to attain a given credit level against the Deductible is affected only to a limited extent.

Finally, we emphasize that this report not only provides the formulation of a first Disaster Deductible and insights into its strengths and weaknesses, but it also provides methods and tools to enable FEMA to determine how to adjust it to meet some specific goals with respect to risk reduction, efficiency, and equity. However, not all goals are likely to be met simultaneously, as some of them involve tradeoffs.

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APPENDIX I-A (APPENDIX TO PART I, CHAPTER III). BASIC DATA USED IN CONSTRUCTING FISCAL CAPACITY INDICES

	State	Population As of July 1, 2014	GDP (2005-2014 Ave) (M $)	Total Taxable Resources (2003-2012 Ave) (M $)	Total Actual Revenue (2004-2013 Ave) (M $)	State Surplus/ Deficit (M$) (2004-2013 Ave)	Adjusted State Surplus/ Deficit (M$) (2004-2013 Ave)[a]	State Reserve Funds (M$) (2005-2014 Ave)	Per Capita TTR ($)	Per Capita Surplus/ Deficit ($)	Per Capita Reserve Funds ($)	S&P Bond Rating (2004-2013 Ave)[b]
1	Alabama	4,849,377	191,219.0	211,813.5	26,640.6	-491.3	944.4	192.8	43,678.5	194.7	39.7	8.0
2	Alaska	736,732	55,978.8	55,624.5	13,545.8	2,465.5	3,901.3	9,782.0	75,501.7	5,295.4	13,277.5	8.8
3	Arizona	6,731,484	277,075.9	303,997.4	33,023.5	928.8	2,364.5	311.2	45,160.5	351.3	46.2	7.5
4	Arkansas	2,966,369	114,051.5	129,519.4	19,053.2	1,293.1	2,728.8	2.9	43,662.6	919.9	1.0	8.0
5	California	38,802,500	2,167,628.6	2,303,982.6	278,816.3	8,857.3	10,293.1	1,903.0	59,377.2	265.3	49.0	5.0
6	Colorado	5,355,866	279,990.0	300,340.2	26,983.7	1,077.6	2,513.3	248.0	56,076.9	469.3	46.3	7.7
7	Connecticut	3,596,677	250,986.4	299,528.5	26,560.2	-158.6	1,277.1	751.2	83,279.2	355.1	208.9	8.0
8	Delaware	935,614	62,110.2	66,508.9	12,390.4	84.7	1,520.4	194.9	71,085.8	1,625.1	208.3	5.8
9	DC	658,893	108,980.9	69,069.4	7,943.4	-435.5	1,000.3	466.4	104,826.4	1,518.1	707.9	10.0
10	Florida	19,893,297	816,657.9	988,525.8	90,847.2	7,587.4	9,023.2	828.9	49,691.4	453.6	41.7	9.9
11	Georgia	10,097,343	453,168.5	485,328.8	45,933.4	920.6	2,356.4	674.8	48,065.0	233.4	66.8	10.0
12	Hawaii	1,419,561	73,115.1	77,757.2	11,241.3	-14.1	1,421.6	54.1	54,775.5	1,001.4	38.1	7.7
13	Idaho	1,634,464	60,422.7	67,470.5	8,886.6	653.9	2,089.6	93.1	41,279.9	1,278.5	57.0	8.3
14	Illinois	12,880,580	717,659.4	786,632.3	71,869.3	277.6	1,713.4	182.9	61,071.2	133.0	14.2	6.7
15	Indiana	6,596,855	303,386.0	333,265.4	35,655.1	1,403.1	2,838.9	384.5	50,518.8	430.3	58.3	9.4
16	Iowa	3,107,126	156,243.6	167,400.5	20,268.6	1,405.2	2,841.0	535.4	53,876.3	914.3	172.3	9.6
17	Kansas	2,904,021	138,207.9	154,534.8	16,105.2	57.7	1,493.4	0.0	53,214.1	514.3	0.0	9.0
18	Kentucky	4,413,457	178,355.1	194,245.7	26,624.5	-1,378.9	56.9	100.0	44,012.2	12.9	22.7	7.0
19	Louisiana	4,649,676	244,403.3	248,147.4	31,764.8	-231.9	1,203.9	592.3	53,368.8	258.9	127.4	6.5
20	Maine	1,330,089	55,102.8	62,985.1	9,516.9	329.8	1,765.6	62.0	47,354.1	1,327.4	46.6	7.8
21	Maryland	5,976,407	332,534.9	406,347.7	36,451.3	-544.5	891.2	807.0	67,992.0	149.1	135.0	10.0
22	Massachusetts	6,745,408	428,916.7	473,409.9	51,740.2	-159.0	1,276.7	1,705.6	70,182.5	189.3	252.9	8.1
23	Michigan	9,909,877	435,249.6	485,804.4	64,549.8	972.6	2,408.3	129.3	49,022.2	243.0	13.0	7.4
24	Minnesota	5,457,173	296,753.7	317,786.3	39,112.3	1,228.7	2,664.4	749.3	58,232.8	488.2	137.3	9.8

25	Mississippi	2,994,079	102,736.9	115,438.9	20,474.8	531.5	1,967.3	165.3	38,555.7	657.1	55.2	8.0
26	Missouri	6,063,589	273,700.4	306,078.6	32,769.5	2,854.4	4,290.2	280.1	50,478.1	707.5	46.2	10.0
27	Montana	1,023,579	40,554.3	44,894.7	7,178.9	516.1	1,951.8	0.0	43,860.5	1,906.8	0.0	7.6
28	Nebraska	1,881,503	99,149.3	104,763.4	10,389.4	1,020.3	2,456.0	469.3	55,680.7	1,305.3	249.4	9.3
29	Nevada	2,839,099	134,736.1	154,520.5	14,141.6	1,616.5	3,052.2	93.0	54,425.9	1,075.1	32.8	8.5
30	New Hampshire	1,326,813	67,713.8	82,103.2	7,579.0	207.8	1,643.6	35.2	61,880.0	1,238.7	26.6	8.0
31	New Jersey	8,938,175	535,813.5	646,196.9	64,549.2	-1,435.7	0.0	233.0	72,296.3	0.0	26.1	7.6
32	New Mexico	2,085,572	90,449.1	97,871.0	16,411.3	-610.9	824.9	654.4	46,927.7	395.5	313.8	9.0
33	New York	19,746,227	1,286,926.4	1,396,767.5	181,577.6	5,429.3	6,865.1	1,261.6	70,735.9	347.7	63.9	8.0
34	North Carolina	9,943,964	452,662.4	475,531.5	55,161.9	3,996.8	5,432.6	521.2	47,821.1	546.3	52.4	10.0
35	North Dakota	739,482	39,977.9	38,954.1	6,324.5	1,301.8	2,737.6	336.0	52,677.6	3,702.0	454.3	8.5
36	Ohio	11,594,163	551,128.7	596,406.8	82,784.5	6,161.8	7,597.5	630.0	51,440.3	655.3	54.3	9.0
37	Oklahoma	3,878,051	166,580.5	181,239.7	23,348.0	1,772.3	3,208.0	539.3	46,734.7	827.2	139.1	8.6
38	Oregon	3,970,239	199,610.2	211,570.4	27,452.8	1,936.7	3,372.5	140.8	53,289.1	849.4	35.5	8.0
39	Pennsylvania	12,787,209	627,387.2	703,755.4	82,036.5	-1,251.3	184.5	340.6	55,035.9	14.4	26.6	8.0
40	Rhode Island	1,055,173	53,330.1	62,824.0	8,414.6	205.7	1,641.4	127.1	59,539.1	1,555.6	120.5	7.9
41	South Carolina	4,832,482	179,627.5	198,840.9	27,799.6	-1,046.2	389.6	252.5	41,146.8	80.6	52.2	9.1
42	South Dakota	853,175	41,704.1	46,400.9	4,716.4	452.6	1,888.3	134.0	54,386.1	2,213.3	157.1	8.4
43	Tennessee	6,549,352	279,549.0	299,494.2	30,540.0	720.3	2,156.0	465.0	45,728.8	329.2	71.0	8.8
44	Texas	26,956,958	1,387,127.7	1,394,061.6	121,677.8	7,523.9	8,959.6	4,490.2	51,714.4	332.4	166.6	8.6
45	Utah	2,942,902	128,462.0	133,243.0	16,214.5	541.4	1,977.2	332.1	45,276.1	671.9	112.9	10.0
46	Vermont	626,562	28,417.5	32,874.6	5,919.3	219.5	1,655.2	62.8	52,468.3	2,641.8	100.3	9.0
47	Virginia	8,326,289	447,570.2	510,748.1	45,376.9	1,624.2	3,059.9	736.4	61,341.6	367.5	88.4	10.0
48	Washington	7,061,530	389,043.0	416,981.1	44,349.6	263.2	1,699.0	161.3	59,049.7	240.6	22.8	8.7
49	West Virginia	1,850,326	69,280.4	77,255.1	13,811.0	1,396.8	2,832.6	628.6	41,752.2	1,530.8	339.7	7.5
50	Wisconsin	5,757,564	276,295.6	303,329.8	38,607.9	1,354.4	2,790.2	42.6	52,683.7	484.6	7.4	7.6
51	Wyoming	584,153	41,806.7	44,691.9	6,833.0	1,388.2	2,824.0	589.0	76,507.1	4,834.3	1,008.2	8.9
	Total	318,857,056	16,189,538.9	17,666,864.4	2,001,963.9	64,821.3						
	Median								**53,214.1**	**514.3**	**57.0**	**8.4**

[a] Since we need non-negative figures to construct the fiscal capacity index, we scale the numbers for each state up by $1,435.7M, which is the deficit for New Jersey (the highest deficit among the states and DC).

[b] We designate the following numerical values to the ratings: AAA = 10; AA+ = 9; AA = 8; AA- = 7; A+ = 6; A = 5; A- =4; BBB+ = 3; BBB = 2.

APPENDIX I-B (APPENDIX TO PART I, CHAPTER VI). ACTIVITY ANALYSIS

An example of one of the mathematical programming (MP) problems, organized in what is known as *activity analysis* form is presented in Appendix Table I-D. The table represents an organizing framework for the concepts, objectives, constraints, functional relationships, and numerical values of key parameters of an optimization problem.

The example is that of minimizing risk reduction expenditure for a 50% risk reduction target for California for the AAL-based risk case. Each row in the table represents an equation in this problem. This specific problem corresponds to the objective function specified in the first row, where the unit (1.0) coefficient values refer to the fact that dollar expenditures are all weighted equally across risk reduction options in terms of absolute costs. It also further corresponds to the second and third equations, which specify that the risk reduction target is 50% (.50) of the total risk of two target values: state total expected risk and state deductible risk, across different threat types that CA faces in 2015.[33] The third equation is necessary since we want to cap the state risk by the state adjusted deductible, i.e., CA will not undertake activities to reduce risk by more than 50% of the state adjusted deductible.

The first 5 numerical columns in the table (A1 through A5) represent risk reduction activities from mitigation for each of the 5 types of threats. The next two numerical columns (A6 and A7) represent risk reduction from spending on insurance and relief fund.

The conversion of dollars of spending into risk reductions are presented in rows 4 thorough 18, in relation to spending constraints. The diagonal value presented in each row in the first five numerical columns is the BCR ratio that reflects the potential of this mitigation spending to reduce risk of a specific threat.[34] For insurance and relief fund, the BCRs are 1.0 across all threat types. The constraints presented in rows 4 through 18 require that risk reduction from the risk reduction strategy for each threat should not exceed 50% of the maximum annual risk from that threat).[35,36]

The last row of the table lists the variables we use to represent each of the mitigation activities. The solution to the MP problem provides their numerical values.

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[33] In the MP simulation, since the variables and coefficients in these two equations are all the same, the solution finds the minimum level of the two: 50% maximum risk and 50% of state deductibles.

[34] These BCRs are known as the “structural coefficients” of the MP problem.

[35] Note that in the formal MP problem set-up, “slack” variables are needed for each of these 15 rows in case the optimized spending for the associated threat falls short of the constraint. A slack variable thus makes up the difference, transforming the potential inequality into an equality, thereby facilitating the mathematical solution.

[36] The coefficients and constraints are given negative values in the table because it is the convention to express “inputs” (in this case, risk reduction per dollar spent on mitigation) negative values and to express “outputs” (in this case, mitigation activity in dollar terms) in positive terms.

Appendix Table I-B. Activity Analysis Table for the MP Problem of Minimizing Risk Reduction Expenditure for a 50% Risk Reduction Target – California

Equation	Mitigation Activities					Insurance	Relief Fund	
	A1 (Mitigation-Hurricane)	A2 (Mitigation-Flood)	A3 (Mitigation-Severe Storm)	A4 (Mitigation-Earthquake)	A5 (Mitigation-Other)	A6 (Spending on Insurance across 5 Threat Types)	A7 (Spending on Relief Fund across 5 Threat Types)	Constraint on Spending
1. Objective Function (Minimize Expenditure)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	
2. Risk Reduction Target	0.51	4.8	3.18	0.42	3.18	1.0	1.0	0.5(1,334.33)
3. State Deductible Constraint	0.51	4.8	3.18	0.42	3.18	1.0	1.0	0.5(141.03)
4. Risk Reduction from Mitigation-Hurricane	-0.51							0.5(-0.0)
5. Risk Reduction from Mitigation-Flood		-4.8						0.5(-866.67)
6. Risk Reduction from Mitigation-Severe Storm			-3.18					0.5(-33.98)
7. Risk Reduction from Mitigation-Earthquake				-0.42				0.5(-373.92)
8. Risk Reduction from Mitigation-Other					-3.18			0.5(-59.75)
9. Risk Reduction from Insurance-Hurricane						-1.0		0.5(-0.0)
10. Risk Reduction from Insurance-Flood						-1.0		0.5(-866.67)
11. Risk Reduction from Insurance-Severe Storm						-1.0		0.5(-33.98)
12. Risk Reduction from Insurance-Earthquake						-1.0		0.5(-373.92)
13. Risk Reduction from Insurance-Other						-1.0		0.5(-59.75)
14. Risk Reduction from Relief Fund-Hurricane							-1.0	0.5(-0.0)
15. Risk Reduction from Relief Fund-Flood							-1.0	0.5(-866.67)
16. Risk Reduction from Relief Fund-Severe Storm							-1.0	0.5(-33.98)
17. Risk Reduction from Relief Fund-Earthquake							-1.0	0.5(-373.92)
18. Risk Reduction from Relief Fund-Other							-1.0	0.5(-59.75)
Spending (in million $)	X1	X2	X3	X4	X5	X6	X7	

APPENDIX I-C1 (APPENDIX TO PART I, CHAPTER VI). BASIC DATA FOR MP ANALYSIS (AALRI CASE)

Basic Data for California

(shaded)	Common parameters across states
(shaded)	State specific data
(shaded)	Calculated state values

aij — Loss reduction multipliers

	mitigation	insurance	relief-funds
hurricane	0.51	1	1
flood	4.75	1	1
severe-storm	3.18	1	1
earthquake	0.42	1	1
other	3.18	1	1

ri

	Maximum Risk	Weights
hurricane	0.00	0.0%
flood	866.67	65.0%
severe-storm	33.98	2.5%
earthquake	373.92	28.0%
other	59.75	4.5%
total	1334.33	100.0%

dj — credit multiplier

mitigation	insurance	relief-funds
3	2	1
State Adjusted Deductible		141.03

ci — maximum credit for insurance and relief funds by threat

	Maximum Credit
hurricane	0.00
flood	45.80
severe-storm	1.80
earthquake	19.76
other	3.16
total	70.51

* Calculated by distributing the credit target (50% of state adjusted deductible) among threats based on the weights of threat expected losses.

Basic Data for Mississippi

	Common parameters across states
	State specific data
	Calculated state values

aij	Loss reduction multiplier		
	mitigation	insurance	relief-funds
hurricane	0.51	1	1
flood	4.75	1	1
severe-storm	3.18	1	1
earthquake	0.42	1	1
other	3.18	1	1

ri		
	Maximum Risk	Weights
hurricane	24.77	24.9%
flood	58.82	59.2%
severe-storm	12.68	12.8%
earthquake	2.33	2.3%
other	0.74	0.7%
total	99.34	100.0%

dj	credit multiplier	
mitigation	insurance	relief-funds
3	2	1

State Adjusted Deductible	13.32

ci	maximum credit for insurance and relief funds by threat
	Maximum Credit
hurricane	1.66
flood	3.94
severe-storm	0.85
earthquake	0.16
other	0.05
total	6.66

* Calculated by distributing the credit target (50% of state adjusted deductible) among threats based on the weights of threat expected losses .

Basic Data for Ohio

	Common parameters across states
	State specific data
	Calculated state values

aij	Loss reduction multiplier		
	mitigation	insurance	relief-funds
hurricane	0.51	1	1
flood	4.75	1	1
severe-storm	3.18	1	1
earthquake	0.42	1	1
other	3.18	1	1

ri		
	Maximum Risk	Weights
hurricane	0.00	0.0%
flood	187.22	88.8%
severe-storm	20.15	9.6%
earthquake	1.57	0.7%
other	1.97	0.9%
total	210.91	100.0%

dj	credit multiplier	
mitigation	insurance	relief-funds
3	2	1

State Adjusted Deductible	25.86

ci	maximum credit for insurance and relief funds by threat
	Maximum Credit
hurricane	0.00
flood	11.48
severe-storm	1.24
earthquake	0.10
other	0.12
total	12.93

* Calculated by distributing the credit target (50% of state adjusted deductible) among threats based on the weights of threat expected losses .

Appendix I-C2 (Appendix to Part I, Chapter VI). Basic Data for MP Analysis (PARI Case)

Basic Data for California

(shaded)	Common parameters across states
(shaded)	State specific data
(shaded)	Calculated state values

aij — Loss reduction multipliers

	mitigation	insurance	relief-funds
hurricane	0.51	1	1
flood	4.75	1	1
severe-storm	3.18	1	1
earthquake	0.42	1	1
other	3.18	1	1

ri

	Maximum Risk	Weights
hurricane	0.00	0.0%
flood	10.23	4.5%
severe-storm	72.61	32.3%
earthquake	14.45	6.4%
other	127.69	56.8%
total	224.98	100.0%

dj — credit multiplier

mitigation	insurance	relief-funds
3	2	1
State Adjusted Deductible		72.89

ci — maximum credit for insurance and relief funds by threat

	Maximum Credit
hurricane	0.00
flood	1.66
severe-storm	11.76
earthquake	2.34
other	20.68
total	36.44

* Calculated by distributing the credit target (50% of state adjusted deductible) among threats based on the weights of threat expected losses.

Basic Data for Mississippi

	Common parameters across states
	State specific data
	Calculated state values

aij	Loss reduction multiplier		
	mitigation	insurance	relief-funds
hurricane	0.51	1	1
flood	4.75	1	1
severe-storm	3.18	1	1
earthquake	0.42	1	1
other	3.18	1	1

ri		
	Maximum Risk	Weights
hurricane	99.02	94.4%
flood	0.20	0.2%
severe-storm	5.37	5.1%
earthquake	0.00	0.0%
other	0.31	0.3%
total	104.91	100.0%

dj	credit multiplier	
mitigation	insurance	relief-funds
3	2	1

State Adjusted Deductible	35.73

ci	maximum credit for insurance and relief funds by threat
	Maximum Credit
hurricane	16.86
flood	0.03
severe-storm	0.91
earthquake	0.00
other	0.05
total	17.87

* Calculated by distributing the credit target (50% of state adjusted deductible) among threats based on the weights of threat expected losses .

Basic Data for Ohio

	Common parameters across states
	State specific data
	Calculated state values

aij — Loss reduction multiplier

	mitigation	insurance	relief-funds
hurricane	0.51	1	1
flood	4.75	1	1
severe-storm	3.18	1	1
earthquake	0.42	1	1
other	3.18	1	1

ri

	Maximum Risk	Weights
hurricane	1.01	4.3%
flood	0.00	0.0%
severe-storm	20.15	87.1%
earthquake	0.00	0.0%
other	1.97	8.5%
total	23.13	100.0%

dj — credit multiplier

mitigation	insurance	relief-funds
3	2	1

State Adjusted Deductible	10.26

ci — maximum credit for insurance and relief funds by threat

	Maximum Credit
hurricane	0.22
flood	0.00
severe-storm	4.47
earthquake	0.00
other	0.44
total	5.13

* Calculated by distributing the credit target (50% of state adjusted deductible) among threats based on the weights of threat expected losses .

APPENDIX I-D. DEDUCTIBLE SENSITIVITY

This appendix displays the normalized deductible for each of the 50 states and Washington, DC under a range of sensitivity scenarios. Entries are color-coded by state, so that the state's lowest deductible is green, the second lowest deductible is slightly red, and subsequent deductibles are progressively higher, until the state's highest deductible is dark red. Several dimensions of sensitivity are considered. The overall Fiscal Capacity Index is capped at either 5 or 10, individual components of the Fiscal Capacity Index are capped at either 5 or 10, and the Combined Index is calculated with greater weight being placed on either the Risk Index or the Fiscal Capacity Index. Some combinations are considered, such as placing more weight on the Risk Index when the components of the Fiscal Capacity Index are capped at 10.

The full list of included sensitivity analyses are:

1. Current Indicator: This corresponds to setting a deductible equal to the current FEMA PA per capita indicator. This is expositional for the purpose of comparing the "winners and losers" under the current PA per capita indicator structure to the "winners and losers" under each proposed deductible.
2. Baseline: No cap on Fiscal Capacity, Equal weight between Risk and Fiscal Capacity
3. Cap of 5 on the Overall Fiscal Capacity Index
4. Cap of 10 on the Overall Fiscal Capacity Index
5. Cap of 5 on the components of the Fiscal Capacity Index
6. Cap of 10 on the components of the Fiscal Capacity Index
7. 25% weight on Risk, 75% weight on Fiscal Capacity
8. 75% weight on Risk, 25 % weight on Fiscal Capacity
9. 25% weight on Risk, 75% weight on Fiscal Capacity and a cap of 5 on components of the Fiscal Capacity Index
10. 75% weight on Risk, 25% weight on Fiscal Capacity and a cap of 5 on components of the Fiscal Capacity Index
11. 25% weight on Risk, 75% weight on Fiscal Capacity and a cap of 10 on components of the Fiscal Capacity Index
12. 75% weight on Risk, 25% weight on Fiscal Capacity and a cap of 10 on components of the Fiscal Capacity Index

APPENDIX I-E. DEDUCTIBLE CALCULATOR[37]

This appendix describes an Excel spreadsheet that allows for the calculation of states' DDF deductible under a range of assumptions and sensitivities. The sheet incorporates the most recent (as of 2/29/16) calculations of the Risk Index and the Fiscal Capacity Index.

The parameters that can be modified are located in Columns T-U, in rows 6-10. The parameters available to modify are the: 1) cap on the Risk Index, 2) the cap on the overall Fiscal Capacity Index, 3) cap on the components of the Fiscal Capacity Index, 4) weight placed on the Risk Index, and 5) baseline deductible. Modifying the values in any of these cells will recalculate the normalized deductibles for each of the 50 states and Washington, DC. Normalized deductibles are displayed in column Q, which is highlighted in yellow. Column P displays the un-normalized deductible. In the case of the caps (Risk, overall Fiscal Capacity, and Fiscal Capacity elements), when a binding cap is in place, the affected value is highlighted in red. For example, if a cap of 5 is placed on the Risk Index, Louisiana's Risk Index value is highlighted.

[37] This spreadsheet was developed by Colt Hagmaier and enhanced by James Ruger, both of FEMA.

PART II. BROADER ISSUES IN DESIGNING A DISASTER DEDUCTIBLE/CREDIT SYSTEM

EXECUTIVE SUMMARY FOR PART II

Part II of this report analyzes refinements of the Basic Disaster Deductible Formula (DDF1). This includes considering alternative combinations of indicators including a Risk Index that incorporates forecasts of some changing conditions that can cause future increases in risk, a broader risk framework that offers more insight into state government motivations and also provides a capability to fine-tune the federal-state share, a DDF that goes beyond a focus on property damage to include life-saving and reduction of government interruption, and the addition of post-disaster resilience tactics as a means to both reduce risk and to obtain credits against the Deductible.

Part I of this study established a Base Deductible as the median value of 17-year average of PA expenditures across all states. In Part II, we instead utilize a Base Deductible based on the 10-year average of PA expenditures in order to remain consistent with our data range for the Risk Index calculation in this Part of the Report. The Base Deductible was adjusted for each state's Fiscal Capacity and underlying Risk Exposure, and then extreme values were capped and the final Adjusted Deductible was normalized (proportionally shifted so that the mean value was consistent with the original base level across states). By itself, a Deductible shifts the responsibility of funding the first dollar of public assistance to the states, and away from FEMA. However, when combined with Credits offsetting the Deductible for spending on mitigation and other disaster-reduction activities, each state has additional incentives to reduce both its total cost of disasters and reduce its need for PA compared to a Deductible alone.

A Mathematical Programming (MP) model was used to determine the least-cost combination of the state response to the Disaster Deductible through mitigation, insurance and relief fund expenditures to achieve specified risk-reduction or deductible-reduction goals. While mitigation measures are generally preferred because they offer higher benefit-cost ratios (BCRs), the optimal solution for some states was to choose a mix of mitigation and insurance often depending on the particular threats the state faces. The results were then analyzed in a Burden Analysis (BA) to measure the fiscal impacts of the response on the states and FEMA.

In Part I, we examined a Deductible for which only property damage and spending to prevent some further government interruption represented the risk level, and for which only spending on mitigation against property damage, as well as spending on insurance and relief funds were eligible for credits against the Deductible. Accordingly, the benefit-cost ratios (BCRs) of mitigation only represented the benefits of mitigation against property damage.

In Part II of the study, we have critically examined the Disaster Deductible/Credit System presented in Part I. This includes the following refinements, which can be considered various policy levers that FEMA can utilize to achieve its goals:

- Consideration of an alternative Fiscal Capacity Index
- Consideration of a broader set of credit eligible expenditures on risk reduction to include (pre-disaster) mitigation of the fatalities and government interruption (GI) in addition to property damage, and (post-disaster) resilience expenditures to reduce GI
- Use of expanded BCRs as appropriate for the various refinements above
- Consideration of a revised formula for insurance crediting against the deductible

We perform the analyses by simulating the implications of each of the changes in assumptions and parameters one at a time to isolate its implications for the optimal mix of risk reduction strategies and for federal and state expenditures on post-disaster spending. We also examine the implications of combining all of the aforementioned refinements into a single formulation that we refer to as the "Full DDF." However, this simulation is for the purposes of illustration only; it is not intended as a single alternative to DDF1. Furthermore, the various simulations of the individual changes in assumptions and parameters should be taken as a menu of possible individual refinements to DDF1. We also emphasize that we have taken a long-run view of the Deductible/Credit System in terms of possible future refinements. That is, we have analyzed some refinements that require further conceptual analysis and collection of pertinent data before they can be implemented.

We have also made two important extensions of the analysis in Part I. The first is to include the development of a risk-sharing framework between the federal government and state governments. It can be used to analyze adjustments in the Deductible, the state share of post-disaster assistance, and even the disaster declaration threshold, in order to achieve various risk-sharing/expenditure outcomes. The second is a set of recommendations on the implementation of the Deductible/Credit System in relation to both federal and state government considerations. The recommendations are based on previous experience with policy implementation and are intended to translate the design of the System into a policy that achieves its objectives.

We once again use the MP model to identify the least-cost combination of risk reduction strategies state can use to achieve goals such as risk reduction or credit attainment against the Deductible. We also use the BA to estimate the federal and state expenditure shares. These models, along with various spreadsheet and visualization tools, can be used by FEMA to analyze various formulations of the DDF and by the states to help identify their desired response.

The analyses in Part I and Part II are not directly comparable in one major way. At a late stage in the research, it was decided to change the Risk Index used in DDF1. Originally, we had based the Risk Index calculation on a regression analysis of causal factors affecting PA expenditures between 2005 and 2014. However this method has a major limitation caused by the relatively short analysis period (ten years) and the "chance" occurrence of major disasters in some states, but none in others. In searching for alternative bases for developing the Risk Index, we considered fitting a probability distribution to data on PA expenditures between 1999 and 2015 for each state, which we refer to as the Public Assistance Risk Index (PARI). Another method was to base the Risk Index on the simulation of disaster losses using the FEMA loss-estimation methodology known as HAZUS, which we refer to as the Average Annualized Loss Index (AAL). Both these methods are included in the Part I analysis, but rather than re-run all of the simulations in Part II to conform to these new risk indices, we chose to leave Part II intact, as it is the general insights that are important in this analysis, rather than the specific numbers. In essence, these general insights would not differ if we used the new risk indices.

In comparison to DDF1, some of the major findings of the study include:

- The refinement that has the greatest effect on federal and state expenditure levels and shares is the consideration of fatalities in a state's total risk and the inclusion of mitigation to prevent fatalities.
- All of the refinements to expand the eligibility of expenditures to reduce risk in addition to the mitigation property damage have significant effects on the mix of risk reduction strategies for one of the example states, Mississippi, but not for another, Ohio. The results not only depend on the risk coverage and level, but also the specific threats the state faces, as well as the corresponding BCRs.
- The inclusion of credits for resilience changes state optimal mix of risk reduction strategies and helps reduce the state total expenditures to achieve the same risk reduction goal.
- The implications of the Full DDF bear a closer resemblance to the cases of individual refinements than they do to DDF1.
- The cross-state equity implications, in terms of fairness of the initial Adjusted Deductible and the state expenditure shares following the calculation of the optimal mix of risk reduction strategies, is only minimally different between the Full DDF and DDF1.

I. Introduction and Overview

A. Background

This Part of the Report summarizes additional possible features of a Disaster Deductible/Credit System applied to FEMA's Public Assistance (PA) Program. This policy initiative is intended to incentivize states "to increase their capability to withstand disasters" (FEMA, 2015a; p. 2).

The current FEMA PA Program provides funding for emergency and permanent work in communities in relation to public facilities following a Presidential Disaster Declaration. This Declaration is triggered if the expected losses exceed the threshold value as determined by simply multiplying a $1.41 factor to the state's population from the last census. The actual eligible PA costs are split between FEMA and the state at a nominal 75:25, but the FEMA share can increase to 90%, or even 100%. Based on PA data from 2005 to 2014, the average FEMA share nationally was 77.5%.

Under the proposed Disaster Deductible Formula (DDF) program, disasters will still be declared using the current system. However, a Deductible composed of a base level for all states and then adjusted state by state according to state fiscal capacity and state risk is proposed. Individual states would pay for those disaster losses, eligible to be covered by PA, up to the level of their Adjusted Deductible minus credits they earn for qualifying expenditures on risk reduction through mitigation, insurance, relief funds and resilience in the previous year. For declared disasters, the Net Deductible (Deductible less Credits) would be applied beginning January 1 on an annual, rather than on an event, basis. Once the Net Deductible is met from state spending, the remaining public assistance spending would be split between FEMA and the state along the lines of the current system.

Part II of this Report is a companion to Part I, which presented a Disaster Deductible Formula (DDF1) based on FEMA's suggested assumptions and parameters (FEMA, 2015b). In designing DDF2, the research team considered alternatives to many of the assumptions and parameters of the first report, in this case based on its own assessment of the objectives of the Deductible/Credit System and features that would best meet these objectives. Alternative assumptions/parameters of DDF2 include: a revised Fiscal Capacity Index, use of predicted future risk, inclusion of crediting against the Deductible for the mitigation of fatalities and government interruption, inclusion of crediting for pre-disaster expenditures in enhancing resilience capacity and post-disaster spending on emergency recovery measures, and revised formula for insurance crediting. It also includes sensitivity tests such as: yet another specification of the Fiscal Capacity Index, alternative projections of terrorism risk, alternative weighting of adjustment indices, a re-examination of annualized expenditures and benefit-cost ratios (BCRs), declining BCRs over time, an alternative risk framework, and alternative risk reduction and credit attainment targets. Again, we also performed an assessment of the DDF in terms of meeting various stated objectives, as well as considerations relating to interstate fairness (equity) and political feasibility and effectiveness with respect to implementation issues.

The analysis was performed in a comparative static mode, meaning that we began with the Base Case DDF 1 and changed its various assumptions and parameters (where applicable) one at a time for purposes of comparison of each refinement of DDF2. Then, we ran all of the refinements of DDF2 together for an overall comparison of the two formulas. DDF2 can be viewed as an entirely separate alternative to DDF1 or a menu of individual or a combination of refinements of DDF1.

Note that the alternative assumptions/parameter options were not restricted to those for which data currently exist or for which implementation might be easy at present. In fact, in this report, we have taken a longer-term view of the DDF, which we view as an evolving process of policy formulation. Thus, not all of the options are ready for inclusion in a final DDF composition to be developed by FEMA this year. However, we urge further study and reconsideration of them in the future.

The reader is referred to Part I for background on DDF1 and for more details of its various components in general. That first report also provides details of methods and models used in the analysis of this report.

B. Overview

This report offers the following contributions to formulating and analyzing a Disaster Deductible Formula:

- Develops and computes alternative state Fiscal Capacity and Risk indices
- Calculates an alternative Adjusted Disaster Deductible for all states
- Analyzes the state response to a broader range of incentives to reduce risk and obtain credits against the Deductible
- Analyzes the role of resilience in the state response to the Deductible
- Analyzes the state response to an alternative crediting approach for insurance
- Conducts a Burden Analysis for sample states of the implications of DDF2
- Develops a Burden Analysis spreadsheet capability
- Develops an enhanced framework to evaluate risk and applies it to a break-even analysis of federal-state risk sharing
- Simulates the time-path of the implications of the DDF2
- Provides an assessment of the assumptions and parameters underlying the analysis of DDF2
- Analyzes the equity implications of the DDF2
- Analyzes the Implementation issues associated with DDFs
- Evaluates the advantages and disadvantages of DDF2

II. Overview of Assumptions and Parameters

A. Assumptions and Parameters

Table II-1 presents a summary of the assumptions and parameters used in this Part of the Report and compares them with assumptions and parameters in Part I, in which these assumptions/parameters were consistent with those presented in the FEMA (2015b) White Paper. Note that a few of the more minor assumptions and parameters are the same between the two parts, but most of the major ones have been changed for the present analysis.

Throughout this report our focus is on Public Assistance spending, but when relevant we distinguish between the components relating to spending on Permanent work, which reduces property damage and disruption of government activity/services, and spending on Emergency work, which relates to maintaining critical government functions and accelerating their recovery (see Table II-2).

To evaluate implications of each alternative assumption/parameter, we conducted a set of comparative static analyses. This involved changing only one assumption or parameter and holding all others the same as in the DDF1 Base Case. This way the implications of each assumption/parameter change could be evaluated in isolation. The research culminates in an analysis of what we refer to as the "Full DDF2," which combines all of the changes in major assumptions and parameters together. This is done to analyze any synergies or other interaction effects. It is not intended as an endorsement of the need to take all of the assumption parameter changes into account in formulating a desirable Disaster Deductible/Credit System.

Note, however, that the Base Case Deductible that we use in Part II below differs from the Base Case Deductibles we presented in Part I of this Report in two major ways. The Base Case here uses only three indicators rather than four to construct the Fiscal Capacity Index. The Base Case here also includes a different Risk Index, which is estimated on the basis of state-level Public Assistance data for the period 2005-14, regressed on explanatory variables (see details in Appendix II-B).

Table II-1 is provided as an overview of our analysis. Each assumption and parameter is explained in detail in the relevant section below.

Table II-1. Summary of Disaster Deductible Assumptions and Parameters

Assumption/Parameter	DDF1	DDF2
Deductible Base Level		
2015	Median of states' 17-year (1999-15) average of total annual PA funding: $22.2 million per state	Median of states' 10-year (2005-14) average of total annual PA funding: $26.9 million per state
2035	n.a.	Median of projected annual PA across states in 2035: $42.5 million per state
Fiscal Capacity Index		
2015	Based on TTR, Surplus/Deficit, Reserve Funds, Bond Rating	Based on General Funds, Reserve Funds, Bond Rating
2035	same data as above	Based on 2035 projected General Funds; same data on Reserve Funds and Bond Rating as for 2015
Risk Index		
2015	AALRI, based on annual average losses as estimated by HAZUS; PARI, based on average of statistically fit distribution to 17-year historical PA data	Average annual hurricane, severe storm, flood, and earthquake losses based on econometric relationships between PA and disaster magnitude, GSP and infrastructure
2035	same data as above	Projected annual public sector losses (for 4 major threat categories) in 2035; assuming GSP grows at the same rate as population
Adjusted Base Deductible		
2015	25:75 weights between Fiscal Capacity Index and Risk Index to calculate Combined Index; adjusted deductible is normalized back to a $22.2 million state average	50:50 weights between DDF2 Fiscal Capacity Index and Risk Index to calculate Combined Index; adjusted deductible is normalized back to a $26.9 million state average
2035	n.a.	50:50 weights between projected Fiscal Capacity Index and projected Risk Index to calculate Combined Index; adjusted deductible is normalized back to a $42.5 million state average
Deductible Cap	Cap of $138.6 million is applied to eliminate outliers	same as DDF1

Loss Reduction Multipliers		
Mitigation adjusted for property damage only	- Floods— 4.75:1 - Hurricanes— 0.51:1 - Earthquakes— 0.42:1 - Severe storms— 3.18:1 - Other— 3.18:1	same as DDF1
Mitigation BCRs with property damage and reduction in fatalities	n.a.	- Floods— 4.90:1 - Hurricanes— 2.89:1 - Earthquakes— 1.33:1 - Severe storms— 3.72:1 - Other— 3.72:1
Mitigation BCRs with property damage and reduction in government interruption	n.a.	- Floods— 4.80:1 - Hurricanes— 1.52:1 - Earthquakes— 0.55:1 - Severe storms— 3.34:1 - Other— 3.34:1
Mitigation BCRs with reduction of property damage, fatalities, and government interruption	n.a.	- Floods— 4.95:1 - Hurricanes— 3.90:1 - Earthquakes— 1.46:1 - Severe storms— 3.88:1 - Other— 3.88:1
Resilience BCRs	n.a.	- Floods— 4.0 - Hurricanes— 4.0 - Earthquakes— 4.0 - Severe storms— 4.0 - Other— 4.0
Full BCRs	- Floods— 5.00:1 - Hurricanes— 3.90:1 - Earthquakes— 1.50:1 - Severe storms— 4.00:1 - Other— 4.00:1	same as DDF1
Relief Fund BCR	1:1 (applies to all threat)	same as DDF1
Insurance BCR	1:1 (applies to all threats)	same as DDF1
Limits on Risk Reduction	- Mitigation: 50% of risk for each threat type because	- Mitigation: same

	not all risks can be mitigated - Relief fund: 50% because this is only risk spreading and not actually risk reduction, but it is a higher payout by the state than is insurance - Insurance: 50% because not all property is insurable	- Relief fund: same - Insurance: same - Resilience: also 50% because not all BI/GI risks can be mitigated
Credit Multipliers	- Mitigation—3:1 - Relief funds—1:1 (because this is risk spreading rather than risk reduction) - Insurance—2:1 (because this is risk spreading rather than risk reduction, but provides more leverage than a relief fund) - assume a fixed 5% of deductible for insurance	- Mitigation—same - Relief fund—same - Insurance: Credit for insurance is given on a lump-sum basis. Proportional credit up to 10% of deductible is given for hazard insurance coverage of public facility stock (e.g., 90% coverage yields 9% credit). - Resilience — 2:1

[1] Applicable to the year in which the expenditure is made.
[2] Applicable only in year the Relief Fund is initiated, or year in which any subsequent increases to it are made.

Table II-2. Total FEMA Public Assistance by Work Category, 2005 to 2014
(2015 million dollars)

Expenditure Category	Dollar Amount	Percent of Total
Z (State Management)	1,327	2.2
A (Debris Removal)	8,755	14.9
B (Protective Measures)	11,959	20.1
C (Roads and Bridges)	5,436	9.1
D (Water Control Facilities)	729	1.2
E (Public Buildings)	18,920	31.8
F (Public Utilities)	9,306	15.6
G (Other/Recreational)	3,094	5.2

Source: FEMA (2015b).

B. Summary Descriptions of Cases in Part II

Please note the following abbreviations for the simulation cases and tables below:

PA: Public Assistance
PD: Property Damage
PDO: Property Damage Only
GI: Government Interruption
BI: Business Interruption

1. *DDF1 Base Case*:

Deductible is $26.9 million, adjusted by Risk Index and 4-component Fiscal Capacity Index;
Risk Level is Property Damage + GI (as non-property damage portion of PA as proxy);
BCRs are based on property damage only. Note that this Base Case varies slightly from the Base Case presented in Part I of this Report. It utilizes the DDF2 Risk Index and includes Washington, DC in the calculations.

2. *DDF2 Base Case*:

Deductible is $26.9 million, adjusted by Risk Index and 3-component Fiscal Capacity Index;
Risk Level is Property Damage + GI (as non-property damage portion of PA as proxy);
BCRs are based on property damage + GI

3. *DDF2 PA +Fatality Risk; PD+GI+Fatality BCRs*:

   Deductible is $26.9 million, adjusted by Risk Index adjusted for fatalities and 3-component Fiscal Capacity Index;
   Risk Level is Property Damage proportion of PA + GI (as non-property damage portion of PA as proxy) + value of fatalities;
   BCRs are based on property damage + GI + fatalities.

4. *DDF2 PA Risk w/ Adj GI; PD+GI BCRs:*

   Deductible is $26.9 million, adjusted by Risk Index adjusted for GI and 3-component Fiscal Capacity Index;
   Risk Level is Property Damage + GI (based on ratio of state expenditure to state capital stock times property damage);
   BCRs are based on property damage + GI.

5. *DDF2 PA Risk w/ Adj GI; PD+GI + Resilience BCRs:*

   Deductible is $26.9 million, adjusted by Risk Index adjusted for GI and 3-component Fiscal Capacity Index;
   Risk Level is Property Damage + GI (based on ratio of state expenditure to state capital stock times property damage);
   BCRs are based on mitigation of property damage + GI, and resilience against GI.

6. *Full DDF2:*

   Deductible is $26.9 million, adjusted by Risk Index adjusted for fatalities, GI and 3-component Fiscal Capacity Index;
   Risk is Property Damage + GI (based on ratio of state expenditure to state capital stock times Property Damage) + Value of Fatalities;
   BCRs are based on mitigation of property damage + GI + fatalities, and resilience against GI.

C. Summary Tables

Table II-3 presents the results for each of the alternative assumptions/parameter changes to be analyzed in Sections IV and V, as well as the combination of all of them in Section VI. Again, the results are presented in a comparative static manner, with each column representing the implications of a change in a major assumption/parameter. The corresponding results for the DDF1 Base Case are also presented in the left-hand column as a reference.

The results are presented for 2 states. Ohio (OH) was chosen as a representative state in general, while Mississippi (MS) was chosen as a state representative of those that have incurred significant disaster losses over the last decade.

The results for each case are presented in terms of key variables such as the Fiscal Capacity index, Risk Index, and Adjusted Deductible. We also present results of a Mathematical Programming (MP) analysis of the state response in terms of an assumed goal of reducing risk by the lesser of 50% of their expected annual risk or 50% of the full value of their Deductible. The results are also presented for a Burden Analysis (BA), which measures the impact of the DDF in terms of the change in the federal and state shares of spending for each case.

Table II-4 presents the results of sensitivity tests on what we deem to be less important variables. Again, the analysis was performed in a comparative static mode in relation to the DDF 1 Base Case results presented in the left-hand column of the table. In a few of the sensitivity tests presented in Section VII we did not run MP and BA analyses because the changes from the base case are predicted to be relatively minor.

In both Table II-3 and Table II-4, the results are presented in terms of changes in the level of each variable. For the Adjusted Deductible, the State Response (MP) Analysis and Burden Analysis, they are expressed in millions of 2015 dollars. An annotation is also made to indicate a range of percentage changes from the DDF1 Base Case. Tables II-3 and II-4 are primarily provided as a guide through the remainder of the report as to main cases and sensitivity cases, in order to give the reader a general feel for the results. Most results indicate that the analysis of the DDF 1 Base Case is robust—changing some major assumptions and parameters does not affect the qualitative nature of the basic results very much. However, the reader is encouraged to read carefully the distinctions between cases and the subtle changes that take place.

