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Disasters: Issues for State and Federal Government Finances

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Abstract

Extreme events like hurricanes, earthquakes, or terrorist attacks present major challenges for fiscal systems at all levels of government. Analysts concerned with the fiscal and financial impacts of disasters must attempt to assess the likelihood of rare events of large magnitude such as Hurricane Katrina. Extreme value theory, applied here to flood damage data for Louisiana, offers one promising methodology for this purpose. The experience of Katrina and 9/11 also show that large disasters have large intergovernmental impacts. Individual states could, in principle, engage in more extensive ex ante financial and policy preparations for disasters, including disaster avoidance, but the "revealed institutional structure" exposed by recent experience shows that the US federal system shifts much of the economic incidence of local disasters to the rest of society through intergovernmental transfers. This raises policy questions regarding the assignment of responsibility for disaster avoidance in the US federation. In particular, Federal "ownership" of the consequences of disasters may invite or necessitate new forms of Federal "control" of subnational government.

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1. Introduction

Disasters and catastrophes often result in policy responses by all levels of government in an affected society. In the US context, the terrorist attacks of 9/11 and the Gulf Coast hurricane disasters of 2005 are recent examples of significant events that have presented a wide range of policy challenges for Federal, state, and local governments (Chernick (2001), Wildasin (2002), Chernick and Haughwout (2006)).[1] Effective public-sector post-disaster relief and recovery efforts present policy challenges, particularly of coordination and financing. The prospect of future catastrophes raises equally important concerns regarding disaster avoidance and preparedness. In the days, months, years, and decades prior to natural or man-made disasters, households and firms make a host of decisions that affect the probability and magnitude of disaster-related losses of property and life, decisions that are significantly influenced by government policy, both at the national and subnational levels.

Because of their extreme nature, disasters and catastrophes can reveal deep institutional structures in a society, not otherwise readily apparent. The Katrina (and Rita, and other) disasters of the 2005 hurricane season have prompted major new Federal legislation aimed at disaster relief and recovery, much of which takes the form of transfers to state and local governments, and ultimately to households and businesses, in the affected region. We discover from these disasters that the Federal government may, and in some cases has, come to the assistance of a devastated region, creating entirely new programs where necessary. These occurrences present great challenges for empirical analysis, precisely because of their unsystematic nature, and yet they warrant close attention, in part for the same reason: The role that ad hoc programs of fiscal transfers do or should play in federations bring basic and difficult questions of institutional design to the fore. Some view “bailouts” and similar extraordinary intergovernmental fiscal interventions as potentially highly problematic, because they may be fiscally destabilizing, create perverse incentives, tend to be poorly designed and implemented, inequitable, or wasteful. Others might view such interventions as necessary and flexible mechanisms for dealing with contingencies that demand a public sector response if it is to fulfill fundamental obligations.

As discussed in the next section, extreme meteorological events like the Gulf Coast hurricanes, and the economic damages associated with them, have been the focus of significant scientific and statistical investigation by climate scientists, statisticians, actuaries, and others. It is characteristic of these events that comparatively few of them account for a large share of the damages that they produce. The statistical distributions of climatic events may thus be expected to produce similarly-distributed "fiscal echoes" in which hurricanes like Katrina produce major shocks to the fiscal system. Indeed, this one event has given rise to a remarkable surge in Federal fiscal transfers to the affected region. However, estimating the likely damages from extreme events such as major hurricanes is, by its nature, a challenging statistical problem, as discussed and illustrated in Section 2.2 with specific reference to flood damages in Louisiana. Section 2.3 discusses some of the implications of disasters for financial management and fiscal policy, again using Louisiana as an illustrative case.

As is already evident, major disasters raise a host of difficult issues for public policy and for research, including, in particular, for intergovernmental fiscal and regulatory relations. Section 3 attempts to frame some of these issues, largely in order to identify potentially fruitful approaches for future research. It begins by noting that while post-disaster intergovernmental transfers can provide much-needed relief to affected regions, they may also distort incentives that increase the frequency or magnitude of disasters. This raises the question whether regulatory “mandates” imposed by superior governments will or should play a role in mitigating the potential adverse effects of distorted incentives. Section 4 concludes with brief remarks concerning long-term policy and institutional adaptation in response to recent disasters.