III. Base Deductible and Deductible Adjustments

A. Base Deductible

The Base Deductible in Part II is set at $26.9M. This is established as the median amount of annual expected PA across the 50 states and DC (based on 2005-2014 PA expenditure data). In the absence of risk and fiscal capacity adjustments, this would suggest that, if every state experienced disasters resulting in their average annual PA needs, one half of states would receive FEMA funding while the other half would pay for all of their PA needs because their PA did not exceed their Deductible.[38] Note also that the median annual average PA value is substantially lower than the mean annual average PA value (the mean annual average PA is $106M). This indicates that, in the absence of mitigation and credits against the deductible, the Base Deductible would reduce FEMA expenditure by approximately

[38] In practice, however, a state's expected annual PA is correlated with its Risk Index, which results in states with low expected PA having a lower Adjusted Deductible than states with high expected PA.

Table II-3. Summary Table of Simulations of DDF2 Assumptions and Parameters: Main Cases

(change from DDF1 Base Case in millions of 2015 dollars for Adjusted Deductible, State Response Analysis and Burden Analysis)[a]

	DDF1 Base Case[b] (1)	DDF2 Base Case PA Risk; PD+GI BCRs (2015) (2)	DDF2 PA+Fatal Risk; PD+GI+Fatal BCRs (2015) (3)	DDF2 PA Risk w/ Adj GI; PD+GI BCRs (2015) (4)	DDF2 PA Risk w/ Adj GI; PD+GI+Resilience BCRs (2015) (5)	Full DDF2 (2015) (6)
MS						
Fiscal Index	0.98	0.90	0.90	0.90	0.90	0.90
Risk Index	2.18	same[c]	6.85***	9.65***	9.65***	4.65***
Combined Index	1.58	1.54	3.87***	5.27***	5.27***	2.78**
Adjusted Deductible	28.61	28.00	54.22**	72.78***	72.78***	45.19**
State Response (MP) Analysis[d]						
Mitigation Exp	2.81	5.46**	6.58***	19.87***	0.59**	4.67**
Insurance/Relief Fund Exp	4.51	0.00***	0.00***	0.00***	0.00***	0.00***
Resilience Exp	n.a.	n.a.	n.a.	n.a.	8.36[n.a.]	0.72[n.a.]
Burden Analysis						
Expected Loss (311.87[e])	311.87	311.87	603.51**	339.00	339.00	627.47***
State Share (70.17)	89.60	81.50	163.00**	98.20*	125.60*	151.77**
Federal Share (214.70)	229.60	221.80	420.00**	224.30	186.00*	458.49**
OH						
Fiscal Index	1.07	1.08	1.08	1.08	1.08	1.08
Risk Index	0.80	same	0.88*	0.85	0.85	0.76
Combined Index	0.94	0.94	0.98	0.97	0.97	0.92
Adjusted Deductible	16.91	17.13	15.03*	13.66*	13.66*	15.01*
State Response (MP) Analysis[d]						
Mitigation Exp	2.66	2.56	1.89*	2.05*	0.67**	1.88*
Insurance/Relief Fund Exp	0.00	0.00	0.00	0.00	0.00	0.00
Resilience Exp	n.a.	n.a.	n.a.	n.a.	1.15[n.a.]	0.00[n.a.]
Burden Analysis						
Expected Loss (31.60[e])	31.60	31.60	105.20***	30.00	30.00	92.30***
State Share (7.11)	14.80	15.10	31.20***	13.10	15.20	38.29***
Federal Share (24.49)	11.0	10.50	68.40***	12.10*	9.80*	48.36***

[a] Change from DDF1 Base Case: * 10 to 50%; ** 50 to 100%; *** more than 100%.
[b] This Base Case varies slightly from the Base Case presented in Part I of this Report. It utilizes the DDF2 Risk Index and includes Washington, DC in the calculations.
[c] Same as Base Case DDF1.
[d] MP goal is reduction of risk equal to the lesser of 50% of risk and the state's Deductible.
[e] Values in parentheses are status quo burdens.

Table II-4. Summary Table of Simulations of DDF2 Assumptions and Parameters: Sensitivity Tests

(change from DDF1 Base Case in millions of 2015 dollars for Adjusted Deductible, State Response Analysis and Burden Analysis)[a]

Variable	DDF1 Base Case[b] (1)	DDF2 Base Case PA Risk; PD+GI BCRs (2015) (2)	DDF2 PA Risk; PD+GI BCRs (2035) (3)	DDF2 Declining PDO BCRs (2015) (4)	DDF2 Declining PDO BCRs (2035) (5)	DDF2 Full BCRs (2015) (6)	DDF2 25 Fiscal Capacity: 75 Risk Weights (2015) (7)
MS							
Fiscal Index	0.98	0.90	0.94	0.90	0.90	0.90	0.90
Risk Index	2.18	same[c]	2.30	same	same	same	same
Combined Index	1.58	1.54	1.62	1.54	1.54	1.54	1.86*
Adjusted Deductible	28.61	28.00	47.16**	28.00	28.00	28.00	34.68*
State Response (MP) Analysis[d]							
Mitigation Exp	2.81	5.46**	12.42***	2.37*	0.70**	3.40*	7.66***
Insurance/Relief Fund Exp	4.51	0.00***	0.00***	0.00***	11.40***	0.00***	0.00***
Resilience Exp	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Burden Analysis							
Expected Loss (311.87[e])	311.87	311.87	332.53	311.87	311.87	311.87	311.87
State Share (70.17)	89.60	81.50	98.60*	85.60	90.40	84.20	83.00
Federal Share (214.70)	229.60	221.80	231.80	214.70	219.60	217.00	219.20
OH							
Fiscal Index	1.07	1.08	1.02	1.08	1.08	1.08	1.08
Risk Index	0.80	same	0.87	same	same	same	same
Combined Index	0.94	0.94	0.95	0.94	0.94	0.94	0.87
Adjusted Deductible	16.91	17.13	27.57**	17.13	17.13	17.13	16.26
State Response (MP) Analysis[d]							
Mitigation Exp	2.66	2.56	4.44**	1.12**	0.00***	2.14*	2.43
Insurance/Relief Fund Exp	0.00	0.00	0.00	0.00	8.57***	0.00	0.00
Resilience Exp	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Burden Analysis							
Expected Loss (31.60[e])	31.60	31.60	32.31	31.60	31.60	31.60	31.60
State Share (7.11)	14.80	15.10	19.60*	16.98*	20.40*	15.60	14.70
Federal Share (24.49)	11.0	10.50	3.30**	7.17*	11.20	9.60*	11.20

[a] Change from DDF1 Base Case: * 10 to 50%; ** 50 to 100%; *** more than 100%.
[b] This Base Case varies slightly from the Base Case presented in Part I of this Report. It utilizes the DDF2 Risk Index and includes Washington, DC in the calculations.
[c] Same as Base Case DDF1
[d] MP goal is reduction of risk equal to the lesser of 50% of the risk and the state's deductible.
[e] Values in parentheses are status quo burdens.

25%.[39] Finally, to the extent that the selection of the Basel Deductible is, in some ways, arbitrary, consistency with the DDF in Part I allows a clearer comparison of the results presented in Part II.[40]

B. Fiscal Capacity Index

The Fiscal Capacity Index reflects a state's ability to build disaster response capacity, and to plan for disasters (GAO, 2012). In the DDF2 Base Case, we construct the Fiscal Capacity index on the basis of three indicators: State General Fund, State Reserve (Rainy Day) Fund, and the State Bond Rating (see the basic data for these indicators in Appendix II-A). The General Fund is a good proxy for the discretionary funds available to states to finance the deductible, as well as any disaster-related activities such as mitigation, purchasing disaster insurance for public facilities, and establishing a relief fund. The Rainy Day Fund may provide a source of support to pay for post-disaster emergency expenses. Finally, Bonding capacity may be called upon if the state issues post-disaster debt obligations.

We first computed the indices for the individual Fiscal Capacity indicators using the following formulas (subscript *i* represents individual state):

1. Per Capita General Fund Index

$$Per\ Capita\ General\ Fund_i = \frac{General\ Fund_i}{Population_i} \quad (1)$$

$$Per\ Capita\ General\ Fund\ Index_i = \frac{Per\ Capita\ General\ Fund_i}{Median\ Per\ Capita\ General\ Fund} \quad (2)$$

2. Per Capita Reserve Fund Index

$$Per\ Capita\ Reserve\ Fund_i = \frac{Reserve\ Fund_i}{Population_i} \quad (3)$$

$$Per\ Capita\ Reserve\ Fund\ Index_i = \frac{Per\ Capita\ Reserve\ Fund_i}{Median\ Per\ Capita\ Reserve\ Fund} \quad (4)$$

3. Bond Rating Index

$$Bond\ Rating\ Index_i = \frac{Bond\ Rating_i}{Median\ Bond\ Rating} \quad (5)$$

The first three numerical columns in Table II-5 present the values of the indices of the three Fiscal Capacity indictors for the 50 states and DC. In Column 4, we computed the simple average of the three fiscal capacity indices, which represents an application of equal weights in integrating the three indices into one overall index.[41] The overall Fiscal Capacity Index ranges from 0.53 in Michigan to 79.46 in Alaska (mainly due to its high per capita Reserve Fund Index).

[39] $26.9M / $106M x 100 = 25.38%

[40] The baseline deductible is arbitrary in the sense that there is not an optimal deductible or a corollary to a market deductible in the presence of federally subsidized insurance.

[41] In the Visualization Tool, we will provide the capability to adjust the weights of these indices.

We also performed a sensitivity analysis on the Fiscal Capacity Index, in which we use only the state General Funds to construct the index. The values of this alternative Fiscal Capacity Index are presented in Column 2 of Table II-5.

In Figure II-1, we compare these three Fiscal Capacity (FC) Indices: DDF1, DDF2 (3 Indicators), and DDF2 (GF only). The figure indicates that the Base Case DDF2 FC Index (based on 3 indicators) is very similar to the DDF1 FC Index, especially for those states that have high Reserve Funds (such as Alaska, North Dakota, and Wyoming). This is largely because, for these states, the very high value of the per capita Reserve Funds index dominates in the calculation of the combined FC index in both the DDF1 Base Case and the DDF2 Base Case. When we construct the FC index based on just the state General Funds, a relatively larger departure from the DDF1 FC index can be observed. This is primarily because there is only a low positive correlation (about 0.2305) between the state General Funds and Reserve Funds.

Table II-5. Fiscal Capacity Indices

	State	Per Capita General Fund Index	Per Capita State Reserve Funds Index	Bond Rating Index	Average of Three Indices
1	Alabama	1.00	0.70	0.96	0.88
2	Alaska	4.19	233.12	1.05	79.46
3	Arizona	0.70	0.81	0.90	0.80
4	Arkansas	0.76	0.02	0.96	0.58
5	California	1.26	0.86	0.60	0.91
6	Colorado	0.74	0.81	0.92	0.82
7	Connecticut	2.35	3.67	0.96	2.32
8	Delaware	1.88	3.66	0.69	2.08
9	DC	4.65	12.43	1.19	6.09
10	Florida	0.66	0.73	1.18	0.86
11	Georgia	0.88	1.17	1.19	1.08
12	Hawaii	1.93	0.67	0.92	1.17
13	Idaho	0.81	1.00	0.99	0.93
14	Illinois	1.00	0.25	0.80	0.68
15	Indiana	1.03	1.02	1.12	1.06
16	Iowa	0.95	3.03	1.15	1.71
17	Kansas	1.03	0.00*	1.07	0.70
18	Kentucky	1.05	0.40	0.84	0.76
19	Louisiana	0.97	2.24	0.78	1.33
20	Maine	1.17	0.82	0.93	0.97
21	Maryland	1.22	2.37	1.19	1.60
22	Massachusetts	2.00	4.44	0.97	2.47
23	Michigan	0.47	0.23	0.88	0.53
24	Minnesota	1.63	2.41	1.17	1.74
25	Mississippi	0.77	0.97	0.96	0.90
26	Missouri	0.68	0.81	1.19	0.89
27	Montana	0.89	0.00*	0.91	0.60
28	Nebraska	0.91	4.38	1.11	2.13

29	Nevada	0.58	0.58	1.01	0.72
30	New Hampshire	0.54	0.47	0.96	0.65
31	New Jersey	1.76	0.46	0.91	1.04
32	New Mexico	1.41	5.51	1.07	2.67
33	New York	1.42	1.12	0.96	1.16
34	North Carolina	1.00	0.92	1.19	1.04
35	North Dakota	1.13	7.98	1.01	3.37
36	Ohio	1.22	0.95	1.07	1.08
37	Oklahoma	0.81	2.44	1.03	1.43
38	Oregon	0.81	0.62	0.96	0.80
39	Pennsylvania	1.07	0.47	0.96	0.83
40	Rhode Island	1.55	2.12	0.94	1.54
41	South Carolina	0.64	0.92	1.09	0.88
42	South Dakota	0.71	2.76	1.00	1.49
43	Tennessee	0.88	1.25	1.05	1.06
44	Texas	0.78	2.92	1.03	1.58
45	Utah	0.85	1.98	1.19	1.34
46	Vermont	0.92	1.76	1.07	1.25
47	Virginia	1.01	1.55	1.19	1.25
48	Washington	1.08	0.40	1.04	0.84
49	West Virginia	1.09	5.96	0.90	2.65
50	Wisconsin	1.20	0.13	0.91	0.75
51	Wyoming	2.71	17.70	1.06	7.16
	Standard Deviation	**0.80**	**32.49**	**0.13**	**10.99**

*According to the National Association of State Budget Officers (2015), Kansas and Montana have no Reserve Fund.

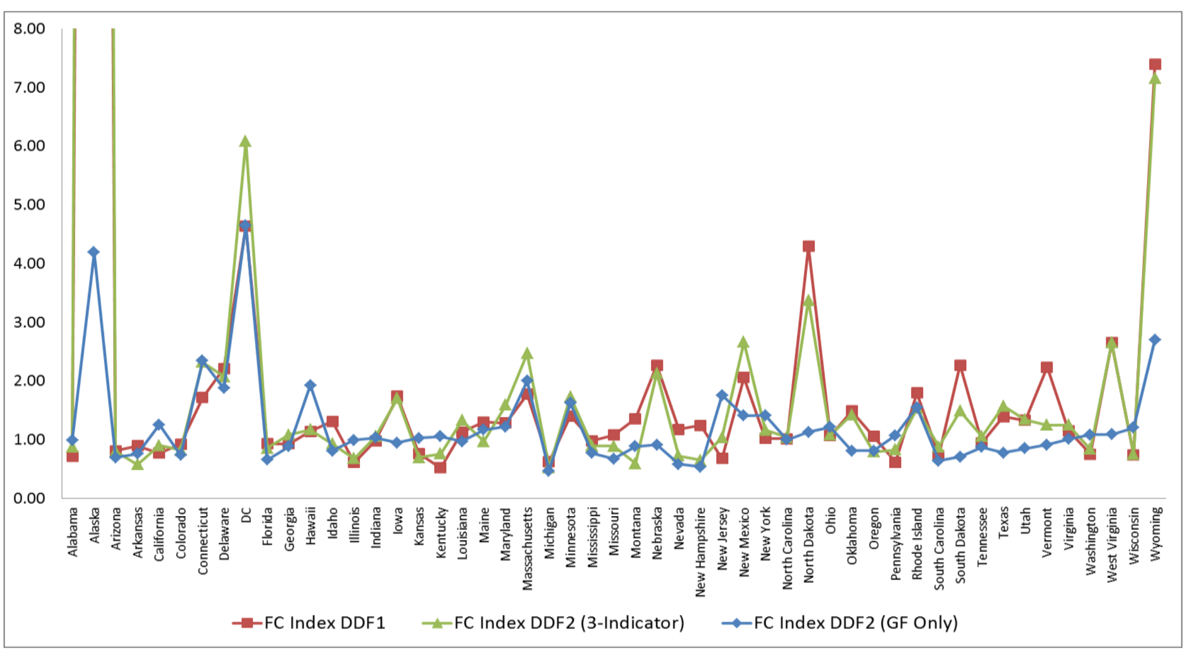

Figure II-1 Comparison of Fiscal Capacity Indices

C. Risk Index

1. Projected Risk Index

For the Base Case DDF of Part II of this Report, we adjust for disaster risk using a different model of estimated disaster risk than was used in Part I. Risk is modeled econometrically, to smooth the effect of large, idiosyncratic disaster events (see details in Appendix II-B). A state's Risk Index is driven by the frequency with which it experiences disasters and the magnitude of the disaster event, as well as state characteristics like gross state product and infrastructure.[42]

The Disaster Deductible is designed to be a multi-year policy tool, reflective of the fact that disasters occur infrequently and the benefits of mitigation are often realized over a period of decades. Because of the long-run nature of the DDF, it is important to consider how the Risk Index (and therefore the Deductible) changes over time as disaster risk evolves.

In order to account for these changes, we project disaster risk from the Year 2015 to 2035 and recalculate the Risk Index in each interim year. Risk is modeled as a function of disaster frequency, disaster magnitude, gross state product, and state infrastructure.[43] Future disaster risk can be predicted by substituting future values of the explanatory variables into the estimating equation. Because projections of our disaster magnitude measures are unavailable we focus on the change in disaster risk that arises because of changes in gross state product. This can be interpreted as the increase in PA needs resulting from the increase in the amount and stock of assets that are vulnerable to disasters, as well as increased labor costs associated with higher economic activity.

Because gross state product projections are no longer tabulated by the Bureau of Labor Statistics, we use the population growth rate as a proxy for the growth rate in gross state product.[44] Risk is projected for hurricanes, severe storms, and floods by using the projected gross state product value in the reduced form risk equations. Earthquake events are not modeled econometrically, so for these events we calculate the weighted-average growth rate of hurricanes, severe storms, and floods at the state level, and apply this growth rate to earthquake risks in that state.

Risk Indices, calculated for each year between 2015 and 2035, are presented in Figure II-2. Total risk is calculated by summing risk across hurricane, severe storm, flood, and earthquake risks, and the Risk Index is calculated for each state by dividing total risk by the median amount of total risk across all 50 states and DC.

[42] The magnitude of the disaster event is expressed in objective terms such as hurricane wind speed or earthquake magnitude, rather than in dollar terms.

[43] While the deductibles should change over time as mitigation reduces expected PA, this requires a time-path analysis of mitigation strategies for each state over multiple years. Moreover, because state deductibles are interrelated by the normalization, it is not possible to incorporate mitigation expenditure in future deductibles for a single state. Calculating the stream of risk reduction strategies for each state over time is beyond the scope of this project.

[44] The correlation between population and gross state product is 0.98.

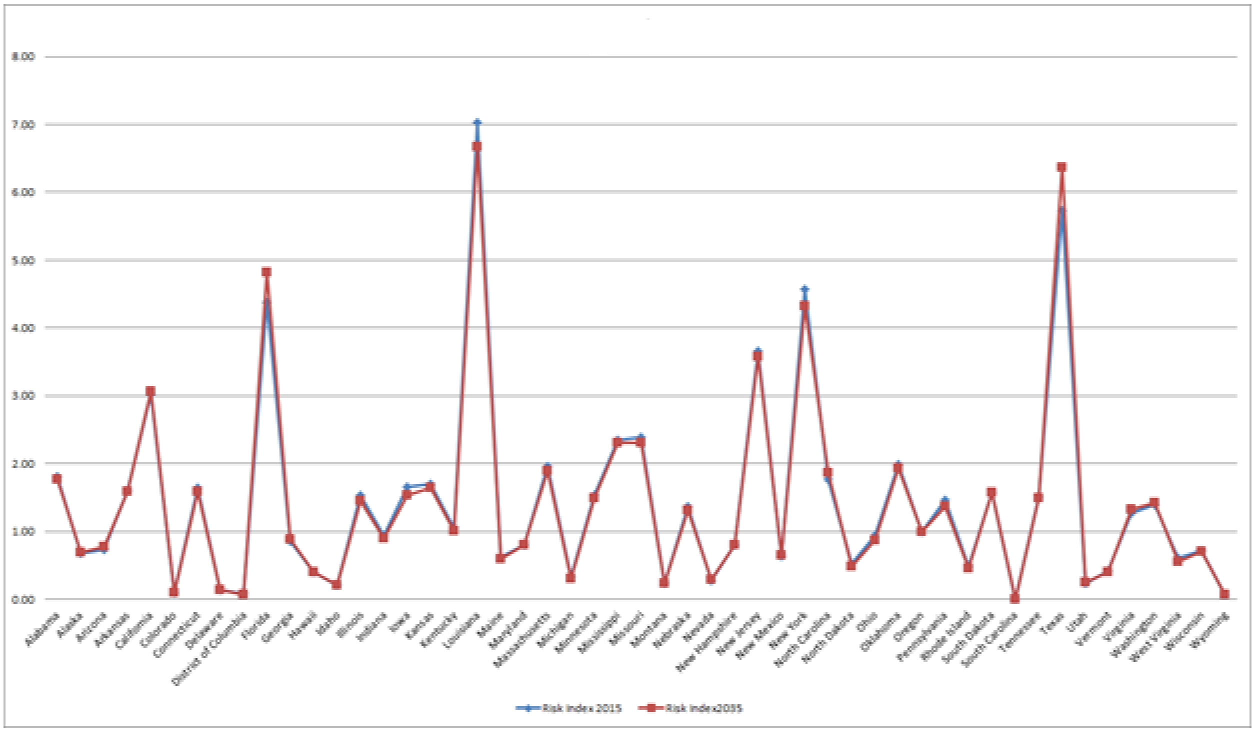

Figure II-2. DDF over Time

Note that Risk Indices are quite similar between 2015 and 2035. This occurs because population growth is only a portion of a state's risk value, disaster magnitude and frequency are assumed to be constant, and because the difference between population growth in a high-growth state and a low-growth state are relatively similar in absolute terms. Still, there is a noticeable effect over time. The Risk Index increases for sun-belt states like Florida and Texas that are projected to have faster than average population growth, while the Risk Index falls for states like Iowa, Kansas, Louisiana, and New York that are projected to have below average population growth.

These results suggest both that the Disaster Deductible need not be updated frequently – because the underlying components of the disaster estimating equation change slowly – and that disaster magnitude and frequency projections should be considered in a thorough projection of the disaster deductible.

2. Incorporating Fatalities

Our previous consideration of the DDF has focused primarily on property damage, and the construction of the risk index is reflective of this decision. In a larger consideration of instituting a deductible for post-disaster aid, it is important to consider other risks, such as loss of human life from disasters. Because the value of a statistical life is quite high – the Department of Transportation currently uses a value of $9.1 million (DOT, 2013) – loss of life could prove to be an important component of risk reduction. Moreover, it may vary significantly from state to state.

In order to assess the potential importance of human life in the calculation of the Risk Index, we incorporated fatalities using the National Weather Service's (NWS) database of Storm-related fatalities (see Appendix II-C for the basic data). The NWS tabulates information on storm damages and fatalities from a variety of sources, including federal, state, and local government agencies. While the NWS has been reporting storm damages since 1950, we limit our analysis to the period between 2005 and 2014 in order to match our analysis of PA risk. The NWS reports 4,481 storm events that resulted in deaths between 2005 and 2014, totaling 8,073 deaths. The NWS database does not include injuries so to the extent that injuries cause financial damage, we are underestimating the mortality and injury related costs. This will result in a lower deductible for high human-injury states and a higher deductible for low human-injury states relative to the deductible if injury was taken into account.

Total Risk was calculated by adding average annual value of lives lost (# of fatalities * 9.1 million) to average annual PA.[45] Incorporating human life induces large changes in the Risk Index, particularly for states that experienced very deadly disaster events, such as the 2011 tornados in Alabama. Figure II-3 shows the Risk Index with and without mortality components. Most states experience relatively minor changes. However, there are large changes in states that experienced particularly deadly events, and in states that experienced events that resulted in substantial amounts of federal PA.[46]

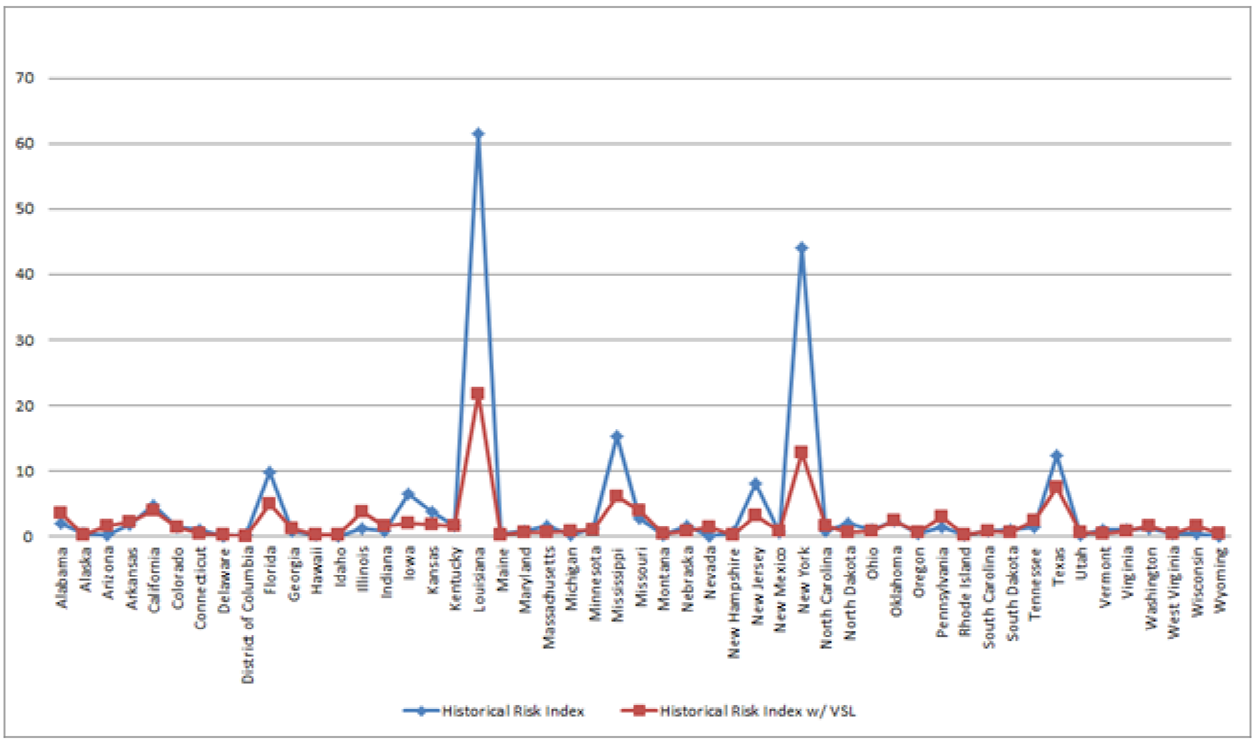

Figure II-3. State Risk Index with and without Fatalities

[45] A lower value of a statistical life – such as the $6.6 million number suggested in Security Notes (2014) – would result in higher Risk Index numbers for high-PA states such as Louisiana and lower Risk Index numbers for low-PA/high-fatality states such as Arizona.

[46] This analysis uses *historical* rather than *modeled* PA, which results in big spikes from big events. That is why these fatality-adjusted Risk Index numbers differ from those of DDF1.

We offer a caveat about the accuracy of the fatality count of the events included in our tabulations. This NWS data is not a 1-to-1 mapping with our PA dataset. The NWS contains many events that are not disaster declarations, and it is possible that there are FEMA disasters that do not show up in the NWS database. It appears that the NWS will contain more deaths associated with smaller events (heat waves, for example) than the set of FEMA disasters.

3. Incorporating Business Interruption

While FEMA PA is primarily thought of as a response to property damage, about 35% of the PA expenditure is actually used to reduce interruption due to disasters. For example, removing debris and clearing roads is not directly related to property damage, but rather to allowing commerce and government functions to continue. In order to account for these risks, we calculate the risk associated with business and government interruption. Business interruption (BI) is calculated by multiplying modeled PA by the ratio of total capital to state GDP, while government interruption (GI) is calculated by multiplying modeled PA by the ratio of government capital to state government expenditures. BI and GI are discussed in more detail in Sections IV-C and V-A below and the calculation of GI risk is presented in detail in Appendix II-E.

The resulting Risk Indices are shown in Figure II-4, and indicate the indices for these two types of risk are very close. Large differences occur only when a state-government spends substantially more or less than other states relative to its capital base. Note that the modeled risk shown in blue is adjusted for underestimation in order to keep BI and GI consistent with the scale of PA.

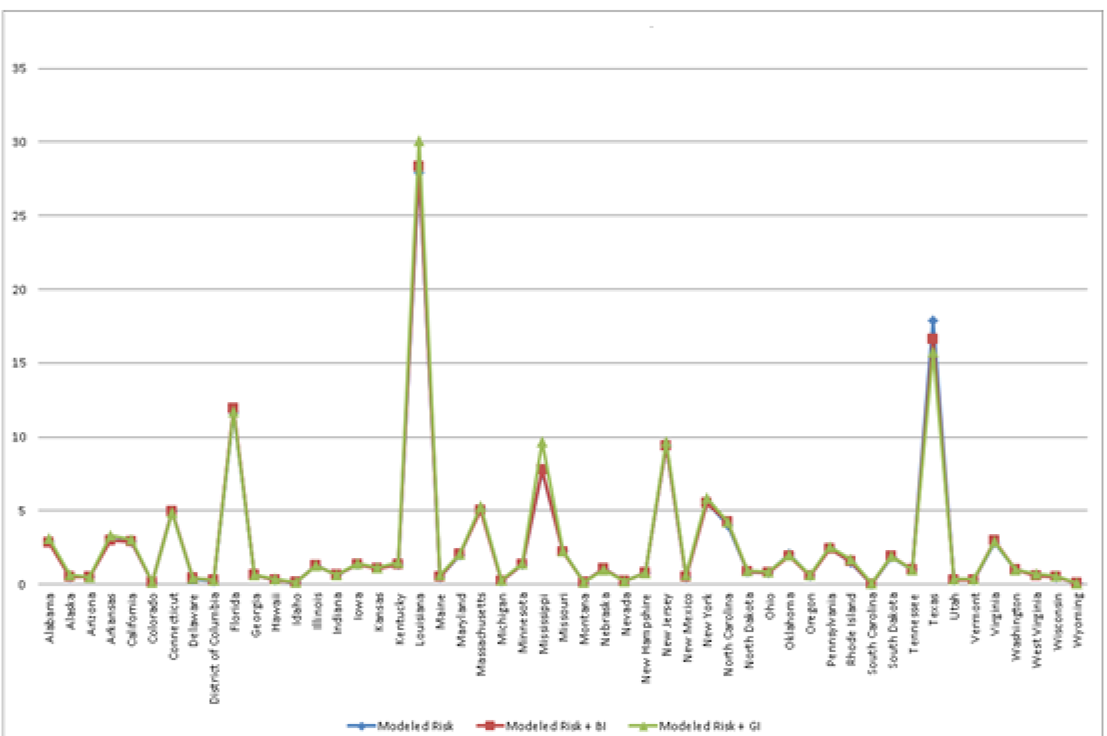

Figure II-4. Risk Index with Business Interruption and Government Interruption

D. Combined Index and Adjusted Disaster Deductible

As in the DDF1 report, for DDF2, we calculate a state's Combined Base Case Index (i.e., with respect to property damage only at this point) as the simple average of its Risk and Fiscal Capacity Indices, though these differ from DDF1, as presented in sub-sections I-B and II-C. The Combined Index and the Baseline Deductible are multiplied in order to obtain the Adjusted Deductible. The Adjusted Deductible is then capped at $138.6M (the 95th percentile of disaster events) and normalized so that its average is equal to the Baseline Deductible. Figure II-5 presents the Normalized Deductibles for each state in 2015 and in 2035 under DDF2, compared with the Normalized Deductible under the DDF1. Note that in 2015 the Baseline Deductible is set at $26.9M, the median 10-year average annual PA, while in 2035 the Baseline Deductible is set at $42.5M, the median projected annual PA across the states in 2035.

Normalized Deductibles under DDF1 and DDF2 are strikingly similar. DDF2 versions are generally higher in 2035 than in 2015. This is not surprising because the Baseline Deductible increased over time. The increase in Normalized Deductibles is most noticeable in high population growth states like Texas and Florida. This occurs because projections of the growth rate in PA are tied to population growth. Similarly, states like South Dakota, which are projected to have below average population growth rates, are projected to have lower Normalized Deductibles in 2035 than in 2015.

As shown in Figure II-6, inclusion of fatalities in the construction of the Risk Index can result in relatively large changes in Normalized Deductibles. This is particularly true in states that have relatively low PA from disasters, because even a single death can substantially increase their total costs from disasters. Still, the effect of including fatalities in the Risk Index is small in relation to the difference between DDF2 Normalized Deductibles in 2015 and in 2035.

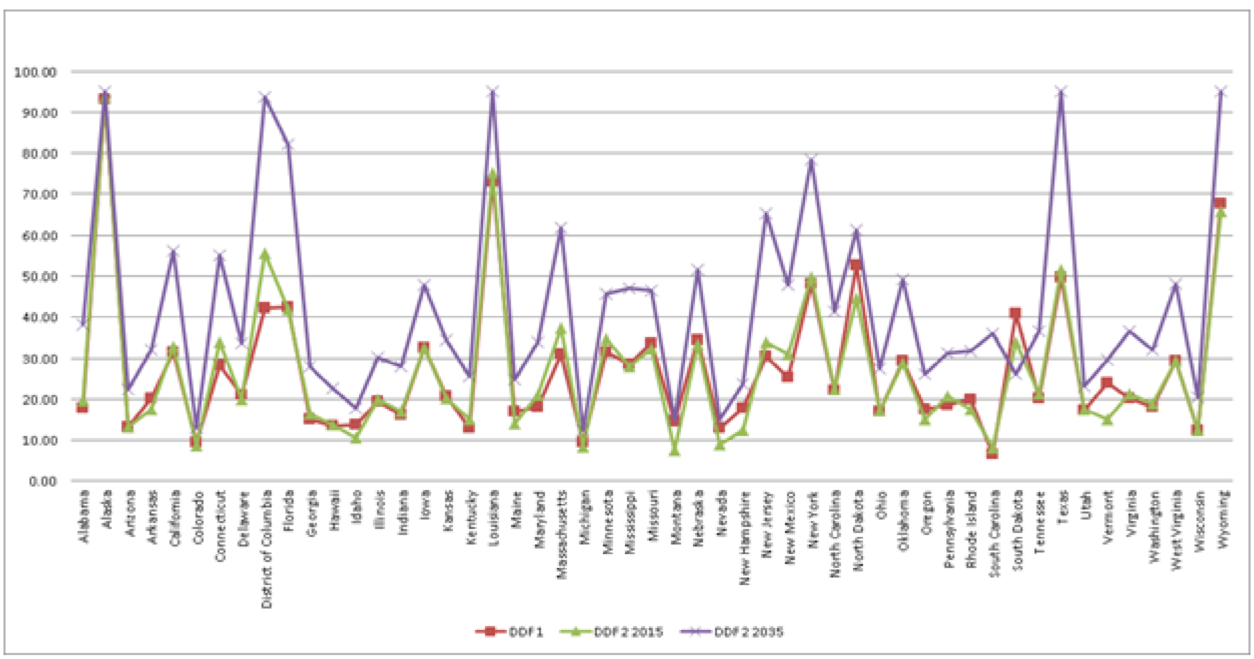

Figure II-5. Comparison of Disaster Deductibles over Time

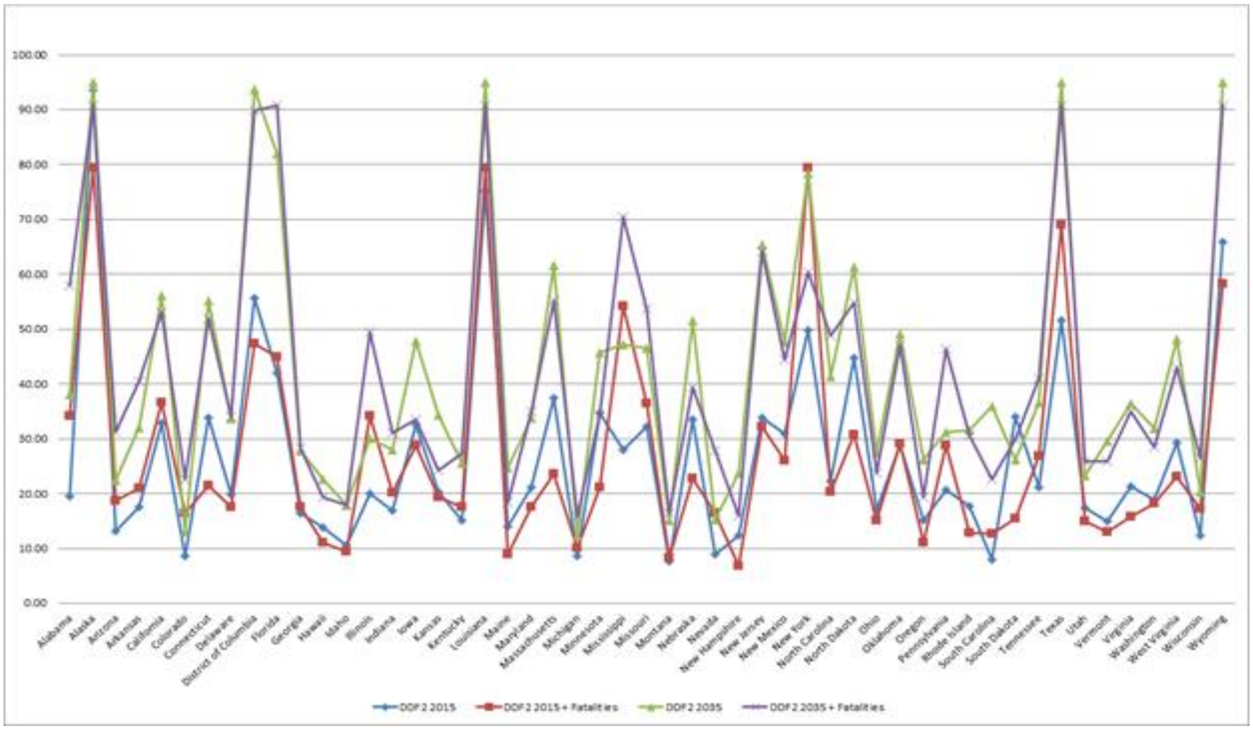

Figure II-6. Comparison of Disaster Deductible with Fatalities

IV. Deductible Credit Eligibility Implications -- Mitigation

In Part I of the Report, we developed an analytical framework and practical method for estimating the state response to the proposed Deductible/Credit System. This framework stipulated to alternative objectives that states would pursue:

- Reduction in state risk
- Attainment of credit against the Deductible

There is insufficient data and prior analysis to determine precisely which of these goals states will pursue and at what levels. Therefore, we established the base case that states would engage in activities so as to achieve 50% each of these objectives, though separately and mutually exclusively (the former is also limited to spending that does not exceed the value of the state's Deductible). Also, it was not known whether states would be so incentivized as to attempt to fully achieve either of these goals. Therefore, we established as the base case a pursuit of 50% of these objectives. Sensitivity cases are performed for alternative levels of 25% and 75%.

The means by which states retain their objectives include various risk reduction strategies, which are the subject of this section. These include mitigation, which refers to pre-disaster activities to reduce the frequency and magnitude of disaster impacts, with the primary focus on property damage, but with the ability also to reduce deaths and injuries, and interruption of government activities. It also includes post-disaster activities that would place under the heading of Resilience[47] (see further discussions in Section V). It also includes risk-spreading options (though they are risk reducing for state governments) of Insurance and Relief Funds. Thus, we take a broader view of risk in DDF2 than we did in DDF1 by considering the reduction in risk of fatalities and government interruption. Of course, there are many real world impediments to the full realization of disaster reduction strategies (broader categories of loss reduction activities, such as mitigation, resilience, insurance, and relief funds) and of individual tactics under each strategy (specific actions such as structural reinforcement of buildings, buyouts of properties in floodplains, relocation of government activities, and purchase of emergency electricity generating equipment). These are taken into account as well by constraints on the potential of each strategy or tactic.

The ability and cost of each strategy or tactic to achieve a unit of risk reduction is reflected in a benefit-cost ratio (BCR). The BCRs for mitigation are initially taken from the *Mitigation Saves* Study (MMC, 2005). We also adjust the BCR's for government interruption (GI) and for resilience activities intended to also reduce GI. This need not be dollar-for-dollar, and is a strong policy lever for FEMA to utilize in steering their incentives in certain directions. For example, it would be reasonable to offer a higher credit for mitigation, which actually does reduce losses, than for insurance and relief funds, which only spread the risk, as we have assumed in this Report (see Section II-A).

To quantify the analysis, we have placed the various aspects just discussed into a Mathematical Programming (MP) framework. This is a valuable modeling approach that explicitly and transparently stipulates objectives, capabilities of achieving objectives, and constraints into a consistent computational framework. It assumes that states optimize the attainment of their objectives through the choice of a mix of strategies and tactics available to them subject to constraints. The results of the MP analyses provide estimates of the extent to which objectives are met, the choice of strategies/tactics, and their costs (the reader is referred to Part 1 of this Report for more details of the modeling).

A. Mitigation Spending on Property Damage Reduction

1. MP Analysis

As mentioned in the earlier section, federal public assistance (PA) covers spending on two broad categories post-disaster: Emergency work, which is debris removal and protective measures, and Permanent work, which is primarily repair and reconstruction of public facilities and buildings. The latter may be broadly termed spending to cover property damage. The former relates to maintaining critical government functions and accelerating their recovery.

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[47] Many analysts use the term *resilience* to cover any reduction in losses from disasters; however, we consider the term *mitigation* to adequately cover actions accomplished pre-disaster and confine resilience to cover actions taken following the disaster. We also note, however, that resilience is a process, and that resilience capacity can be enhanced prior to the disaster, so post-disaster refers to the implementation of resilience (Rose, 2009b). Furthermore, because FEMA Public Assistance pertains to Emergency work following the disaster, we need not address the capacity building aspect for our purposes -- PA for disasters that have already taken place.

Table II-6 presents the MP results for the risk reduction goal for Year 2015. Summary tables that present the basic data and parameters used in the MP analysis are presented in Appendix II-F. Losses are expected public assistance, which includes both property damage, and emergency work, which we are assuming, at this point is a proxy for government interruption.[48] Because of this combination of two loss categories, we use a BCR that includes both property damage and GI. The example states are Mississippi and Ohio. The MP analysis uses the 2015 modeled losses by threat as the constraints (i.e., risk reduction from each individual strategy cannot exceed 50% of the maximum risk of the relevant threat type). Compared with the DDF1 Base Case, the differences in this DDF2 Base Case are the use of the new three-indicator fiscal capacity index, and the use of a BCR that includes both the property damage reduction from mitigation but also the government interruption reduction from keeping more buildings and infrastructure intact. On the one hand, by using the new three-indicator fiscal capacity index, the resulting state Adjusted Deductibles for both MS and OH in the DDF2 Base Case are slightly higher than those in DDF1 Base Case. When the state adjusted deductible is lower than the state total expected losses (risks), which is the case for both MS and OH, the objective function in the MP analysis becomes the state reducing 50% of the Adjusted Deductible. However, on the other hand, the DDF2 Base Case uses higher BCRs for mitigation, which combine both property damage reduction and GI reduction from mitigation. Therefore, comparing to DDF1 Base Case, less needs to be spent by the state to achieve the risk reduction target. The expenditure of MS reduces from $7.32 in DDF1 Base Case to $5.46 million in DDF2 Base Case, while the expenditure of OH reduces from $2.66 to $2.56 million.