2. Extreme Meteorological Events and Economic Losses

Since hurricanes and floods are random events, effective financial and fiscal planning and policy depends upon an understanding of the underlying statistical distribution of these events and their economic and fiscal consequences. This section therefore begins by summarizing some of the empirical findings and analytical methods that have been developed and applied in private-sector actuarial modeling and risk management. Subsection 2.2 presents calculations based on flood-loss data for Louisiana that illustrate, on the one hand, some of the typical empirical findings for hurricane and flood damages, and, on the other hand, the analytical challenges involved in assessing the likelihood of rare events with drastic consequences. Subsection 2.3 discusses some of the fiscal and financial consequences of disasters for state and local government policymaking and for intergovernmental fiscal and regulatory relations.

2.1 The Distribution of Hurricane Damages

Hurricanes are by no means infrequent occurrences along the Atlantic and Gulf Coasts of the US, as all are aware. The precise frequency, severity, and geographical scope of these events and the damage that they cause is, however, the subject of ongoing investigation by climatologists. Some analysts assert that hurricane intensity or perhaps frequency have increased in recent decades, possibly due to global warming (anthropogenic or not) (Emmanuel (2005)), although this connection, while possible, seems to be unconfirmable at present (Pielke et al. (2005)). In any event, hurricanes, and the flooding associated with them, can cause significant economic damage with far-reaching fiscal implications. The policy debate concerning the avoidance and recovery from such disasters will intensify if, as some anticipate, global warming brings about rising sea levels and increased flooding in coastal regions.

Although the measurement of hurricane and flood disasters and damages is highly imperfect (see, e.g., Pielke et al. (2002), Downton et al. (2005)), major storms and the damages that they cause have been the subject of intense scrutiny not only by hydrologists and climatologists but by actuaries, statisticians, and others concerned with avoidance of flood damages (e.g., civil engineers engaged in the design of dams, levees, dikes, etc.) or with management of financial risks associated with them (e.g. insurance companies, financial analysts). Empirically, certain qualitative features of floods and flood damages now seem to be well-established. In particular, the flooding associated with hurricanes and other major storms are known to be characterized by empirical distributions in which extreme losses are of key importance. The statistical distributions of floods and other extreme events are often heavy-tailed, in which extreme outcomes occur with greater frequency -- perhaps orders of magnitude more frequently -- than would be predicted by models based on normal or other common distributions. Extreme value theory (EVT) provides a statistical methodology that has been successfully applied in the study of meterological events and their associated financial losses.[2] To date, it appears that this technique has been utilized rarely, if at all, in the analysis of storm losses at the level of subnational jurisdictions. The next subsection examines flood losses in Louisiana, an interesting case that illustrates the potential usefulness and difficulties involved in such applications of EVT.

2.2 Flood Damages in Louisiana

As a backdrop to later discussion of fiscal policy issues, and to provide a relevant empirical illustration of the importance of extreme values and the potential uses of EVT, consider flood damages in Louisiana. Empirically, flooding in Louisiana is quite common, with non-negligible losses (greater than $1 million, 1995 dollars) occurring in 31 of the 46 years from 1955-2003 for which such data are available (Pielke et al. 2002; data collection was interrupted from 1980-1982.) Although flooding is frequent, the bulk of flood damages occur in just a handful of years: the 8 years with the greatest losses account for approximately 95% of total damages over the 46 years. Katrina itself, of course, easily dwarfs all previous losses (which total less than $8.5 billion 1995 dollars). The loss data for Katrina are still being compiled, but one major private (re-)insurer estimates total property losses from Katrina and Rita (in all states) at roughly $125B, of which about half are privately insured (MunichRe, 2006). The BEA (2006) reports storm damages to fixed assets (i.e., property losses) at $70.1B during August-September 2005 (the Katrina and Rita months). A report to the President (GPO, 2006) finds that Katrina alone resulted in $96B in property damages. These figures do not include non-property losses and do not break down losses by state, but, under reasonable assumptions, the 2005 losses suffered in Louisiana appear to be roughly an order of magnitude larger than the *cumulative* real damages of the previous half-century.

For many analytical purposes, it is helpful to express these losses relative to the size of the state's economy rather than in absolute terms.[3] Over the half-century prior to Katrina, mean annual flood damages were about 0.28% of state personal income (SPI, closely related to GSP), while the median was a much smaller 0.0008%, indicating the importance of the upper tail. Flood damages exceeded 1% of SPI on four occasions prior to 2005, with a maximum value of 3.7% of SPI in 1992 (Hurricane Andrew), while final tabulations of Katrina- and Rita-related losses may well amount to 40-60% of SPI. For the purposes of state and local financial management and fiscal planning, it is evident that flood damages in Louisiana cannot be ignored, but, at the same time, it is clear that a small number of observations in the upper tail of the distribution of storm damages are of decisive importance.