Table II-6. MP Analysis of DDF2, Year 2015 – Mississippi and Ohio
(50% risk reduction, PA Risk; Property Damage Plus GI BCRs for Mitigation, in million dollars)

	MP Analysis – 50% Risk Reduction			
	Mississippi		Ohio	
Strategy	**Expenditure**	**Risk Reduction Attained**	**Expenditure**	**Risk Reduction Attained**
Mitigation				
Hurricanes	2.76	4.20		
Floods	0.54	2.60		
Severe Storms	2.16	7.20	2.56	8.57
Earthquakes				
Other				
Insurance/Relief Fund				
Hurricanes				
Floods				
Severe Storms				
Earthquakes				
Other				
Total	5.46	14.00	2.56	8.57

[48] A more detailed discussion of government interruption appears in Sections IV-C and V-A.

Table II-7 presents the MP results for the 50% risk reduction case for Year 2035 simulated based on the projected public assistance in 2035 and property damage plus GI BCRs for Mississippi and Ohio. Compared with the Year 2015 simulation results, since the state Adjusted Deductible increases from $28.00 million to $47.16 million for MS and from $17.13 million to $27.57 million for OH, the total expenditure for MS increases from $5.46 million to $12.42 million and from $2.56 million to $4.44 million for OH to achieve the risk reduction target.[49]

Table II-7. MP Analysis of DDF2, Year 2035 – Mississippi and Ohio (50% risk reduction, PA Risk; Property Damage Plus GI BCRs for Mitigation, in million dollars)

	MP Analysis – 50% Risk Reduction			
	Mississippi		Ohio	
Strategy	Expenditure	Risk Reduction Attained	Expenditure	Risk Reduction Attained
Mitigation				
Hurricanes	10.00	15.21	0.58	0.88
Floods	0.21	1.00		
Severe Storms	2.21	7.38	3.59	12.00
Earthquakes				
Other			0.27	0.91
Insurance/Relief Fund				
Hurricanes				
Floods				
Severe Storms				
Earthquakes				
Other				
Total	12.42	23.58	4.44	13.79

2. Burden Analyses

The burden analysis shows the impact of the DDF on state and federal spending under specific conditions. The burden analysis is informed by the results of the MP analysis above. Table II-8 shows the impact of the DDF2 on Mississippi and Ohio considering the property damage only benefits of mitigation under the conditions of the DDF2 described above, and taking the parameters from the MP analysis. The results for the base case of DDF1 are presented as a reference.

Section A of the table shows the current situation with expected annual losses and total public assistance spending and the shares covered by FEMA, and the state's share calculated at the average of 22.5%. Section B shows the situation if the deductible only were charged to the state, while Section C shows the effect of mitigation on expected losses and the effect of credits on the deductible and overall state spending.

[49] See Section IV-C4 for a discussion of the year 2035 risk levels used in the analysis.

Table II-8 Burden Analysis for DDF2 – Mississippi and Ohio, Property damage and Gov't Interruption BCRs (50% risk reduction)				
	Expenditures ($millions)			
	Mississippi		Ohio	
	DDF1	DDF2	DDF1	DDF2
	(1)	(2)	(3)	(4)
A. Status Quo				
Total expected losses	311.9	311.9	31.6	31.6
State share of expected losses	70.2	70.2	7.1	7.1
Federal share of expected losses	241.7	241.7	24.5	24.5
B. Deductible only				
Total expected losses	311.9	311.9	31.6	31.6
State deductible	28.6	28.0	16.9	17.1
PA after state pays deductible	283.3	283.9	14.7	14.5
State share of remaining PA	63.7	63.9	3.3	3.3
State total spending (deductible + state share)	92.3	91.9	20.2	20.4
Federal PA	219.5	220.0	11.4	11.2
Change in State burden	22.2	21.7	13.1	13.3
Change in Federal burden	-22.2	-21.7	-13.1	-13.3
C. Mitigation with DDF credit				
Total expected losses	311.9	311.9	31.6	31.6
Spending on mitigation	2.8	5.5	2.7	2.6
Insurance premiums	4.5	0.0	0.0	0.0
Additions to relief fund	0.0	0.0	0.0	0.0
Reduction in PA from expenditures	14.3	14.0	8.5	8.6
Total actual PA	297.6	297.9	23.1	23.0
State deductible less credit	15.7	11.6	8.9	9.4
PA less deductible	281.9	286.2	14.2	13.6
State share of remaining PA	63.4	64.4	3.2	3.1
State total spending (mitig. + deduct. + state share)	86.4	81.5	14.8	15.1
Federal PA	218.5	221.8	11.0	10.5
Change in State burden from status quo	16.2	11.3	7.7	8.0
Change in State burden relative to deductible only	-5.9	-10.4	-5.4	-5.3
Change in Federal burden from status quo	-23.2	-19.9	-13.5	-14.0
Change in Fed. burden relative to deductible only	-1.1	1.8	-0.4	-0.7

Comparisons are to DDF1 Base Case, for which risk level equals Public Assistance (composed of property damage and non-property damage as a proxy for government interruption).

Comparing the base case DDF1 with the base case DDF2 for Mississippi (columns 1 and 2) we see some difference in the impacts of the formulas. There is a shift away from insurance to using all mitigation, which causes different impacts due to the different credits each strategy applies. Comparing the base case DDF1 with the base case DDF2 (columns 3 and 4) for Ohio we see very little difference in the impacts of the formulas.

Regarding the role of multipliers in the choice of optimal strategy (MP analysis) and the impact of those strategies on state and federal spending (Burden analysis), there is some distinctions to note. The MP analysis achieves the goal of risk reduction equal to 50% of the deductible or expected loss, whichever is smaller using the loss multipliers associated with strategies (the BCRs), and doesn't consider the credit multipliers associated with those strategies. However, the Burden analysis does consider the credit multipliers to calculate the net deductible, and hence total state spending, given the optimal expenditures determined by the MP analysis.

Table II-9
Burden Analysis for DDF2 – Mississippi and Ohio, Property damage Plus GI BCRs 2015 and 2035 (50% risk reduction)

	Expenditures ($millions)			
	Mississippi		**Ohio**	
	2015 Base Case	2035 Base Case	2015 Base Case	2035 Base Case
	(1)	(2)	(3)	(4)
A. Status Quo				
Total expected losses	311.9	332.5	31.6	32.3
State share of expected losses	70.2	74.8	7.1	7.3
Federal share of expected losses	241.7	257.7	24.5	25.0
B. Deductible only				
Total expected losses	311.9	332.5	31.6	32.3
State deductible	28.0	47.2	17.1	27.6
PA after state pays deductible	283.9	285.4	14.5	4.7
State share of remaining PA	63.9	64.2	3.3	1.1
State total spending (deductible + state share)	91.9	111.4	20.4	28.6
Federal PA	220.0	221.2	11.2	3.7
Change in State burden	21.7	36.5	13.3	21.4
Change in Federal burden	-21.7	-36.5	-13.3	-21.4
C. Mitigation with DDF credit				
Total expected losses	311.9	332.5	31.6	32.3
Spending on mitigation	5.5	12.4	2.6	4.4
Insurance premiums	0.0	0.0	0.0	0.0
Additions to relief fund	0.0	0.0	0.0	0.0
Reduction in PA from expenditures	14.0	23.6	8.6	13.8
Total actual PA	297.9	309.0	23.0	18.5
State deductible less credit	11.6	9.9	9.4	14.2
PA less deductible	286.3	299.1	13.6	4.3
State share of remaining PA	64.4	67.3	3.1	1.0
State total spending (mitig. + deduct. + state share)	81.5	89.6	15.1	19.6
Federal PA	221.8	231.8	10.5	3.3
Change in State burden from status quo	11.3	15.4	8.0	9.9
Change in State burden relative to deductible only	-10.4	-6.3	-5.3	-3.4
Change in Federal burden from status quo	-19.9	-27.0	-14.0	-17.3
Change in Fed. burden relative to deductible only	1.8	-5.3	-0.7	-4.0

Comparisons are to DDF1 Base Case, for which risk level equals Public Assistance (composed of property damage and non-property damage as a proxy for government interruption).

Comparing the base case DDF2 in 2015 and 2035 for Mississippi in Table II-9 (columns 1 and 2) shows an increased expected annual loss and deductible in Section B, which results in a greater transfer of burden to the state through the deductible only program. Section C highlights the increase in mitigation spending by both states in 2035. There is a transfer of burden toward Mississippi, but little change for Ohio.

B. Mitigation Spending on Fatality Reduction

1. MP Analysis

Table II-10 presents the MP results for the 50% risk reduction case for Year 2015 simulated based on the property damage and government interruption BCRs plus human casualty BCRs for Mississippi and Ohio. In this simulation, the expected losses are the sum of expected public assistance and losses from fatalities. After integrating fatality into consideration, the adjusted deductible for MS increases from $28.00 million in the DDF2 Base Case to $54.22 million in this case, while OH decreases from $17.13 million to $15.10 million.[50] This results in increased risk reduction expenditures for MS (from $5.46 to

Table II-10. MP Analysis of DDF2, Year 2015 – Mississippi and Ohio (50% risk reduction, PA Risk Plus Fatality Losses; Property Damage Plus Fatality BCRs for Mitigation, in million dollars)

	MP Analysis – 50% Risk Reduction			
	Mississippi		Ohio	
Strategy	Expenditure	Risk Reduction Attained	Expenditure	Risk Reduction Attained
Mitigation				
Hurricanes	2.09	8.15		
Floods	1.01	5.03		
Severe Storms	3.48	13.94	1.89	7.55
Earthquakes				
Other				
Insurance/Relief Fund				
Hurricanes				
Floods				
Severe Storms				
Earthquakes				
Other				
Total	6.58	27.11	1.89	7.55

[50] Note that the deductible can decline because each state's Risk Index depends on the median value of risk across all states. A state might have higher expected damages (PA + fatalities) but receive a lower deductible if the percentage increases in median expected damages in high. Further, a state might receive a lower deductible if other states are relatively more impacted by fatalities – leading to a greater normalization effect.

$6.58 million) and decreased expenditures for OH (from $2.56 to $1.89 million) to achieve the risk reduction target. However, the mix of risk reduction strategies for both MS and OH remains the same as in the DDF2 Base Case.

2. Burden Analysis

The comparison of the DDF2 base case of PA losses only with the case of adding fatality reduction for mitigation is presented in Table II-11.

Table II-11
Burden Analysis for DDF2 – Mississippi and Ohio, Property damage only and fatality BCRs (50% risk reduction)

	Expenditures ($millions)			
	Mississippi		Ohio	
	2015 Base	2015 PA + fatal.	2015 Base	2015 PA + fatal.
	(1)	(2)	(3)	(4)
A. Status Quo				
Total expected losses	311.9	603.5	31.6	105.2
State share of expected losses	70.2	135.8	7.1	23.7
Federal share of expected losses	241.7	467.7	24.5	81.5
B. Deductible only				
Total expected losses	311.9	603.5	31.6	105.2
State deductible	28.0	54.2	17.1	15.1
PA after state pays deductible	283.9	549.3	14.5	90.1
State share of remaining PA	63.9	123.6	3.3	20.3
State total spending (deductible + state share)	91.9	177.8	20.4	35.4
Federal PA	220.0	425.7	11.2	69.8
Change in State burden	21.7	42.0	13.3	11.7
Change in Federal burden	-21.7	-42.0	-13.3	-11.7
C. Mitigation with DDF credit				
Total expected losses	311.9	603.5	31.6	105.2
Spending on mitigation	5.5	6.6	2.6	1.9
Insurance premiums	0.0	0.0	0.0	0.0
Additions to relief fund	0.0	0.0	0.0	0.0
Reduction in PA from expenditures	14.0	27.1	8.6	7.6
Total actual PA	297.9	576.4	23.0	97.6
State deductible less credit	11.6	34.5	9.4	9.4
PA less deductible	286.2	541.9	13.6	88.2
State share of remaining PA	64.4	121.9	3.1	19.8
State total spending (mitig. + deduct. + state share)	81.5	163.0	15.1	31.2
Federal PA	221.8	420.0	10.5	68.4
Change in State burden from status quo	11.3	27.2	8.0	7.5
Change in State burden relative to deductible only	-10.4	-14.8	-5.3	-4.2
Change in Federal burden from status quo	-19.9	-47.7	-14.0	-13.2
Change in Fed. burden relative to deductible only	1.8	-5.7	-0.7	-1.5

Comparisons are to DDF1 Base Case, for which risk level equals Public Assistance (composed of property damage and non-property damage as a proxy for government interruption).

For Mississippi, the comparison of the base case DDF2 with DDF2 including fatality reductions (columns 1 and 2) for year 2015 shows a substantial increase in expected losses in Section A, with a corresponding increase in state share under the status quo. Section C reveals an increase in mitigation spending, which generates a larger credit. However the credit is not enough to offset the increase in deductible and so the remaining deductible increases from $11.6 million to $34.5 million. The state burden increases due to increased mitigation spending, increased remaining deductible and increased PA, assuming it covers these losses, which must be shared with FEMA. Compared to the status quo, the state burden increases compared to the base case (from +$11 million to +$27 million). The federal burden decreases compared to the base case because of the greater burden taken on by the state.

For Ohio, the comparison of the base case with the DDF2 including fatality reductions (columns 3 and 4) for year 2015 shows a substantial increase in expected losses in Section A. However, because of the way the adjusted deductible is calculated, relative to the median deductible, the state deductible falls slightly for Ohio. This causes mitigation spending to be similar to the base case, and the resulting burdens are not substantially different to the base case burdens for Ohio.

C. Mitigation Spending to Reduce Government Interruption

1. Introduction

Until the last decade, natural hazard loss estimation, developed primarily by engineers, focused mainly on property damage, with any other disaster costs generally considered "indirect" or "secondary." However, economists have broadened this framework into what is known as "economic consequence analysis," a major emphasis of which is that disasters incur other major types of costs to society that are no less important (Rose, 2004; 2009a). Property damage represents a reduction of the capital *stock* and generally takes place at a given point in time. However, the capital stock itself does not directly affect the well-being of the citizenry; instead it is the *flow* of goods and services (including government services) produced from the capital stock that does so. Rather than just taking place at a point in time, these flow losses begin when the disaster strikes and continue until a business or the economy has recovered, or reached an alternative goal, typically referred to as a "new normal." These flow losses are typically measured in terms of gross domestic product (GDP), personal income, profits, and employment, but in general are referred to as *business interruption* (BI). Of course, it is legitimate to separate the counterpart pertaining to loss of government services, or *government interruption* (GI).

Also, in fact, both direct stock and flow losses have *indirect* counterparts. Indirect stock losses include ancillary fires or toxic releases. Indirect flow losses refer to ripple, or multiplier, effects up and down the supply chain. Recent events have brought direct and indirect flow losses to the fore.[51] For example, Rose et al. (2009) estimated that the BI losses from the September 11, 2001, World Trade Center attacks of slightly more than $100 billion were four times the property damage, and the vast majority of these

[51] The economic classification system just described for analyzing the cost of disasters is now well developed. It is embodied in major studies such as the *Mitigation Saves* report (MMC, 2005), three National Research Council reports over the last decade (NRC, 2005; 2011; 2012).

losses were of an “off-site” nature associated with a behavioral response (a “fear factor”) manifesting itself in an almost two-year decline in air travel and related tourism.[52] Because BI continues until an economy has recovered to its pre-disaster level, many consider this loss type stemming from Hurricane Katrina continuing to this day.[53]

Actions that take place before an event, typically referred to as *mitigation*, reduce the frequency and magnitude of property damage. Of course, they also have the effect of reducing potential BI and GI, but there is another way to reduce these latter types of losses, even after the disaster has struck: *resilience*. This will be more clearly defined and its potential role in the DDF explained in sub-Section V-A.

Note that mitigation in relation to BI includes all of the following:

- Primacy of preventing property damage, where BI is just a joint product (sometimes not even an intentional one)

- Property damage and BI are equal concerns

- Cases where BI is paramount, such as preventing electricity outages

2. Government Interruption

The question arises as to whether BI covers government interruption (GI):

- Is BI sufficiently comprehensive to include GI?

- Is GI more important for the present study, since it relates more to the focus of Public Assistance?

To answer the first question we note that, while data on BI is extensive, data on GI is not. Government activity is often measured in terms of expenditures or sometimes on a net basis in terms of employee compensation. However, these measures might be reconsidered. When government goods and services are not provided some adjustments might be needed. Provision of some government activities might simply be delayed to a later date. Also, some revenue might be shifted to other purposes. We note that some conceptual work is needed to establish a basic definition of GI for the purpose of formulating a DDF, and that standards be established for its measurement.[54] We use an approximation method below.

3. Analysis

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[52] In the analysis below we confine our attention to direct BI/GI (see also Rose, 2015).

[53] Others prefer the reference point to be a “new normal,” referring to a more viable level of economic activity for New Orleans, for example, whose economy was in decline before the disaster. The new normal, however poses grater measurement challenges for BI.

[54] We note two fruitful approaches. One is case studies of the costs of state and local GI (e.g., Minnesota Management and Budget, 2011). Another is to use private-sector analogues. There are numerous studies of the reduction in GDP stemming from electricity outages. Even those related to privately-owned electric utilities are applicable to the case of municipal electric utilities.

We proceed to analyze reduction in GI risk alongside mitigation of property damage and fatalities. In the base case, PA included property damage as measured by Permanent work, and a proxy for GI as measured by the Emergency work. Now that an alternative measure of government interruption is available, we will replace the Emergency work component of PA with the new measure of spending to reduce GI losses.

To analyze the role of mitigation of GI in the context of the Deductible, we must do the following:

- Adjust the BCR's in the *Mitigation Saves* study for the inclusion of mitigation against GI
- Estimate the GI risk for each state, at the same time delete the GI proxy measure from PA figures
- Adjust the Disaster Deductible for GI
- Establish a credit for GI reduction

a. BCRs adjusted for GI (which include both property damage and GI) are presented below:

Floods— 4.80:1 (1%)
Hurricanes— 1.52:1 (26 %)
Earthquakes— 0.55:1 (10%)
Severe storms— 3.34:1 (5%)
Other— 3.34:1 (5%)

The BCRs are adjusted by the percent of the benefits that BI presents for each threat, which are noted for each threat in parentheses. In the *Mitigations Saves* study nearly all of the BI measured was in fact government service-related, so it is effectively GI.

b. Estimates of GI risk for each threat by state are presented in Appendix II-E. They are based on estimates intended at this point to illustrate the role of including GI loss reduction would have in a Deductible/Credit System.

The calculations began with state-level capital stock estimates from Yamarik (2011), adjusted by the ratio of total capital stock (from summing across states) to FED (2016) total capital stock estimates. This ratio was needed to scale up Yamarik state-level capital stock estimates, which we considered to be low, and which was confirmed by the fact that they were in total significantly lower than the FED total. We then calculated the amount of state-level government capital stock under the assumption that 10% of the total capital stock is government owned. We then calculated GI losses as the ratio of government expenditure/government capital stock times PA damage in each state.

These adjusted capital-output ratios range from a low of 1.39 in Alaska to a high of 5.5 in Texas. Generally GI losses are approximately 40% of government property damage losses across states and are generally higher in those states with higher expenditure-capital ratios and a disproportionate share of property damage from wind threats, which have the highest GI to property damage ratios.

c. The Adjustment of DDF2 for GI is presented in Figure II-7. It represents the addition of GI to the Base Case Risk Index, and then combining it with the Base Case Fiscal Capacity Index. Note that Figure II-7 compares the Adjusted Deductible with the Base Case version. Unsurprisingly, the inclusion of GI in the Adjusted Deductible results in higher values for most high risk states. This has the interesting effect of increasing the magnitude of the normalization – which substantially reduces the deductible for states with high fiscal capacity, such as Alaska and Wyoming.

d. We assume the credit multiplier for BI reduction is the same as that for mitigation of property damage, or a value of 3.0. This is based on the premise that a dollar of GI loss averted is no less valuable than a dollar of property damage (or a dollar for fatalities).

4. MP ANALYSIS OF PA RISK WITH ADJUSTED GOVERNMENT INTERRUPTION RISK REDUCTION

Table II-12 presents the MP results for the 50% risk reduction case for Year 2015 simulated based on the PA risk with the adjusted government interruption risk for Mississippi and Ohio. The BCRs are assumed to be the same as the BCRs of property damage plus government interruption as specified in Section IV-2a. After adding the adjusted risk of GI to risk of property damage, the adjusted deductible for MS increases from $28.00 million in the DDF2 Base Case to $72.78 million in this case, while OH decreases from $17.13 million to $13.66 million (primarily because of the relatively low government expenditure to capital ratio of the state and the normalization process). This results in increased risk reduction expenditures for MS and decreased expenditures for OH to achieve the risk reduction target. For MS, the total expenditure increases from $5.46 million to $19.87 million, and for OH, the total expenditure decreases from $2.56 million to $2.05 million. However, the mix of risk reduction strategies for both MS and OH remains the same as in the DDF2 Base Case.

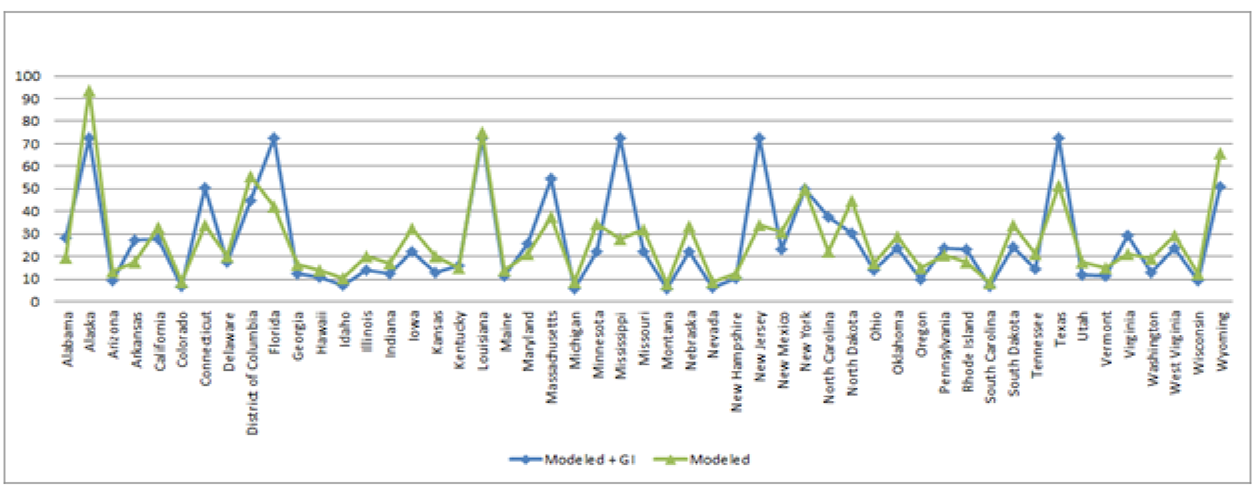

Figure II-7. Adjusted Deductible with Government Interruption

Table II-12. MP Analysis of DDF2, Year 2015 – Mississippi and Ohio
(50% risk reduction, PA Risk with Adjusted GI Risk; PD + GI BCRs for Mitigation, in million dollars)

Strategy	MP Analysis – 50% Risk Reduction			
	Mississippi		Ohio	
	Expenditure	Risk Reduction Attained	Expenditure	Risk Reduction Attained
Mitigation				
Hurricanes	16.93	25.74		
Floods	0.59	2.83		
Severe Storms	2.34	7.83	2.05	6.83
Earthquakes				
Other				
Insurance/Relief Fund				
Hurricanes				
Floods				
Severe Storms				
Earthquakes				
Other				
Total	19.87	36.39	1.94	6.83

5. BA Analysis of Property Damage plus Government Interruption Risk Reduction

Table II-13 shows a comparison of the base case using property damage only BCRs with an inclusion of government interruption reduction BCRs for both Mississippi and Ohio. Expected losses increase by the addition of business interruption losses to the base case losses. Consequently the deductible increases for Mississippi, but perhaps unexpectedly decreases for Ohio. The result for Ohio is a consequence of the way the adjusted deductible is calculated, based on the median loss, and then normalized to the mean loss. In Mississippi's case, mitigation increases and the burden increases, but in Ohio's case, mitigation spending falls, and the burden changes for the state are smaller than in the base case. The response from Mississippi is to move to a large expenditure on mitigation, while Ohio reduces mitigation spending slightly. Consequently, the burden for Mississippi rises relative to the status quo, and the base case, while for Ohio the state burden falls relative to the status quo, and the base case.

Table II-13
Burden Analysis for DDF2 – Mississippi and Ohio,
Property damage and Government Interruption BCRs
(50% risk reduction)

	Expenditures ($millions)			
	Mississippi		**Ohio**	
	2015 Base	2015 PA + GI	2015 Base	2015 PA + GI
	(1)	(2)	(3)	(4)
A. Status Quo				
Total expected losses	311.9	339.0	31.6	30.0
State share of expected losses	70.2	76.3	7.1	6.7
Federal share of expected losses	241.7	262.7	24.5	23.2
B. Deductible only				
Total expected losses	311.9	339.0	31.6	30.0
State deductible	28.0	72.8	17.1	13.7
PA after state pays deductible	283.9	266.2	14.5	16.3
State share of remaining PA	63.9	59.9	3.3	3.7
State total spending (deductible + state share)	91.9	132.7	20.4	17.3
Federal PA	220.0	206.3	11.2	12.6
Change in State burden	21.7	56.4	13.3	10.6
Change in Federal burden	-21.7	-56.4	-13.3	-10.6
C. Mitigation with DDF credit				
Total expected losses	311.9	339.0	31.6	30.0
Spending on mitigation	2.8	19.9	2.7	2.0
Insurance premiums	4.2	0.0	0.0	0.0
Additions to relief fund	0.0	0.0	0.0	0.0
Reduction in PA from expenditures	14.0	36.4	8.6	6.8
Total actual PA	297.9	302.6	23.0	23.1
State deductible less credit	15.4	13.2	9.1	7.5
PA less deductible	282.5	289.4	14.0	15.6
State share of remaining PA	63.6	65.1	3.1	3.5
State total spending (mitig. + deduct. + state share)	85.9	98.2	14.9	13.1
Federal PA	218.9	224.3	10.8	12.1
Change in State burden from status quo	15.8	21.9	7.8	6.3
Change in State burden relative to deductible only	-5.9	-34.5	-5.5	-4.2
Change in Federal burden from status quo	-22.8	-38.4	-13.7	-11.1
Change in Fed. burden relative to deductible only	-1.1	18.0	-0.4	-0.5

Comparisons are to DDF1 Base Case, for which risk level equals Public Assistance (composed of property damage and non-property damage as a proxy for government interruption).

V. Deductible Credit Eligibility -- Other

A. Resilience Spending to Reduce Government Interruption

1. Introduction

In this section, we discuss various aspects of the Disaster Deductible related to the concept of *resilience*. This involves a discussion of the disruption of business and government activity and their subsequent recovery, in contrast to the focus on property damage and repair/reconstruction that has dominated the analysis up to now. The section initially focuses on some existing aspects of FEMA's Public Assistance Program over and above covering property damage. The discussion also focuses on eligibility for credit against the Deductible for risk reduction, where risk is broadened to include disaster losses other than those stemming from building and infrastructure damage itself. The fact that some resilience options are already eligible for PA may help facilitate their legitimacy, and legitimacy of the broader category of what we term resilience in general, as eligible for credits against the Deductible as well.

We build on the discussion in sub-Section IV-C above where we presented the case for addressing business interruption (BI) and government interruption (GI) losses through pre-disaster mitigation. We now focus on ways to reduce GI with a post-disaster strategy for which we reserve the term *resilience*. As noted previously, BI losses can rival property damage in magnitude for large disasters, as in the case of 9/11, and, of course, GI losses are large as well (Rose et al., 2009).

We reiterate the distinction that actions that take place before an event, typically referred to as *mitigation*, reduce the frequency and magnitude of property damage. Of course, they also have the effect of reducing potential BI and GI, but there is another way to reduce these latter types of losses: *resilience*. Economic Resilience has come to be known as actions that utilize remaining resources more efficiently (static resilience) and actions that help recover more quickly through investment in repair and reconstruction (dynamic resilience) (Rose, 2009b).[55]

Resilience *tactics* include conservation of critical inputs, finding domestic or imported substitutes for them,[56] use of inventories and excess capacity, business relocation, and recapturing lost production by working overtime and extra shifts. Note that resilience is a *process*. Capacity can be built up ahead of time, but it is only implemented after the disaster strikes (e.g., stockpiling critical supplies, purchasing portable electricity generators). It is also important to distinguish between *inherent* resilience, which already exists in the system naturally or by actions in advance, and *adaptive* resilience, which emanates from ingenuity and improvisation (e.g., technological change, supply-chain adjustments) (Rose, 2009b).

[55] Again, these definitions of economic resilience capture the essence of definitions across disciplines, which generally are: actions that maintain function and recover more quickly (see also Holling, 1973; Pimm, 1984; Tierney, 2007; and Cutter, 2015).

[56] For example, substitutes for air travel were factored into the Rose et al. (2009) 9/11 study, and thus reduced the direct and indirect BI to the levels reported above.

2. PA, Business Interruption and Resilience

The categorization of eligible work under FEMA's Public Assistance program was discussed earlier in Section II-A. The category Z of *State Management* refers to covering the costs of state governments administering aspects of Public Assistance grants.[57] Category A, *Debris Removal,* refers to actions intended to address health and safety issues, as does Category B, *Protective Measures*. Categories A and B are components of Emergency work as defined in the FEMA (2007; 2014) *Public Assistance Guide*. The remaining categories are included in Permanent work, and cover repair and reconstruction of public facilities, buildings and infrastructure. A large portion of the *Protective Measures* would not fall under the heading of resilience either. Hence, only a very small percentage of PA expenditures are devoted to resilience. Examples under Emergency Protective Measures (considered "non-permanent") include: temporary emergency medical facilities, temporary electricity generators for these facilities and restoration of access to them, and emergency communications and transportation. Categories C though G in Table II-2 (considered "permanent work"), do not appear to include any activities that fall under the heading of resilience.

A question arises as to the extent that PA spending promotes resilience. To some degree the utilization of PA to repair and rebuild government structures and public infrastructure helps promote dynamic resilience by accelerating that process in relation to other sources of funds. A related question is whether the DDF will inspire more resilience or risk reduction in general. On the surface, it should have a similar effect on (post-disaster) resilience as on (pre-disaster) mitigation on a dollar for dollar basis, perception problems with respect to awareness of resilience options aside. Since some fraction of post-disaster PA is typically used to mitigate future losses, PA can also be used to improve resilience, but for the next disaster. While the goal of the DDF is to reduce future PA, a significant proportion of mitigation, and some resilience, is funded by post-disaster PA. The irony is that one has to suffer a disaster in order to receive funding to be better prepared for the next one.

3. Resilience and the DDF

This brings up two issues for this study. First, have we adequately characterized resilience actions in the first DDF? Resilience, as defined in this section is not mitigation, insurance, or relief funds; hence, it has not been taken into account explicitly. Implicitly, because resilience generates a loss reduction, rather than just a loss transfer, it has some similarities to mitigation. However, resilience tactics are implemented after the disaster strikes, and most do not involve pre-disaster expenditures that can attain credit toward the deductible under the design of the first DDF, although, as noted above, PA payments can be used to promote some resilience to the current disaster and help increase resilience capacity for future ones.

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[57] Much of this category is actually devoted to expenditures for management of PA for disasters below the Disaster Declaration threshold, so we do not include it in our GI approximation. Because of the ambiguity of this category, we have only included Categories A and B in our consideration of post-disaster GI-related activities subject to the Deductible.

Second, as to current qualifying resilient actions noted in the previous section, or others that might be introduced, it is necessary to have benefit-cost, or at least cost-effectiveness, ratios for them to make their incorporation into the Deductible/Credit system operational. We discuss estimates in the following section.

There are actions that can be taken before the disaster to increase resilience capacity, such as lining up back-up locations, keeping excess capacity in good working order, etc., but their effectiveness is difficult to measure. A more general approach to improving resilience capacity is to impart greater flexibility into structures and procedures (Zolli and Healy, 2012), but this is especially hard to quantify. On the other hand, there are other actions that have or can more readily be estimated in terms of their (flow) loss reduction capabilities, including purchase of back-up electricity generators and implementation of microgrids or distributed generation in general, emergency management drills, build-up of inventories or stockpiles (Rose et al., 2007; Kajitani and Tatano, 2009; Rose and Wei, 2013).

For those resilient actions that generally take place after the disaster strikes, the issue is whether they should be included as eligible for PA. These include many adaptive versions of resilience such as input and import substitution, conservation, logistical shifts and technological change. One of the major resilience tactics that can promote continuity of government is production recapture, which refers to working overtime or extra shifts to make up deficits in interrupted services. This would incur the cost of overtime pay or pay for temporary workers. The disaster loss reduction can be large from government activity specifically such as processing paperwork to facilitate rebuilding and more general operations that restore order and public confidence in general and thereby promoting public health, safety, and increasing economic activity.

As to the crediting of resilience expenditures and the credit multiplier, there is no inherent reason that FEMA cannot incorporate these features into a DDF. The first is a grand policy decision, while the second is a more precise policy lever. The latter is also quite apart from the issue of the resilience BCR. It would be specified at a level at which FEMA might seek to encourage resilience, including possible differential credits for various types of resilience tactics or threats.

4. Resilience Benefit-Cost Ratios

a. Empirical Measurement of Resilience

Several studies have examined economic resilience in actual disasters or with the use of simulation studies. The major pioneer is Tierney (1997), who surveyed businesses in the aftermath of the Northridge Earthquake and Midwest Floods. Rose and Lim (2002) translated Tierney's findings into specific measures of resilience of the Los Angeles electricity system. They identified such factors as time-of-day-use, electricity "importance" (dependence), and production recapture as key to understanding why businesses that averaged a X% reduction of electricity were able to continue operation at much less than a X% reduction in their production goods and services. In fact, they found that these micro-level tactics resulted in a reduction of business interruption losses by more than 90 percent of baseline estimates, a level consistent with Tierneys' survey responses.

Other estimates of resilience have been less evidence-based, but are still prominent in literature. Several resilience factors were incorporated by the Adam Rose and Stephanie Chang into FEMA's loss estimation tool—HAZUS (FEMA, 2015d). The Direct Economic Loss Module (DELM) includes factors for individual businesses making up lost production at a later date either by working overtime or extra shifts after their utility lifelines had been restored or after building damage had been repaired. These "recapture factors" were based on a synthesis of the literature, and the indication is that these factors are very high (ranging between 50 and 98 percent for most sectors) for short periods. That is, customers are unlikely to cancel their orders for the output of disaster-sickened industries for short periods of time, because they have inventories on hand or long-standing supply-chain relationships. On the other hand, this type of resilience is likely to decline over time, and is likely to fall to zero after one year, if not after several months. The HAZUS Indirect Loss Module (IELM) includes such resilience factors as inventories, excess capacity, and the ability of increased imports and exports.

Several other simulation studies have been undertaken to estimate the effects of resilience on losses from disasters, using the metric presented in the previous section. Kajitani and Tatano (2009) used a survey to estimate the resilience of Japanese industries to various types of lifeline disruptions from disasters and found residence levels to be relatively high in most sectors. Rose et al. (2007a; 2007b) estimated the resilience of the Los Angeles water and power systems to a two-week outage due to a terrorist attack. They found that resilience could be as high as 90 percent, primarily due to production recapture. Rose and Wei (2013) examined such resilience tactics as excess capacity, inventories, and export diversion to reduce potential losses from a 90-day shutdown of a major U.S. seaport complex in a regional economy dominated by petrochemical production. Overall, they found that the implementation of these resilience tactics could reduce GDP losses in the regional by more than 70 percent.

Note, however, that an important distinction should be made between terrorism and natural disasters in applying these results. In the case of the former, a specific infrastructure provider is targeted, but the rest of the economy is unscathed. Hence, when water or power is restored, firms can resume production immediately. This is not the case for natural disasters, which inflict widespread damage, such that factories need to be repaired in addition to having their lifelines restored

It is important to note that the simulation studies cited above are biased towards estimating resilience at its maximum effectiveness. This is not always the case due to the disarray accompanying most disasters, administrative obstacles, and personal failings. Moreover, Rose (2009b) has pointed out that resilience can be eroded during large disasters as inventories are depleted, Draconian conservation becomes onerous, and opportunities for production recapture decline as customers abandon their traditional suppliers who are unable to deliver within a time threshold.

b. Cost-Effectiveness

To make prudent resource management decisions, one must consider the cost of each resilience tactic as well as its effectiveness. One tactic might be capable of reducing more than twice the BI losses of another, but if it costs 10 times as much to implement, the former is not the better option.

We begin with a general overview of cost considerations. Most adaptive Conservation more than pays for itself when it represents a productivity improvement, such as an increase in energy-efficiency (producing the same amount but with less energy). A more general definition of Conservation (reducing the amount of an input irrespective of its effect on output) can incur net positive costs. Input Substitution requires a small penalty for using a less optimal input combination. Import Substitution involves an increase in costs from utilizing higher-cost sources and/or increasing transportation distances. Relocation can be somewhat expensive if it involves a physical move; however, increasing the role of telecommunications, and the prospects for working in cyberspace and tele-commuting, have significantly decreased this cost. Emergency Planning Exercises take little time and incur relatively low costs. Production Rescheduling involves the payment of overtime wages.

Some resilience tactics are primarily inherent, and simply await their utilization once the disaster strikes. The cost of inventories is just the carrying charge and not the value of the inventories themselves, which simply replace resources that would've been paid for otherwise. Excess Capacity involves a similar cost, though some excess capacity is often planned in order to enhance business flexibility or to accommodate downtime for maintenance; these aspects should not be charged to disaster resilience. Production Isolation, instances where some production activities are separated from the need for one or more inputs, is inherent in the system, and should likewise not be charged to resilience unless it is expressly done for that purpose.

Once the cost per unit of effectiveness, expressed in percentage terms or in terms of dollars of net revenue from business interruption loss prevention, is determined, the options can be ranked for implementation. This ranking would reflect an increasing marginal cost curves (or step-function if the cost-effectiveness of resilience tactics is measured as a constant); this limit would be the maximum percentage or dollar amount of resilience possible. Note that since most conservation more than pays for itself, the function would begin in the negative cost range.

The context in which the disaster strikes and resilience is implemented also has an influence on the effectiveness side. Relevant factors include the disaster type, magnitude, and recovery duration, as well as background conditions relating to the economy, such as its economic health at the time of the disaster and its geographic location. For example, inventories are finite and more likely to run out in disasters for which the duration of recovery is long. Production recapture also erodes over time, as customers begin to seek other suppliers. Excess capacity is dependent on the business cycle (e.g., one reason that relocation was so effective after the World Trade Center attacks was because New York City was in the throes of a recession, which then provided a great deal of vacant office and manufacturing space).

c. Cost-Benefit Analysis of Resilience

Resilience can be couched in a benefit-cost analysis (BCA) framework by bringing its rewards formally into the picture. For purposes of simplification, we can think of the benefits as the net revenue of BI losses averted, or the GI averted. Initially, this might best be represented by a constant per unit marginal benefit level function, reflecting equal additional increments of benefits for each percentage increase in resilience. For example, if potential GI losses are $1,000,000 in net revenue terms, then each percentage of resilience has a marginal benefit of $10,000. In this case, the marginal benefit function is constant by definition. The optimal level of resilience would be at the point at which the marginal cost and marginal benefit curve intersect. Even without a precise numerical example, we can draw some insights from the example. All cost-saving resilience options would be implemented, because they yield guaranteed net benefits. Also, given the relatively low cost of many of the tactics, at least in some of their initial applications, it is likely that a fairly high level of resilience would be chosen.

We note additional considerations relating to important characteristics of resilience tactics. One pertains to whether a given tactic yields benefits only to an individual business or whether these benefits apply more broadly. Nearly all of the micro-level resilience tactics that we have discussed thus far, with a focus on the customer-side, have limited spillover effects. However, the opposite is true for resilience tactics on the supplier-side. An example is that of redundancy, such as the presence of a back-up water pipeline system or back-up electricity generator. Here, the benefits are not simply limited to maintaining revenue to the supplier, but to the avoidance of BI or GI for all its customers. Thus, while redundant systems are relatively much more expensive than the resilience options just discussed, their benefits are much more widespread.

A further consideration needs to be taken into account on the cost side for redundant system, as well as some demand-side tactics, such as inventories or back-up equipment. Rose (2009) and others make the case that customer-side resilience tactics need not be implemented until the disaster strikes, which would appear to give them a cost advantage over mitigation and supplier-side tactics such as redundancy. However, most forms of inherent resilience, such as inventories and back-up equipment, are in place whether or not the disaster strikes. While they lack the flexibility that other customer-side tactics have, there is a positive ramification of this—they exist to protect against *many* threats over the course of their lifetime. Thus, their cost-effectiveness is much higher than if one considers only a single threat. The BCRs in our analysis can readily be adjusted for these features by incorporating all of these benefits of implementing the given resilience tactic and also considering a distribution of threats for which it reduces BI/GI losses. Thus, the larger the number of customers the water utility with a redundant system serves, the greater its benefits, and the more threats a stockpile protects against, the greater its benefits.

Also, the fact that benefits of a redundant system accrue beyond simply the electric or water utility providing the service and extend to all of their customers would significantly increase the overall benefits. Implicitly, benefits have been defined thus far in terms of the rewards to the entity implementing the resilience tactic—the supplier. However, the gains to all the *customers* are likely to be much greater; in essence, it would be the net revenue losses avoided by this resilience tactic, and thus likely to be at least an order of magnitude larger than the benefits to the utility itself.[58] The latter essentially represents a type of social benefit of implementing the resilience tactic.

[58] The order-of-magnitude estimates stems from a simple back-of-the-envelope calculation. Electricity and water inputs represent less than 5% each on average of total production costs of all businesses in the economy. Assuming, rates of return (or profit rates in general) are reasonably equal across all business enterprises, again on

One further ramification of this situation is the difference between the private optimum and social optimum, as well as the associated motivations. The utility's decision to implement this resilience tactic would be based on its own private marginal benefits, while, from the standpoint of society, it would be best to implement a higher level (the classic "club good" problem). This raises public policy issues related to how to induce behavior consistent with the best interests of society as a whole. This is achieved more readily in the cases of government-owned utilities. For investor-owned utilities, subsidies or some form of regulation would be required.

d. Estimates of Resilience Effectiveness, Benefits, and Costs

Examples of some of the basic data for the calculation of BCRs relating to resilience to electric power disruptions are summarized in Table II-14 and are based on simulation studies by Rose et al. (2007). We have chosen an electric utility as an example because it can represent either a private business or a government operation.[59] The table identifies alternative tactics (options) electricity customers can use to reduce the impacts to the power outage. Each entry in the first numerical column measures the percentage reduction in BI/GI[60] that each tactic can provide in the aftermath of a power disruption, i.e., the estimate of resilience potential.[61] Note that resilience is not additive across all tactics (indicators), as there is some overlap; hence, total resilience is not the simple sum of the column entries in Table II-14.

In essence the entries in Table II-14 denote the effectiveness of the various resilience tactics.[62] Although an emphasis is usually placed on costs and benefits, effectiveness measures the extent to which the tactics can be applied, and represents a fundamental step in the analysis. This effectiveness aspect plays a key role in the Mathematical Programming (MP) Model of state responses to the deductible. They serve as constraints on the application of the various risk reduction and credit attainment strategies in that model.

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average, this means that net revenue losses are more than 20 times higher for the economy than for the utility supplier. Moreover, this number increases when indirect (multiplier or general equilibrium) effects are taken into account.

[59] The counterpart pertaining to loss of government services, would be referred to as *government interruption* (GI). While data on BI are extensive, data on GI are not. Government activity is often measured in terms of expenditures or sometimes on a net basis in terms of employee compensation. However, these measures might be reconsidered. When government goods and services are not provided some adjustments might be needed. Provision of some government activities might simply be delayed to a later date. Also, some revenue might be shifted to other purposes. We note two fruitful approaches. One is case studies of the costs of state and local GI (e.g., Minnesota Management and Budget, 2011). Another is to use private-sector analogues. There are numerous studies of the reduction in GDP stemming from electricity outages. Even those related to privately-owned electric utilities are applicable to the case of municipal electric utilities.

[60] This also includes some government services.

[61] Rose et al. (2007) distinguish between direct (partial equilibrium, PE) and indirect (multiplier, or broader general equilibrium, GE) reductions in BI. The figures in Table II-15 combine the two effects. Note also that we are analyzing losses at the regional level only. It is also a legitimate to consider losses at the broader state or national level as well. This is conceptually a simple extension of the analysis, though empirically it requires the use of a model that covers a broader geographic area.

[62] The tactics and their effectiveness would serve as individual indicators in the compilation of a resilience index (Rose and Krausmann, 2013). The relative effectiveness of the various residence tactics could serve as weights in developing the index. Most studies to date have simply assumed equal weight across indicators.

We now turn to the costs of various options, including those listed in Table II-2. Several resilience tactics are available on the supplier-side as well (see, e.g., Lave et al., 2005). However, these are dominated by relatively expensive options, such as spare transformers, as well as less expensive options, such as expediting service restoration (basically dynamic economic resilience in the form of recovering more quickly).

On the customer-side, there are more widespread and less expensive options. We discuss the benefits and costs of the tactics in Table II-14 in turn. First, note that the total losses from the two-week power outage are $14.6 billion in gross output (sales revenue) updated to 2015 dollars. The 86% reduction potential of resilience would reduce this by $12.61 billion. Essentially, the second column, translates resilience effectiveness into dollar benefits.

Increased (adaptive) inter-fuel substitution[63] has the potential to increase the elasticity of substitution between electricity and various fuels by 10 percent, and would result in a decrease of BI of 0.81 billion. We have assumed that this improved capability to switch to other fuels still comes with a 20% cost penalty as an upper bound. Unlike other inputs, conservation of electricity is a very limited option -- Rose and Liao (2005) and Rose et al. (2007a) estimate it to be 5 percent based on a refinement of survey data by Tierney (1997). However, a good deal of conservation is in the category of energy efficiency, which means it can be attained at a cost savings (negative cost). Therefore, we have entered a range of cost estimates of plus/minus 10% of the dollar benefits.

Inventor (customer storage) is not a major option in the case of electricity. Electricity isolation, which pertains to those aspects of the production process that do not require electricity in the first place, differs by sector, ranging from levels of 70 percent in various transportation-related sectors to zero percent in various manufacturing sectors (ATC, 1991). However, this is inherent resilience, and the cost is effectively zero.

On-site alternatives to centralized electricity delivery, or distributed generation (micro-grid electricity generation, solar panels or back-up electricity generators) differ by location, but for the City of Los Angeles values ranged from 10 percent in most sectors to 50 percent in sectors with very large firms (e.g., Petroleum Refining), sensitive production processes (e.g., Semi-conductors), or where implementation is relatively easy (e.g., Security Brokers). The incremental cost of most distributed generation alternatives (tactics) are relatively modest, and some may be cost saving. Still, we have entered a cost of 20% of the benefits of this tactic as an upper bound.

Production rescheduling (recapture) also differs by sector, with very high rates for those sectors whose deliveries are not time-sensitive (e.g., Durable Manufacturing) and low rates for those whose are (e.g., Hotels and Restaurants) (Rose and Lim, 2002; FEMA, 2015d). The analysis also assumed that a two-week outage will not cause any permanent change in customer-supplier relationships. The majority of the cost of production rescheduling can readily be calculated in terms of overtime pay, which represents the cost entry of $2.71 billion in Table II-14.

[63]The existing substitution possibilities represent inherent resilience, and the increased substitution possibilities (increased elasticity of substitution values) represent adaptive resilience.

Table II-14. Relative Prominence of Resilience Adjustments for Electric Power Outages in Los Angeles

Resilience Factor	Overall Effectiveness (%)	Benefits (billion$)[a]	Costs (billion$)[a]	Benefit-Cost Ratio
Adaptive Electricity Substitution	5.5	.81	.16	5.06
Electricity Conservation	5.5	.80	-.08 to +.08	-.10 to +10
Electricity Isolation	15.1	2.21	0	undefined
Distributed Generation	20.4	2.99	.60	4.98
Production Rescheduling	77.1	11.30	2.71	4.17
Total	86.0	12.61	3.39 to 3.55	3.55 to 3.72

Source: Columns 2 and 3: Rose et al. (2007b); Column 4: Author's judgement.

[a] Converted to billions of 2015 dollars of gross output (sales revenue).
[b] Column sums exceed totals because of overlap in resilience tactic effects.

We are now able to derive a ballpark benefit-cost ratio for resilience to electricity power disruption. The methodology can be followed for other interruptions of government services and business activity as well. Taking the ratio of total benefits to total costs, and using an average of the range for electricity conservation, yields an overall BCR of 3.63. Resilience BCRs for individual tactics can be calculated in a like manner by dividing the Table II-14 entries in numerical column 2 by the corresponding entries in numerical column 3. This makes many individual resilience tactics and overall resilience to the electricity disruption threat competitive with some of the mitigation options evaluated in the Mitigation Saves Study (MMC, 2005).

At the same time, these estimates must be tempered by several considerations, such as the fact that mitigation benefits carry over to decades of a useful life of a mitigation project, and most resilience options pertain to risk reduction only on a one-shot basis. Hence, to render the BCRs for these two risk reduction strategies comparable, three adjustments are needed.

First, BCRs tactics that build up resilience capacity prior to disasters (e.g., increased inventories or stockpiles of critical materials, purposeful construction of excess capacity, back-up equipment) need to be calculated for their entire useful life. This would be analogous to what is done for mitigation BCRs and would mean calculating the flow of future benefits from say, portable electricity generators, and discounting them; the ensuing BCR would be at least several times the annual BCR for this tactic (though the useful life of these tactics is not as likely to be as lengthy as the useful life of mitigation tactics such as building codes, levees, buyouts of property in flood plains).

Second, BCRs for the capacity-building resilience tactics put into place before the disaster need to be adjusted for the probability of occurrence of a disaster. This has been embodied in the calculation of mitigation BCRs used here, as adapted from the *Mitigation Saves* Study (MMC, 2005; Rose et al., 2007). A similar adjustment would be needed for the capacity-building resilience tactics. In fact, the probabilities would be the same, though applied to fewer years. On the other hand, post-disaster resilience tactics maintain the strong advantage over mitigation and pre-disaster resilience of not requiring to be adjusted by probabilities of occurrence; the occurrence is known because the disaster has happened.

Third, most resilience tactics applied to the customer side represent ways by a business/government/household to coping with disruption of the supply of its critical inputs, as well as to coping with damage to its operating facilities. Thus, they pertain to reducing losses across various threats; in contrast, most mitigation measures are threat specific (building codes, levees, warming systems). This essentially increases the BCRs associated with resilience in relation to those associated with mitigation.

e. Additional Resilience BCRs

The analysis in the previous sub-section focused on customer side resilience to electric utility disruptions, and was limited to a sub-set of tactics. Moreover, many of the complications noted in the previous paragraph would not come into play. We now turn our attention to examples of disruption of manufacturing, service, and government activities, which encompass a broader set of tactics. We focus, however, on those resilience tactics identified in several studies as having the greatest effectiveness (ability to reduce BI the most): relocation and production recapture. Here we will summarize ballpark estimates of the associated BCRs.

Table II-15 illustrates the costs and benefits faced by selected industries for relocating their production when their current location is made inoperable. Note that these costs apply to owner-occupied locations only, as they will need both to pay the cost of relocating and the cost of renting a new location; businesses that rent their location will simply shift their current rental payments to the owner of their new location, and thus only incur the nominal relocation costs, dramatically increasing the overall BCR.

Rental, relocation, and recovery time were all adapted from HAZUS (FEMA, 2015d) and Rose and Lim (2002); total relocation cost is calculated by multiplying the rental cost by the recovery time for 100 square feet (as a base unit), plus a one-time relocation cost multiplied by 100 square feet. Relocation Benefit is calculated by multiplying the average output for 100 square feet (also adapted from HAZUS) by the recovery time. BCRs are presented in the last column, and are high relative to many other resilience and mitigation tactics.

Production Recapture reflects the fact that, following a period of disruption, employees can work extra shifts to recapture the gross output lost due to said disruption. Benefits are assumed to decrease over time (see also Rose and Lim, 2002). Costs are measured as the wages paid during these extra shifts.

Supplementing production recapture factors by Rose and Lim (2002), data were utilized from the 2011 U.S. I-O table (IMPLAN, 2011) on sectoral production and employee compensation and from BLS (2016) on sectoral employment and earnings.[64] For each sector, the BCR is determined using overtime pay per hour, the number of employees, the gross output generated per hour of work, and production recapture

TABLE II-15. Relocation BCRs for Owner-Occupied Buildings for Selected Sectors

Sample Sectors	Rental Cost[a] ($/sqft)	Relocation Cost[b] ($/sqft)	Recovery Time[c] (days) Moderate	Extensive	Complete
Light Mfg	0.86	1.52	90	240	360
Food, Drug, Chem	0.86	1.52	90	240	360
Metal Processing	0.64	1.52	90	240	360
High Technology	1.09	1.52	135	360	540
Admin. Services	4.36	3.04	90	360	480

	Relocation Cost[e] (per 100 sqft, 2015$)			Relocation Benefit[f] (per 100 sqft, 2015$)			Relocation BCR		
	Mod	Ext.	Com.	Mod.	Ext.	Com.	Mod.	Ext.	Com.
Light Mfg	412	844	1,190	81,605	217,613	326,420	198.16	257.80	274.31
Food, Drug, Chem	412	844	1,190	24,057	64,151	96,227	58.42	76.00	80.86
Metal Processing	345	665	921	22,671	60,455	90,682	65.80	90.94	98.46
High Technology	642	1,459	2,112	22,603	60,276	90,414	35.19	41.31	42.80
Admin. Services	1,611	5,530	7,273	9,127	36,508	48,678	5.67	6.60	6.69

Source: Adapted from HAZUS (FEMA, 2015) and Rose and Lim (2002).

[a] Refers to renting a temporary location, by industry.
[b] Refers to the direct cost of transferring equipment and set-up at the new location, by industry.
[c] Days required to restore original facility to working condition, by industry, depends on nature of disaster.
[d] Entered as 100 square feet as a base unit.
[e] Varies by industry, recovery time, and total sqft affected. Equal to Relocation*sqft + Rent*Recovery Time*sqft
[f] Varies by industry, recovery time, and total sqft affected. Equal to Sales Revenue/sqft/day*Recovery Time*sqft

[64] Overtime pay per hour for Food Manufacturing, Fabricated Metals, and Machinery Manufacturing was calculated from the reports mentioned above. Due to a lack of data concerning overtime work, overtime pay per hour for Administrative Support Services was assumed to be time-and-a-half (150% of average hourly wages). Number of sectoral employees within LA County is determined using a ratio of Total Employees in a given national sector: total employee compensation (I-O table) and LA County sectoral employee compensation. Gross output per hour is determined by dividing sectoral gross output by total number of hours (Average total hours *52).

Table II-16. Production Recapture Benefit-Cost Ratio for Selected Sectors

	Cost		Benefit	Recapture Factors	
Sample Sectors	Overtime ($/ hour)	Employees (FTE)	Gross Output/hour (millions $)	Months 1-3	Months 10-12
Food Manufacturing	$26.42	38,482	8.93	95%	20%
Fabricated Metal Manufacturing	$31.78	8,763	5.41	99%	24%
Machinery Manufacturing	$38.09	16,858	2.86	99%	24%
Admin Support Services	$26.72	66,497	12.07	70%	0%

Average Hour Scenarios (millions $)						
	Months 1-3			Months 10-12		
Sample Sectors	Cost	Benefit	BCR	Cost	Benefit	BCR
Food Manufacturing	$1.02	$8.48	8.3	$1.02	$1.79	1.8
Fabricated Metal Manufacturing	$0.28	$5.36	19.2	$0.28	$1.30	4.7
Machinery Manufacturing	$0.64	$2.84	4.4	$0.64	$0.69	1.1
Admin Support Services	$1.78	$8.45	4.8	$1.78	$0	0

Sources: Adapted from HAZUS data (FEMA, 2015d); IMPLAN (2011); BLS (2016).

factors.[65] Note that recapture potential is much lower for Administrative Support Services (a proxy for Government Services) than for the other sample sectors. This is due to the fact that service provision is more time sensitive than production of commodities.

A BCR is calculated for two different scenarios (disruptions time periods), where each one refers to a given hour of a disruption during the recapture factor variability. Cost is calculated as Average Overtime Pay * Number of Employees. Benefit is calculated as Gross Output per hour * the Recapture Factor. For the case of disaster declarations, the more relevant BCRs are those in the last column.

[65] Because the ability to recoup lost production decreases over time, as customers abandon suppliers, it is assumed that there is a 25 percent point reduction every three months during a one-year disruption period.

Of course, the above analyses are relatively crude, but they do provide a general indication of the magnitude of BCRs for some major resilience tactics. They indicate that resilience can be more cost-effective than mitigation (even when one considers the returns to mitigation to include not only reduction in BI but also reductions in property damage and fatalities). In the analysis below, we will utilize a resilience BCR of 4.0 as a conservative approximation given the estimates above. In addition, resilience will be restricted to reduction of 50% of risk, as in the case of the other resilience categories.

Referring back to some comparisons made earlier, we note that mitigation benefits span a large number of years, while resilience benefits, especially post-disaster tactics, pertain to only a single year. However, the multiple year benefits of mitigation tactics are, in fact, taken into account in the numerical values calculated in the *Mitigation Saves* study. The main reason they are relatively lower than resilience BCRs is that the former are implicitly multiplied by probabilities of occurrence, which, for large disasters, are much lower than 1.0. But again, no such multiplication by probabilities is applicable to post-disaster resilience such as relocation and production recapture, because the event has taken place.

5. Summary

Overall, it is possible that some business, household and government expenditures to promote resilience can reduce losses much more than the equivalent dollar expenditures on mitigation, insurance, and relief funds. This possibility should be examined in more detail. The current structure of the FEMA Public Assistance Program provides funding for only a limited group of resilience tactics, and there is a question of whether tactics that would qualify for the credit against a deductible would be limited to this group as well. Consideration should be given to expanding both the range of eligible tactics for PA itself and credit against the DDF.

Of course, this broadening of PA cannot be implemented without more precise assessments of resilience effectiveness, benefits and costs with regard to averting loss of government services. Nearly all the research done on the subject thus far, however, indicates that resilience is a relatively low-cost approach to reducing disaster losses, and thus we could reasonably expect that BCRs for resilience would rival those for mitigation.

6. MP Analysis

We now proceed to analyze the implications of incorporating resilience into the MP Model to analyze the potential state response to the eligibility of this loss reduction tactic for credit against the deductible. We are thus able to examine the trade-offs between pre-disaster strategies to reduce disaster losses and post-disaster strategies. This has rarely been accomplished and empirical analyses prior to this study.

In the MP analysis, the losses are the public assistance relating to property damage as measured by Permanent work, plus the adjusted GI. We use the property damage plus GI BCRs for mitigation and a BCR of 4.0 for resilience oriented at reducing GI risk in the MP analysis as well. Comparing to the Case presented in IV-C5, three additional constraints are added: 1) risk reduction of GI from resilience for each threat should not exceed 50% of the maximum annual GI losses of that threat; 2) risk reduction of GI from mitigation for each threat should not exceed 50% of the maximum annual GI losses of that threat; 3) risk reduction of GI from the combination of mitigation and resilience for each threat should not exceed 50% of the maximum annual GI losses of that threat.

Table II-17 presents the MP results. For MS, since Mitigation-Floods has the highest BCR (4.80), this strategy is used by the state until it reaches the constraint of 50% risk reduction from this threat type. For the remainder of the 50% risk reduction target, the Model chooses resilience for hurricanes. However, we note that, since resilience for all threat types has the same BCR (4.00), there would be no difference in choosing from resilience for different threat types. The reason that the model chooses hurricanes is because it is the first threat type that is entered into the model. For OH, since the state does not have any risk of floods, resilience becomes the strategy that has the highest BCR. The model first chooses resilience for Hurricanes, Severe Storms, and Other until all of them reach the 50% GI reduction constraint. The remaining risk reduction target is achieved by mitigation of Severe Storms and Other. Comparing to the PA with adjusted GI (without resilience) case (the case presented in Section IV-C4), after introducing resilience, MS reduces total expenditure by 55% and OH reduces by 11% to achieve the risk reduction target.

Table II-17. MP Analysis of DDF2, Year 2015 – Mississippi and Ohio (50% risk reduction, PA Risk with Adjusted GI Risk; PD + GI BCR for Mitigation, Including Resilience Oriented at GI, in million dollars)

	MP Analysis – 50% Risk Reduction			
	Mississippi		Ohio	
Strategy	Expenditure	Risk Reduction Attained	Expenditure	Risk Reduction Attained
Mitigation				
Hurricanes				
Floods	0.59	2.83		
Severe Storms			0.41	1.37
Earthquakes				
Other			0.26	0.86
Resilience				
Hurricanes	8.39	33.57	0.23	0.93
Floods				
Severe Storms			0.86	3.44
Earthquakes				
Other			0.06	0.23
Insurance/Relief Funds				
Hurricanes				
Floods				
Severe Storms				
Earthquakes				
Other				
Total	8.98	36.39	1.82	6.83

7. Burden Analysis

The burden tables corresponding to the MP analysis above (Table II-17) are presented in Table II-18.

Table II-18.
Burden Analysis for DDF2 – Mississippi and Ohio,
Property damage and Government Interruption (with Resilience)
(Mitigation targets property damage only)

	Expenditures ($millions)			
	Mississippi		**Ohio**	
	2015 Base	2015 PA + GI(R)	2015 PD only	2015 PD + GI(R)
	(1)	(2)	(3)	(4)
A. Status Quo				
Total expected losses	311.9	339.0	31.6	30.0
State share of expected losses	70.2	76.3	7.1	6.7
Federal share of expected losses	241.7	262.7	24.5	23.2
B. Deductible only				
Total expected losses	311.9	339.0	31.6	30.0
State deductible	28.0	72.8	17.1	13.7
PA after state pays deductible	283.9	266.2	14.5	16.3
State share of remaining PA	63.9	59.9	3.3	3.7
State total spending (deductible + state share)	91.9	132.7	20.4	17.3
Federal PA	220.0	206.3	11.2	12.6
Change in State burden	21.7	56.4	13.3	10.6
Change in Federal burden	-21.7	-56.4	-13.3	-10.6
C. Mitigation with DDF credit				
Total expected losses	311.9	339.0	31.6	30.0
Spending on mitigation	2.8	19.9	2.7	2.0
Insurance premiums	0.0	0.0	0.0	0.0
Additions to relief fund	4.2	0.0	0.0	0.0
Reduction in PA from expenditures	14.0	36.4	8.6	6.8
Total actual PA	297.9	302.6	23.0	23.1
State deductible less credit	15.4	13.2	9.1	7.5
PA less deductible	282.5	289.4	14.0	15.6
State share of remaining PA	63.6	65.1	3.1	3.5
State total spending (mitig. + deduct. + state share)	85.9	98.2	14.9	13.1
Federal PA	218.9	224.3	10.8	12.1
Change in State burden from status quo	15.8	21.9	7.8	6.3
Change in State burden relative to deductible only	-5.9	-34.5	-5.5	-4.2
Change in Federal burden from status quo	-22.8	-38.4	-13.7	-11.1
Change in Fed. burden relative to deductible only	-1.1	18.0	-0.4	-0.5

Comparisons are to DDF1 Base Case, for which risk level equals Public Assistance (composed of property damage and non-property damage as a proxy for government interruption).

Table II-18 shows a comparison of the base case using base case BCRs with an inclusion of government interruption reduction BCRs for both Mississippi and Ohio. Expected losses increase by the addition of government interruption losses to the property damage and government interruption losses. Consequently the deductible increases for Mississippi, but a counterintuitive reduction for Ohio is explained by the method by which the adjusted deductible is calculated, based as it is on the median deductible and normalized to the mean loss. Section C of the table shows that Mississippi responds by shifting expenditure away from mitigation and insurance to resilience. This reduces the credit and causes state expenditures to increase compared to the base case. For Ohio spending shifts away from mitigation to resilience with a lower credit, leaving the state to pay more through the deductible.

Table II-19 shows a comparison of the base case using property damage only BCRs with an inclusion of government interruption reduction BCRs with the interaction of resilience, for both Mississippi and Ohio. Expected losses increase by the addition of government interruption losses to the property damage only losses. Consequently, the deductible increases for Mississippi, but a counterintuitive reduction for Ohio is explained by the method by which the adjusted deductible is calculated, based as it is on the median deductible and normalized to the mean loss. Section C of the table shows that Mississippi responds by shifting expenditure away from mitigation and insurance to resilience. This reduces the credit and causes state expenditures to increase compared to the base case. For Ohio spending shifts away from mitigation to resilience with a lower credit, leaving the state to pay more through the Deductible. In both cases states pay more relative to the status quo, and the federal share falls correspondingly compared to the status quo.

Table II-19.
Burden Analysis for DDF2 – Mississippi and Ohio,
Property damage and Government Interruption (with Resilience)
(Mitigation targets property damage and government interruption together)

	Expenditures ($millions)			
	Mississippi		**Ohio**	
	2015 PD only	2015 PD + GI(R)	2015 PD only	2015 PD + GI(R)
	(1)	(2)	(3)	(4)
A. Status Quo				
Total expected losses	311.9	339.0	31.6	30.0
State share of expected losses	70.2	76.3	7.1	6.7
Federal share of expected losses	241.7	262.7	24.5	23.2
B. Deductible only				
Total expected losses	311.9	339.0	31.6	30.0
State deductible	28.0	72.8	17.1	13.7
PA after state pays deductible	283.9	266.2	14.5	16.3
State share of remaining PA	63.9	59.9	3.3	3.7
State total spending (deductible + state share)	91.9	132.7	20.4	17.3
Federal PA	220.0	206.3	11.2	12.6
Change in State burden	21.7	56.4	13.3	10.6
Change in Federal burden	-21.7	-56.4	-13.3	-10.6

C. Mitigation with DDF credit				
Total expected losses	311.9	339.0	31.6	30.0
Spending on mitigation	2.8	0.6	2.7	0.7
Insurance premiums	0.0	8.4	0.0	1.2
Additions to relief fund	4.2	0.0	0.0	0.0
Reduction in PA from expenditures	14.0	36.4	8.6	6.8
Total actual PA	297.9	302.6	23.0	23.1
State deductible less credit	15.4	62.6	9.1	10.5
PA less deductible	282.5	240.0	14.0	12.6
State share of remaining PA	63.6	54.0	3.1	2.8
State total spending (mitig. + deduct. + state share)	85.9	125.6	14.9	15.2
Federal PA	218.9	186.0	10.8	9.8
Change in State burden from status quo	15.8	49.3	7.8	8.4
Change in State burden relative to deductible only	-5.9	-7.1	-5.5	-2.2
Change in Federal burden from status quo	-22.8	-76.7	-13.7	-13.4
Change in Fed. burden relative to deductible only	-1.1	-20.3	-0.4	-2.9

Comparisons are to DDF1 Base Case, for which risk level equals Public Assistance (composed of property damage and non-property damage as a proxy for government interruption).

B. Insurance

In DDF1, insurance of public facilities (the state's physical stock) was modeled simply, and was assumed to have a loss reduction multiplier, or the equivalent of a benefit-cost ratio, of 1. However, spending on commercial insurance was given a 2x credit multiplier. In DDF2, we model insurance with more detail, and also with the goal of better reflecting how states actually insure their facilities against disaster. States can purchase insurance (which may include disaster coverage) for public facilities, but they can—and do primarily—also self-insure some fraction of the stock. The value of a state's physical stock can be quite large at any one time, measured in the billions of dollars. For reference, the estimated value of all state's structures in 2014 was $9.6 trillion, with $250 billion in equipment (Board of Governors of the Federal Reserve System, 2015). A state, and other government agencies may choose to insure some fraction of this stock by buying commercial insurance, while self-insuring for the remainder.

For modeling purposes, however, rather than assume values for the total at risk physical stock, or the coverage rate, we can make assumptions about the behavior of states as they respond to the incentives provided by the DDF. The risk reduction multiplier for insurance remains as it was in DDF1, at 1:1, since on average, and over time, the state will pay the actuarially fair premium equal to the expected loss (assuming no transactions costs or profits). However, the incentive provided by credits toward the deductible are modeled differently in DDF2, and are no longer a simple multiple of the amount spent on insurance. The state receives a proportionate credit up to 10% of the deductible for the fraction of the stock that is insured. If the state insures 90% of its stock, the credit is 9% of the deductible, but, if coverage is only 50%, then the state only receives a 5% credit toward the deductible. The credit is designed to reflect the objective of the DDF—to provide incentives to protect facilities from damage through mitigation, or compensate for damage through insurance. Rather than focus on the value of insured losses, the DDF encourages states to insure a greater fraction of their at-risk facilities by offering a comparable credit against the deductible.

This new insurance model alters the way we analyze insurance as a strategy. For our simulations, the state will be assumed to purchase insurance to cover 50% of the stock, with the other 50% being covered by self-insurance (by definition). This may not be an unreasonable assumption (although it is a modeling parameter and can be changed in the simulations) since states may not purchase disaster insurance for every building or plant or facility because they are not considered at risk, some may be un-insurable, and others may be explicitly self-insured. The state will reduce the risk by the amount spent on insurance (in dollar terms this is 5% of the deductible) and reduce the deductible by 5%. That is, since the insurance premium is assumed to be actuarially fair, paying $1 million in premiums will offer, on average, coverage of $1 million in expected losses to the insured facilities each year.

The cost of insurance, and hence the credit awarded to the state in the DDF is tied to the size of the deductible because we can reasonably assume a state with a higher deductible has some combination of higher risk, or higher fiscal capacity which should be positively correlated with larger physical stock. States with a higher deductible, for whatever combination of reasons, will therefore be paying more to insure a given (say 50%) of their at risk physical stock.

The base case for DDF2 will set the credit limit at 10% of the deductible. We will perform a sensitivity analysis with a higher, 20% limit for insurance credit against the deductible. Note that all DDF2 analyses will result in the state spending some amount on insurance, which is, in fact, reflective of the current situation. DDF2 will reward states for maintaining current levels of insurance, and also encourage higher levels of insurance than does DDF1.

Table II-20 presents the MP analysis results for the 50% credit attainment case for MS and OH for Year 2015 with the inclusion of the Insurance Requirement -- that for each state, 5% of the credit is attained by purchasing insurance to cover 50% of the stock. The remaining 45% of the credit is attained by mitigation and/or Relief Fund, with the former having a credit multiplier of 3 and the latter a credit multiplier of 1. The results indicate that except for purchasing insurance to attain 5% of the deductible credit, both MS and OH choose to mitigate hurricanes to attain the remaining 45% of the deductible credit. However, we note that it actually makes no difference in choosing among the various mitigation strategies since they all have a credit multiplier of 3. Mitigation of hurricanes is chosen by the model because, when searching for the optimal solution, the model always chooses the strategy that is entered into it first if there are multiple strategies with the same "effectiveness coefficient," in this case that of the credit multiplier.

Table II-21 shows the burden analysis for DDF2 on Mississippi and Ohio for the goal of attaining a 50% reduction in the deductible through credits, where insurance of public facilities is credited proportionately up to 10% of the deductible for insuring 100% of all public facilities. The table compares the impact of the DDF for both Mississippi and Ohio under the alternative goals of attaining a 50% reduction in risk and attaining a 50% reduction in the deductible through credits for the base case parameters. The 50% reduction in deductible goal reflects the impact of the credit for insurance.

Table II-20. MP Analysis of DDF2 – Mississippi and Ohio (50% credit attainment, Year 2015, PA Risk; Property Damage +GI BCRs for Mitigation, in million dollars)

	MP Analysis – 50% Credit Attainment			
	Mississippi		Ohio	
Strategy	Expenditure	Deductible Credit Attained	Expenditure	Deductible Credit Attained
Mitigation				
Hurricanes	4.20	12.60	2.57	7.71
Floods				
Severe Storms				
Earthquakes				
Other				
Insurance	1.40	1.40	0.86	0.86
Relief Fund				
Hurricanes				
Floods				
Severe Storms				
Earthquakes				
Other				
Total	8.72	29.68	2.02	7.52

As shown in Section C of the table, the state of Mississippi will increase spending on mitigation and reduce its spending on insurance to achieve the goal of a 50% reduction in the deductible. This occurs because the insurance credit is limited to 10% of the deductible, and to compensate the state must increase its spending on mitigation (rather than moving to the relief fund as the relief fund credit is lower than the credit for mitigation). This results in a lower state burden and an increased federal burden, although the changes are not large. A similar result is seen in Ohio; however, the state spends the limit on insurance and lowers mitigation correspondingly to achieve the credit goal. In this case, however, the burden shifts toward the state as well as to FEMA because the credit against the deductible is lower than in the 50% risk reduction case, and results in an increased burden.

Table II-21. Burden Analysis for DDF2 – Mississippi and Ohio, property damage only BCRs (50% risk reduction vs. 50% deductible reduction from credits)				
	Expenditures ($millions)			
	Mississippi		**Ohio**	
	50% risk red.	50% deduct.	50% risk red.	50% deduct.
	(1)	(2)	(3)	(4)
A. Status Quo				
Total expected losses	311.9	311.9	31.6	31.6
State share of expected losses	70.2	70.2	7.1	7.1
Federal share of expected losses	241.7	241.7	24.5	24.5
B. Deductible only				
Total expected losses	311.9	311.9	31.6	31.6
State deductible	28.0	28.0	17.1	17.1
PA after state pays deductible	283.9	283.9	14.5	14.5
State share of remaining PA	63.9	63.9	3.3	3.3
State total spending (deductible + state share)	91.9	91.9	20.4	20.4
Federal PA	220.0	220.0	11.2	11.2
Change in State burden	21.7	21.7	13.3	13.3
Change in Federal burden	-21.7	-21.7	-13.3	-13.3
C. Mitigation with DDF credit				
Total expected losses	311.9	311.9	31.6	31.6
Spending on mitigation	2.8	4.2	2.7	2.6
Insurance premiums	4.2	1.4	0.0	0.9
Additions to relief fund	0.0	0.0	0.0	0.0
Reduction in PA from expenditures	14.0	14.0	8.6	8.6
Total actual PA	297.9	297.9	23.0	23.0
State deductible less credit	15.4	14.0	9.1	8.6
PA less deductible	282.5	283.9	14.0	14.5
State share of remaining PA	63.6	63.9	3.1	3.3
State total spending (mitig. + deduct. + state share)	85.9	83.5	14.9	15.2
Federal PA	218.9	220.0	10.8	11.2
Change in State burden from status quo	15.8	13.3	7.8	8.1
Change in State burden relative to deductible only	-5.9	-8.4	-5.5	-5.1
Change in Federal burden from status quo	-22.8	-21.7	-13.7	-13.3
Change in Fed. burden relative to deductible only	-1.1	0.0	-0.4	0.0

Comparisons are to DDF1 Base Case, for which risk level equals Public Assistance (composed of property damage and non-property damage as a proxy for government interruption).

VI. Full DDF

A. Assumptions and Parameters

In the Full DDF2 analysis, we combine the various innovations we have examined in the previous sections. These include integrating state risk for property damage, fatality, and government interruption, using the full BCRs for the mitigation strategies for the various threat types, and integrating resilience oriented at reducing GI losses. In the credit attainment analysis in the next sub-section, we will also apply the new approach to simulate the state spending on disaster insurance.

B. Analysis

1. MP Analysis

Table II-22 presents the MP results for the risk reduction target simulation. For MS, the model first chooses mitigation of floods and severe storms (which have a BCR of 5.00 and 4.00, respectively) until both strategies reach the constraint of 50% risk reduction from each threat type. For the remainder of the risk reduction target, the Model chooses resilience for hurricanes. For OH, since the state does not have any risk of floods, the model chooses mitigation of severe storms to achieve the risk reduction goal. However, for both states, since both mitigation of severe storms and resilience for all threat types have the same BCR (4.00), there would be no difference in choosing from these alternative risk reduction strategies.

Table II-22. MP Analysis of DDF2, Year 2015 – Mississippi and Ohio (50% risk reduction, PA Risk with Adjusted GI Risk + Fatalities; PD + GI + Fatal BCR for Mitigation, Including Resilience Oriented at GI, in million dollars)

	MP Analysis – 50% Risk Reduction			
	Mississippi		Ohio	
Strategy	Expenditure	Risk Reduction Attained	Expenditure	Risk Reduction Attained
Mitigation				
Hurricanes				
Floods	1.05	5.23		
Severe Storms	3.62	14.49	1.88	7.50
Earthquakes				
Other				
Resilience				
Hurricanes	0.72	2.88		
Floods				
Severe Storms				
Earthquakes				
Other				
Insurance/Relief Funds				
Hurricanes				
Floods				
Severe Storms				
Earthquakes				
Other				
Total	5.39	22.59	1.88	7.50

Table II-23 presents the MP analysis results for the 50% credit attainment case for MS and OH for Year 2015 with the inclusion of the Insurance Requirement -- that for each state, 5% of the credit is attained by purchasing insurance to cover 50% of the capital stock. The remaining 45% of the credit is attained by mitigation, resilience, and/or relief fund, with mitigation having a credit multiplier of 3, resilience for a credit multiplier of 2, and relief fund a credit multiplier of 1. The results indicate that, except for purchasing insurance to attain 5% of the Deductible credit, both MS and OH choose to mitigate hurricanes to attain the remaining 45% of the credit. However, we note that it actually makes no difference in choosing among the various threats that mitigation reduces, since they all have a credit multiplier of 3. As explained in the previous sections, mitigation of hurricanes is chosen by the model because, when searching for the optimal solution, the model always chooses the strategy that is entered into it first if there are multiple strategies with the same credit multiplier.

Table II-23. MP Analysis of DDF2 –Mississippi and Ohio (50% credit attainment, Year 2015, PA Risk with Adjusted GI Risk + Fatalities, in million dollars)

	MP Analysis – 50% Credit Attainment			
	Mississippi		Ohio	
Strategy	Expenditure	Deductible Credit Attained	Expenditure	Deductible Credit Attained
<u>Mitigation</u>				
Hurricanes	6.78	20.34	2.25	6.75
Floods				
Severe Storms				
Earthquakes				
Other				
<u>Resilience</u>				
Hurricanes				
Floods				
Severe Storms				
Earthquakes				
Other				
<u>Insurance</u>	2.26	2.26	0.75	0.75
<u>Relief Fund</u>				
Hurricanes				
Floods				
Severe Storms				
Earthquakes				
Other				
Total	9.04	22.59	3.00	7.50

2. Burden Analysis

Table II-24 shows a comparison of the DDF2 Base Case accounting for only those losses covered by PA with the Full DDF2 case, where all benefits of mitigation are included -- mitigation of property damage, fatalities, and government interruption; as well as resilience reduction of government interruption. Expected losses are significantly higher, but the deductible is unchanged. Hence, the state's responses are still slight due to the goal of reducing risk equal to half the deductible. However, remaining PA increases substantially, with these costs covered by the existing share arrangement. The state burdens do not differ substantially from the status quo; however, the burdens for FEMA fall compared to the deductible only case because of some state risk reduction.

Table II-24
Burden Analysis for Full DDF2 – Mississippi and Ohio
All Benefits Included

	Mississippi		**Ohio**	
	Base Case	Full DDF2	Base Case	Full DDF2
	(1)	(2)	(3)	(4)
A. Status Quo				
Total expected losses	311.9	627.5	31.6	92.3
State share of expected losses	70.2	141.2	7.1	20.8
Federal share of expected losses	241.7	486.3	24.5	71.5
B. Deductible only				
Total expected losses	311.9	627.5	31.6	92.3
State deductible	28.0	28.0	17.1	28.0
PA after state pays deductible	283.9	599.5	14.5	64.3
State share of remaining PA	63.9	134.9	3.3	14.5
State total spending (deductible + state share)	91.9	162.9	20.4	42.5
Federal PA	220.0	464.6	11.2	49.8
Change in State burden	21.7	21.7	13.3	21.7
Change in Federal burden	-21.7	-21.7	-13.3	-21.7
C. Mitigation with DDF credit				
Total expected losses	311.9	627.5	31.6	92.3
Spending on mitigation	5.5	4.7	2.6	1.9
Insurance premiums	0.0	0.7	0.0	0.0
Additions to relief fund	0.0	0.0	0.0	0.0
Reduction in PA from expenditures	14.0	22.6	8.6	7.5
Total actual PA	297.9	604.9	23.0	84.8
State deductible less credit	11.6	13.3	9.4	22.4
PA less deductible	286.3	591.6	13.6	62.4
State share of remaining PA	64.4	133.1	3.1	14.0
State total spending (mitig. + deduct. + state share)	81.5	151.8	15.1	38.3
Federal PA	221.8	458.5	10.5	48.4
Change in State burden from status quo	11.3	10.6	8.0	17.5
Change in State burden relative to deductible only	-10.4	-11.1	-5.3	-4.2
Change in Federal burden from status quo	-19.9	-27.8	-14.0	-23.2
Change in Fed. burden relative to deductible only	1.8	-6.1	-0.7	-1.5

Comparisons are to DDF1 Base Case, for which risk level equals Public Assistance (composed of property damage and non-property damage as a proxy for government interruption).

C. Summary and Comparison of Results

Up to this point, we have provided comparative static analyses of individual innovations in the Disaster Deductible Formula. That is, we have analyzed each of them one at a time and compared each one to the same DDF2 Base Case (for which the only difference between it and DDF1 is the use of an alternative Fiscal Capacity Index). This way the reader can evaluate the implications of each innovation in isolation. We now turn to the simulation of the entirety of all of the innovations analyzed above together, or what we refer to as the “Full DDF2.” This way the reader can evaluate the potential complete impacts of undertaking all the innovations together. Note, however, that the results below are not additive of all of the individual changes above because of interactive effects between some of the individual refinements. Keep in mind that we view DDF2 not necessarily as an entirely different alternative, but as also a menu of possible innovations that can be made with respect to DDF1 on an as needed basis.

Table II-25 presents the summary and comparison of the results of the various cases we have analyzed in Sections IV to VI. The results are presented in terms of changes in the level of key variables (such as the Fiscal Capacity index, Risk Index, and Adjusted Deductible) in comparison to DDF1 Base Case. We also present results of a Mathematical Programming (MP) analysis of the state response in terms of an assumed goal of reducing risk by the lesser of 50% of their expected annual risk or 50% of the full value of their Deductible. The results are also presented for a Burden Analysis (BA), which measures the impact of the DDF in terms of the change in the federal and state shares of spending for each case. For the Adjusted Deductible, the State Response (MP) Analysis and Burden Analysis, they are expressed in millions of 2015 dollars.

An annotation is also made to indicate a range of percentage changes from the DDF1 Base Case. From the summary table we can see that the results for the federal and state shares change by more than 50% for only the case where we add fatalities and for the Full DDF. This is because inclusion of fatalities substantially increases both state and federal expenditure because total PA and the state’s share of total PA rise. While mitigation can reduce these expenditures over time, because the burden analysis is a snapshot of a single year the increase in total PA dominates the effect of mitigation.

Another finding is that there is only one change of greater than 50% in any of the other variables across various cases for OH. However, for MS, there are many changes in other variables for several cases. The larger changes for MS than for OH in the results of the various DDF2 cases compared to DDF1 Base Case are caused by two major reasons:

1. <u>Risk Levels</u>. MS has relatively higher expected losses from fatalities and GI. Therefore, the inclusion of the additional loss categories in DDF2 results in big changes to the Risk Index, and thus the Combined Index and the Adjusted Deductible. The level of the Adjusted Deductible will in turn affect the MP results, since for MP, the goal is to reduce 50% of the state’s Deductible for MS. OH has relatively low expected losses from fatalities and GI. Therefore, the changes in the Risk Index, Combined Index, and Adjusted Deductible in the various DDF2 Cases are minor compared to DDF1 Base Case.

2. Mitigation BCRs. For MS, most of the state expected losses are from hurricanes. However, in the DDF1 Base Case, since Property Damage Only BCRs are used, the BCR for hurricanes (which is 0.51) is lower than the BCR for insurance and relief fund. Therefore, in the DDF1 Base Case, a large proportion of expenditures for MS is on insurance/relief fund. In the various DDF2 Cases, PD + GI or PD + GI + Fatalities BCRs are used. With higher BCRs, mitigation of hurricanes becomes more economically attractive than insurance/relief fund in these cases. The risk reduction expenditures are then shifted to mitigation only or mitigation plus resilience (when the latter comes into play) in the DDF2 Cases. For OH, in nearly all cases, the risk reduction goal is achieved by mitigation of severe storms (the threat type that the state has the highest expected losses). The BCR for severe storms does not change much when we add additional loss categories: 3.18 for Property Damage Only; 3.72 for PD + Fatalities; and 3.34 for PD + GI; and 4.00 for Full BCR. The only case where OH has a greater than 50% change is for the case that resilience is included. Since resilience has a higher BCR than mitigation of severe storms, substantial amount of risk reduction expenditures is shifted to resilience in this case.

Table II-25 summarizes the results of our analyses of various scenarios in DDF2 for our example states of Mississippi and Ohio. The table presents the basic parameters of the DDF including the Risk and Fiscal Capacity Indices and the Adjusted Deductible, the optimal choices from the MP Analysis, and the resulting spending by the state and FEMA from the Burden Analysis.

Highlights of the Table II-25 include:

1. DDF1 only considered property damage BCRs, resulting mitigation against hurricanes (the major source of extreme damages) not being economically viable because insurance and relief funds have a higher BCR than hurricane mitigation. DDF2, by considering government interruption and fatalities (separately) in addition to property damage, allows for a greater range of economically viable mitigation options. As a result of the shift from relief funds and insurance toward mitigation, as well as the compounding effect of mitigation across multiple years, states with large hurricane risks are predicted to receive greater benefits from the DDF over time than in DDF1.

2. The Adjusted Deductible of states can increase or decrease when more risk categories (fatalities and GI) are taken into consideration in DDF2. The direction of the change results mainly from the different expected losses of the different risk types of each state and the normalization process across the states.

3. Total risk reduction expenditures by the states depend on two major factors: BCRs and risk levels. By incorporating more risk categories, mitigation BCRs increase; however, as pointed out in #2, the risk levels can increase or decrease. With higher BCRs, the states can achieve higher risk reduction levels for the same amount of mitigation spending. However, the impact of risk levels on the risk reduction expenditures is two-fold. In general, more mitigation expenditures are needed to achieve a given percentage risk reduction goal when the risk levels become higher. Conversely, in some cases, higher risk levels also mean that more risk reduction expenditures can be made on more economically viable mitigation strategies before the opportunities are exhausted (i.e., the constraint of a maximum of 50% risk reduction from each threat type is reached). The net effect varies across the states.