Needless to say, the magnitude of future storm losses cannot be foreseen with certainty. Yet some characterization of the distribution of such losses, and especially some assessment of the upper tail of that distribution, is essential for policy purposes. With what probability could a Katrina-like loss occur in the future? What is the chance that two such storms could strike in the same year? Prior to Katrina, such questions might have seemed somewhat scholastic, although even on the basis of pre-Katrina data, it should have been obvious that it is the infrequent but disastrous storms that are of utmost importance. Subsequent to Katrina, this fact is unarguable.

Given inevitable data limitations, no statistical method can determine the probability distributions for rare events with great accuracy, and analysts should be prepared to explore alternative approaches. To illustrate the challenges, suppose that we wish to estimate a univariate distribution for storm damages in Louisiana for the years 1955-2003, expressed as a proportion of SPI. One potentially promising approach is to exploit the statistical theory of extreme values (see, e.g. Coles (2001)), for instance by fitting a Generalized Pareto Distribution (GPD)

$$H(y) = 1 - (1 + \xi y / \sigma)^{(-1/\xi)}$$

to the distribution of exceedances $y > 0$ of damages over some threshold u, classically assumed to be iid, where σ is a modified scale parameter, and where ξ denotes the shape parameter of the distribution. A basic theorem of extreme value theory (EVT) shows that the GPD is the limiting distribution of exceedances above a high threshold for random variables with distributions that lie in a large class of "well-behaved" statistical distributions (including all "textbook" distributions), just as the better-known central limit theorem shows that the mean of a large sample is normally distributed in many cases. To appreciate the role of the GPD shape parameter, note that if $\xi > 0$, the distribution of exceedances is unbounded, the distribution has an infinite variance if $\xi > 1/2$, and it has an infinite mean if $\xi > 1$.[4] These latter properties may raise philosophically disturbing questions, but exemplify heavy-tailed distributions. (Heavy-tailed distributions are certainly not unknown in economics: the classical Pareto distribution, often used to describe income distributions, has an infinite mean and variance for sufficiently large values of its index parameter.) As an alternative to the GPD, which leaves unspecified the underlying distribution of damages, one might consider an explicit distributional form like the lognormal – a distribution that might seem a priori well-suited to skewed distribution bounded below like the Louisiana data under consideration.

Parameter estimates for the parameters of the lognormal and GPD distributions fitted to these data are presented in Table 1. The small standard errors and other standard diagnostics suggest that the lognormal offers a reasonable model for flood losses. The GPD estimates exhibit some sensitivity to the choice of threshold, but the shape parameter is estimated to be fairly close to 1 for a wide range of threshold values and standard diagnostics (e.g., a QQplot) are acceptable. The standard errors for the GPD estimates, however, are quite large, so that values for ξ as low as 0 and as high as 2 cannot be ruled out.

Another way to assess the estimates in Table 1 is to compare the estimated probabilities of large losses with the empirically observed losses. Table 2 shows that the GPD estimates in Table 1 imply that a loss of 1% of SPI or greater in any year has a probability of .2, whereas the lognormal estimates imply that this probability is about .07. The latter is much smaller than the former and much closer to the observed frequency of 8.6% (the row labeled "empirical"). A loss as large as the largest observation in the data would occur about 6.5% of the time, according to the GPD estimates in Table 1, while probability of such an event, using the lognormal estimates, is only .026 -- again, far closer to the empirically observed 2.2%, corresponding to a single occurrence in the 46 annual observations. These comparisons highlight the much heavier weight in the tail of the estimated GPD as compared to the lognormal and seem to speak in favor of the lognormal as a better fit to the empirical distribution.

Suppose, however, that we use these estimates to predict the likelihood of much larger damages than those observed in the data up through 2003. Damages as high as 10% of SPI would be expected with a probability of about .025 using the GPD estimates but less than half as often -- just 1% of the time -- according to the lognormal estimates. An even larger loss, as high as 50% of SPI, only has a probability of .0007 (less than once per millenium, on average) under the lognormal estimates, but a probability -- still very small, but much larger -- of .0027, using the GPD estimates. These figures illustrate a typical feature of a heavy-tailed distributions, namely, that the probability of extreme values dies out very slowly relative to lighter-tailed distributions.