Table II-25. Summary Table of Simulations of DDF2 Assumptions and Parameters: Main Cases

(change from DDF1 Base Case in millions of 2015 dollars for Adjusted Deductible, State Response Analysis and Burden Analysis)[a]

	DDF1 Base Case[b] (1)	DDF2 Base Case PA Risk; PD+GI BCRs (2015) (2)	DDF2 PA+Fatal Risk; PD+GI+Fatal BCRs (2015) (3)	DDF2 PA Risk w/ Adj GI; PD+GI BCRs (2015) (4)	DDF2 PA Risk w/ Adj GI; PD+GI+Resilience BCRs (2015) (5)	Full DDF2 (2015) (6)
<u>MS</u>						
Fiscal Index	0.98	0.90	0.90	0.90	0.90	0.90
Risk Index	2.18	same[c]	6.85***	9.65***	9.65***	4.65***
Combined Index	1.58	1.54	3.87***	5.27***	5.27***	2.78**
Adjusted Deductible	28.61	28.00	54.22**	72.78***	72.78***	45.19**
State Response (MP) Analysis[d]						
Mitigation Exp	2.81	5.46**	6.58***	19.87***	0.59**	4.67**
Insurance/Relief Fund Exp	4.51	0.00***	0.00***	0.00***	0.00***	0.00***
Resilience Exp	n.a.	n.a.	n.a.	n.a.	8.36[n.a.]	0.72[n.a.]
Burden Analysis						
Expected Loss (311.87[e])	311.87	311.87	603.51**	339.00	339.00	627.47***
State Share (70.17)	89.60	81.50	163.00**	98.20*	125.60*	151.77**
Federal Share (214.70)	229.60	221.80	420.00**	224.30	186.00*	458.49**
<u>OH</u>						
Fiscal Index	1.07	1.08	1.08	1.08	1.08	1.08
Risk Index	0.80	same	0.88*	0.85	0.85	0.76
Combined Index	0.94	0.94	0.98	0.97	0.97	0.92
Adjusted Deductible	16.91	17.13	15.03*	13.66*	13.66*	15.01*
State Response (MP) Analysis[d]						
Mitigation Exp	2.66	2.56	1.89*	2.05*	0.67**	1.88*
Insurance/Relief Fund Exp	0.00	0.00	0.00	0.00	0.00	0.00
Resilience Exp	n.a.	n.a.	n.a.	n.a.	1.15[n.a.]	0.00[n.a.]
Burden Analysis						
Expected Loss (31.60[e])	31.60	31.60	105.20***	30.00	30.00	92.30***
State Share (7.11)	14.80	15.10	31.20***	13.10	15.20	38.29***
Federal Share (24.49)	11.0	10.50	68.40***	12.10*	9.80*	48.36***

[a] Change from DDF1 Base Case: * 10 to 50%; ** 50 to 100%; *** more than 100%.
[b] This Base Case varies slightly from the Base Case presented in Part I of this Report. It utilizes the DDF2 Risk Index and includes Washington, DC in the calculations.
[c] Same as Base Case DDF1.
[d] MP goal is reduction of risk equal to the lesser of 50% of risk and the state's Deductible.
[e] Values in parentheses are status quo burdens.

4. The inclusion of resilience in the state disaster risk reduction mix can, in some cases, decrease total mitigation because the resilience BCR is greater than all mitigation BCRs other than floods. Accordingly, it also reduces the total expenditures of the states to achieve a risk reduction goal.

5. The more sophisticated formulation of insurance in DDF2 allows for relatively low-risk states (which will have relatively low insurance premiums) to obtain credits against the deductible at low cost. Thus, insurance might be the cheapest way of offsetting the Deductible for such states. By comparison, the simple 2:1 credit multiplier for insurance in DDF1 means that states will only turn to insurance after mitigation (which has a credit multiplier of 3:1) opportunities are exhausted.

6. Compared to the current expected losses and federal/state shares (status quo), DDF2 shows an increase in state spending through a combination of mitigation, insurance resilience spending, the net deductible, and remaining state share similar to DDF1. However, the outcome varies across states. Note, however, that the Deductible itself is the major factor influencing the outcome. When the Deductible is similar across scenarios, the resulting burdens are similar.

7. Variations in state spending under alternative PA Program assumptions remain relatively small when the Deductible is similar. When the expected loss and Deductible increase substantially, as in the case of adding fatalities and in the case of the Full DDF2, the burdens increase for both the state and FEMA.

VII. Assessment

A. Assumptions and Parameters

The specification of **Base Case DDF2** and the incentivization response is based on several major assumptions and key parameters. In this section, we discuss each in greater detail and indicate some of the major implications, including the sensitivity of the DDF to changes in the values used. Further sensitivity tests are discussed below.

- **Deductible Base Level**. Based on the median of states' 10-year (2005-14) average of total annual PA funding. This time range corresponds to the range of data used in the calculation of the DDF2 Risk Index. The result is a Base Deductible of $26.9 million per state. The advantage of this specification is that it represents a pure level without any initial bias relating to state conditions. Of course, the state-specific conditions are important and are factored in through the Fiscal Capacity Index and Risk Index Adjustments.
- **Fiscal Capacity Index Adjustment**. We chose two specifications for the fiscal capacity measures, one as the Base Case and one as the sensitivity case. The Base Case includes the General Fund, the size of the state's Reserve (Rainy Day) Fund, and the state's Bond Rating, with the former two on a per capita basis. The state's General Fund is a proxy for the discretionary funds available to states to finance the deductible, as well as any disaster-related activities such as

mitigation, purchasing disaster insurance for public facilities and establishing a relief fund. The Rainy Day Fund may provide a source of funds to support post-disaster emergency expenses. Finally, bonding capacity may be called upon if the state issues post-disaster debt obligations. Separate indices for each state are computed by calculating the ten-year average value for each state and dividing by the median value across states. Then, for the composite index of three components, the average value of the three indices is used as the Fiscal Capacity Index adjustment factor (together with the Risk Index) applied to the Base Deductible. For the sensitivity case, we will use only the state General Funds to construct the index.

- **Risk Adjustments**. We utilized a statistical analysis of 10-year (2005-14) average public sector losses for each of 4 major threat categories (hurricanes, floods, severe storms, and earthquakes). The statistical analysis enables users of the DDF to make forecasts of future risk based on projections of such factors as population, gross state product (GSP), and possibly climate change. For the Base Case DDF, we simply use GSP. This adjustment is also applied to the Base Deductible by calculating the value for each state. The Risk Index is projected out to 2035 by assuming that GSP grows at the same rate as population, and inserting the projected GSP value into the estimating equations. For lack of data, earthquake risks in each state are assumed to grow over time at the weighted average of the growth rate of severe storm, floods, and hurricanes in the state.
- **Adjusted Base Deductible**. The Fiscal Capacity Index and Risk Index are applied with equal weight to the Base Deductible. In addition, the result is normalized back to a $26.9 million state average to control for the type of "bracket creep" that arises with the application of the two adjustment indices.
- **Deductible Cap**. A cap of $138.6 million is applied to eliminate outliers. The $138.6 million is based on the 95th percentile of disaster damages by event, which is then normalized to $94.6 million in the base case.[66]
- **Loss Reduction Multipliers**. This refers to the benefit-cost ratios (BCRs) associated with risk reduction strategies.
  -- **For mitigation**, these were derived from the *Mitigation Saves* Report to Congress (MMC, 2005), and for DDF2 consider benefits from mitigating losses from property damage and government interruption:[67]

[66] We do not recalculate the deductible cap in either the 2035 case or the fatality or business interruption analyses because we in are unable to project losses on a per-event basis that would correspond to the deductible cap.
[67] The BCRs derived in the *Mitigation Saves* Report to Congress (MMC, 2005) include a range of benefits categorized broadly as property damage, casualty, historical and environmental, and business interruption. Mitigation projects for various threats tend to emphasize more of some benefits than others. For example, the *MS* Study found that casualty reduction was the largest benefit in wind-related mitigation projects, while property damage reduction was the largest benefit for flood-related projects. Since federal public assistance is mainly limited to property damage (permanent work) and some government interruption (emergency work), we have calculated BCRs for property damage and government interruption for the base case. The Study only identified three threat types: Wind, Flood and Earthquake, whereas we have five types. The adjusted BCRs are calculated as the property damage and government interruption (using business interruption as a proxy) share of benefits over the entire costs, thereby creating lower BCRs. These are for earthquakes: (28%+10%) *1.5 = .57; hurricanes (13%+26%) *3.9 = 1.52; flood: (95%+1%) *5.0 = 4.8. The overall BCR is a weighted average of the component BCRs

- Mitigation of property damage only
  - Floods— 4.75:1
  - Hurricanes— 0.51:1
  - Earthquakes— 0.42:1
  - Severe storms— 3.18:1
  - Other— 3.18:1

- Mitigation BCRs including both property damage and business interruption (the Base Case) are:
  - Floods— 4.80:1
  - Hurricanes— 1.52:1
  - Earthquakes— 0.57:1
  - Severe storms— 3.34:1
  - Other— 3.34:1

- Mitigation BCRs for the inclusion of reduction in fatalities are::
  - Floods— 4.90:1
  - Hurricanes— 2.89:1
  - Earthquakes— 1.33:1
  - Severe storms— 3.72:1
  - Other— 3.72:1

- Mitigation BCRs including property damage, fatalities, and business interruption are:
  - Floods— 4.95:1
  - Hurricanes— 3.90:1
  - Earthquakes— 1.46:1
  - Severe storms— 3.88:1
  - Other— 3.88:1

-- **For resilience**, we consider the expansion of the current PA categories eligible for credit for reducing business interruption (BI) and government interruption (GI) losses. We derive BCRs from the studies on resilience effectiveness, costs and benefits. They are:

- Floods— 4.0
- Hurricanes— 4.0
- Earthquakes— 4.0
- Severe storms— 4.0
- Other— 4.0

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using cost as the weights and changes from 4.0 to 3.34. This BCR is also used for the other categories of severe storm and other.

-- **For relief funds**, we assume the "loss reduction" is 1:1. Note that this strategy, however, applies to all threats (and is not just threat-specific). Most importantly, it is not actually a reduction in risk but simply a shift in the risk from the federal government to the state.
-- **For insurance**, credit for insurance is given on a lump-sum basis. Credit up to 10% of deductible is given for hazard insurance coverage of public facility stock proportionately. For example, if 50% of stock has disaster insurance credit is 5%, or 90% of stock is covered, credit is 9%.
--In our incentivization analysis, we will place the following **limits on risk reduction** strategies:
- Mitigation: 50% of risk for each threat type because not all risks can be mitigated
- Relief fund: 50% because this is only risk spreading and not actually risk reduction
- Insurance: 50% because this is only risk spreading and not actually risk reduction
- Resilience: 50% because not all BI/GI risks can be mitigated

- **Credit Multipliers**. In order to incentivize risk reduction behavior, we assume that FEMA would provide credits for state implementation of various strategies. The credit multipliers are as follows:
  - Mitigation—3:1[68]
  - Relief funds—1:1[69]
  - Insurance – 10% of coverage rate (e.g., 90% coverage offers 9% credit against deductible)
  - Resilience—2:1

  We assumed that credits for mitigation are applied the first year after expenditures are made, while credits for other activities are contemporary.
- **Useful life of mitigation projects** is assumed to be 50 years. This reflects the useful life of most buildings and various other structures like bridges, levees and dams (MMC, 2005).

The aforementioned assumptions and parameters fall into three 3 groups. First, we can identify objective values to which an accuracy test can be applied. This would include the BCRs and useful life of mitigation projects. A second category is more subjective and can have a test of "reasonableness" applied, such as the decision to adjust the Base Deductible by Fiscal Capacity and Risk Indices. This also applies to the 3:1 credit for risk reduction expenditures via mitigation and the application of this credit to only the first year. A final category pertains to equity or fairness considerations with respect to the initial $26.9 million Base Deductible and the imposition of a cap on outliers. The Base Deductible level chosen is considered fair from the standpoint of applying an equal baseline deductible across states. Moreover, by selecting the median of average annual PA, we ensure that half of the states will expect PA that falls below the baseline deductible and one-half of states will expect PA that is above the deductible. The equity of variations of DDF2 and the state response are examined formally below.

We acknowledge that our illustrative results of the application of the DDF are sensitive to the various assumptions and parameters. The implications of any of them are straightforward in that the adjustment factors are applied in a multiplicative fashion, as are the Deductible Credit Multiplier and

[68] Applicable to the year in which the expenditure is made.
[69] Applicable only in year the Relief Fund is initiated, or year in which any subsequent increases to it are made.

Loss Reduction Multipliers (BCRs). Use of forecasts of risk are less transparent, because they would likely be based on differentials in population and economic growth rates across states, as well as potentially changing climatic conditions. However, we will perform sensitivity tests on this aspect as well as many of the assumptions and parameters disused above.

B. Formal Assessment of the DDF

The specification of the second, alternative, Disaster Deductible Formula (DDF2) presented here can be assessed against selected criteria. These criteria include:

- *Achieve FEMA's goals*. The DDF2 shifts more initial responsibility for disaster risk to states and provides incentives for states to reduce this risk.
- *Stability* The application of caps on deductibles prevents extreme outliers from having too much influence. This controls for both extreme values in the measures of fiscal capacity and the influence of extreme disasters. Stability can also be achieved by not changing the deductible too frequently.
- *Economic efficiency*. This is promoted by giving each state a choice to achieve a least-cost portfolio of risk reduction and deductible credit strategies.
- *Equity and fairness*. The Base Deductible satisfies some of the fundamental principles of equity. Each state starts off with the same deductible before adjustments are made for risk and fiscal capacity, which is consistent with Horizontal equity. Each state deductible is then adjusted for risk exposure, from all relevant hazards it faces, and adjusted for the fiscal capacity to fund both the deductible and the state's share of post-disaster public assistance, both of which relate to Ability to Pay equity[70]. Overall the adjustments address both Horizontal and Vertical equity objectives: similar states are treated similarly, but different states are treated differently.
- *Flexibility.* FEMA's choice of credit multipliers sets both the overall level of incentives for state disaster risk reduction expenditures and the relative reward for alternative tactics. Each type of mitigation can be credited differently, as can be the credit for purchasing insurance for public facilities and the credit for establishing a disaster relief fund. The credits can be set to affect the portfolio choice of disaster risk reduction response.
- *Transparency*. The DDF is easily calculated. This is attained by a relatively simple formula using publicly available data and with only a few parameters. The least predictable element is the adjusted deductible since it is based on the median expected loss value, a function of all state's loss experience. This effect may be moderated by not changing the deductible too frequently.
- *Political feasibility*. Establishing an equal Base Deductible makes the DDF more feasible. Allowing states to choose how to achieve a given reduction in their deductible via alternatives such as mitigation, insurance, resilience, or establishing a relief fund empowers the states, and encourages participation in the program.

[70] Ability to Pay is indirectly affected by the need for covering losses.

C. Sensitivity Tests

1. Incorporating Terrorism into the Risk Index

While most PA is related to natural disasters, FEMA has also provided PA for terrorist events. Given the relative rarity of terrorist events, it is not possible to model expected PA for them explicitly. Still, although highly-damaging terrorist attack have not occurred in most states, it is important to consider the potential losses from such events because mitigation actions such as implementing building codes could reduce damages and PA if a terrorist attack occurred.

We use metropolitan-level expected terrorism losses from Willis et al. (2005), accounting for inflation between 2005 and 2014, and aggregating expected damages across metropolitan areas in each state. We then add expected terrorism risks to modeled damages and calculate the Risk Index for each state as total damages (modeled PA plus terrorism) divided by median total damages across states.

Figure II-8 presents the effect of terrorism on the Risk Index. As shown, the effect of projected terrorism risk is small for most states. The biggest effects are seen in high population states that have relatively infrequent natural disasters, such as New York and Illinois. States like Louisiana, on the other hand, have lower Risk Indices when terrorism is incorporated because they have less than the median level of projected terrorism risk.

2. State General Funds only

In the DDF2 Base Case, the Fiscal Capacity index is constructed based on three indicators: State General Fund, State Reserve (Rainy Day) Fund, and the State Bond Rating. We also performed a sensitivity analysis on the Fiscal Capacity Index, in which we use only the state General Funds to construct the index. Please see Section III-B for this sensitivity analysis, as well as a comparison of this General Funds only Fiscal Capacity Index with the ones used in DDF1 Base Case and DDF2 Base Case.

3. Alternatives of 50:50 Weights (25:75 and 75:25) for the Two Indices

The deductible in the Base Case assumed that the combined index was calculated as a simple average of the Risk Index and Fiscal Capacity Index. As a sensitivity test, we calculate the combined index by placing 75% of the weight on the Risk Index and 25 % of the weight on the Fiscal Capacity Index. This serves to increase the deductible of relatively risky states and decrease the deductible of relatively financially capable states. Louisiana, for example, sees its normalized deductible increase from approximately $75 million to $95 million, reaching the deductible cap. Wyoming, by contrast, will have its deductible reduced from $66 million to $35 million. If, instead, we place 75% of the weight on Fiscal Capacity and 25% of the weight on Risk, the effect is the opposite. Louisiana’s deductible falls relative to the baseline, to $49 million, while Wyoming’s deductible increases to $92 million. Deductibles under the alternative weights schemes are shown in Figure II-9. Note that in the case of Alaska the Fiscal Capacity Index is sufficiently high that Alaska reaches the deductible cap even when Fiscal Capacity receives only a 25% weight.

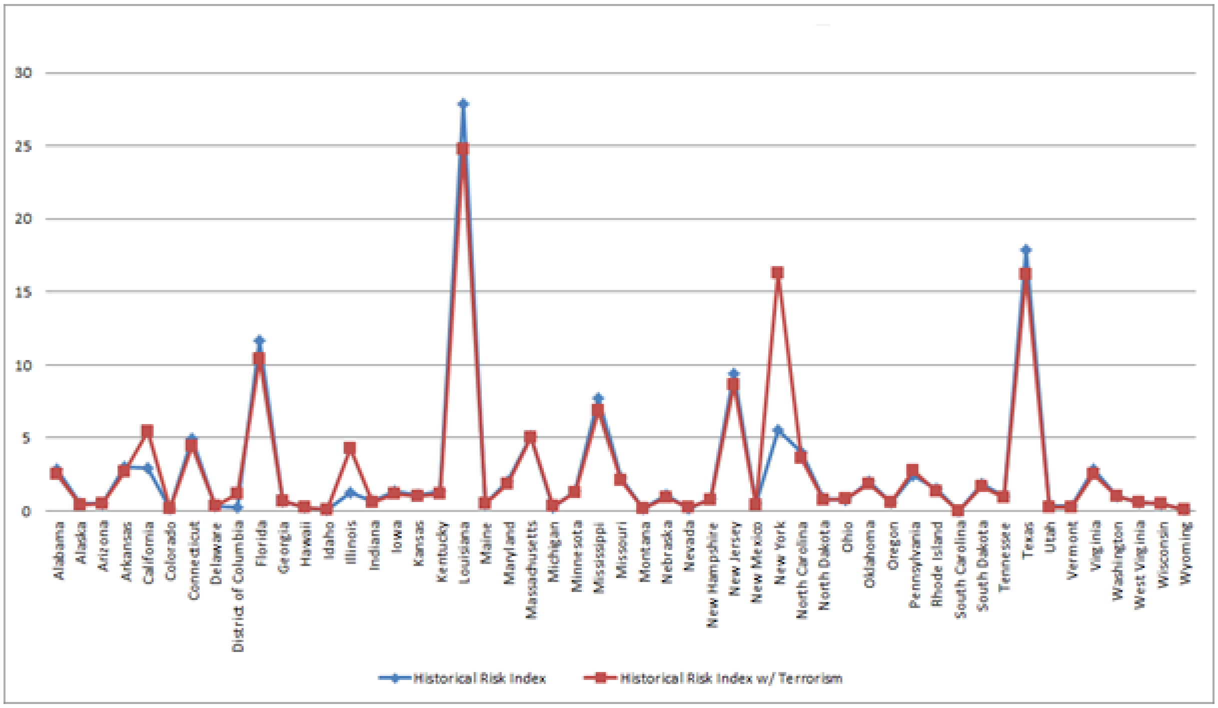

Figure II-8. Inclusion of Terrorism in Risk Index

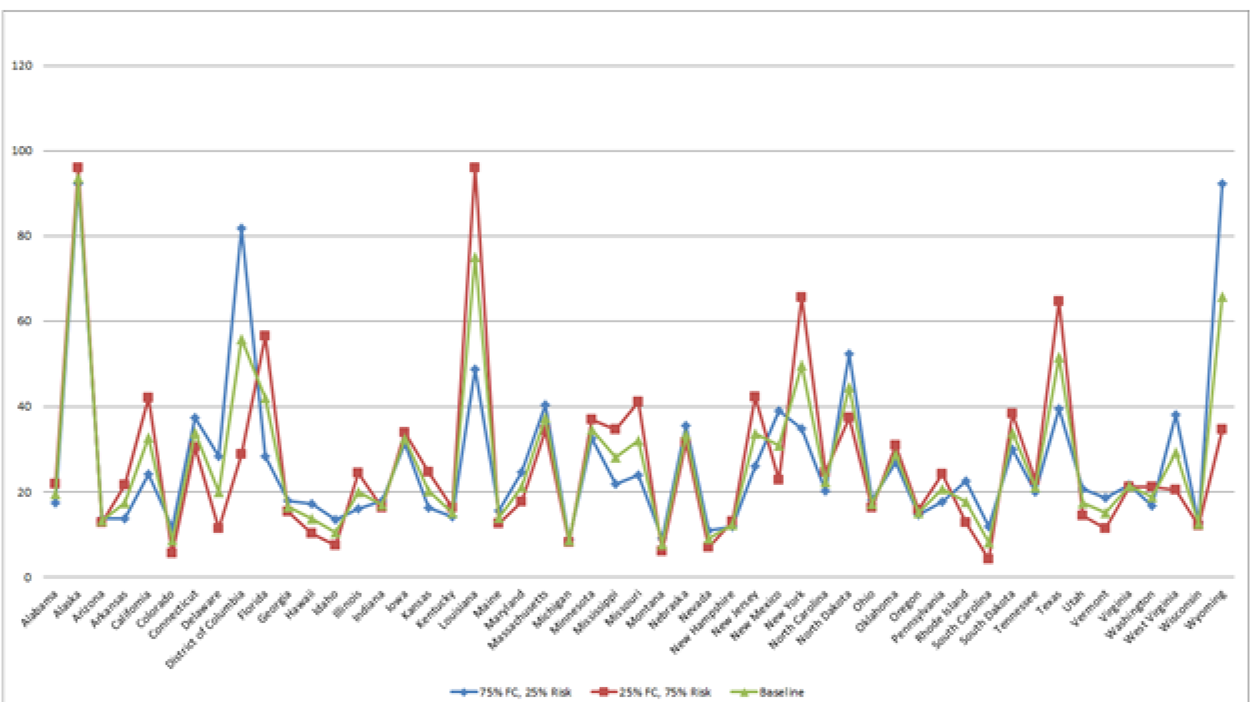

Figure II-9. Normalized Deductible under Alternative Weighting Schemes

a. MP Analysis:

Table II-26 presents the MP results of the sensitivity analysis for which we use the 25:75 weights for the Fiscal Capacity Index (three-indicator based) and Risk Index. When greater weight is placed on the Risk Index, the Adjusted Deductible for MS increases from $28.00 million in DDF2 Base Case to $34.68 million, while the Deductible for OH decreases from $17.13 to $16.26 million. Accordingly, the total expenditure for MS increases from $5.46 to $7.66 million, and for OH decreases from $2.56 to $2.43 million to achieve the risk reduction target. However, the mix of the risk reduction strategies remains the same between this sensitivity case and the DDF2 Base Case for both states.

b. Burden Analysis

Table II-27 shows a comparison of the base case with equal weighting of the risk and fiscal indices in determining the deductible with the case where the risk index is weighted more heavily than the fiscal capacity index (25:75). The adjusted deductible does not change, but mitigation spending for Mississippi increase slightly, while for Ohio is decreases slightly, due to how the deductible is calculated and normalized. Consequently, there is a slight decrease, (less than 10%), in burden compared to the status quo, and the base case for Mississippi, and a slight increase, (less than 10%), in the burden compared to the status quo and the base case for Ohio. The impact of the deductible with mitigation credit is relatively insensitive to changes in the index weighting.

4. TIME-PATH ANALYSIS

The DDF will be in effect for multiple years, so it is important to consider the implications of the DDF over time. Because the benefits of mitigation are cumulative, after many years of mitigation, PA will fall substantially. Figures II-10 and II-11 present the effect of the DDF over time for California and Mississippi, assuming that states offset one half of their deductible with mitigation, insurance, or relief funds. These graphs consider PA and expenditure contingent on an event of average magnitude occurring. The graphs should be viewed as the costs of the DDF Program in a given year that a large disaster occurs, rather than as a stream of costs over time.[71]

[71] While mitigation projects result in benefits over multiple years, the BCRs reported in the *Mitigation Saves* study are discounted net present values of the stream of benefits. The benefits of insurance and relief funds, by contrast, occur entirely in the time period that they are utilized.

Table II-26. MP Analysis of DDF2, Year 2015 –Mississippi and Ohio, 25:75 Weights for FCI & RI (50% risk reduction, PA Risk; Property Damage + GI BCRs for Mitigation, in million dollars)

	MP Analysis – 50% Risk Reduction			
	Mississippi		Ohio	
Strategy	Expenditure	Risk Reduction Attained	Expenditure	Risk Reduction Attained
Mitigation				
Hurricanes	4.96	7.54		
Floods	0.54	2.60		
Severe Storms	2.16	7.20	2.43	8.13
Earthquakes				
Other				
Insurance/Relief Fund				
Hurricanes				
Floods				
Severe Storms				
Earthquakes				
Other				
Total	7.66	17.34	2.43	8.13

Table II-27
Burden Analysis for DDF2 – Mississippi and Ohio,
Sensitivity Case: 25-75% weights on Risk and Fiscal Indices

	Expenditures ($millions)			
	Mississippi		Ohio	
	50:50 weights	25:75 weights	50:50 weights	25:75 weights
	(1)	(2)	(3)	(4)
A. Status Quo				
Total expected losses	311.9	311.9	31.6	31.6
State share of expected losses	70.2	70.2	7.1	7.1
Federal share of expected losses	241.7	241.7	24.5	24.5
B. Deductible only				
Total expected losses	311.9	311.9	31.6	31.6
State deductible	28.0	34.7	17.1	16.3
PA after state pays deductible	283.9	277.2	14.5	15.3
State share of remaining PA	63.9	62.4	3.3	3.5
State total spending (deductible + state share)	91.9	97.0	20.4	19.7
Federal PA	220.0	214.8	11.2	11.9
Change in State burden	21.7	26.9	13.3	12.6

Change in Federal burden	-21.7	-26.9	-13.3	-12.6
C. Mitigation with DDF credit				
Total expected losses	311.9	311.9	31.6	31.6
Spending on mitigation	5.5	7.7	2.6	2.4
Insurance premiums	0.0	0.0	0.0	0.0
Additions to relief fund	0.0	0.0	0.0	0.0
Reduction in PA from expenditures	14.0	17.3	8.6	8.1
Total actual PA	297.9	294.5	23.0	23.5
State deductible less credit	11.6	11.7	9.4	9.0
PA less deductible	286.3	282.8	13.6	14.5
State share of remaining PA	64.4	63.6	3.1	3.3
State total spending (mitig. + deduct. + state share)	81.5	83.0	15.1	14.7
Federal PA	221.8	219.2	10.5	11.2
Change in State burden from status quo	11.3	12.8	8.0	7.5
Change in State burden relative to deductible only	-10.4	-14.0	-5.3	-5.1
Change in Federal burden from status quo	-19.9	-22.5	-14.0	-13.2
Change in Fed. burden relative to deductible only	1.8	4.4	-0.7	-0.6

Comparisons are to DDF1 Base Case, for which risk level equals Public Assistance (composed of property damage and non-property damage as a proxy for government interruption).

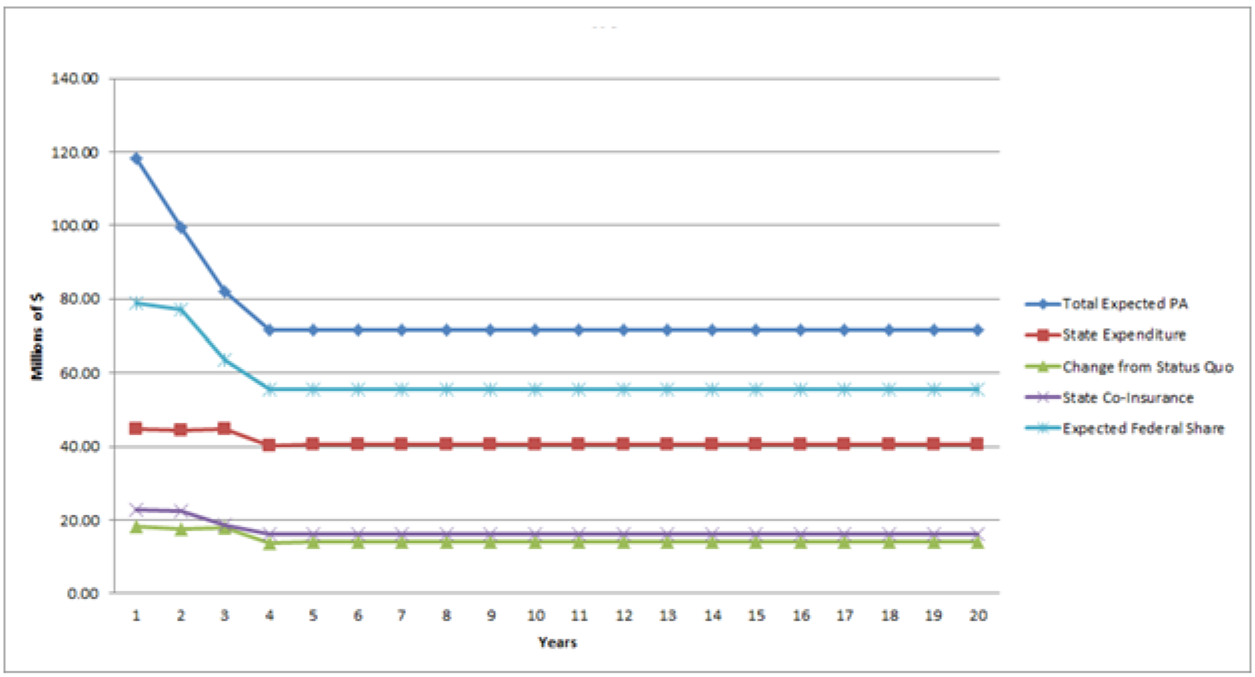

Figure II-10. Effect of DDF on California Public Assistance over Time

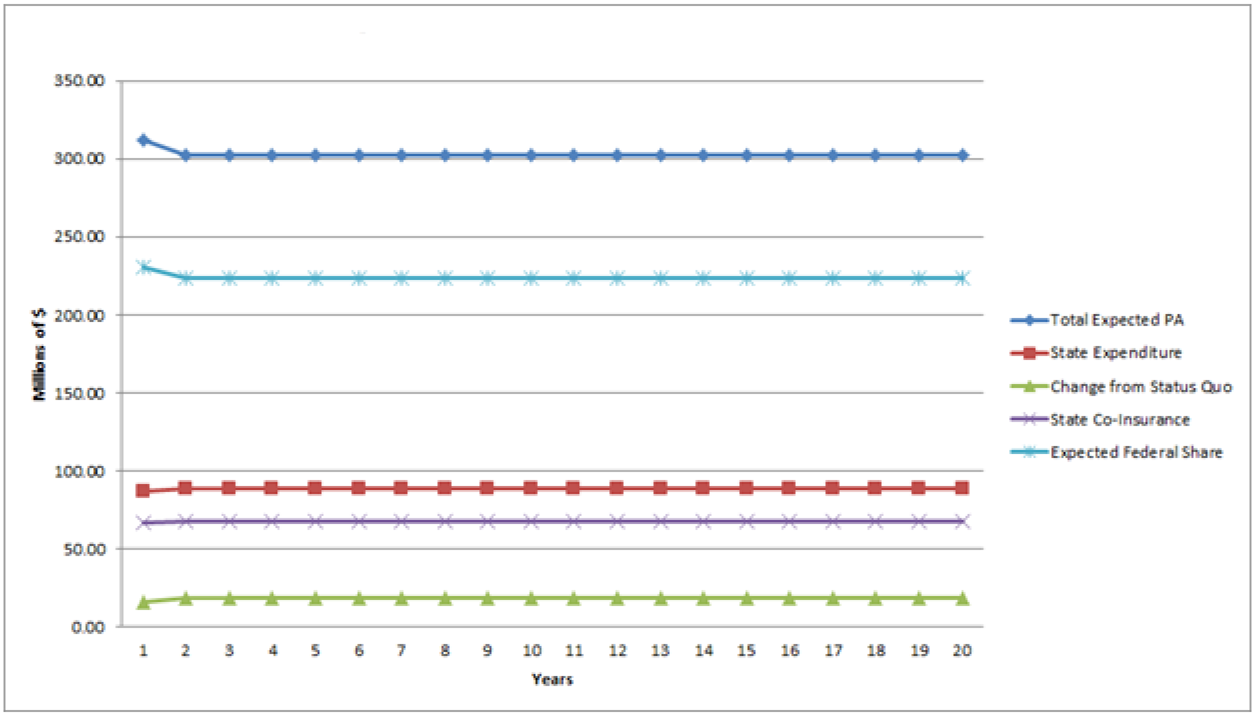

Figure II-11. Effect of DDF on Mississippi Public Assistance over Time

In the Base Case, mitigation only yields benefits in terms of reduced property damage, and only floods, severe storms, and other disasters have BCRs that are greater than 1. California and Mississippi will mitigate until these threat categories reach the maximum level of 50% mitigation. After these options are exhausted, they will switch to insurance or relief funds. Note that in California, mitigation options are exhausted in Year 4, while in Mississippi all mitigation opportunities are completed in Year 1. Mississippi in particular sees relatively little mitigation because most of its risk is from hurricanes, which have a property damage BCR that is below one.

If, instead, states consider both PA and the value of avoided fatalities the BCR for all threat categories exceeds one. This allows substantially more mitigation to take place before states exhaust their mitigation opportunities. Figure II-12 and Figure II-13 show the effect of the DDF over time if fatalities are considered.

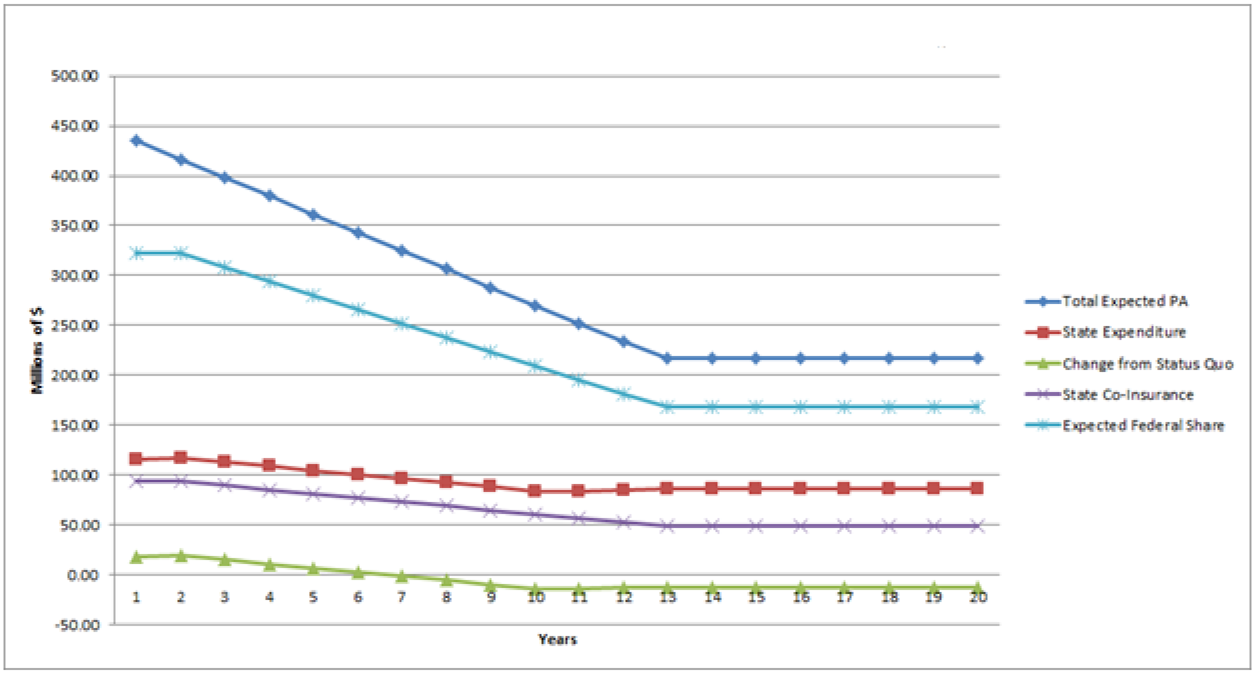

Figure II-12. Effect of DDF on California Public Assistance Including Fatalities over Time

While risk is substantially higher when fatalities are considered, mitigation opportunities and benefits are also larger. Note now, that both states have mitigation opportunities for at least ten years before mitigation is exhausted. Importantly, because risk is higher the benefits from mitigation are higher, and when fatalities are considered both California and Mississippi are eventually better off under the DDF than under the status quo. In both states this occurs around Year 8.[72]

[72] If the value of a statistical life is lowered to a more conservative value, such as the $6.6 million, risk decreases and the states have fewer mitigation opportunities. Counter-intuitively, California and Mississippi have slightly higher deductibles – meaning more mitigation, relief fund, or insurance – because fatalities affect other states more and the deductible is normalized based on the average deductible across states.

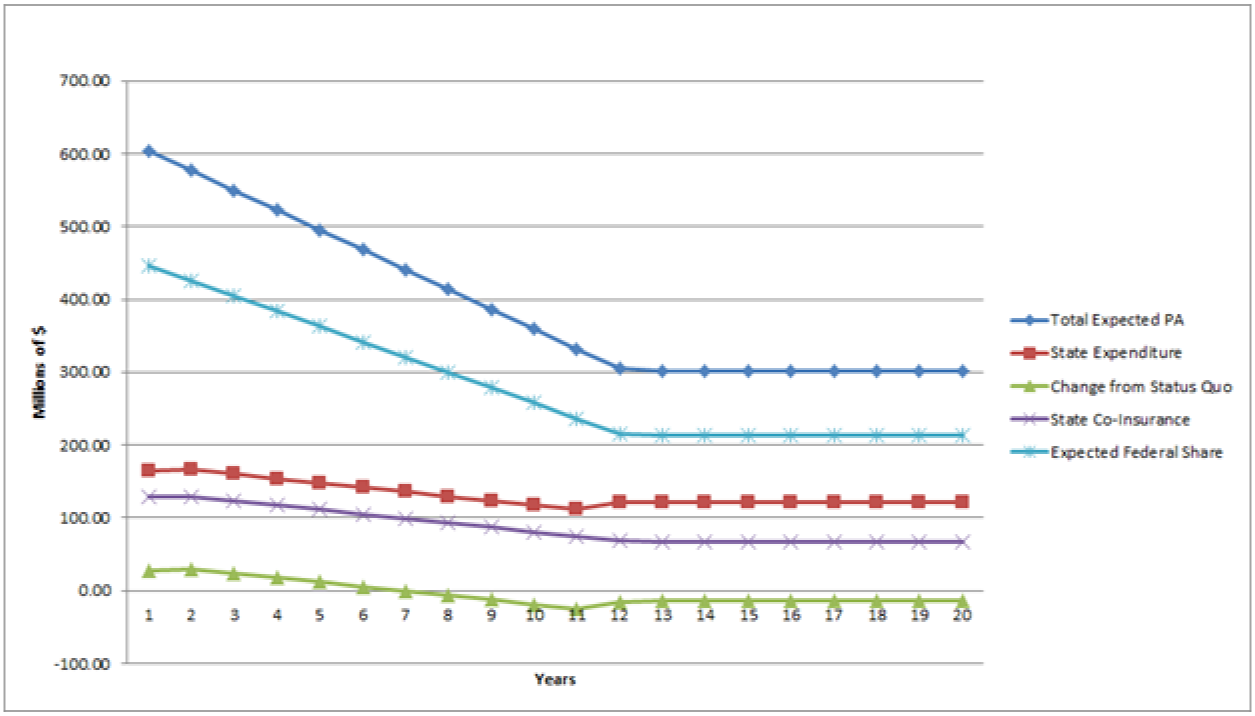

Figure II-13. Effect of DDF on Mississippi Public Assistance Including Fatalities over Time

Similar to the inclusion of fatalities, if Government Interruption is included there are more potential mitigation opportunities, and the BCR for mitigation is higher. This results in greater potential benefits from mitigation induced by the DDF relative to the Base Case for both California and Mississippi. Unlike the fatalities case, California is not better off relative to the status quo within the 20-year time horizon. This occurs because losses from fatalities are so large that California has a great deal of economically viable mitigation options. Note though, that Mississippi is briefly better off than the status quo, but then expenditure rises as Mississippi is required to spend more in order to offset its deductible because it must use insurance and relief funds instead of mitigation.

In general, using BCRs that reflect only property damage, it is unlikely that states will ever be better off under the DDF relative to the status quo. This occurs because, under this restriction, mitigation is not economically viable for all threat types (nearly all BCRs are less than 1.0). This is confounded by the fact that total PA is relatively low, which means that the total achievable reductions in PA, and in the achievable reduction in the states' cost share of PA, is small. If government interruption and fatalities are considered, there are greater possibilities for economically viable mitigation, both because total PA is higher and because more PA categories can viably receive mitigation.

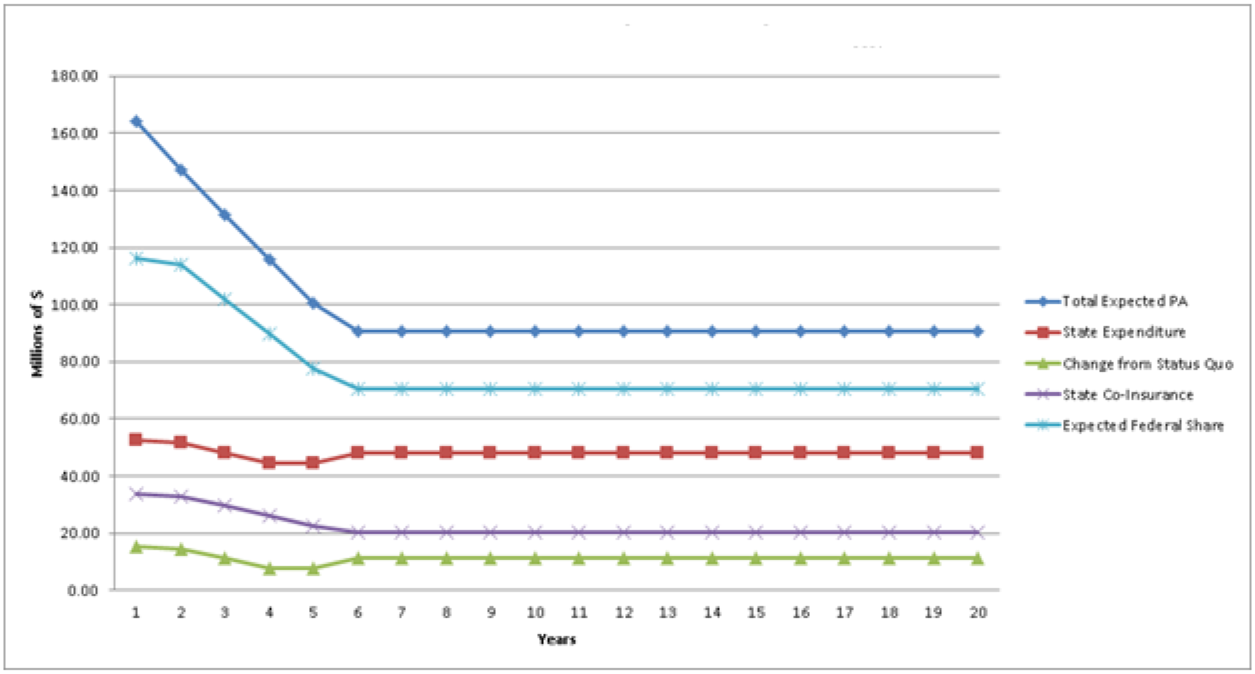

Figure II-14. Effect of DDF on California Public Assistance Including GI over Time

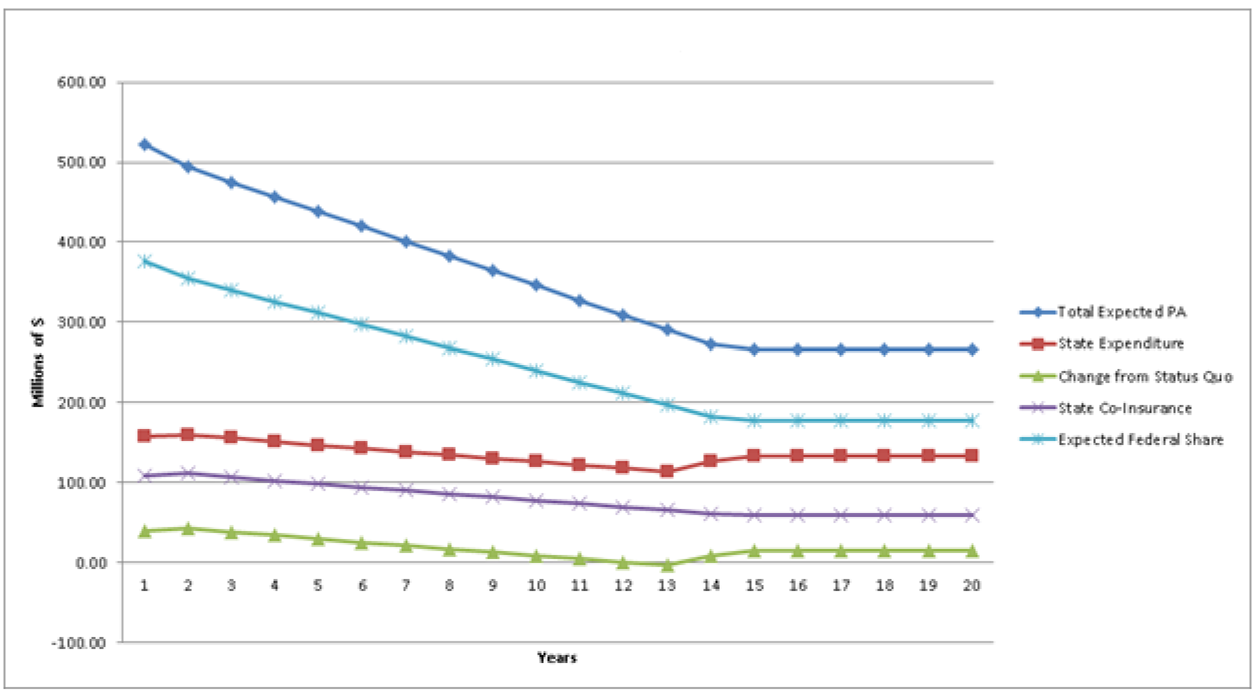

Figure II-15. Effect of DDF on California Public Assistance Including GI over Time

The key driver that affects whether a state will be better or worse off under the DDF is the ratio of economically viable mitigation opportunities to the Deductible. As mitigation opportunities grow relative to the deductible, it becomes more likely that the benefits of reduced PA cost share by states, due to cumulative mitigation, will exceed the cost of the deductible.

For example, consider the following scenarios:

Scenario 1: (High Property Damage Only BCR Applicable to a State Threat)

- $200 million in expected flood PA
- $0 in expected earthquake PA
- 4.8:1 BCR for flood mitigation (Property Damage Only BCR)
- 0.42:1 BCR for earthquake mitigation ((Property Damage Only BCR)
- $20 million deductible
- $10 million annual risk reduction goal
- 50% of expected PA can be reduced through mitigation

- Scenario 2: (High Property Damage Only BCR Not Applicable to a State Threat)

  - $0 in expected flood PA
  - $200 million in expected earthquake PA
  - 4.8:1 BCR for flood mitigation ((Property Damage Only BCR)
  - 0.42:1 BCR for earthquake mitigation (Property Damage Only BCR)
  - $20 million deductible
  - $10 million annual risk reduction goal
  - 50% of expected PA can be reduced through mitigation

- Scenario 3: (BCR Covering All Benefits and Risk Reduction Strategies)

  - $0 in expected flood PA
  - $400 million in expected earthquake PA
  - 5:1 BCR for flood mitigation (Full BCR)
  - 1.5:1 BCR for earthquake mitigation (Full BCR)
  - $20 million deductible
  - $10 million annual risk reduction goal
  - 50% of expected PA can be reduced through mitigation

Before the DDF policy, expenditure is:

- Scenario 1: $50 million ($200 million * 0.25 state cost share)
- Scenario 2: $50 million ($200 million * 0.25)
- Scenario 3: $100 million ($400 million * 0.25)

After the DDF policy is put into place a state will eventually run out of economically viable mitigation options. This can occur because the state reaches the 50% limit on PA reduction from mitigation or because the BCR of mitigation is less than the BCR of relief funds/insurance. Total expected PA after all economically viable mitigation has been undertaken is:

- Scenario 1: $100 million because the state will mitigate against flood PA until it reaches its 50% risk reduction from mitigation constraint and then meet its risk reduction goal using relief funds or insurance
- Scenario 2: $200 million because the state will always use relief funds or insurance to meet its risk reduction goal because the BCR of earthquake mitigation is less than the BCR of relief funds and insurance
- Scenario 3: $200 million because the state will mitigate against earthquake PA when the full BCRs are considered rather than the property damage only BCRs. After reaching the 50% risk reduction from mitigation constraint the state will meet its risk reduction goal using relief funds or instance.

Total expected state expenditure after all economically viable mitigation has been undertaken is:

- Scenario 1: $42.5 million ($10 million + $10 million + $90 million * 0.25), as the state pays a $10 million deductible, spends $10 million on relief funds/insurance, and pays a 25% share of the remaining $90 million in total PA (total PA is $100 million and the state offsets $10 million through relief funds/insurance)
- Scenario 2: $67.5 million ($10 million + $10 million + $190 million * 0.25), as the state pays a $10 million deductible, spends $10 million on relief funds/insurance, and pays a 25% of the remaining $190 million in total PA (total PA is $200 million and the state offsets $10 million through relief funds/insurance)
- Scenario 3: $67.5 million ($10 million + $10 million + $190 million * 0.25), as the state pays a $10 million deductible, spends $10 million on relief funds/insurance, and pays a 25% of the remaining $190 million in total PA (total PA is $200 million and the state offsets $10 million through relief funds/insurance)

In Scenario 1 and Scenario 3, total state expenditure is lower than total state expenditure in the status quo because there are large potential reductions in total PA due to mitigation. As a result of these large total reductions, the state's share of PA falls enough to offset the additional $10 million in annual risk reduction expenditure on relief funds and insurance.

In Scenario 2, by contrast, there are no economically viable mitigation opportunities and the state continues to have $200 million in total annual expected PA, and the state pays a $50 million share of total PA. Because total PA has not been reduced, the only change occurs in the additional state expenditure toward the deductible and relief funds/insurance.

5. Declining BCRs

a. Estimation of BCRs

We have considered the possibility that benefit-cost ratios would decline over time, and thus change the optimal mix of mitigation, insurance, and relief funds. This is likely if one assumes that the highest BCRs of various mitigation projects in any state are not the same, there is a limited pool of such projects, and the highest return projects will be chosen first. However, various complexities and uncertainties relating to BCR values over time are substantial and include:

- It is not known whether states optimize their risk reduction strategies. This argues in favor of using an average BCR for the base case.
- Declining BCRs may be offset by technological improvements over time. This argues for avoiding any steep decline over time.
- It is not known if the pool of mitigation projects is large, nor is the percentage of projects chosen in any given year a large proportion of the total. This argues in favor of not deviating too far from the average BCR.

Therefore, we have opted for a straightforward approach. This involves using the *Mitigation Saves* BCRs adjusted by one standard deviation from the sample used in that study and applied to the DDF2 (also DDF1) Base Case values. Our methodology for calculating declining BCRs is as follows:

1. Begin with the Base Case Average Total BCR for each threat.

2. Add one standard deviation to the total BCRs in 2015; subtract one standard deviation to the total BCRs in 2035 (however, set the lower limits for the 2035 values at 1.0 to reflect the fundamental rule that only mitigation projects with positive net benefits should be undertaken). The standard deviations of BCRs for Earthquake, Wind, Flood, and Severe Storm/Other threats, respectively, are: 0.51, 2.75, 1.06, and 4.32.

3. Multiply the total BCRs in step 2 by the proportion of property damage mitigated by each threat to obtain the BCR values for 2015 and 2035 used in the sensitivity test. These proportions are 0.28 for earthquakes, 0.13 for wind threats, and 0.95 for flood threats. The property damage only proportion for the severe storm/other threats is assumed to be that of all threats combined, at 0.80.

The property damage only BCRs in 2015 for each threat are as follows, adding one standard deviation: earthquake 1.08, for wind 4.27, for flood 5.86, and for severe storm/other 7.66. The property damage BCRs for 2035, subtracting one standard deviation are: earthquake 0.06, for wind 0.39, for flood 3.74, and for severe storm/other 0.85.

b. Projected PA

While we project PA out to 2035, the MP cannot be directly applied in 2035 because of the implications of cumulative mitigation. We assume that states will seek to reduce a substantial amount of risk each year, and states rapidly reach the 50% maximum level of mitigation. This leaves no available mitigation opportunities in 2035, which would lead the MP to select only insurance and relief funds.

Even though a state has reached 50% mitigation of their expected PA – and mitigation is ineffective in reducing expected annual PA, mitigation may still be effective in reducing damages in the event of an extreme disaster event. It is therefore unreasonable to assume that states will not perform any mitigation in 2035. We model this by using 2015 modeled PA as a proxy for 2035, allowing states to continue the same mitigation rates into the future, but we apply lower BCRs to mitigation to reflect the changes in available mitigation opportunities.

c. MP Analysis

Table II-28 presents the MP analysis results for Year 2015 for the declining BCRs case. Not surprisingly, with the much higher BCRs for 2015 in this case, the expenditure for both MS and OH greatly reduced compared to the DDF2 Base Case. MS decreases from $5.46 million to $1.77 million, OH decreases from $2.56 million to $1.03 million.

Table II-28. MP Analysis of DDF2 –Mississippi and Ohio
(50% risk reduction, Year 2015, Projected Property Damage plus GI Risk; PD+GI Declining BCRs, in million dollars)

	MP Analysis – 50% Risk Reduction			
	Mississippi		Ohio	
Strategy	Expenditure	Risk Reduction Attained	Expenditure	Risk Reduction Attained
Mitigation				
Hurricanes	0.90	6.80		
Floods				
Severe Storms	0.87	7.20	1.03	8.57
Earthquakes				
Other				
Insurance/Relief Fund				
Hurricanes				
Floods				
Severe Storms				
Earthquakes				
Other				
Total	1.77	14.00	1.03	8.57

Table II-29. MP Analysis of DDF2 –Mississippi and Ohio
(50% risk reduction, Year 2035, Projected Property Damage + GI Risk; PD+GI Declining BCRs)

	MP Analysis – 50% Risk Reduction			
	Mississippi		Ohio	
Strategy	Expenditure	Risk Reduction Attained	Expenditure	Risk Reduction Attained
Mitigation				
Hurricanes				
Floods	0.70	2.60		
Severe Storms				
Earthquakes				
Other				
Insurance/Relief Fund				
Hurricanes	11.40	11.40		
Floods				
Severe Storms			8.57	8.57
Earthquakes				
Other				
Total	12.10	14.00	8.57	8.57

Table II-29 presents the MP analysis results for Year 2035 for the declining BCRs case. In this case, except for mitigation of floods, the BCRs of all the other mitigation strategies become lower than 1. With the much lowered BCRs, the expenditure for both MS and OH greatly increased compared to the DDF2 Base Case. MS increases from $5.46 million to $12.10 million, OH decreases from $2.56 million to $8.57 million. In addition, more expenditure is spent on Insurance/Relief Fund, as their BCR (which is 1) becomes more attractive than the BCRs of mitigation strategies other than floods. In fact, since OH does not have any flood risk, all the state expenditure will be on Insurance/Relief Fund.

d. Burden Analysis for MS and OH

The burden analysis shows the impact of the DDF on state and federal spending under specific conditions. The burden analysis is informed by the results of the MP analysis above. Table II-30 shows the impact of the DDF2 on Mississippi for the declining BCR simulation compared to both DDF1 and DDF2 base cases.

Section A of the table shows the current situation with expected annual losses and total public assistance spending and the shares covered by FEMA, and the state's share calculated at the average of 22.5%. Section B shows the situation if the deductible only were charged to the state, while Section C shows the effect of mitigation on expected losses and the effect of credits on the deductible and overall state spending.

Table II-30.
Burden Analysis for DDF2 – Mississippi (50% risk reduction)
Declining BCRs from 2015 to 2035

	Expenditures ($millions)			
	DDF1	DDF2		
		2015 Base Case	2015 High BCR	2035 Low BCR
	(1)	(2)	(3)	(4)
A. Status Quo				
Total expected losses	311.9	311.9	311.9	311.9
State share of expected losses	70.2	70.2	70.2	70.2
Federal share of expected losses	241.7	241.7	241.7	241.7
B. Deductible only				
Total expected losses	311.9	311.9	311.9	311.9
State deductible	28.6	28.0	28.0	28.0
PA after state pays deductible	283.3	283.9	283.9	283.9
State share of remaining PA	63.7	63.9	63.9	63.9
State total spending (deductible + state share)	92.3	91.9	91.9	91.9
Federal PA	219.5	220.0	220.0	220.0
Change in State burden	22.2	21.7	21.7	21.7
Change in Federal burden	-22.2	-21.7	-21.7	-21.7
C. Mitigation with DDF credit				
Total expected losses	311.9	311.9	311.9	311.9
Spending on mitigation	2.8	5.5	2.4	0.7
Insurance premiums	4.5	0.0	0.0	7.2
Additions to relief fund	0.0	0.0	0.0	4.2
Reduction in PA from expenditures	14.3	14.0	14.0	14.0
Total actual PA	297.6	297.9	297.9	297.9
State deductible less credit	15.7	11.6	20.9	18.7
PA less deductible	281.9	286.3	277.0	279.2
State share of remaining PA	63.4	64.4	62.3	62.8
State total spending (mitig. + deduct. + state share)	86.4	81.5	85.6	93.6
Federal PA	218.5	221.8	214.7	216.3
Change in State burden from status quo	16.2	11.3	15.4	23.4
Change in State burden relative to deductible only	-5.9	-10.4	-6.3	1.7
Change in Federal burden from status quo	-23.2	-19.9	-27.0	-25.4
Change in Fed. burden relative to deductible only	-1.1	1.8	-5.3	-3.7

Comparisons are to DDF1 Base Case, for which risk level equals Public Assistance (composed of property damage and non-property damage as a proxy for government interruption).

The columns of the table show three DDF2 scenarios compared to the base case DDF1 (column 1). Column (2) represents the base case for DDF2. The next column (3) shows the 2015 impact assuming the state chooses mitigation projects with high (mean plus one standard deviation) BCRS, and column (4) shows the impact if the state has, after 20 years, only lower (mean less one standard deviation) BCR mitigation projects to choose from. As might be expected, the state spends less on mitigation in 2015 to achieve the desired risk reduction, and only uses mitigation. In 2035, the state only spends a small amount on mitigation due to its lower return, and moves to insurance to achieve the loss reduction. In this case state spending rises and the burden increases. The impact on FEMA is less desirable than in 2015, but still moves burden toward the state.

A similar analysis is provided for the state of Ohio in Table II-31. The qualitative results are similar to those for Mississippi; however, the values are substantially different.

Table II-31.
Burden Analysis for DDF2 – Ohio (50% risk reduction)
Declining BCRs from 2015 to 2035

	Expenditures ($millions)			
	DDF1	DDF2		
		2015 Base Case	2015 High BCR	2035 Low BCR
	(1)	(2)	(3)	(4)
A. Status Quo				
Total expected losses	31.6	31.6	31.6	31.6
State share of expected losses	7.1	7.1	7.1	7.1
Federal share of expected losses	24.5	24.5	24.5	24.5
B. Deductible only				
Total expected losses	31.6	31.6	31.6	31.6
State deductible	16.9	17.1	17.1	17.1
PA after state pays deductible	14.7	14.5	14.5	14.5
State share of remaining PA	3.3	3.3	3.3	3.3
State total spending (deductible + state share)	20.2	20.4	20.4	20.4
Federal PA	11.4	11.2	11.2	11.2
Change in State burden	13.1	13.3	13.3	13.3
Change in Federal burden	-13.1	-13.3	-13.3	-13.3
C. Mitigation with DDF credit				
Total expected losses	31.6	31.6	31.6	31.6
Spending on mitigation	2.7	2.6	1.1	0.0
Insurance premiums	0.0	0.0	0.0	8.6
Additions to relief fund	0.0	0.0	0.0	0.0
Reduction in PA from expenditures	8.5	8.6	8.6	8.6
Total actual PA	23.1	23.0	23.0	23.0
State deductible less credit	8.9	9.4	13.8	8.6
PA less deductible	14.2	13.6	9.3	14.5
State share of remaining PA	3.2	3.1	2.1	3.3
State total spending (mitig. + deduct. + state share)	14.8	15.1	17.0	20.4
Federal PA	11.0	10.5	7.2	11.2
Change in State burden from status quo	7.7	8.0	9.9	13.3
Change in State burden relative to deductible only	-5.4	-5.3	-3.4	0.0
Change in Federal burden from status quo	-13.5	-14.0	-17.3	-13.3
Change in Fed. burden relative to deductible only	-0.4	-0.7	-4.0	0.0

Comparisons are to DDF1 Base Case, for which risk level equals Public Assistance (composed of property damage and non-property damage as a proxy for government interruption).

The columns of the table show three DDF2 scenarios compared to the base case DDF1 (column 1). Column (2) represents the base case for DDF2. The next column (3) shows the 2015 impact assuming the state chooses mitigation projects with high (mean plus one standard deviation) BCRS, and column (4) shows the impact if the state has, after 20 years, only lower (mean less one standard deviation) BCR mitigation projects to choose from. As might be expected, the state spends less on mitigation in 2015 to achieve the desired risk reduction, and only uses mitigation. In 2035, the state no longer spends on mitigation, and moves to insurance to achieve the loss reduction. In this case state spending rises and the burden increases. The impact on FEMA is less desirable than in 2015, but still moves burden toward the state.

6. Full BCRs

a. MP Analysis

In this sensitivity analysis, we investigate the effect of using the overall BCRs from the *Mitigation Saves* study (MMC, 2005): rather than the property damage plus GI BCRs used in the DDF2 Base Case. The full BCRs include all benefits, not just those that would reduce public assistance.

Table II-32 presents the MP analysis results. With higher BCRs of mitigation, less needs to be spent by the state to achieve the 50% risk reduction goal. MS's expenditures decrease from $5.46 million in DDF2 Base Case to $3.40 million in the full BCRs case, while the OH's expenditures decrease from $2.56 million to $2.14 million.

Table II-32. MP Analysis of DDF2 –Mississippi and Ohio
(50% risk reduction, Year 2015, PA Risk with Full BCRs, in million dollars)

	MP Analysis – 50% Risk Reduction			
	Mississippi		Ohio	
Strategy	Expenditure	Risk Reduction Attained	Expenditure	Risk Reduction Attained
Mitigation				
Hurricanes	1.08	4.20		
Floods	0.52	2.60		
Severe Storms	1.80	7.20	2.14	8.57
Earthquakes				
Other				
Insurance/Relief Fund				
Hurricanes				
Floods				
Severe Storms				
Earthquakes				
Other				
Total	3.40	14.00	2.14	8.57

b. Burden Analysis

Table II-33. Burden Analysis for DDF2 – Mississippi and Ohio, Base Case Losses, All Damage BCRs				
	Expenditures ($millions)			
	Mississippi		**Ohio**	
	2015 PD only	2015 All BCR	2015 PD only	2015 All BCR
	(1)	(2)	(3)	(4)
A. Status Quo				
Total expected losses	311.9	311.9	31.6	31.6
State share of expected losses	70.2	70.2	7.1	7.1
Federal share of expected losses	241.7	241.7	24.5	24.5
B. Deductible only				
Total expected losses	311.9	311.9	31.6	31.6
State deductible	28.0	28.0	17.1	17.1
PA after state pays deductible	283.9	283.9	14.5	14.5
State share of remaining PA	63.9	63.9	3.3	3.3
State total spending (deductible + state share)	91.9	91.9	20.4	20.4
Federal PA	220.0	220.0	11.2	11.2
Change in State burden	21.7	21.7	13.3	13.3
Change in Federal burden	-21.7	-21.7	-13.3	-13.3
C. Mitigation with DDF credit				
Total expected losses	311.9	311.9	31.6	31.6
Spending on mitigation	2.8	3.4	2.7	2.1
Insurance premiums	0.0	0.0	0.0	0.0
Additions to relief fund	4.2	0.0	0.0	0.0
Reduction in PA from expenditures	14.0	14.0	8.6	8.6
Total actual PA	297.9	297.9	23.0	23.0
State deductible less credit	15.4	17.8	9.1	10.7
PA less deductible	282.5	280.1	14.0	12.3
State share of remaining PA	63.6	63.0	3.1	2.8
State total spending (mitig. + deduct. + state share)	85.9	84.2	14.9	15.6
Federal PA	218.9	217.0	10.8	9.6
Change in State burden from status quo	15.8	14.0	7.8	8.5
Change in State burden relative to deductible only	-5.9	-7.7	-5.5	-4.8
Change in Federal burden from status quo	-22.8	-24.7	-13.7	-14.9
Change in Fed. burden relative to deductible only	-1.1	-3.0	-0.4	-1.7

Comparisons are to DDF1 Base Case, for which risk level equals Public Assistance (composed of property damage and non-property damage as a proxy for government interruption).

Table II-33 shows a comparison of the base case using property damage only BCRs with the case where all benefits of mitigation are included. The adjusted deductible does not change, but mitigation spending for Mississippi increases slightly, while for Ohio it decreases slightly, due to the nature of the hazards faced by each state. Consequently, there is a slight decrease (less than 10%) in burden compared to the status quo and the base case for Mississippi, and a slight increase (less than 10%) in the burden compared to the status quo and the base case for Ohio.

D. Summary Comparison of Results

Table II-34 presents the results of the various sensitivity analysis cases presented in the previous section. Again, the analysis was performed in a comparative static mode in relation to the DDF 1 Base Case results presented in the left-hand column of the table. An annotation is again used to indicate a range of percentage changes from the DDF1 Base Case. The results indicate that the only significant change in federal and state shares takes place for OH in sensitivity case #3 (analysis for 2035). Moreover, it shows that the state share goes up and the federal share goes down by more than 50%. This is because Ohio's projected Deductible in 2035 is higher than its Deductible in 2015. As a result, the DDF policy results in an increase in state expenditure and a decrease in federal expenditure as the Deductible shifts burden from FEMA to the state.

The other significant changes relate to the MP variables for nearly all cases for MS and for some MP variables for case #5 for OH. The reason for these significant changes in results varies across the sensitivity cases. For Case 3, the projected risks in 2035 are significantly higher than the modeled risks for 2015 in DDF1 Base Case for both states. This increases the expenditures needed to achieve the 50% risk reduction goal. In addition, PD + GI BCRs rather than PD only BCRs are used in this case. For MS, mitigation of hurricanes becomes economically viable in Case 3, and thus all risk reduction expenditures become mitigation only, rather than a combination of mitigation and insurance/relief fund as in DDF1 Base Case. For Case 4, it is not surprising that when we add one standard deviation to the BCRs, the total risk reduction expenditures decrease substantially in both states. For Case 5, when we subtract one standard deviation from the BCRs, only mitigation of floods has a BCR greater than one. And given the low risk of floods in MS and zero risk of floods in OH, over 90% of the risk reduction expenditures of MS and 100% of the expenditures of OH become insurance/relief fund. For Case 6 and Case 7, the change in results is only significant for MS. The reason is that when the full BCRs or PD + GI BCRs are used, respectively, mitigation of hurricanes become more economically attractive than insurance/relief fund. Therefore, the risk reduction expenditures become mitigation only, rather than a combination of mitigation and insurance/relief fund as in DDF1 Base Case. While the MP results show significant changes in the optimal mix between mitigation and insurance/relief fund strategies, the burden analysis shows relatively little change in total state, or federal, spending. Given the goal of a 50% reduction in expected risk or the deductible, whichever is smaller, state spending is relatively insensitive to changes in the optimal mix. Spending is determined primarily by the expected loss, the size of the net deductible, and the remaining PA share. Changes in the optimal mix affect the net deductible through the credit multipliers, but the effect is relatively small compared to the effect of the other components.

Table II-34. Summary Table of Simulations of DDF2 Assumptions and Parameters: Sensitivity Tests

(change from DDF1 Base Case in millions of 2015 dollars for Adjusted Deductible, State Response Analysis and Burden Analysis)[a]

Variable	DDF1 Base Case[b] (1)	DDF2 Base Case PA Risk; PD+GI BCRs (2015) (2)	DDF2 PA Risk; PD+GI BCRs (2035) (3)	DDF2 Declining PDO BCRs (2015)[a] (4)	DDF2 Declining PDO BCRs (2035)[a] (5)	DDF2 Full BCRs (2015) (6)	DDF2 25 Fiscal Capacity: 75 Risk Weights (2015) (7)
MS							
Fiscal Index	0.98	0.90	0.94	0.90	0.90	0.90	0.90
Risk Index	2.18	same[c]	2.30	same	same	same	same
Combined Index	1.58	1.54	1.62	1.54	1.54	1.54	1.86*
Adjusted Deductible	28.61	28.00	47.16**	28.00	28.00	28.00	34.68*
State Response (MP) Analysis[d]							
Mitigation Exp	2.81	5.46**	12.42***	2.37*	0.70**	3.40*	7.66***
Insurance/Relief Fund Exp	4.51	0.00***	0.00***	0.00***	11.40***	0.00***	0.00***
Resilience Exp	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Burden Analysis							
Expected Loss (311.87[e])	311.87	311.87	332.53	311.87	311.87	311.87	311.87
State Share (70.17)	89.60	81.50	98.60*	85.60	90.40	84.20	83.00
Federal Share (214.70)	229.60	221.80	231.80	214.70	219.60	217.00	219.20
OH							
Fiscal Index	1.07	1.08	1.02	1.08	1.08	1.08	1.08
Risk Index	0.80	same	0.87	same	same	same	same
Combined Index	0.94	0.94	0.95	0.94	0.94	0.94	0.87
Adjusted Deductible	16.91	17.13	27.57**	17.13	17.13	17.13	16.26
State Response (MP) Analysis[d]							
Mitigation Exp	2.66	2.56	4.44**	1.12**	0.00***	2.14*	2.43
Insurance/Relief Fund Exp	0.00	0.00	0.00	0.00	8.57***	0.00	0.00
Resilience Exp	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Burden Analysis							
Expected Loss (31.60[e])	31.60	31.60	32.31	31.60	31.60	31.60	31.60
State Share (7.11)	14.80	15.10	19.60*	16.98*	20.40*	15.60	14.70
Federal Share (24.49)	11.0	10.50	3.30**	7.17*	11.20	9.60*	11.20

[a] Change from DDF1 Base Case: * 10 to 50%; ** 50 to 100%; *** more than 100%.
[b] This Base Case varies slightly from the Base Case presented in Part I of this Report. It utilizes the DDF2 Risk Index and includes Washington, DC in the calculations.
[c] Same as Base Case DDF1
[d] MP goal is reduction of risk equal to the lesser of 50% of the risk and the state's deductible.
[e] Values in parentheses are status quo burdens.

E. Equity Analysis of Full DDF2

In this section we analyze the equity implications of the Full DDF2 itself and the Burden associated with it in terms of common measures of inequality. Figure II-16 presents the Lorenz Curve associated with the Normalized Adjusted Deductibles across states for the Full DDF2. The Lorenz curve plots the cumulative Disaster Deductible on the vertical axis in relation to individual state allocations with respect to per capita GSP on the horizontal axis (the states are ordered from lowest to highest in terms of per capita GSP deductibles). The 45° line represents perfect equality. In this case, the perfect equality condition represents proportional relationship between state deductibles and state per capita GSP (i.e., state that has twice per capita GSP of another state should also have twice deductibles). The difference between the curve and the 45° line is the extent of inequality. The Gini Coefficient measures this by the ratio of the area between the curve and the 45° line in relation to the triangle delineated by the 45° line and horizontal and vertical axes. Gini Coefficient values range between 0 and 1, with higher levels indicating higher levels of inequality

In Figure II-16, the Gini Coefficient value is .3021, indicating a modest amount of inequality across states in terms of the Disaster Deductible itself.[73] (This is slightly higher than the counterpart coefficient for DDF1, at .2749). However, in Figure II-17, the Gini Coefficients corresponding to the Burden of the Deductible (the bottom line economic outcome after the response, in contrast to just the Deductible itself) is .5219 (significantly lower than the counterpart coefficient for DDF1 of .6735). This is about a 72.8 percent greater level of inequality compared to the DDF2 alone. This reflects a combination of aspects of individual state risk and mitigation expenditures that have a strong bearing on the results. In Figure II-18, we also plotted the Lorenz curve for the change in state burden with respect to the status quo. The associated Gini Coefficient value is .3076 (compared to a value of .3632 for DDF1). This indicates a modest inequality in the distribution of the change in the burden.

One way to evaluate which equity principle best reflects the DDFs calculated in this report is correlation analysis. We calculated correlations for both the initial allocation and outcome with the following results:

Adjusted (and capped) State Deductibles and State Populations: 0.261

Adjusted (and capped) State Deductibles and GSPs: 0.284

Adjusted (and capped) State Deductibles and per capita GSPs: 0.365

State Burden and Populations: 0.426

State Burden and GSPs: 0.411

State Burden and per capita GSPs: -0.098

[73] The Gini coefficient for total GSP itself across states is 0.5330.

Potentially the Ability to Pay[74] principle would be relevant to the Deductible, while the Vertical Equity principle would be relevant to the Burden, the reason being that the former is an allocation-based principle, while the latter is outcome-based. The Egalitarian Principle would be relevant to both.

Beginning on the Deductible side, the correlations for Population and GSP are very low that none of these equity principles seems operative. If we focus on the correlation between the Adjusted State Deductible and per capita GSP, the correlation of 0.365 does indicate some relevance of the Ability to Pay principle. (However, see below the discussion of the correlation between the actual Burden and per capita GSP). We can also make assessments regarding other equity principles. By inspection of the poorest states, we can also note that the Rawlsian Maximin principle[75] does not apply. We also know by inspection that the Deductible does not reflect Horizontal Equity. In fact, it appears that the state Deductibles are rather random with respect to GSP, the reference base by which most equity principles are measured. However, since most equity measures use income, or wealth, as the basis for comparison, some of the adjustments for individual states can create unanticipated results. For example,

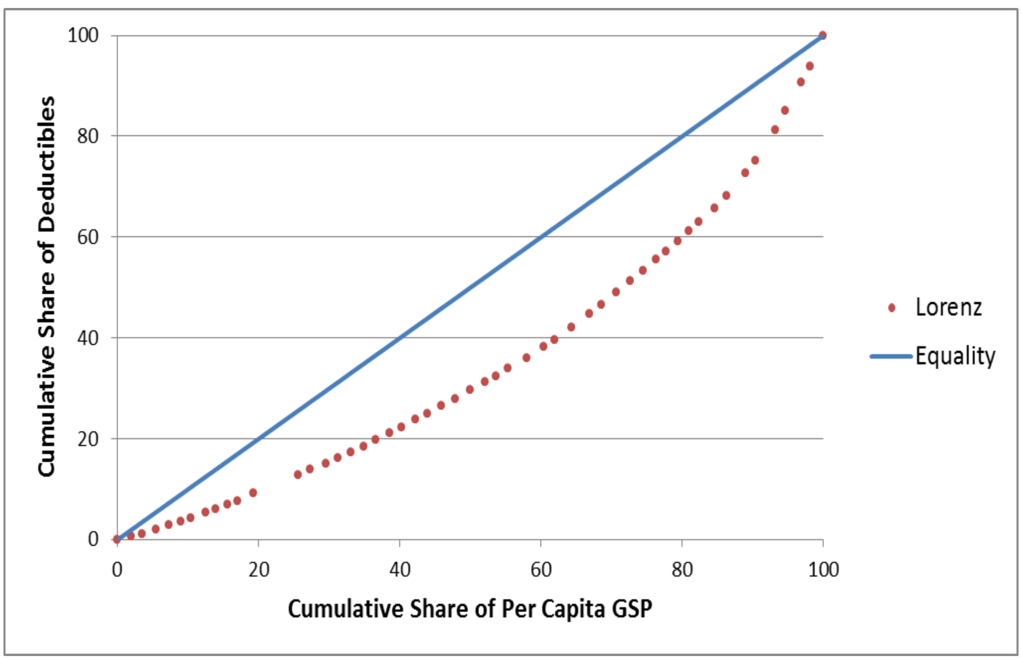

Figure II-16. Lorenz Curve of State Adjusted Deductibles for Full DDF2
(states are ordered by per capita GSP adjusted deductibles)

[74] The reader is referred to Part I of this Report for definitions of the equity principles.
[75] This principle calls for favoring the bottom tier of least well-off states.

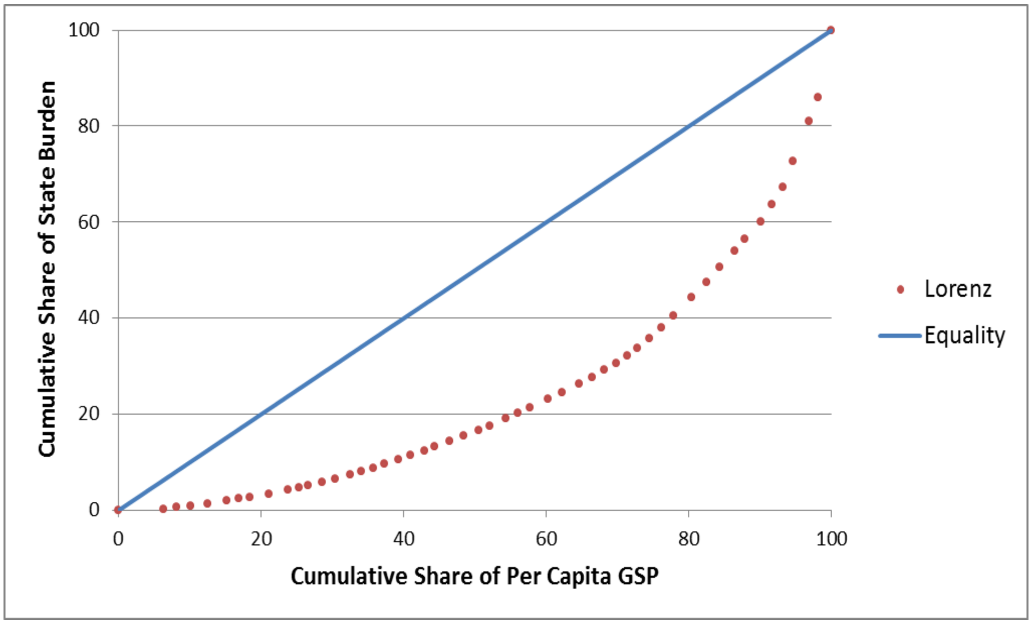

Figure II-17. Lorenz Curve of State Burdens for Full DDF2
(states are ordered by per capita GSP state burdens)

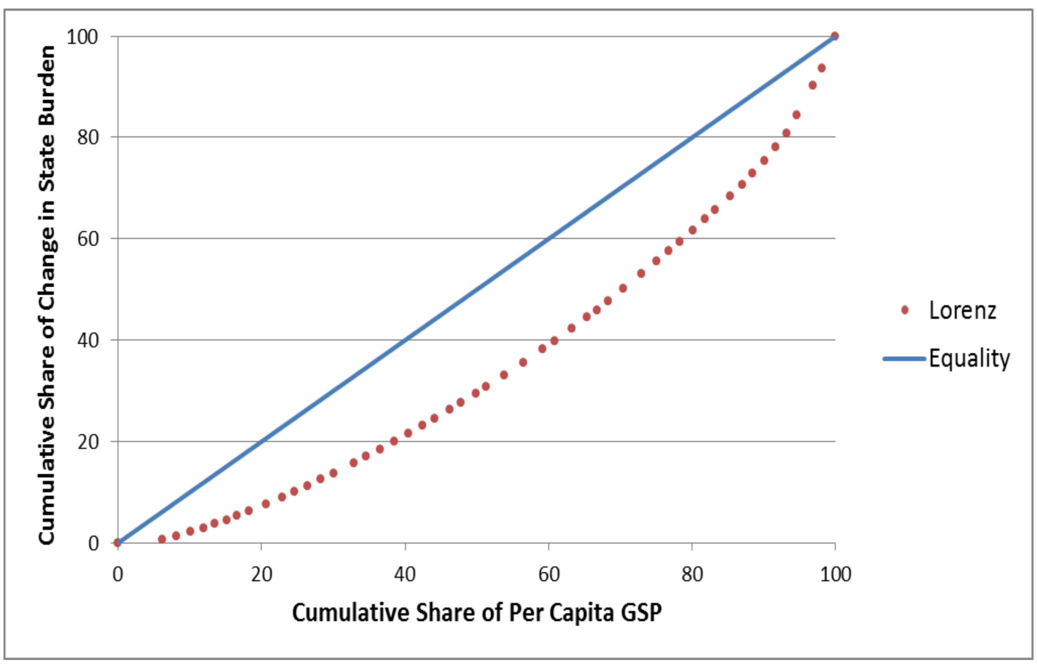

Figure II-18. Lorenz Curve of Change in State Burdens (with respect to Status Quo) for Full DDF2
(states are ordered by change in state burdens over per capita GSP)

although wealthier states may suffer greater loss for a given hazard, hazards tend to be distributed randomly with regard to wealth.[76]

The correlations are higher with respect to the State Burden (except for per capita GSP) than for the Deductible, though still low. Thus, this indicates some tendency toward aspects of both the Vertical Equity (reducing the relative disparity between rich and poor states) and the Egalitarian principle at the "outcome" level. This happens because the most populous states are also the relatively more well-off states. While this is not the case at the international level, it is the case for advanced countries like the U.S. (cf., Rose et al., 1998; Rose and Zhang, 2004). Further research is needed to explain the factors that affect the equity impacts of the DDF on State Burdens. However, the correlation between the actual Burden (the bottom-line state expenditure) and per capita income is very low and negative. This undercuts the tendency toward the Vertical Equity principle.

F. Broader Issues

1. Disaster Declaration Threshold

The analysis of DDF1 and DDF2 has largely been based on a state's annual average disaster damages. Because the existing system – the Disaster Declaration threshold – is based on a per-disaster basis rather than an annual basis, it is useful to consider how the Deductible will affect state and federal expenditure relative to the existing structure. Kousky et al. (2016), for example, considered fixed per-disaster deductibles and found that the implementation of a deductible would lead to substantial reductions in the number of disaster declarations receiving public assistance. In order to analyze these considerations, we compute the annual amount of PA for each state in each of the last ten years. Under the threshold structure, states will receive 77.5% of this total PA amount. With a deductible, however, states will receive 77.5% of the total PA amount minus their deductible. Using the Base Case DDF2 Deductibles – and assuming for the purpose of comparison with Kousky et al. that there is no mitigation or credits against the deductible – we calculate total state expenditure and total federal expenditure.

Figure II-19 shows state expenditure under the threshold and under the deductible, while Figure II-20 shows the federal counterpart. Because we are considering the scenario without credits or mitigation, state expenditure uniformly rises and federal expenditure uniformly falls. In cases where total damages are dominated by large events – such as Hurricanes Katrina and Sandy in Louisiana and New York – state expenditure is relatively under the threshold and the deductible. In states with relatively low PA with relatively high deductibles – such as Wyoming and Alaska – annual damages never exceed the state's deductible. This results in states receiving no federal PA. While there have been 355 state-year combinations that received federal PA in the last 10 years, 164 of these state-years would not receive

[76] One possible exception, where there may be a strong positive correlation between wealth and disaster loss is when wealth accumulates in geographical areas that are more prone to disaster loss such as in coastal areas, mountainous or heavily wooded areas. Heavily populated commercial areas are also often located on coasts and more prone to storm surge or tsunami hazards.

federal PA under the DDF without obtaining credits against the deductible. Because total expenditure is dominated by extreme events, though, total federal expenditure would only fall by 10% (and total state expenditure would rise by only 10%). Figure II-21 shows the number of years in which states would receive FEMA PA under the deductible, i.e. the number of years that states' PA would exceed their deductible. As shown, every state sees at least one year in which a disaster occurred that the deductible would not be exceeded, indicating that the state would bear the full PA costs of these disasters. In the case of Alaska, Delaware, the District of Columbia, Idaho and Wyoming the deductible would not have been met in any of the years in the sample.