As noted, the data for the Katrina-Rita year of 2005 are still being compiled. Somewhat speculatively, suppose that we extend the data from 1955-2003 to include two more years -- 2004, to which we assign a value of zero, and 2005, the year of Katrina, to which we may assign estimated damages of, say, 50% of SPI.[5] In this case, the empirical distribution described in Table 2 would have to be adjusted to incorporate two more years and one major new loss observation. The row labeled "empirical (augmented)" shows the re-calculated empirical frequencies of losses of different sizes, taking these two latest years into account. Note first that that the GPD estimates now correspond more closely to the empirical distribution in the first two columns. Losses like those experienced in 2005 are still improbable using either the GPD or the lognormal estimates, but the heavier tail of the former attaches a much higher probability to such an event than the latter.

Of course, if one could really include these two additional observations in the data, it would make sense to re-estimate the parameters of the two models in order to take these observations into account. The results from doing so are presented in Tables 3 and 4. A noteworthy difference in the estimates is that the GPD shape parameter is considerably higher than that estimated using only the data through 2003, now taking on a value of 1.66, well above the critical value of 1 above which the mean does not exist. Table 4 shows that the estimated lognormal loss probabilities continue to fit the empirical loss distribution quite well for losses of the magnitude observed *prior* to Katrina. According to both sets of estimates, the probability of a loss as large as 50% of SPI is now much higher than previously estimated: the lognormal estimate puts this probability at .003 (about 10 times larger) and the GPD estimate is now 1.8%, also about an order of magnitude larger -- but also now very close to the empirical frequency of 2.1%.

This analysis is intended only to be illustrative. It by no means offers a definitive characterization of the distribution of flood damages in Louisiana, a subject that deserves far more attention than can be offered here.[6] Even this cursory treatment, however, illustrates the challenges that are likely to arise in any attempt to assess the economic and fiscal uncertainties associated with disasters. First, the most important economic losses from disasters result from a small number of extreme events. Although the true magnitude of the losses inflicted on Louisiana by Katrina is still uncertain, enough is already known to say with confidence that the losses from this one event will easily exceed the total of all losses for the past half century. In this respect, the Louisiana experience typifies the empirical findings of an extensive literature in climatology, hydrology, and actuarial studies. For practical purposes, to ignore the infrequent "outlier" cases of major disasters is to ignore disasters.[7] Second, as a corollary, however, it follows that projections of the economic losses from disasters are fraught with uncertainty, since observations in the tails of distributions are inevitably sparse. Under such circumstances, it seems advisable to explore a range of statistical methodologies – EVT methods, in particular -- in order to extract whatever insights they can offer. Finally, in rare but important instances, the magnitude of flood damages can be large enough to have major impacts on state and regional economies and, by extension, on the fiscal systems of state governments, their subordinate local governments, and, potentially, on the national government as well.

2.3 Fiscal Management for an Isolated State

As a first step in analyzing some of the fiscal implications of extreme disasters, consider the problem of financial and fiscal policy management for a single jurisdiction like the state of Louisiana, abstracting from intergovernmental issues (discussed in Section 3) by imagining that the state is "isolated" from the rest of the world and, in particular, must manage its finances without assistance from a higher-level government. State governments can and do utilize a wide variety of fiscal and financial instruments, including debt policy and the accumulation of financial reserves (e.g., "rainy day funds") to manage stochastic fiscal shocks. (A disaster like Katrina certainly qualifies as a "rainy day.") It is natural to ask how a state like Louisiana might manage its finances in order to deal with such events, either after the fact or in anticipation of them. For the moment, let us ignore the fact that the state could easily have implemented policies prior to Katrina (major levee upgrades, land use controls, and other precautionary actions) that would have dramatically reduced the losses associated with it, in which case the fiscal shock caused by this storm would have been far smaller and much more easily managed. Instead, let us start from the observation that major fiscal shocks, preventable as they may appear in hindsight, do and will occur from time to time.