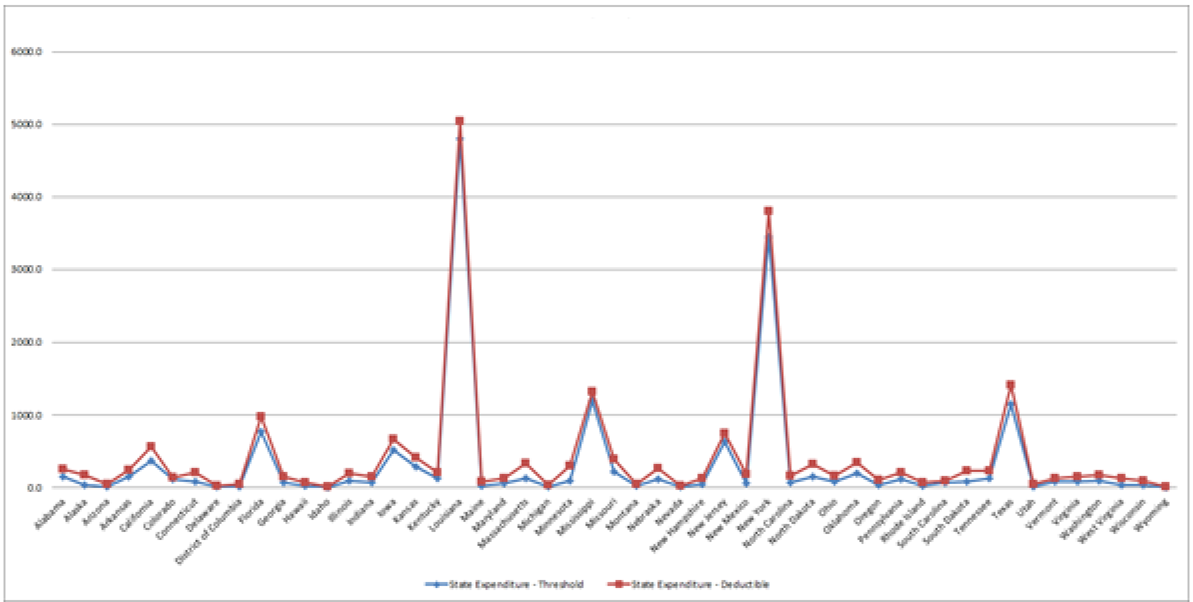

Figure II-19. State Expenditure

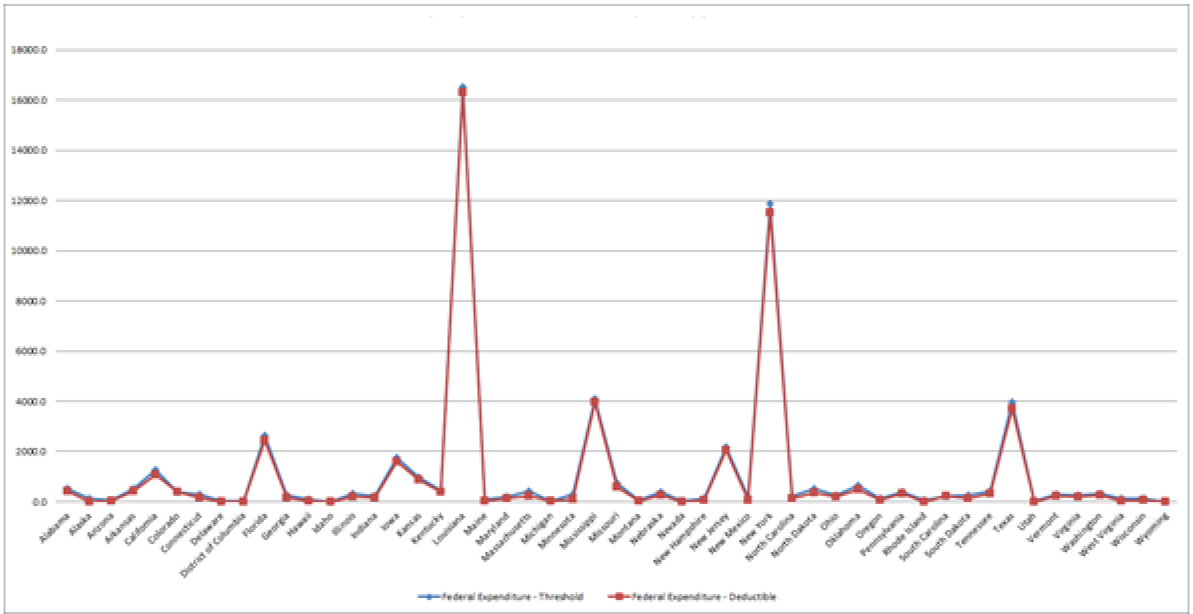

Figure II-20. Federal Expenditure

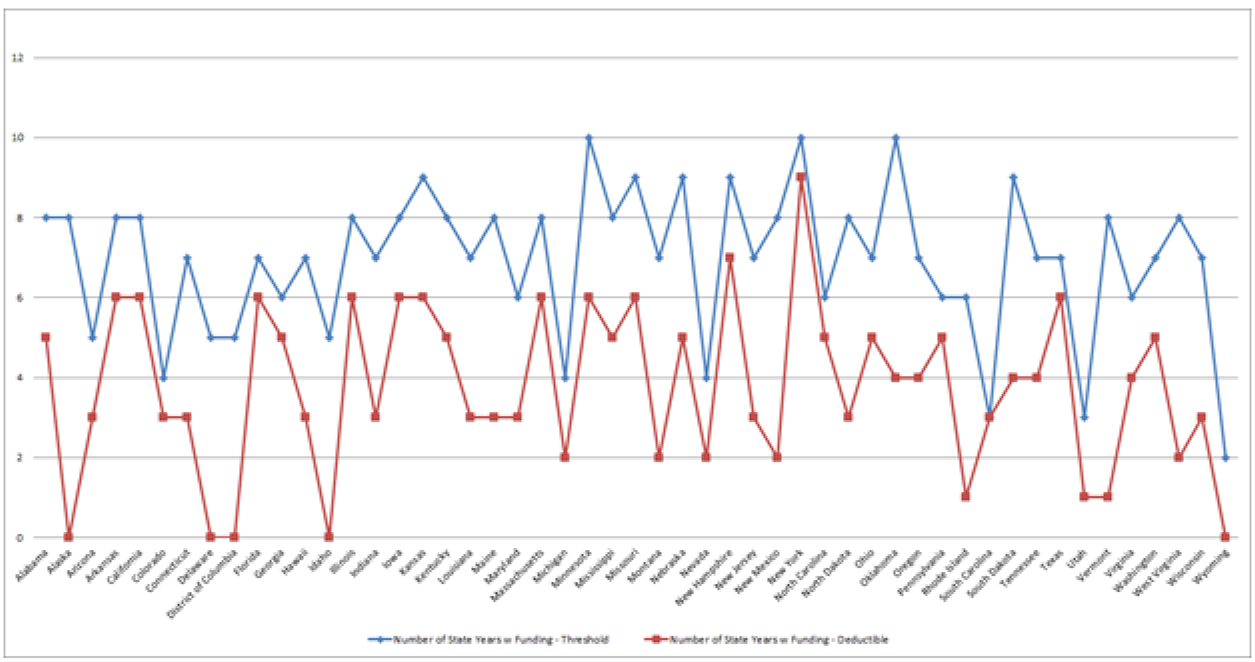

Figure II-21. Years with FEMA Funding

2. Consistency Issues

Some issues have arisen with regard to the relationship of the CREATE team's inclusion of BI and Resilience in DDF 2 and its consistency with the current FEMA Public Assistance Program. Below, we discuss reasons why there is an inconsistency and suggest some ways to resolve it:

a. Our formulation and analysis of DDF1 was limited to considering that PA only covered property damage. We therefore adjusted the *Mitigation Saves* BCRs for property damage alone.

b. However, it turns out that PA also covers various expenditures that we place under the heading of Resilience, such as temporary locations, overtime pay, and debris removal. These are intended to reduce government interruption (GI).

c. PA for property damage represents funding for repair and reconstruction and this corresponds in dollar value to the property damage. On the other hand, the PA expenditures on resilience are intended to reduce GI, but are not equal to the GI loss itself (the direct correspondence between this type of loss and PA does not exist here). An example would be the rather minimal expenses for a tent that can provide the equivalent of tens of thousands of government services. Thus, we have a problem with using PA expenditures on resilience to measure GI risk.

d. We can reconcile the situation if we consider broadening PA to cover more risk categories, though this should not be the main reason we expand PA. Table II-35 presents an evaluation of the current PA Program and how we modeled it in DDF1, how we are modeling it in DDF2, and what might be the case if we considered a more idealized PA Program.

Table II-35. Risk Reduction and Public Assistance Reconciliation

	DDF1 Modeled in the Base Case	Potential Reformulation for Consistency with Current PA	Potential Reformulation for Ideal Risk Management
Risk	property damage (PD) +GI expenditure	PD + GI loss	what risk does FEMA want to reduce? PD + GI + fatalities?
PA	PD + resilience expenditures treated like PD	PD + resilience expenditures treated like post-disaster risk reduction	assistance to match goals and provide incentives
Credit	PD only, through mitigation, insurance, relief fund expenditures	PD + GI loss, through mitigation, resilience, insurance, relief fund	credit can help align risks and PA
Mitigation Effectiveness	BCRs low when PD only (some < 1.0)	BCRs to include post - disaster action to reduce GI	BCRs to include broader set of tactics and types of risk
Resilience Effectiveness	not modeled	BCRs high; some pertain to pre-disaster (multi-year benefits); some pertain to post-disaster (single year benefits, but probability of disaster =1.0)	BCRs are relatively high and have broad applicability
DDF	deductible based on estimated PA (to reflect PD only)	deductible based on estimated PA (to reflect PA expenditure to reduce GI)	deductible based on total risk (to reflect losses rather than expenditures)

G. Broader Risk Framework

In this section we develop a risk-based approach to setting a disaster deductible based on a State's risk profile. We encode the State's disaster risk by a probability density function (pdf) over disaster losses, given an event. This pdf is obtained through a statistical fit to past State disaster losses calculated from public assistance data. The proposed approach sets a disaster deductible so that neither the state nor FEMA are better or worse off when compared to the current threshold and share system. To encourage mitigation, we assume that with mitigation the pdf shifts to lower losses and that the state benefits from this shift by a reduced Deductible and reduced expected losses.

The current system. Under the current system, states have to cover 100% of their losses in an event with losses that are smaller than a disaster declaration threshold $m=a*p$, where a is a multiplier that grows with inflation and p is the population of the State. Using California as an example, the value of a currently is 1.41 and California has a population of 38.8 million, so the disaster declaration threshold is m=\$54.7 million. When losses exceed m, the state pays 25% as a share and FEMA pays the remaining 75%. In practice, FEMA pays a higher share, when disaster losses are extremely large, so the actual percent over a series of events is less than 25%.

If we characterize the potential per-event losses of a State as a pdf, the current system can be described as shown in Figure II-22.

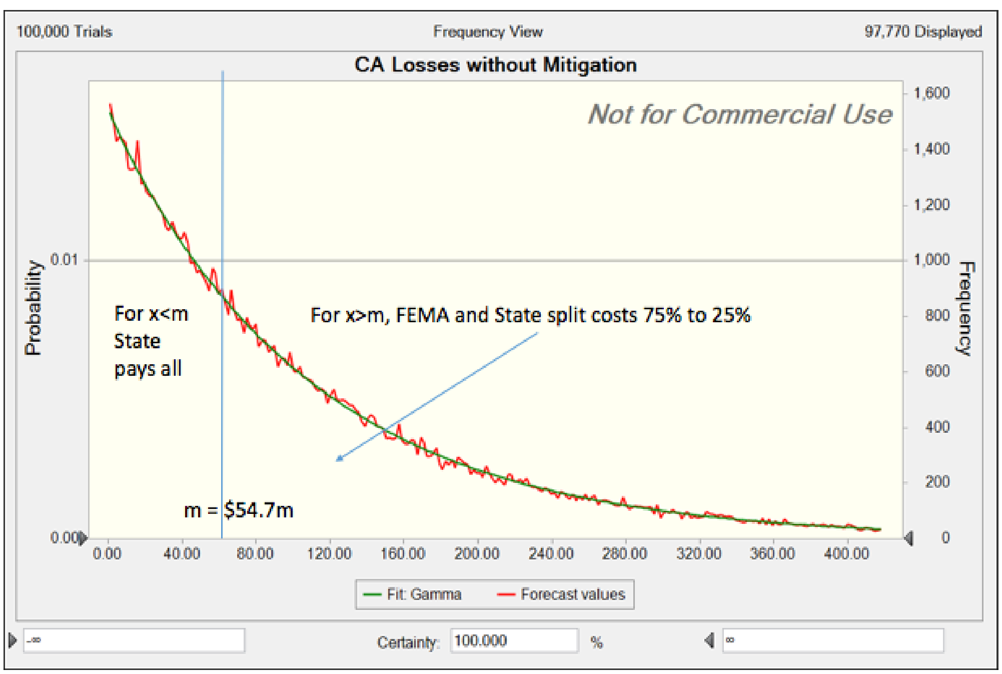

Figure II-22. Probability Distribution of Disaster Losses in California

(Best fitting distribution based on disaster losses in California between 1999 and 2014; red line shows simulated data, green line is a fit with an exponential distribution)

If x is the uncertain loss in a given disaster, *m* is the State threshold loss for a disaster declaration, and *f(x)* is the probability density function for disaster losses in case of an event, then, under the current threshold system, FEMA's expected payout is given by

$$EL^t_F = 0.75 \int_m^\infty x\, f(x)\, dx, \quad (1)$$

and the State's expected payout is

$$EL^t_S = \int_0^m x\, f(x)\, dx + 0.25 \int_m^\infty x\, f(x)\, dx, \quad (2)$$

where the superscript *t* stands for "threshold" and the subscript stands for either FEMA (F) or State (S).

A system with a disaster deductible. Suppose that FEMA abolishes the threshold scheme and instead requires a disaster deductible *d* from the State, to be paid in case of each event. In this case the expected loss for FEMA is

$$EL^d_F = 0.75 \int_d^\infty (x-d)\, f(x)\, dx = 0.75 \int_d^\infty f(x)\, dx - 0.75\, d\, [1-F(d)] \quad (3)$$

and the expected loss by the state is

$$EL^d_S = \int_0^d x\, f(x)\, dx + \int_d^\infty [d + 0.25(x-d)] f(x)\, dx =$$

$$= \int_0^d x\, f(x)\, dx + 0.25 \int_d^\infty x\, f(x)\, dx + 0.75\, d\, [1-F(d)], \quad (4)$$

where the superscript *d* stands for the deductible scheme and *F(x)* is cumulative distribution function of x. Using equations (2) and (4), we can define the deductible *d*, so that the State is, on average, not better or worse off with a deductible system when compared to the current threshold system, by setting $EL^t_S = EL^d_S$ in equation 4. It also can be shown that if this equation holds, FEMA is not better or worse off with a deductible scheme than with the threshold scheme. Note that the partial expected losses for the State and for FEMA have to add to *E(x)*, the expected value or average of the loss distribution.

As an example we use an exponential distribution of the per-event losses in California, which is the best fitting distribution to the actual disaster losses between 1999 and 2014 (see Figure II-22). California currently has a value of *m* = 54.7 million (the position of the vertical line in Figure II-22). By equating EL^t_S with EL^d_S, we determined that the value of *d* that matches the expected losses under the current threshold system is $10.4 million/event. Figure II-23 shows how the expected losses for California vary as a function of the deductible and it also shows the cross over point between the expected losses of the current system vs. the deductible system at $10.4 million. Below the cross-over point of $10.4 million, the State gains and FEMA loses in expected value relative to the current system, above the cross-over point the State loses and FEMA gains.

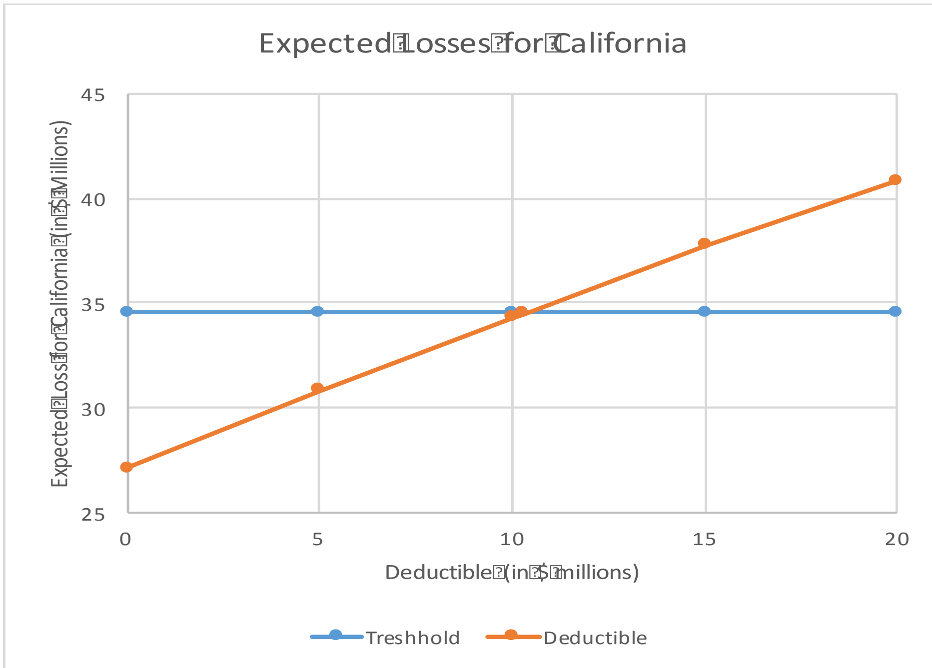

Figure II-23. Expected Losses for California under the Threshold System and for Different Values of a Deductible (Break-even Deductible at $10.4 Million/Event)

Keeping the disaster declaration threshold and adding a deductible. It has been suggested that the threshold for a disaster declaration should be maintained at $m=a*p$ and that the deductible be applied to any amounts above the threshold. This leads to the following expected losses for FEMA:

$$EL^{dt}{}_F = 0.75 \int_m^\infty (x-d)\, f(x)\, dx = 0.75 \int_m^\infty x\, f(x)\, dx - 0.75\, d\, [1-F(m)], \qquad (5)$$

and the expected loss by the state is

$$EL^{dt}{}_S = \int_0^m x\, f(x)\, dx + \int_m^\infty [d + 0.25\,(x-d)]\, f(x)\, dx =$$

$$= \int_0^m x\, f(x)\, dx + 0.25 \int_m^\infty x\, f(x)\, dx + 0.75\, d\, [1-F(m)], \qquad (6)$$

where the superscript *dt* stands for the expected losses calculated with a mixed deductible and threshold model. Using equations 1 and 5, we can determine that FEMA's expected losses under the mixed deductible and threshold model (5) are smaller than under the pure threshold model (1):

$$EL^t{}_F - EL^{dt}{}_F = .75\, d\, [1-F(m)]. \qquad (7)$$

Using equations 2 and 6, we can show that the expected losses for the State are larger in the mixed model than in the pure deductible model:

$$EL^d{}_S - EL^{dt}{}_S = -\, 0.75\, d\, [1-F(m)]. \qquad (8)$$

In short, the expected losses for FEMA decrease linearly in the deductible *d*, while the corresponding expected losses to the State increase by the same amount.

Using the California example and *m*=54.7, the expected loss for the State is plotted as a function of the deductible d in Figure II-24.

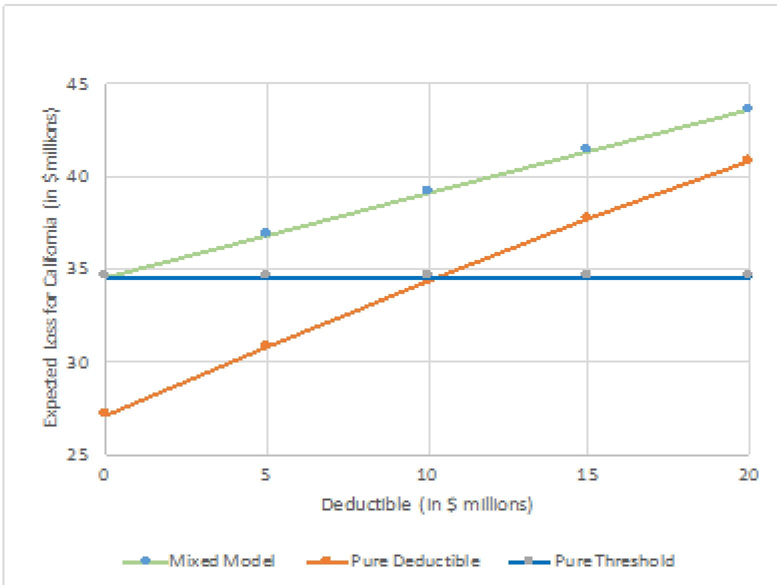

Figure II-24. Expected Losses for California for Three Models

Varying both the disaster declaration threshold and the Deductible. As shown in the previous sub-section, introducing a Disaster Deductible while keeping the disaster declaration threshold will necessarily increase the State's expected losses over the current system while decreasing FEMA's expected losses. One way to re-create an equilibrium with the current system is to compensate the expected losses due to the Deductible with a decrease in the disaster declaration threshold. In other words, we want to find combinations of *m* and *d*, such that the State's losses are the same as with the current threshold and a zero deductible. For California we calculated that the pairs (m=54.7, d=0) and (m=0, d=10.4) have identical expected losses of $34.5m for the State. In Figure II-25 we show other combinations of *m* and *d*, which lead to the same expected loss of $34.5m.

It is interesting to note that reducing the deductible from its maximum equilibrium point of $10.4m leads to a very steep increase in the disaster declaration threshold that would maintain the current expected losses for the State. For example, if we reduce the deductible from $10.4m to $8m, a threshold of $33m would still maintain the State's equilibrium expected losses.

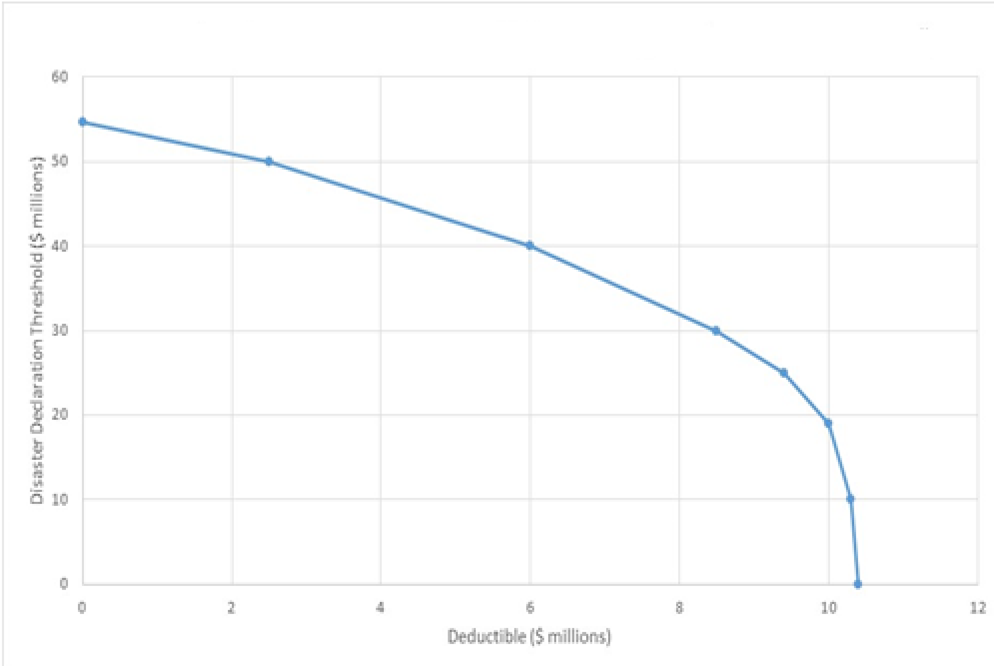

Figure II-25. Combinations of a Disaster Declaration Threshold and a Deductible that Maintain California's Expected Losses When Compared to the Current System

Motivating mitigation. To provide an incentive to the State to mitigate against disaster losses, we propose an approach in which we first re-assess the pdf over losses, given mitigation, then reduce the disaster deductible to d'<*d,* based on the expected risk reduction achieved by mitigation and the cost of mitigation. We consider this case only for the pure deductible model. This leads to the following revision of the expected costs to the State under the current threshold system (equation 5) and under the threshold system (equation 6):

$$EL^{t'}{}_{S} = \int_0^m x\, f'(x)\, dx + 0.25 \int_m^\infty x\, f'(x)\, dx + C \qquad (9)$$

$$EL^{d'}{}_{S} = \int_0^{d'} x\, f'(x)\, dx + \int_{d'}^\infty [d + 0.25\,(x - d')]\, f'(x)\, dx + C =$$

$$= \int_0^{d'} x\, f'(x)\, dx + 0.25 \int_{d'}^\infty x f'(x)\, dx + 0.75\, d'[1 - F'(d')] + C, \qquad (10)$$

where d' is the revised deductible, *f'* is the revised probability density function, *F'* is the revised cumulative density function, and *C* is the cost of mitigation. Figure II-26 shows an overlay of the two probability density functions without (red) and with (blue) mitigation for the California case. For illustration purposes, we assumed in this example that all losses are reduced by 20% due to mitigation. With mitigation, the pdf shifts to the left (higher probabilities of lower losses, lower probabilities of higher losses). The pdf with mitigation crosses the pdf without mitigation at about $100 million and losses exceeding $100 million become less likely for the mitigation case. As a result, the expected losses to both the State and FEMA are reduced substantially. Figure II-27 shows the expected losses with mitigation under the threshold and deductible system as a function of the deductible without considering mitigation cost. It also shows the results shown in Figure II-23 for the non-mitigation case.

Several insights can be obtained from Figure II-25. First, the expected loss for California is reduced by about $4 million for the threshold system and by about $5.5 million for the deductible system. Second, the deductible increases for the mitigation case from $10.4 million to about $12 million, when matching the expected losses under the deductible and the threshold model in the mitigation case. This occurs because the State now has the ability to pay a higher deductible, while still achieving a lower expected overall cost. Not shown in this graph isthe cost of mitigation, which will shift the expected losses for the mitigation case for both the threshold model and the deductible model upwards by the cost of mitigation, but leaving the cross-over point at $12 million.

The net risk reduction for mitigation should be a sufficient incentive for the State to mitigate for costs less than $5.5 million. However, the risk reduction is expressed as an expected value with very large uncertainties, while the cost of mitigation and the increase in the Deductible are clearly defined and certain quantities. Therefore, it may be reasonable to develop a scheme in which FEMA transfers some of its own risk reduction gains from mitigation (about $15 million in expected loss reductions) by reducing the State Deductible or by contributing to the cost of mitigation. For example, if the cost of mitigation is $4 million per event, FEMA could reduce the deductible by $2 million from $10.4 million to $8.4 million, resulting in a net benefit of about $3.5 million for California. While this would reduce the benefit to FEMA from $15 million to $13 million in expected loss reduction, FEMA would still benefit substantially.

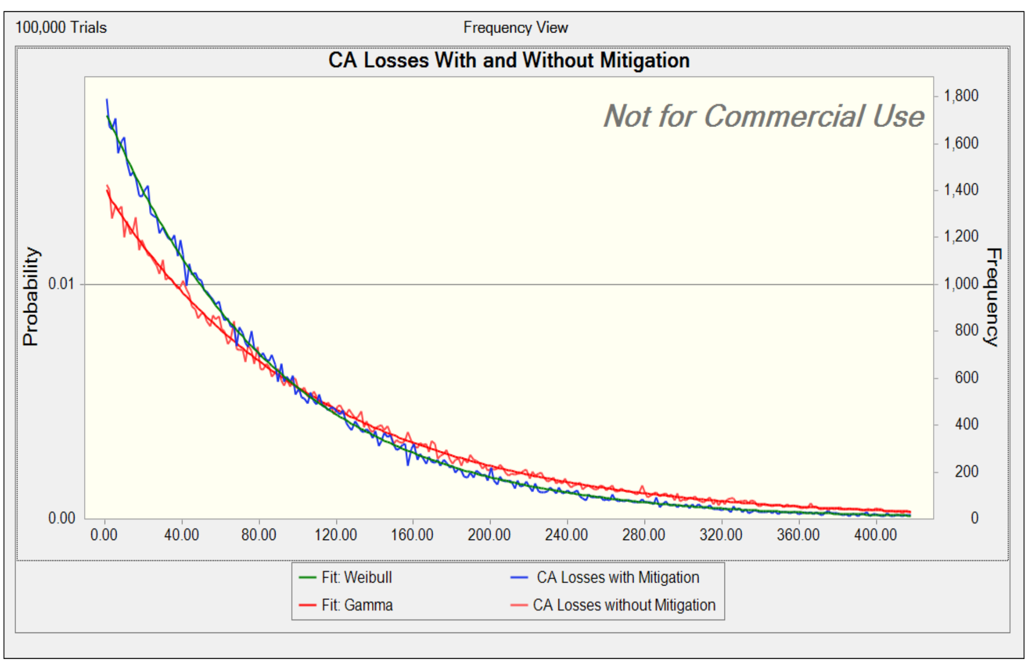

Figure II-26: Probability Distributions of Disaster Losses in California with Mitigation (Blue Line) and without Mitigation (Red Line)

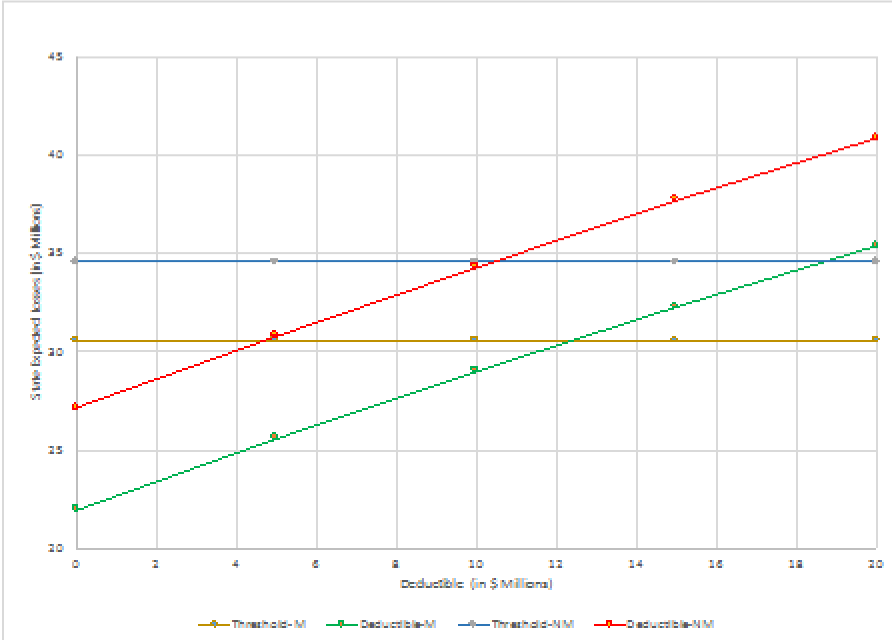

Figure II-27: Expected Losses for California with and Without Mitigation (NM) and with Mitigation (M) under the Threshold System and Deductible Systems (C=0)

Other schemes to share the risk reduction benefits between the State and FEMA are also possible, for example, by reducing the share that the State has to pay above the deductible or by a mix of reducing the deductible and the State's share.

Implementation Issues. The most difficult task in implementing this risk-based deductible system is the estimation of the probability distribution characterizing a State's disaster risk profile. In the example of California, we used standard statistical fitting procedures to estimate the probability distribution over disaster losses for California, based on public assistance data from 1999 to 2014. This estimate was based on a relatively small sample of 19 events in 15 years. It did not include the Northridge earthquake in 1994 or the Loma Prieta earthquake in 1989, which had extremely large losses. While the best fitting distributions are "extreme value" distributions (Exponential, Weibull, Gamma), even these distributions do not have the "fat" tail that would capture the frequency of extremely large losses with any sort of precision. Perhaps the best we can do is to acknowledge that the risk-based approach has value primarily in the case of "normal" disasters of up to $1 billion, but is not applicable for mega-disasters like Katrina, Sandy, Northridge, or Loma Prieta.

Because we used public assistance data to fit the probability distributions, we are under-estimating the frequency of losses that did not qualify for public assistance. This can be corrected by fitting a distribution that is truncated at the disaster declaration threshold and then extrapolating it to lower losses. Preliminary tests of this improved fitting procedure shows that the adjusted probability distribution shifts to higher probabilities of larger losses.

Estimating the shift in the probability distribution for the mitigation case is even more difficult. Most mitigation activities are event specific, e.g., retrofitting buildings to withstand earthquakes or building higher and stronger flood walls to prevent breaches or overtopping in floods. Furthermore, while the costs of these retrofits can usually be estimated fairly well, the reduction of expected losses is harder to determine.

Third, the risk-based model without a disaster declaration threshold does not consider that State's fiscal capacity. Thus it may be desirable to introduce a mixed model, in which a lowered threshold reflects the State's fiscal capacity, while the deductible is used for motivating mitigation.

Fourth, as described here we assume that both the State and FEMA are risk neutral. A reasonable alternative assumption is that the State is risk averse, while FEMA is close to risk neutral. States with less fiscal capacity should be more risk averse than States with more fiscal capacity.

H. Governance and Implementation: Delivering Technical Assistance[77]

This section provides an overview and framework for thinking about the implementation of effective policy. It begins by describing a general program implementation framework that has guided how experts have approached the issue. This discussion is designed to provide FEMA with a sense of the scope of the issues at play in the effective implementation of policy.

The section next turns to the issue of technical assistance and how best to deliver it. It is our view that the effectiveness of the technical assistance that is ultimately provided will be determinative in whether the outcome of the program is a significant change in the way states approach using their resources ex ante to mitigate disaster impacts. This is because such a change will require an understanding of the merits of such investments among multiple decision makers who have multiple perspectives on the value of making these investments. Without an active effort to create such an understanding, the deductible/credit system may not be very effective in incentivizing states to reduce their risk against natural and other disasters.

1. Background

The design of a sophisticated deductible formula with an incentive structure focused on promoting the desired priorities of FEMA, though essential, is only the first step towards the effective implementation of a new deductible policy. Indeed, a sizable literature has made clear that there are multiple dimensions that must be considered if a policy is to be enacted effectively and the desired outcomes achieved.

Two major frameworks illustrate this reality. First, in his seminal work, John Kingdon establishes three conditions that are necessary for a policy to be enacted (Kingdon, 1995). First, there must be a consensus that a given issue is a sufficiently salient problem that warrants action. Such a consensus

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[77] Phuong Nguyen and Krystian Palmero provided research assistance for this section of the report.

often emerges as a result of a *focusing event*. For example, the police response during the 1965 Selma protest march, which was aired on television nationally, brought into clear relief the issues around civil rights and marked an important turning point in the pursuit of civil rights legislation. Similarly, the terrorist attacks in the United States on September 11, 2001 focused the country on issues of national security and led to the establishment of an anti-terrorism infrastructure. Second, there must be a *consensus on the appropriate policy action* to take. In the wake of the Great Recession of the 2000s, for example, there was general acceptance that federal stimulus would be appropriate to try to jumpstart the economy. Finally, there must be *political alignment*, such that agenda-setters and other gatekeepers do not block action. Often, this is satisfied due to the political pressure that builds due to the focusing event. But focusing events alone are not a guarantee that a political alignment will occur. The superstorms that hit the United States during 2012, which included Superstorm Sandy, did not result in comprehensive legislation to ameliorate climate change, despite evidence suggesting that the magnitude of these storms was linked to atmospheric warming.[78]

Sabatier and Mazmanian (1980) developed an influential framework that lays out the issues that must be considered when implementing a policy once it has been enacted. They divide factors according to whether they are statutory in nature or are associated with non-statutory issues. Every governmental agency's ability to implement policy is shaped in a fundamental way by the specifics of the statutory (or regulatory) language. Language that includes ambiguous goals or diagnoses of the problem that are not universally shared by implementers can lead to conflicts among agency staff and, in the case of interagency policies, between agencies. Such conflicts can be a major barrier to any implementation, let alone effective implementation. Adequacy of resources is also an on-going consideration, and statutes that allocate insufficient resources will also inhibit effective implementation. Finally, Sabatier and Mazmanian point to the role of statutes as authorizing documents that empower agencies. If statutes are limiting in this regard, or if there are competing or conflicting authorizations, then agencies might not be able to fully implement the stated mission of a given policy. In the case of the FEMA deductible, statutory issues are less likely to be an issue, but FEMA staff should be cognizant of the possibility that such issues could arise in some circumstances.

The tractability of implementation can be enhanced or inhibited due to non-statutory factors as well. Economic, social or technological evolution can cause challenges to be more easily overcome. For example, changing social norms around smoking has eased the implementation of anti-smoking policies such as the ban on smoking indoors that is in effect in many states. Similarly, media attention (or inattention) and public support can be important enablers of policy implementation. Civil rights policy in the 1960s was instrumental in the establishment of an enforcement regime to promote affirmative action and fair housing programs. Finally, ongoing political and administrative support is critical. The same affirmative action programs that were common and had broad support in the program's early years have been more difficult to implement in recent years due to a weakening of broad-based political support and the rise of political leaders who have not been as supportive, and in some cases have outright opposed, the initial conception of the problem and the notion that affirmative action strategies

[78] The Sandy Recovery Improvement Act of 2013 did make changes to FEMA, though these changes did not address climate change.

are an appropriate solution. A similar ebb and flow in the ability to implement environmental laws has been observed with changes in the leadership of implementing agencies. FEMA must be mindful that whatever programs it establishes are insulated to the extent possible against this wide range of non-statutory factors.

The lessons learned from decades of experience have been distilled through research on the topic. McLaughlin documents the evolution of this body of work. Initial policy analyst sensitivity to the challenges of policy implementation was heightened in the early 1970s in the aftermath of the federal experiences of operating complex Great Society programs. This wave of analysis, which includes the work of Pressman and Wildavsky (1984) and Bardach (1977) found that "implementation dominates outcomes - that the consequences of even the best planned, best supported, and most promising policy initiatives depend finally on what happens as individuals throughout the policy system interpret and act on them" (McLaughlin, 1987, p. 172). Out of this realization emerged a new conception of how to best implement policy. Because of the dynamic nature of implementation processes, the most effective implementation must consider what is best from a systemic perspective rather than considering a specific program or target. Moreover, the multi-stage and evolutionary aspects of implementation require explicit attention to ensure high quality coordination and communication. Finally, there is an on-going tension between macro considerations - embodied in the broader policy objective - and the micro-level concerns of individual implementers. Those that are more talented navigators of this dynamic will be more effective in seeing their policies implemented to greatest effect.

In terms of implementation, one would be remiss to not discuss the importance of managing the political environment. Many studies have pointed out that political and ideological differences can, if not managed well, prevent a technical assistance program from being as successful as it could be. Walker (2004), for example, finds that organizational responses "subverted the goals" of a state's reform initiative. The FEMA deductible program can be viewed as a reform effort to reduce overall long-run spending in response to disasters. FEMA must be skilled in its couching of this program so as to not trigger state-level resistance and potentially subversive activities, either through administrative and operational delay or legislative means. This might be accomplished through the use of focus groups that can provide feedback on messaging and communications strategies for rolling out the program.

2. Technical Assistance

The likelihood that the roll-out of a new deductible policy will be successful in achieving the goal of state-level investment to mitigate the damage incurred in the event of a disaster will be increased if the states fully understand the goals, buy into them as being in their interest, and are well-versed in the means to achieve them. Technical assistance can be an important tool for achieving all three of these objectives. Technical assistance is "a systematic process that uses various strategies involving people, procedures, and products over time to enhance the accomplishment of mutual goals" (Trohanis, 1986, p. 203). When done well, it has been shown to produce measurable benefits for programs (see, for example Solomon and Perry (2011) in the case of small business management and Beam, et al. (2012) and Strunk and McEachin (2013) in the case of school policy).

There has been considerable research on the characteristics of effective technical assistance, and a consensus has emerged that the context is a critical factor (Desai and Snavely, 2007; Walker, 2004; Harbin, 1988). Given that the deductible formula implementation is a federal-state relationship, it is appropriate to focus where possible on lessons learned from these experiences. Harbin (1988) offers a useful framework in this regard through her assessment of how technical assistance might best work in the context of federal education policy that operates through the states.

Like the research discussed above, Harbin (1988) focuses considerable emphasis on the importance of viewing the technical assistance program as a comprehensive system rather than as a series of discrete programs or offerings. This approach will ensure that the overall technical assistance program is designed to facilitate progress by all states, regardless of their initial starting point. In order to accomplish this, agencies providing technical assistance (and the technical assistance provider) must categorize states according to their capacity and needs, as the distribution of capacity will inform the nature and scale of technical assistance. If many states are unfamiliar with the program or lack institutional capacity or political will to respond in desired ways, this will necessitate a very different technical assistance program as compared with the situation where states are well-versed in local mitigation investments and insurance benefit calculations.

Classifying states according to capacity can occur along multiple dimensions. Table II-36, reproduced from Harbin (1988), presents a classification scheme she proposes for a technical assistance program to help states better deliver coordinated education services for young children with handicaps. The table shows key dimensions that define capacity - economics, official support, availability of funds - that FEMA should consider when conducting their own classification. But FEMA should also consider whether there are policy-specific dimensions that should also be considered.

Table II-36. Developmental Levels for a Comprehensive Service Delivery System

	Level I	**Level II**	**Level III**
Economics	Poor economic conditions - High rate of poverty - Poor financial base - Low per capita income - Loss of major income base	Fair economic conditions	Good economic conditions - Many resources for this population group
Services	Little history of the provision of services - Few advocacy groups - Little grass roots support of organization	Some history of provision of services - Grass roots support but often not organized - Some support groups	Good/long history of services - Many efforts undertake on behalf of young children - Many groups

	Level I	Level II	Level III
Political Climate	Political climate not favorable to expansion of services to this population group - Much "turf guarding"	Political climate is conducive to retaining services and coordination to reduce duplication - Okay to serve more children but not to increase dollars - Spirit of cooperation among lower agency staff but no impetus to change structure	Political climate is conducive to expansion of services in this area and seen as valuable
Official Support	No prominent official providing leadership, vision, or impetus	High level official cooperation	High level officials supportive with at least one providing leadership
Entitlement	Lack of entitlement; if a mandate exists, it is not taken seriously	Entitlement to part of the target population	Entitlement to all or most of population with interest in working toward entitlement to all
State Funded Position	No state funded position in lead agency	There is a person responsible for handicapped infants/toddlers, but has many other responsibilities	At least one (usually more) person is responsible for administering statewide programs for this population group
State and Local Dollars	Few state and local dollars spent on this population	Some state and/or local dollars spent on this population	Both state and local dollars are allocated
Administrative Structure	No clear administrative structure	There is an administrative structure, but it may be limited in scope	Administrative structure exists or attitudes are such that structure is being changed to meet broader scope in system
Interagency Agreement	Lack of meaningful interagency agreements	Some interagency agreements exist	Meaningful interagency agreements that include responsibilities
Training	No training programs	There are some training programs and several well-trained professionals	Good training programs and many well-trained people

	Level I	Level II	Level III
Interagency Coordinatio n	Very little support from key decision makers for cooperative efforts; little or no coordination among programs or resources; no real coordination between public and private sector	Some efforts are underway to plan better coordination of services; an interagency council is operating. There is some support from high-level decision makers	There is support from several high-level decision makers; interagency group is functioning well; program, resources, and policies are coordinated
Utilization of Resources	Not utilizing all possible sources of funds, no coordination of use of funds	Most sources of funds are used; some work done on coordination of funding; no new revenues identified	Coordinated system of funding using all possible funding sources; procedures exist for reimbursement and settling disputes among agencies; new sources of funds identified

Source: Harbin, 1988; pp. 27-28.

An additional nuance FEMA will face in the development of a technical assistance program focused on the deductible is that the state-level clients will likely involve agents other than direct employees of the states. Effective mitigation activities may involve decisions and investments by local and regional governmental bodies, as well as any non-profit and private sector organizations that control vital assets that may be vulnerable to loss in the event of a disaster or deliver critical services via either public-private partnerships or contractual arrangements that will need to be preserved in the aftermath of an event. Thus, leaders and employees of local and regional governments, associated non-profit organizations, and private entities can also be targets for the technical assistance that will be delivered.

FEMA will have to decide the extent to which the technical assistance program will target such people. Indeed, many might view these as essential participants if mitigations activities are truly to take hold. If true, then FEMA might need to conduct a more comprehensive assessment of client capacity that looks beyond solely state government capacity and incorporates the capacities of these other players. This decision will have important implications for how the technical assistance program is ultimately designed. Inclusion of a broader set of clients may require a broader scope of the training, but could limit the depth of coverage of individual topics. Alternatively, FEMA could decide that a broader client base necessitates the development of a set of modules that focuses on specific distinct topics, with clients directed to those modules that are most appropriate given their roles in the disaster mitigation, response, and recovery chain.

In addition to considering the client, as alluded to in the foregoing discussion, agencies seeking to deliver technical assistance must also have a clear conception of what they hope to achieve from the technical assistance and how they intend on achieving this. Mattson and McDonald (2005) establish a 7-step planning process for developing a technical assistance plan. Table II-37 summarizes the steps, and

Table II-37. Framework for Developing and Delivering an Effective Technical Assistance Program

Step	Description	Application
1	Investigate and identify priority needs for technical assistance	Needs might include explanation of the concept, the formula, and potential desirable actions states might take
2	Identify technical assistance purposes, measurable goals and objectives, and outcomes	Purpose might be to facilitate the development of a state-level mitigation investment plan, based on maximum leveraging of the deductible and credits, with the goal being the creation of such a plan and the outcome being the number of states with such a plan
3	Identify technical assistance services and agree on the amount and duration	Determine the range and modality of technical assistance provided, perhaps including the identification of possible vendors
4	Develop a technical assistance plan	Establish a program and schedule for delivering it; these will depend on the needs identified in 1 and from the client capacity assessment (described above)
5	Implement the technical assistance plan	Execute the delivery of the plan on time and on budget
6	Establish mutual accountability for technical assistance and outcomes	Make sure the recipients are clear on expected goals and outcomes, ensure that plan moves recipients towards them
7	Develop an evaluation plan of the technical assistance plan and services	Design an evaluation protocol that assesses the achievement of the goals and outcomes and solicits feedback from the recipients

Source: Mattson and McDonald (2005).

describes actions FEMA might take to deliver the technical assistance in a way that maximizes the effectiveness of the deductible in spurring state-level investments that mitigate the damage from disasters. In the context of these steps, Mattson and McDonald (2005) highlight two key aspects. First, they argue that technical assistance is most effective if the client (in this case, the states and potentially others) participate in conceptualizing the program. In this spirit, FEMA should select a few state representatives to serve on a technical assistance planning group to gain state-level buy-in for the entire undertaking. Second, as has been argued in many policy evaluation contexts, the authors recommend an evaluation program for the technical assistance be in place and clearly articulated *prior* to providing any assistance. This will ensure that all parties are clear on performance criteria and program goals.