A state facing such risks has several fiscal options. One possibility is to wait until disaster strikes and to cope with the resulting fiscal stress on a "pay as you go" basis, cutting expenditures for all but the most pressing needs, imposing temporary increases in taxes, and possibly defaulting on outstanding financial obligations. Such a strategy compresses disaster-related fiscal adjustment into a very short period of time. Alternatively, the state may attempt to issue debt in the aftermath of a disaster in order to maintain current public services and meet other financial obligations without major tax increases. The cost of borrowing under such circumstances may be relatively high, however, if the state's ability to service its future debt obligations is in doubt. A third alternative would be to build reserves in advance of major disasters, either in the form of accumulated financial assets ("rainy day funds"), through full or more than full funding of financial obligations like pension funds, through limits on state indebtedness, or through the accumulation of nonfinancial assets such as public lands, real estate, etc. All of these actions would raise the state's net asset position in advance of a disaster and would provide it either with liquid assets, assets that could be liquidated, assets that could collateralize new debt, or, in some other fashion could facilitate access to funds when disaster strikes.

To simplify, let us focus on just two alternatives, namely, the financing of a disaster-related fiscal shock through current taxation ("pay as you go" disaster financing) and the financing of such shocks through debt management, allowing for fiscal surpluses in periods with no disasters which are be used to finance deficits in periods with disasters, utilizing a now standard intertemporal tax optimization approach to debt finance (Barro 1979). Given that taxes in all periods are distortionary, and given that public expenditure requirements fluctuate over time, pay-as-you-go financing of government spending entails higher taxes and tax distortions in some periods than in others. Under certain simplifying assumptions, an optimal ("deadweight-loss minimizing") intertemporal tax structure requires constant tax rates over time. Such tax-smoothing can be achieved if government expenditures can be "unhooked" from taxation through the use of public-sector savings, running fiscal surpluses and accumulating reserves in “normal” periods and running deficits or decumulating reserves in the event of major disasters. Some simple illustrative calculations can show how the stochastic structure of these shocks affects optimal policy.

First, suppose that with probability .98, the state and local governments of a state have expenditure requirements that can be financed with own-source revenues of 12% of SPI, corresponding to combined state-local revenues in Louisiana in 2004. With probability .02, however, the state experiences a Katrina-like disaster, raising the required level of revenues by 30% of "normal year" SPI to 42%. (This is intended as a crude measure of the public sector burden from a Katrina. Given the observed Federal government expenditures to date, this probably understates the immediate cash-flow requirements of such a disaster. On the other hand, some of the immediate expenditures are for capital outlays that will reduce future expenditure requirements; any net public sector investment should presumably be subtracted to arrive at a measure of “net fiscal loss.”)

Abstracting from the possible infusions of resources from a higher-level government, consider the deadweight losses associated with a pay-as-you-go strategy in which the state raises 12% of SPI except for disaster years, where its revenue requirements more than triple, as compared with a steady tax rate that raises the required amount of revenues on average. This steady tax rate is one that the state could use to self-insure by some combination of financial reserves and debt policy that meets expenditure requirements in both good and bad years; it is also the tax rate that would allow the state to purchase actuarially-fair insurance against the postulated disaster risk. To compare the efficiency costs of these two strategies, suppose that the state's tax base X is a non-stochastic and iso-elastic function

$$X = (1 + t)^{(-\varepsilon)}$$

of the tax-inclusive price (1 + t) where t is the per-unit tax rate, the price of the taxed commodity is fixed at 1, and $\varepsilon > 0$ is the elasticity parameter. (This specification normalizes the tax base to 1 when the tax rate is zero.) It is straightforward to calculate closed-form solutions for tax revenue tX and for the deadweight loss from taxation EB for any given tax rate. Suppose that $\varepsilon = 1.1$ so that the tax base is slightly more than unit elastic. The tax rate required to raise revenues in the event of a disaster from this tax base is $t_b = .37$, compared to $t_g = .12$. A tax rate imposed at a rate of $t^* = .127$ would yield revenues that would meet the average revenue requirement across all years, corresponding to the "smooth" efficient tax rate. The deadweight losses from taxation with tax rates of .12, .37, and .127 are .76 , 12.55, and .85, respectively, each expressed as a percentage of SPI. The weighted average efficiency loss with pay-as-you-go financing (i.e., a tax rate of .12 with weight .98 and a tax rate of .37 with weight .02) is 0.88% of SPI, larger than the 0.76% that would be achievable with a steady tax rate high enough to generate surpluses in good years sufficient to offset deficits in bad years. This efficiency gain is about 0.15% of the tax base and constitutes a reduction of some 15% in the deadweight loss relative to pay-as-you-go financing.

These figures are, of course, only illustrative. They are obviously sensitive to the assumed elasticity of the tax base. Furthermore, the tax base has been assumed to be as large as the entire SPI. In practice, only a portion of SPI is taxable and the tax structure would contain many additional distortions, implying higher deadweight losses in each state of the world and, consequently, a larger efficiency gain from tax smoothing. (For instance, if the tax base were only half of SPI, the efficiency gain from tax smoothing would rise to about 0.68% of SPI.) Although these calculations are thus far from definitive, they demonstrate how stochastic expenditure shocks associated with large disasters can result in significant distortionary losses if the costs of these shocks are not distributed over time through some combination of reserve funding and borrowing. The prospect of such fiscal distress may provide an incentive for states to undertake financial and fiscal planning and management strategies that limit the costs of such distortions. Of course, any ex ante fiscal or financial strategy must be based on some assessment of the underlying distribution of risks. In particular, underestimation of the probability of large losses – for instance, assigning a probability of 0 to the "once in a half-century" (p = .02) event postulated above – will lead to inefficient policies.

3. Challenges for Federalism in the Wake of 9/11 and Katrina: Institutions, Incentives, and the Economic Incidence of Disasters

Much of the preceding discussion has referred to the case of Louisiana for purposes of illustration. All regions, however, face some risk from natural or man-made disasters, as does the nation as a whole. The intergovernmental dimensions of disaster policy raise many critical issues of particular interest for public finance economists. The most crucial question – one with no simple answer – concerns the so-called "assignment" problem: which levels of government do, or should, take responsibility for different aspects of disaster policy?

To begin with, note that disaster policy generally can be viewed either from an *ex post* or an *ex ante* perspective. The *ex post* perspective takes the occurrence of a disaster as given, whereupon the problem for policy is to manage disaster recovery and relief. The *ex ante* perspective begins with a recognition that policies implemented prior to a disaster may influence its probability of occurrence and its magnitude. These two perspectives are recursively connected: what is optimal (for any level of government, or from a social viewpoint) *ex ante* must be determined in the light of what will be done *ex post*. As usual, analysis of recursive problems must begin at the end.

3.1 Revealed Institutional Structure

Considering a state like Louisiana in isolation may be a useful fiction when analyzing the *potential* fiscal implications of disasters, but Louisiana has been anything but an "isolated state" in the aftermath of the recent hurricanes. On the contrary, the state has received an extraordinary amount of financial and fiscal assistance from the Federal government. Most overtly, some $81.6B of relief has been provided through *ad hoc* emergency relief legislation (Bea, 2006). In addition, there are many forms of implicit relief built into existing Federal government policies, such as the personal and corporation income tax systems and a wide range of means-tested cash and in-kind benefit programs. These policies increase Federal transfers to and reduce taxes from a disaster-stricken region, thus shifting some of the economic burden of the disaster to the Federal government and thus to the rest of the nation. Only a portion of this explicit and implicit Federal disaster relief takes the form of intergovernmental transfers to affected state and local governments, but even Federal transfers to households and businesses provide significant indirect fiscal relief to state and local governments since these transfers positively affect state and local tax revenues and obviate the need for some types of state and local expenditures. New York (both the city and the state) benefited from significant explicit and implicit transfers from the Federal government following the 9/11 terrorist attacks.[8]

The potential rationale for Federal government disaster relief is easily understood as a form of *ex post* redistribution or as the *ex post* execution of a social insurance contract: the marginal utility of income rises sharply for households in a region that has been struck by a disaster, and *lump-sum non-distorting transfers* from the rest of society to that region would raise utilitarian social welfare or, equivalently expressed, average or *ex ante* expected utility (see, e.g., Varian 1980, Caplan et al. 2000). The normative case for such assistance may strike many as self-evident, and the substantial Federal aid that has been directed to New

York and to the Gulf Coast is a convincing demonstration of the political appeal of such policies.

Would (or will) similar assistance be forthcoming the next time that a major disaster, natural or man-made, strikes a large jurisdiction? No doubt, the 9/11 attacks and the flooding in New Orleans were somewhat unique events that elicited somewhat unique Federal government responses. Perhaps Federal assistance to affected regions and their governments would be far more limited in other, seemingly similar cases – for instance, to name several quite conceivable possibilities, the devastation of Memphis or San Francisco from a large earthquake, the flooding of other major cities as a result of tsunamis or major storms, or the contamination of the center of a major metropolitan area as a result of a chemical, biological, or nuclear attack by a terrorist group.