In addition to these general considerations in the design and implementation of an effective technical assistance program, researchers have studied programs and identified a number of features of technical assistance that promote success. Haslam and Turnbull (1996), among others, highlight a number of these that will be important for FEMA to keep in mind as it develops its program. Translating these to apply to the current context, key lessons include:

- Do not overemphasize mechanical considerations of calculating the deduction and credits at the expense of describing and discussing the actions that can generate the credits.
- Provide incentives for technical assistance providers to incorporate professional development into the training. Such development can help create a cadre of experts well-versed in the goals and objectives of the program who can be ambassadors for the program in the states.
- Make sure that reporting on technical assistance activities is substantive, but work hard to prevent a burdensome reporting regime. A streamlined focused reporting structure will aid providers and monitors in assessing and evaluating program progress.
- Consider contracting with an external program evaluator to conduct assessments. Periodic deep dives to develop a more comprehensive understanding of what is and is not working can be invaluable.

Another operational consideration is how best to monitor the program and provide oversight. In every environment involving rules established at one level that affect the availability of resources different levels of government, there are multiple types of relationships between government that can arise. While there is arguably a natural propensity for the relationship to settle into an enforcer-subject pattern, the literature on technical assistance effectiveness consistently finds that a more effective posture is one in which the various governments move forward as partners. For example, Miller and Goswami (2007) couch this in terms of how the process should proceed. They argue that technical assistance and, by extension, program outcomes are improved if the process is treated as something of a pilot, where goals are established and then iteratively revised through rounds of experience and feedback from all parties. This approach can build buy-in from the recipient of the assistance and result in more active recipient engagement and pursuit of goals. To the extent possible, FEMA's technical assistance program should be structured to promote a feeling of partnership. The recommendation to establish a deductible working group of state representatives is a first step in this direction, but FEMA should consider other opportunities to build the partnership relationship.

3. A Recent Example

An example of a technical assistance program similar to the one FEMA will contemplate as part of its roll-out of the deductible is the technical assistance effort currently being pursued by the U.S. Department of Housing and Urban Development as part of its reboot of its "affirmatively furthering fair housing" regulation (U.S. Department of Housing and Urban Development, 2015a; 2015b). The structure underlying this effort mirrors that associated with introducing a deductible. It features the same interagency challenges FEMA will face, as the revised regulation requires state and local grantees of several HUD programs to embark on a planning exercise for future grant expenditures based on a new suite of data and planning criteria. Moreover, as is being contemplated here, HUD has developed a new web-based geospatial tool that manipulates the data and allows the jurisdictions, as well as other interested parties, to analyze and evaluate demographic trends and historical investment patterns.[79]

HUD has developed a two-pronged technical assistance program that seeks to assist those jurisdictions currently required to satisfy the new regulatory requirements as well as prepare those who will have to do so in coming years.[80] HUD has partnered with a team led by Enterprise Community Partners to build local teams that will deliver direct technical assistance to local staff and conduct workshops that provide general training on the reporting requirements and the use of the new data tool. The experience that emerges from this initiative could potentially assist FEMA in designing and implementing its own technical assistance program.

VIII. Conclusion

Part II of this study further develops and analyzes a Disaster Deductible, including a Credit System, to promote FEMA's two goals of encouraging states to acknowledge their fiscal responsibility in responding to disasters, while offering incentives to states to reduce disaster losses through actively engaging in mitigation, resilience, and generally being better prepared for disasters.

Part I of this Report presented an initial Disaster Deductible Formula (DDF1), based on recommended assumptions and parameters presented in a FEMA (2015b) White Paper. This serves as the basis for the development of an alternative formulation of the Disaster Deductible/Credit System (DDF2) in Part II. DDF2 presents alternative specifications of many of the assumptions and parameters of DDF1.

Part II has three aspects: the specification of variants of DDF2; a prediction of the optimal response to that formulation through the choice of disaster-related strategies to achieve a specified goal at the state level; and an analysis of the impacts of those choices on both state and FEMA spending for post-disaster assistance each year.

In the DDF2 Base Case, we construct the Fiscal Capacity index from three indicators. The State General Fund is a good proxy for the discretionary funds available to finance the deductible, as well as any disaster-related activities such as mitigation, purchasing disaster insurance for public facilities and establishing a relief fund. The Rainy Day Fund may be used to pay for post-disaster expenses, and, finally, Bonding Capacity may be called upon if the state issues post-disaster debt obligations. Not surprisingly, this revised Fiscal Capacity index is highly correlated with the index used in DDF1 especially for a few states that have high Rainy Day Funds, such as Alaska and Wyoming.

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[79] The tool can be accessed at https://egis.hud.gov/affht/.

[80] The regulatory regime establishes a schedule whereby a subset of covered jurisdictions must complete the reporting and planning requirements in any given year.

In the DDF2 Base Case, we use a Risk Index that differs from the indices we presented in Part I of this Report in one major way. The Risk Index in Part II is estimated on the basis of state-level Public Assistance data for the period 2005-14, regressed on explanatory variables.

As we did in DDF1, the Adjusted Deductibles in DDF2 were calculated by applying the Risk index and Fiscal Capacity index to the Base Deductible, then capped and normalized back so that the mean Adjusted Deductible was equal to the mean Base Deductible of $26.9 million.

Throughout Part II of this Report, we employ a comparative static analysis method and first compare the DDF2 Base Case with a Deductible Formula Base Case based on an econometrically estimated Risk Index and a revised Fiscal Capacity Index. Then we compare each alternative scenario of DDF2 with the DDF2 Base Case. Throughout these scenario analyses, the structure of the DDF remains constant, but we consider the states' responses with expanded loss categories, and additional loss reduction strategies. We also simulated scenarios that included fatality risk and government interruption risk.

The DDF2 Base Case considers FEMA eligible Public Assistance Program categories of Emergency work and Permanent work. Permanent work is essentially coverage of property damage, while Emergency work includes debris removal and protective measures, "work to allow continued safe operation of governmental functions or to alleviate an immediate threat…" and "those prudent actions taken by a community to warn residents, reduce the disaster damage, ensure the continuation of essential public services…" (FEMA, 2007; p.68 and 71). Given these definitions, we characterize the Base Case as including coverage of property damage and a crude proxy for government interruption expenditure. We find similar state responses in the DDF1 and DDF2 Base Cases in this Part of the Report. However, because of the revised interpretation of public assistance in DDF2, we see movement away from insurance and use of relief funds toward more mitigation in DDF2 as hurricane mitigation has a higher PA return than property damage only return.

A state's response to the DDF depends on risk levels, the risk reduction returns to mitigation and other strategies (the BCRs), and credits against the deductible. As we add additional loss categories to the Base Case, the optimal strategies of the state vary, but sometimes in unpredictable ways. This is because adding loss categories increases the expected losses, allowing more mitigation spending, but depending on the nature of the risks faced by a state, the mix of risk reduction strategies can be more, or less, expensive. For example, we observe an increase in mitigation spending for Mississippi as expected losses increase due to the inclusion of fatalities, while we see reduced spending on mitigation in Ohio under the same scenario.

One important innovation in DDF2 is the explicit inclusion of resilience strategies to the menu of actions the state can take to recover from disasters, including the associated increases in BCRs and the availability of credits toward the Deductible for resilience spending. Spending on pre-disaster, but mainly post-disaster, resilience has been shown to generate a substantial return, implying relatively high BCRs. We find that states adjust to the availability of resilience by sometimes reducing mitigation spending in favor of resilience spending. While this is an optimal strategy at the time of the event, mitigation may be a better long-term expenditure, as its effects are cumulative, while the benefits of resilience spending are often limited to the current disaster event.

Another innovation introduced in DDF2 is the more realistic modeling of insurance purchased by states to cover disaster losses to public facilities. In DDF1, spending on insurance premiums was credited in the same manner as spending from a relief fund, which does not reflect the very different nature of pre-disaster insurance and post-disaster funding of losses. One goal of the DDF is to encourage states to take more financial responsibility for disaster losses, and one important way of doing this is to purchase insurance for the stock of public assets, thereby shifting the risk to the private sector. DDF2 includes a credit of up to 10% of the deductible in proportion to the coverage ratio of public facilities. For example, if 90% of public buildings are insured, the state receives a 9% credit of the deductible. In order to solve for the state's optimal strategy to achieve the risk reduction goal we assume the state insures a specific proportion of its assets.

The Burden Analysis of each scenario considers the impact of the DDF on state and federal spending. Although considering only the resulting change in expenditures as a measure of impact is limited, it is important as it not only measures the opportunity cost of the policy, it also reflects the likelihood, at least in part, that states will be favorably disposed to this FEMA policy. As we found in our analyses of DDF1, imposing an annual deductible on Public Assistance funding shifts spending from FEMA toward the states and increases the burden on all states. Giving credit for spending on mitigation, resilience, purchasing insurance, and building relief funds reduces the Deductible and reduces the burden on the states. Since some responses also reduce expected losses, the burden is not necessarily shifted back to FEMA, as when risk is reduced, at which point both the state and FEMA benefit. However, it may take several years for the cumulative effects of risk reduction strategies to make states better off than under the status quo.

As we did for DDF1, we consider additional sensitivity tests of various parameters and assumptions in DDF2 using both the MP and Burden Analysis tools. Our sensitivity tests include adding terrorism to the risk index, which for most states does not alter the index substantially. We consider different weights for the risk and fiscal indices when determining the combined index to apply to the Base Deductible. As we found in DDF1, the alternative weights change the Deductible for those states more, or less, sensitive to a high Fiscal or Risk Index in predictable ways.

In our time-path analysis, we offer examples to show how mitigation spending can be cumulative, and help reduce losses, and thus state and federal spending over time. Although the predicted time-path is dependent on the scenario being considered, a general result emerges: the net effect of the Deductible on state expenditure depends on how much economically viable mitigation can be undertaken and on the level of the Deductible. After the state has exhausted economically viable mitigation opportunities (which depends primarily on the level of risk and the BCRs for mitigation) and the type of risk, the state will be better under the DDF when (and if) the cumulative reduction in total PA times the state's share is greater than the Deductible.

We also perform a sensitivity analysis applying BCRs for all damage categories to the Base Case loss scenario. As we found with the DDF1, with the expected losses and Deductible the same, the only significant difference is the level of mitigation chosen in the optimal response, as well as a relatively small change in both state and federal spending to alter the burden slightly.

We also consider a broader theoretical framework of the relationship between state and FEMA expenditure under a deductible scheme. For simplicity, we abstract from the annual deductible to a per-event deductible that facilitates interaction with the existing threshold structure. If the threshold is retained, we find that states are always worse off under a Deductible structure in any given year. If the Deductible replaces the threshold, however, there is a Deductible-level that holds both a state and FEMA at the same level as under the current threshold scheme.

We calculate the Deductible that leaves the state no worse off than the threshold, using California as an example. Given California's current threshold level of $54.7 million, a Deductible of $10.4 million per event would hold California's share of post disaster expenditure at current levels. If mitigation is undertaken, for example, the Deductible that holds state expenditure constant increases relative to the no mitigation case, because mitigation substantially reduces expected losses.

Once FEMA settles on a final Disaster Deductible Formula, the focus will shift from program design to program implementation. The challenge of implementation should not be overlooked; many studies have found that implementation is far more determinative regarding outcomes than design. Effective implementation will rely critically upon the extent to which there is a consensus on the utility of a Deductible, a political alignment such that gatekeepers or agenda-setters do not block the action, a focusing event or set of events that generates broad public support, and an ability to leverage economic, social and technological realities that shape an ability to build and establish an infrastructure to operate the deductible framework.

The other important aspect of the implementation of the Deductible/Credit System is ensuring that FEMA's clients and partners have the requisite skills to make decisions that are maximally responsive to the new incentives that the DDF introduces. The technical assistance that FEMA delivers will be important in ensuring that state-level skill sets are sufficiently strong to make good decisions that result in meaningful investments to reduce the damage and costs created by future disaster events. To design an effective technical assistance program, two actions are essential. First, there must be ex ante agreement by FEMA and its clients and partners on the core skills that need to be developed. Second, FEMA must assess existing state-level capacities for evaluating risks and understanding potential mitigation investments and then design a curriculum, or perhaps multiple curricula, targeted at the appropriate level of specificity and difficulty.

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APPENDIX II-A (APPENDIX TO PART II, CHAPTER III). BASIC DATA USED IN CONSTRUCTING FISCAL CAPACITY INDICES

	State	Population As of July 1, 2014	State General Funds (2005-2014 Ave) (M $)	State Reserve Funds (M$) (2005-2014 Ave)	Per Capita GF ($)	Per Capita Reserve Funds ($)	S&P Bond Rating (2004-2013 Ave)[a]
1	Alabama	4,849,377	9,897.8	219.3	2,041.0	39.7	8.0
2	Alaska	736,732	6,333.8	9,784.3	8,597.1	13,277.5	8.8
3	Arizona	6,731,484	9,624.2	311.2	1,429.7	46.2	7.5
4	Arkansas	2,966,369	4,620.5	0.0	1,557.6	1.0	8.0
5	California	38,802,500	100,153.7	1,854.1	2,581.1	49.0	5.0
6	Colorado	5,355,866	8,084.2	250.5	1,509.4	46.3	7.7
7	Connecticut	3,596,677	17,316.5	751.2	4,814.6	208.9	8.0
8	Delaware	935,614	3,607.8	0.0	3,856.1	208.3	5.8
9	DC	658,893	6,288.7	194.9	9,544.3	707.9	10.0
10	Florida	19,893,297	26,783.5	828.9	1,346.4	41.7	9.9
11	Georgia	10,097,343	18,303.1	674.8	1,812.7	66.8	10.0
12	Hawaii	1,419,561	5,619.8	54.1	3,958.8	38.1	7.7
13	Idaho	1,634,464	2,715.0	93.0	1,661.1	57.0	8.3
14	Illinois	12,880,580	26,353.4	182.9	2,046.0	14.2	6.7
15	Indiana	6,596,855	14,000.0	384.5	2,122.2	58.3	9.4
16	Iowa	3,107,126	6,048.9	533.4	1,946.8	172.3	9.6
17	Kansas	2,904,021	6,111.5	0.0	2,104.5	0.0	9.0
18	Kentucky	4,413,457	9,548.4	100.0	2,163.5	22.7	7.0
19	Louisiana	4,649,676	9,279.5	592.3	1,995.7	127.4	6.5
20	Maine	1,330,089	3,202.1	59.4	2,407.5	46.6	7.8
21	Maryland	5,976,407	14,964.0	807.0	2,503.8	135.0	10.0
22	Massachusetts	6,745,408	27,726.9	1,706.1	4,110.5	252.9	8.1
23	Michigan	9,909,877	9,572.5	129.3	966.0	13.0	7.4
24	Minnesota	5,457,173	18,231.1	749.3	3,340.8	137.3	9.8
25	Mississippi	2,994,079	4,727.2	165.3	1,578.8	55.2	8.0

26	Missouri	6,063,589	8,413.3	280.1	1,387.5	46.2	10.0
27	Montana	1,023,579	1,859.1	0.0	1,816.3	0.0	7.6
28	Nebraska	1,881,503	3,529.3	469.3	1,875.8	249.4	9.3
29	Nevada	2,839,099	3,392.7	93.0	1,195.0	32.8	8.5
30	New Hampshire	1,326,813	1,470.0	35.2	1,107.9	26.6	8.0
31	New Jersey	8,938,175	32,256.0	233.0	3,608.8	26.1	7.6
32	New Mexico	2,085,572	6,044.3	654.4	2,898.2	313.8	9.0
33	New York	19,746,227	57,412.9	1,261.6	2,907.5	63.9	8.0
34	North Carolina	9,943,964	20,394.8	521.3	2,051.0	52.4	10.0
35	North Dakota	739,482	1,717.3	336.0	2,322.3	454.3	8.5
36	Ohio	11,594,163	28,932.8	630.0	2,495.5	54.3	9.0
37	Oklahoma	3,878,051	6,470.6	539.3	1,668.5	139.1	8.6
38	Oregon	3,970,239	6,607.3	140.8	1,664.2	35.5	8.0
39	Pennsylvania	12,787,209	28,149.7	340.6	2,201.4	26.6	8.0
40	Rhode Island	1,055,173	3,357.4	127.1	3,181.9	120.5	7.9
41	South Carolina	4,832,482	6,351.7	252.5	1,314.4	52.2	9.1
42	South Dakota	853,175	1,246.9	134.0	1,461.5	157.1	8.4
43	Tennessee	6,549,352	11,788.5	465.0	1,800.0	71.0	8.8
44	Texas	26,956,958	42,919.3	4,490.2	1,592.1	166.6	8.6
45	Utah	2,942,902	5,139.7	332.1	1,746.5	112.9	10.0
46	Vermont	626,562	1,177.5	62.8	1,879.4	100.3	9.0
47	Virginia	8,326,289	17,244.4	736.4	2,071.1	88.4	10.0
48	Washington	7,061,530	15,707.5	161.3	2,224.4	22.8	8.7
49	West Virginia	1,850,326	4,152.1	628.6	2,244.0	339.7	7.5
50	Wisconsin	5,757,564	14,227.7	0.0	2,471.1	7.4	7.6
51	Wyoming	584,153	3,242.2	589.0	5,550.3	1,008.2	8.9
	Total	318,857,056	702,319.3				
	Median				**2,051.0**	**57.0**	**8.4**

[a] We designate the following numerical values to the ratings: AAA = 10; AA+ = 9; AA = 8; AA- = 7; A+ = 6; A = 5; A- =4; BBB+ = 3; BBB = 2.

APPENDIX II-B (APPENDIX TO PART II, CHAPTER III). CONSTRUCTION OF RISK INDEX

A. Risk Methodology

In theory, a state's risk should be calculated by multiplying the probability that it experiences a disaster by its public assistance needs in the event of a disaster, and summing over all potential disasters. After considering both the magnitude of disasters, as well as the disaster type, however, there is a continuum of disasters that should be considered in computing state risk. Estimating the "true" risk facing each state would therefore require knowledge of the probability of a disaster of every magnitude occurring, as well as the PA needs resulting from such a disaster.

Because of difficulties associated with predicting the entire distribution of disaster damages, it is necessary to approximate the expected PA needs of each state, as a proxy for risk. In Part II of this Report we approach this problem by first estimating the PA need when each state is struck by a disaster. We then multiply this expected level of PA by the average number of disasters to strike the state in a given year. As an illustrative example, if the average hurricane striking Alabama is traveling 160 miles per hour, we estimate the relationship between hurricane speed and PA using regression analysis and assign Alabama the predicted PA associated with a 160 mile-per hour hurricane.[81] Then we multiply this expected PA value by the frequency with which Alabama experiences hurricanes that result in PA to calculate Alabama's annual average expected hurricane damages.

The simplest approach to modeling a state's risk would be to take the average of historical PA payments to that state. This can result in an estimate of expected disaster damages that is overly sensitive to sample selection. This occurs because disaster damages are often driven in part by relatively idiosyncratic events. For example, damages from Hurricane Katrina would likely have been lower if levees had not broken. These idiosyncrasies may lead to large variations in perception of state disaster risk depending on the years that are considered in evaluating it. For example, in the ten-year period between 2005 and 2014, Louisiana's average annual federal PA was approximately $1.6 billion. If, instead, the nine-year period between 2006 and 2014 is considered, average annual federal PA to Louisiana was only $160 million.

In order to smooth these idiosyncrasies, we estimate the risk based on the observable characteristics of the disaster and of the state. In the example of Hurricane Katrina, this approach considers the amount of PA that a state with a population of 4.6 million would need when faced by a hurricane with wind speeds of 175 miles per hour. Each state's expected damages are calculated based on the predicted damages of the average disaster facing the state multiplied by the probability that a state experiences a disaster in any given year.

[81] We do not use wind speed alone to estimate PA associated with hurricanes. Rather, we use a more complex metric that incorporates wind speed, as well as distance to a state and the length of time that the storm was in or near the state.

In the case of earthquakes, which do not result in PA frequently enough for statistical analysis, we instead estimate the relationship between PA and total property damage and then predict property damage from earthquakes based on the results of Heatwole and Rose (2013) which estimated earthquake property damage based on earthquake characteristics. The expected amount of public assistance is obtained by inputting the expected property damage estimates from the Heatwole and Rose (2013) model into the reduced form equation relating property damage and PA.

B. Data

Federal PA obligations, as reported in the Open FEMA (2015c) datasets, are estimated, using regression analysis, for four disaster types: hurricanes, severe storms, floods and earthquakes. Combined, these disasters constitute over 90 percent of FEMA PA between 2005 and 2014.

For hurricanes, severe storms, and floods, PA is modeled based on state population and disaster magnitude. Population and gross state product estimates are taken from the U.S. Bureau of the Census (2015) and Bureau of Economic Advisors (2015), respectively. Disaster magnitude is measured by distance-weighted hurricane wind speed, the maximum surge of river gauge sensors, and maximum precipitation for hurricane, flood, and severe storm disasters, respectively. In the case of hurricanes and floods, we find that adjusting for state infrastructure improves model fit. In both cases, we utilize data from the U.S. Department of Transportation (2015). In the case of earthquakes we utilize data on property damage from earthquakes since 1972 from the SHELDUS (2011) database to impute PA needs. Estimates of earthquake probability are derived from USGS (2009).

C. Hurricanes

The natural log of PA is estimated as:

$$\log(PA_{ijt}) = \alpha + \beta\log(mag_{ij}) + \gamma\log(gsp_{jt}) + \eta infra_{jt} + \epsilon_{ijt}.$$

mag_{ij} is the magnitude of disaster *i* affecting state *j*, gsp_{jt} is the gross state product of state *j* at time *t*, and $infra_{jt}$ is a measure of the quality of state *j*'s infrastructure at time *t.* ε_{ijt} is an idiosyncratic error term.

mag_{ij} is the distance-and-time weighted speed of a hurricane affecting a state. It is calculated based on hurricane location and speed data from Unisys Weather (2015). Unisys Weather reports the wind speed, barometric pressure, latitude, and longitude for each hurricane and tropical storm. Observations occur approximately every four hours throughout the duration of the storm, and the time and date of observation is reported.

mag_{ij} is calculated as $mag_{ij} = \sum^{h} \frac{1}{d(Storm_{jh}, State_i)} * Wind_{jh} * (T_h - T_{h-1})$, where

$Wind_{jh}$ is the wind speed of hurricane *j* at time *h*, and $d(Storm_{jh}, State_i)$is the Euclidean distance between the storm at time h and state *i*. $(T_h – T_{h-1})$ I the number of hours between *h* and the previous time reading *h+1.* These weighted Wind speeds are then summed over all of the observations for a storm. Magnitude values are not easily interpretable due to the weighting system, but they increase as storms are closer, faster, or stay in an area longer. Magnitude ranges from to 5.5 (Tropical Storm Irene in Maine in 2011) to 35 (Hurricane Isaac in Louisiana in 2012).

gsp_{jt} is the gross state product of state *j* at time *t.*

These values are taken from the Bureau of Economic Analysis (2015). For the hurricane equation, the variable that resulted in the best model fit was the percentage of roads that were of mediocre quality as determined by the Department of Transportation (2015).

There are 69 hurricanes and tropical storms in the data set, affecting 21 states and the District of Columbia.

D. Floods

The natural log of PA is estimated as

$$\log(PA_{ijt}) = \alpha + \beta \log(mag_{ij}) + \gamma \log(gsp_{jt}) + \eta infra_{jt} + \epsilon_{ijt}.$$

mag_{ij} is the magnitude of disaster *i* affecting state *j*, gsp_{jt} is the gross state product of state *j* at time *t*, and $infra_{jt}$ is a measure of the quality of state *j*'s infrastructure at time *t.* ε_{ijt} is an idiosyncratic error term.

mag_{ij} is the maximum flood surge among USGS flood sensors in state *j.* The USGS reports the height of a range of sensors in rivers, streams, and lakes throughout the United States, as well as the height that constitutes flood conditions. Sensors that record heights greater than 1000 feet are likely to be in lakes and are removed from the sample. Flood surge is calculated at each sensor as the difference between the sensor's height and the height constituting flood conditions. The magnitude of a flood disaster is the maximum flood surge in state *j* throughout the duration of the disaster declaration. The maximum surge is 74 feet, while the minimum surge is zero feet (ie no sensors in the state exceeded flood height during the disaster declaration).

For the flood equation, the variable that resulted in the best model fit was the percentage of roads that were of poor quality as determined by the Department of Transportation (2015).

There are 62 floods in the data set, affecting 32 states.

E. Severe Storms

The natural log of PA is estimated as

$$\log(PA_{ijt}) = \alpha + \beta \log(mag_{ij}) + \gamma \log(gsp_{jt}) + \epsilon_{ijt}.$$

mag_{ij} is the magnitude of disaster *i* affecting state *j* and gsp_{jt} is the gross state product of state *j* at time *t.* ε_{ijt} is an idiosyncratic error term. No infrastructure variables were found that significantly improved the fit of the model.

mag_{ij} is the maximum amount of precipitation recorded by a National Climactic Data Center (2015) weather station in state *j* throughout the duration of the disaster declaration. Rainfall ranged from 0.7 inches to 20.5 inches.

F. Earthquakes

Earthquakes were not modeled econometrically because of the small number of earthquake disasters to receive PA between 2005 and 2014. We instead merged data on earthquake PA since 1972 with data on total property damage from earthquakes. This data came from the SHELDUS (2011) dataset, which contains property damage estimates for a large number of earthquakes including those that did not receive public assistance.

First, the relationship between property damage and PA is estimated for the earthquakes that appear in both datasets. Next, we predict property damage from earthquakes in Alaska, California, Oregon, Washington, Tennessee, and Virginia using the Heatwole and Rose (2013) reduced form relationship between property damage and earthquake characteristics. For each county in the above states, we predict the amount of property damage resulting from an earthquake of a particular magnitude. These property damage values are then translated into PA using the reduced-form estimate described above. Finally, expected PA is calculated by multiplying the PA for a given earthquake magnitude by the probability that the earthquake occurs within 100 kilometers of each county's geographic center in a given year and summing over each potential earthquake magnitude. State-level expected PA is calculated by summing across all of the counties in a state.

G. Total Expected Damages

Annual expected damages are calculated for hurricanes, floods, and severe storms for each state that experienced at least one declaration between 2005 and 2014. For each state and for each disaster type, disaster magnitude is averaged across each disaster. Similarly, gross state product and infrastructure are averaged across each disaster, for each state and for each disaster type. Using the regression equation, modeled PA is calculated by multiplying the regression coefficients with these averaged values and exponentiating.[82] Finally, the average number of disasters per year is calculated for each state and for each disaster type by dividing the total number of disasters between 2005 and 2014 by 10 years. This is then multiplied by modeled PA amount.

Total expected damages for each state are calculated by adding the annual expected damages for each of the modeled disaster types as well as the expected earthquake PA.

[82] Due to natural log transformation in the regression analysis, it is necessary to take the exponential function (the inverse of the natural log) to return to non-logged values.

H. Regression Results

Regression results for hurricanes, floods, severe storms, and earthquakes are presented in Table II-B1.[83] Coefficients are statistically significant at least the 0.1 level for all variables except the intercept of the hurricane regression and the infrastructure variable for floods.[84] The left-hand side of each regression except for the earthquake regression is expressed in natural logs.[85] The coefficients are thus interpreted as a percentage change in public assistance. For example, a one-unit change in log gross state product for states being struck by a hurricane results in approximately an 82 percent increase in public assistance. Hurricane magnitude and severe storm magnitude are measured in logs: the log of the distance-and-time-weighted wind speed and the log of precipitation, respectively. Flood magnitude is measured in levels.

Table II-B1. Threat Risk Regression Results

	Log Hurricane PA	Log Flood PA	Log Severe Storms PA	Earthquake PA
Intercept	-0.49	10.72	8.22	
Log Gross State Product	0.82	0.41	0.46	
Magnitude	2.09	0.03	0.33	
Infrastructure	17.66	4.07		
Property Damage				0.06
Property Damage Squared				3.71*10^-12
Adjusted R-Squared	0.20	0.10	0.15	0.98

Modeled hurricane, flood, and severe storm PA for each state is calculated by averaging gross state product, magnitude, and infrastructure over the observations for each state and multiplying these values by the corresponding regression coefficients. For example, if throughout the ten-year sample, a state averaged a log gross state product of 13.8, a log hurricane magnitude of 2.6, and an infrastructure value of 0.07, then the modeled log PA would be $17.5.[86] Exponentiating this value results in approximately $6 million, meaning that when the state is struck by its average hurricane, PA would be approximately $40 million.[87] The median annual modeled PA across states is $13.2 million. This value is

[83] Earthquake regression results are not presented because we do not estimate damages based on disaster characteristics.
[84] While infrastructure is not statistically significant, its inclusion improves model fit.
[85] Taking the natural log of dependent and independent variables is a standard statistical approach to regression modeling. Taking the natural log allows for a measure of non-linearity in the regression equation, while meeting the statistical assumptions that underpin regression analysis.
[86] -0.49 + 0.82*13.8 + 2.09*2.6 +17.66*0.07 = 17.5
[87] e^17.5 = 39824784

lower than the actual average annual PA, suggesting that the reduced form models tend to underestimate public assistance damages.[88]

PA for earthquakes for Alaska, California, Washington, Oregon, Nevada, Virginia, and Tennessee are obtained by using USGS (2009) estimates of the probability that an earthquake of a given magnitude occurs within 100 kilometers of the geographic county center for each county in the state. For each magnitude level, we estimate total property damage using the estimates from Heatwole and Rose (2013). This is translated to PA for an earthquake of a given magnitude using the regression equation presented in Table II-B1. Finally, we multiply PA by the probability that an earthquake of a given magnitude occurs in a year and sum over the resulting expected PA values.

Risk indices range from 0.04 in DC[89] (modeled PA is approximately 1/25th of the median) to 6.9 in Louisiana (modeled PA is 6.9 times the median). The mean, median and standard deviation are 1.3, 0.9, and 1.3, respectively. Figure II-B1 shows the distribution of Risk Indices across states. The majority of states have Risk Indices that fall between 0.5 and 2. The Risk Index is substantially higher for Florida, Louisiana, New York, and Texas, while the lowest values occur in Colorado, DC, Delaware, and Wyoming.

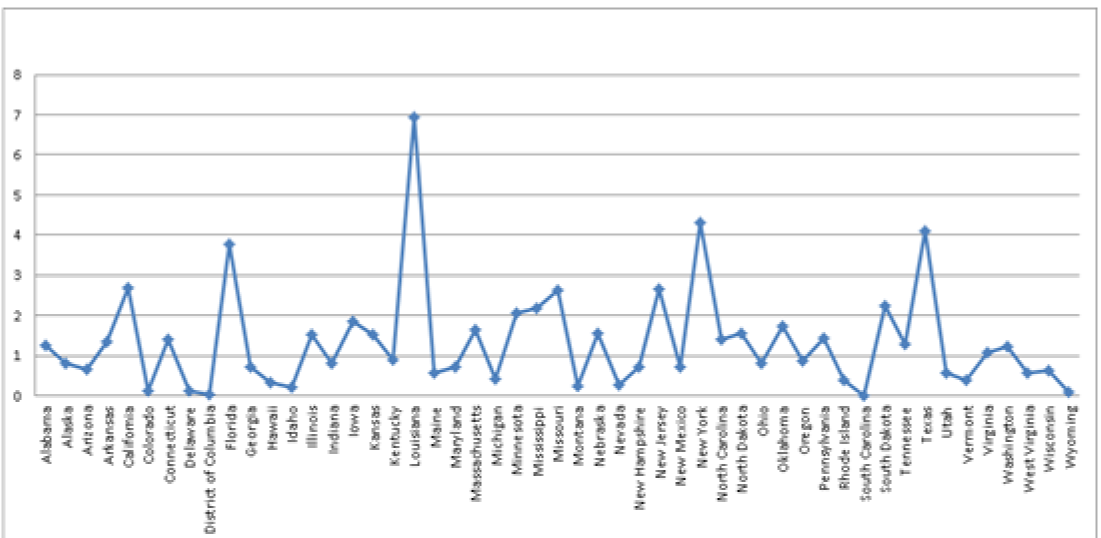

Figure II-B1. State Risk Indices

[88] This results in a Risk Index for high risk states that is slightly lower than the Risk Index would be if extreme events were not underestimated. The Risk Index for low risk states is generally unaffected because low damage events are estimated more accurately. The underestimation only results in reductions in the Risk Index for high risk states; no states receive higher Risk Indices due to the underestimation.

[89] South Carolina had no earthquake, flood, severe storm, or hurricane declarations between 2005 and 2014, so its Risk Index is undefined. It is omitted for the purpose of calculating median modeled damages.

APPENDIX II-C (APPENDIX TO PART II, CHAPTER III). DATA USED FOR FATALITY LOSSES

	State	Average Annual Deaths	Value of Annual Average Deaths at $9.1 million (millions of 2015$)
1	Alabama	38.7	352.17
2	Alaska	1.5	13.65
3	Arizona	19.7	179.27
4	Arkansas	21.7	197.47
5	California	34.2	311.22
6	Colorado	12	109.2
7	Connecticut	2.5	22.75
8	Delaware	2.3	20.93
9	DC	0.3	2.73
10	Florida	33.3	303.03
11	Georgia	12.3	111.93
12	Hawaii	2.3	20.93
13	Idaho	3.6	32.76
14	Illinois	43.3	394.03
15	Indiana	16.9	153.79
16	Iowa	6.2	56.42
17	Kansas	11.8	107.38
18	Kentucky	14	127.4
19	Louisiana	91.3	830.83
20	Maine	1.3	11.83
21	Maryland	6.3	57.33
22	Massachusetts	2.7	24.57
23	Michigan	9.2	83.72
24	Minnesota	9.2	83.72
25	Mississippi	31.7	288.47
26	Missouri	39.6	360.36
27	Montana	5.3	48.23
28	Nebraska	5.9	53.69
29	Nevada	17.2	156.52
30	New Hampshire	1.3	11.83
31	New Jersey	15.5	141.05
32	New Mexico	7	63.7
33	New York	29.7	270.27
34	North Carolina	17.7	161.07
35	North Dakota	2.1	19.11
36	Ohio	8	72.8
37	Oklahoma	22.4	203.84

38	Oregon	6.6	60.06
39	Pennsylvania	31.9	290.29
40	Rhode Island	1	9.1
41	South Carolina	6.9	62.79
42	South Dakota	3.4	30.94
43	Tennessee	26	236.6
44	Texas	55.6	505.96
45	Utah	7.2	65.52
46	Vermont	2.3	20.93
47	Virginia	7	63.7
48	Washington	15.4	140.14
49	West Virginia	3.1	28.21
50	Wisconsin	17.3	157.43
51	Wyoming	5	45.5

	State	Capital Stock (2007 value in millions of 2015$)	Adjusted Capital Stock (2007 value in millions of 2015$)	GDP (2007 value in millions of 2015$)	Ratio of Adjusted Capital to GDP
1	Alabama	190,307.5	554,936.2	189,007.4	2.94
2	Alaska	46,101.7	134,432.3	50,749.4	2.65
3	Arizona	271,096.9	790,517.7	281,611.9	2.81
4	Arkansas	116,708.0	340,320.2	108,722.9	3.13
5	California	2,156,149.3	6,287,325.5	2,066,783.5	3.04
6	Colorado	315,018.1	918,592.0	269,409.4	3.41
7	Connecticut	250,646.6	730,884.9	246,543.2	2.96
8	Delaware	46,845.5	136,601.3	68,534.5	1.99
9	DC	81,414.5	237,404.4	106,953.7	2.22
10	Florida	757,522.0	2,208,932.2	837,351.7	2.64
11	Georgia	469,217.9	1,368,238.3	452,014.6	3.03
12	Hawaii	57,933.8	168,934.7	70,146.5	2.41
13	Idaho	60,675.8	176,930.6	58,309.9	3.03
14	Illinois	726,712.1	2,119,090.7	694,909.8	3.05
15	Indiana	297,332.0	867,019.4	280,940.5	3.09
16	Iowa	141,312.0	412,065.4	147,089.6	2.80
17	Kansas	148,815.1	433,944.3	133,727.7	3.24
18	Kentucky	177,015.4	516,176.3	175,769.8	2.94
19	Louisiana	231,722.7	675,702.8	246,406.4	2.74
20	Maine	52,517.3	153,140.2	54,843.1	2.79
21	Maryland	293,516.3	855,892.9	306,300.9	2.79
22	Massachusetts	429,200.7	1,251,548.1	400,726.0	3.12
23	Michigan	478,156.2	1,394,302.2	435,437.8	3.20
24	Minnesota	299,408.9	873,075.7	290,665.8	3.00
25	Mississippi	100,032.1	291,693.2	100,942.4	2.89
26	Missouri	268,110.5	781,809.6	261,595.8	2.99
27	Montana	47,372.6	138,138.5	39,048.4	3.54
28	Nebraska	104,241.1	303,966.7	91,306.0	3.33
29	Nevada	136,472.3	397,953.0	145,022.8	2.74
30	New Hampshire	70,497.3	205,569.9	65,368.7	3.14
31	New Jersey	519,746.6	1,515,579.8	530,651.8	2.86
32	New Mexico	75,978.7	221,553.6	86,842.9	2.55
33	New York	1,320,726.2	3,851,234.2	1,257,447.4	3.06
34	North Carolina	375,653.9	1,095,405.9	455,368.4	2.41
35	North Dakota	36,069.1	105,177.3	31,606.5	3.33
36	Ohio	523,504.4	1,526,537.4	531,592.3	2.87
37	Oklahoma	228,336.2	665,827.7	158,828.2	4.19
38	Oregon	183,436.5	534,900.3	180,385.6	2.97

39	Pennsylvania	654,092.4	1,907,331.7	605,465.4	3.15
40	Rhode Island	49,013.5	142,923.1	53,466.0	2.67
41	South Carolina	164,596.7	479,963.7	174,226.2	2.75
42	South Dakota	34,643.5	101,020.4	38,684.8	2.61
43	Tennessee	277,084.7	807,978.2	278,010.7	2.91
44	Texas	1,798,988.7	5,245,846.3	1,301,840.1	4.03
45	Utah	118,216.3	344,718.5	120,450.1	2.86
46	Vermont	29,042.1	84,686.7	27,979.0	3.03
47	Virginia	377,158.1	1,099,792.1	436,579.0	2.52
48	Washington	357,294.4	1,041,869.6	354,847.8	2.94
49	West Virginia	79,379.0	231,468.9	65,790.5	3.52
50	Wisconsin	269,805.2	786,751.2	264,814.0	2.97
51	Wyoming	49,285.3	143,715.9	35,926.0	4.00
	Total	16,344,123.8	47,659,421.9	15,667,042.80	

APPENDIX II-E (APPENDIX TO PART II, CHAPTER III). GOVERNMENT INTERRUPTION LOSSES

	State	Government Expenditure (millions of 2011$)	Adjusted Government Capital Stock (millions of 2011$)	Ratio of Government Capital to Government Expenditure
1	Alabama	23,492.5	52,718.9	2.24
2	Alaska	9,191.7	12,771.1	1.39
3	Arizona	28,828.5	75,099.2	2.61
4	Arkansas	14,948.6	32,330.4	2.16
5	California	232,450.3	597,295.9	2.57
6	Colorado	20,926.7	87,266.2	4.17
7	Connecticut	21,569.4	69,434.1	3.22
8	Delaware	6,736.0	12,977.1	1.93
9	DC	10,604.7	22,553.4	2.86
10	Florida	73,266.7	209,848.6	3.11
11	Georgia	41,844.9	129,982.6	1.62
12	Hawaii	9,899.5	16,048.8	2.42
13	Idaho	6,942.6	16,808.4	3.37
14	Illinois	59,749.7	201,313.6	2.88
15	Indiana	28,620.7	82,366.8	2.53
16	Iowa	15,461.8	39,146.2	2.98
17	Kansas	13,824.5	41,224.7	2.07
18	Kentucky	23,738.3	49,036.8	2.24
19	Louisiana	28,603.7	64,191.8	1.83
20	Maine	7,932.1	14,548.3	2.57
21	Maryland	31,694.7	81,309.8	2.65
22	Massachusetts	44,942.6	118,897.1	2.43
23	Michigan	54,581.9	132,458.7	2.60
24	Minnesota	31,880.5	82,942.2	1.49
25	Mississippi	18,629.9	27,710.9	2.95
26	Missouri	25,193.4	74,271.9	2.36
27	Montana	5,553.1	13,123.2	3.69
28	Nebraska	7,834.6	28,876.8	3.52
29	Nevada	10,755.3	37,805.5	3.14
30	New Hampshire	6,226.1	19,529.1	2.59
31	New Jersey	55,530.2	143,980.1	1.39
32	New Mexico	15,110.7	21,047.6	2.42
33	New York	151,481.6	365,867.3	2.42
34	North Carolina	43,051.2	104,063.6	2.65
35	North Dakota	3,777.5	9,991.8	2.18
36	Ohio	66,494.5	145,021.1	3.50

37	Oklahoma	18,051.9	63,253.6	2.47
38	Oregon	20,605.6	50,815.5	2.59
39	Pennsylvania	69,856.7	181,196.5	1.92
40	Rhode Island	7,071.4	13,577.7	1.81
41	South Carolina	25,131.9	45,596.5	2.69
42	South Dakota	3,570.4	9,596.9	3.09
43	Tennessee	24,824.4	76,757.9	5.49
44	Texas	90,852.7	498,355.4	2.56
45	Utah	12,774.2	32,748.3	1.61
46	Vermont	5,007.3	8,045.2	2.83
47	Virginia	36,923.0	104,480.3	2.69
48	Washington	36,822.8	98,977.6	2.16
49	West Virginia	10,165.5	21,989.5	2.41
50	Wisconsin	31,004.0	74,741.4	3.01
51	Wyoming	4,536.4	13,653.0	2.24
	Total	1,648,568.6	4,527,645.1	

Government interruption losses were calculated by multiplying PA property damage by the ratio of government expenditure to government capital. When disasters damage government capital this ratio can be used to compute the value of the lost government expenditures. The ratio of government expenditure to government capital was calculated by first imputing government capital as ten percent of total capital stocks reported by Yamarik (2011).

APPENDIX II-F (APPENDIX TO PART II, CHAPTER IV). BASIC DATA FOR MP ANALYSIS (DDF2 BASE CASE)

Basic Data for Mississippi

(shaded)	Common parameters across states
(shaded)	State specific data
(shaded)	Calculated state values

aij Loss reduction multiplier

	mitigation	insurance	relief-funds
hurricane	1.52	1	1
flood	4.80	1	1
severe-storm	3.34	1	1
earthquake	0.55	1	1
other	3.34	1	1

ri

	Maximum Risk	Weights
hurricane	292.27	93.7%
flood	5.20	1.7%
severe-storm	14.40	4.6%
earthquake	0.00	0.0%
other	0.00	0.0%
total	311.87	100.0%

dj credit multiplier

mitigation	insurance	relief-funds
3	2	1

State Adjusted Deductible	28.00

ci maximum credit for insurance and relief funds by threat

	Maximum Credit
hurricane	13.12
flood	0.23
severe-storm	0.65
earthquake	0.00
other	0.00
total	14.00

* Calculated by distributing the credit target (50% of state adjusted deductible) among threats based on the weights of threat expected losses.

Basic Data for Ohio

	Common parameters across states
	State specific data
	Calculated state values

aij — Loss reduction multiplier

	mitigation	insurance	relief-funds
hurricane	1.52	1	1
flood	4.80	1	1
severe-storm	3.34	1	1
earthquake	0.55	1	1
other	3.34	1	1

ri

	Maximum Risk	Weights
hurricane	6.24	19.7%
flood	0.00	0.0%
severe-storm	23.56	74.6%
earthquake	0.00	0.0%
other	1.80	5.7%
total	31.60	100.0%

dj — credit multiplier

mitigation	insurance	relief-funds
3	2	1

State Adjusted Deductible	17.13

ci — maximum credit for insurance and relief funds by threat

	Maximum Credit
hurricane	1.69
flood	0.00
severe-storm	6.39
earthquake	0.00
other	0.49
total	8.57

* Calculated by distributing the credit target (50% of state adjusted deductible) among threats based on the weights of threat expected losses.