It seems more likely, however, that the recent disasters have exposed a significant feature of the contemporary American federal system, namely, that the responsibility for financing the *ex post* recovery from "local" disasters rests, to a large degree, with the central government. This "assignment of responsibilities" has only become explicit since the 9/11 and Katrina disasters. Like consumers whose preferences are revealed by the choices they make in the marketplace, these disasters have "revealed" an important but hitherto implicit underlying institutional structure in which, to put it succinctly, the Federal government is the insurer of regional disaster risks. The remaining discussion is largely premised on this characterization of the "revealed institutional structure" of the American federation and its *ex post* disaster-response mechanisms.

3.2 Failed Local Incentives? Insurance, Bailouts, and Mandates

The extraordinary Federal responses to the 9/11 and Katrina disasters, combined with the operation of private insurance markets, real estate markets, and markets for private and public financial instruments (bonds and stocks), has spread the losses from these events quite widely throughout the US economy (and, to some degree, abroad). That is, the *economic* incidence of these disasters goes far beyond their *geographic* incidence. Specifically, the Federal government, acting as a backstop source of fiscal and financial relief for regional economies and their subnational governments, has spread much of the economic cost of the disasters to the broader population, which must (in the present or future) pay more in Federal taxes or suffer reduced benefits from Federal public expenditures.

From a public finance perspective, many elements of modern fiscal systems, including income- and consumption-based taxation (whether progressive or not) and income-conditioned transfer payments to individuals, as well as many types of intergovernmental transfers, help to spread risks of all kinds. As was made clear long ago by Domar and Musgrave (1944) and in a vast subsequent literature (e.g., on social insurance, taxation, and the "welfare state"), risk-sharing through the fiscal system can affect risk-taking behavior and can help to reduce the social cost of risk if private insurance markets are imperfect. The "automatic" sharing of income and other risks through the operation of established tax and transfer systems is of course supplemented by emergency fiscal relief for regions struck by natural disasters.

Fiscal transfers, including those that arise in *ad hoc* responses to extraordinary events like disasters, affect incentives because they are generally not lump-sum in nature. Federal relief for regional disasters can crowd out private insurance and introduce adverse selection and moral hazard. In general, anticipated disaster relief, provided directly or indirectly by national or subnational governments, can weaken the incentives for households and firms to purchase private insurance from traditional insurers. It can also weaken the incentives to take a wide array of precautionary actions, leading to increased exposure to disaster risks, reduced precautionary asset accumulation that might facilitate disaster recovery, and other behavioral adjustments that might reduce the distribution of *ex post* Federal disaster relief assistance. In particular, with reference to the recent Gulf Coast disasters, the question naturally arises as whether more precautions "should" have been taken in order to limit the magnitude of major losses due to hurricanes. If so, what form might these precautions have taken, and where (and why) did incentives break down?

One type of precautionary action would have been to augment the flood control and levee system around New Orleans, an action that could have been implemented independently by state and local authorities without any assistance from the Federal government. Subsequent to Katrina, proposals have been made for enhanced flood control infrastructure – presumably sufficient to limit similar future losses – at estimated costs of $3.5B-$9.5B, amounting to some 2.1%-5.7% of 2005 SPI or 11.0%-30.5% of 2003-2004 state and local government expenditures.[9] Using available debt and other financial instruments, such a project could now be financed, and, in the past, could have been financed, entirely from state and local resources, for instance through a comparatively modest increase in sales, income, and property taxes over a period of a decade or so. Whether this cost would be justified in order to avoid a loss of $50B-$100B with a probability of, say, .02, is a non-trivial benefit-cost problem, but we observe in any case that state and local authorities did not elect to pursue such projects.

Quite aside from public infrastructure investments, there are many other *ex ante* policies that could have prevented or diminished the losses from Katrina. First, although it may initially appear counter-intuitive, one should recognize that much of the damage would never have taken place if *no* flood control programs had ever been undertaken. Much of the flooded area of New Orleans lies below sea level and would not be inhabited in the absence of a complex system of levees, pumps, and drainage canals. Without this infrastructure, the extensive economic development of this area would never have occurred and Katrina would then have resulted in far less harm to people and property. Of course, nothing would preclude the installation of flood-control infrastructure *as well as* state or local policies (e.g., land-use controls, investment in roads) that would have limited the settlement and development of flood-prone low-lying areas. Further precautions could have included more extensive preparations for evacuations, public safety, and emergency management in general. The costs and benefits of these precautions would, no doubt, vary widely. All of them could have been undertaken without any financial assistance from the Federal government.

Although the benefits of such precautionary efforts are evident in hindsight, it could be argued that these benefits could not have been foreseen. Indeed, Section 2 has discussed the analytical challenges involved in determining the risks of flood damage. Nevertheless, although residents in the rest of the country would not necessarily follow closely the results of gradually improving meteorological and disaster-preparedness knowledge concerning Gulf Coast hurricanes, basic knowledge of hurricane risks has been readily available and widely shared among Gulf Coast residents, the local business community, and state and local government officials for many decades and, indeed, since the early settlement of the region.[10] Imperfect though it may have been, local knowledge of flood and hurricane risk in the New Orleans area (and, more generally, along the Gulf Coast) was widespread and of long standing.

The fact that state and local governments did not expend more effort and resources on disaster avoidance and preparation raises a basic question concerning decentralization of policymaking and subnational government policy autonomy: why would the residents of a disaster-prone region and their public servants not invest "sufficient" resources to reduce the risk of a major localized disaster? The region had ample resources to fund even the most expensive flood control infrastructure projects, not to mention many less-costly programs, and local information about the benefits of such projects was far from lacking. Basic principles of fiscal decentralization – concentrated local benefits, superior local knowledge of benefits and costs – would not lead one to anticipate inefficient local disaster avoidance and preparedness. Many state and local governments are exposed to some sort of natural or man-made hazards and routinely make policy choices that affect the probability and magnitude of future losses. For instance, almost all state and local tax, expenditure, and regulatory policies directly or indirectly influence the numbers of people and types of property and economic activity situated in particular locations – in or near areas prone to floods, earthquakes, environmental catastrophes, or terrorist attacks – and, according to prevailing doctrine, these governments would appear to have a comparative advantage in managing these policies.

Whether or not state and local governments have undertaken socially-efficient disaster-avoidance and preparation efforts in the past, a growing Federal government role as insurer of last resort for disaster-afflicted regions may weaken their incentives to do so in the future. Because it shifts the incidence of local disasters to non-residents, the *ex post* Federal disaster relief emerging from the "revealed institutional structure" of the American federation implies that the benefits of precautionary *ex ante* disaster avoidance by state and local governments also accrue to non-residents.

To the degree that "ownership" of disaster risks rests with the Federal government (the residual claimant), inefficiencies are likely to arise if it cannot "control" the behavior, including subnational government and private sector behavior, that influences these risks. What form might such controls take? As one possibility, Federal authorities could take control of economic development and land-use policies that influence the locational decisions of households and firms in disaster-prone regions. For instance, a Federal agency could regulate the development of residential housing, commercial and industrial activities, and transportation and other infrastructure within, say, 25 miles of any coastline. To some extent, such regulations already exist, but the Federal role could, in principle, be greatly expanded.

In this way, the society at large, which bears the costs of major disasters, could "mandate" actions at the local level that would reduce risk exposure. In principle, the Federal authorities could also regulate state and local governments to insure that their policies help to limit rather than to increase the risks of major losses in the event of manmade or natural disasters.

Less intrusively, the Federal government might mandate the establishment and funding of *ex ante* contingency reserves ("rainy day" funds) by subnational governments. These could shift more of the financial responsibility for disaster recovery expenditures to state and local governments and reduce the need for large Federal assistance programs (which, to use another water-related and somewhat perjorative term, might be called "bailouts"). To return to the Louisiana case, one could imagine that the Federal government might have imposed an obligation on the state to set aside 1% of SPI annually (say, $1.5B in current dollars) to fund a "disaster relief reserve fund," to be utilized in the event of major flood or other disasters. After one or two decades, such a fund would grow to a substantial sum, and one can speculate that the *ex post* response to a major disaster such as Katrina might then take a rather different course – the justification for Federal disaster assistance to Louisiana following Katrina might have been less compelling if the state of Louisiana had previously accumulated a reserve of multiple tens of billions of dollars. The incentives of state and local policymakers would also be affected by the establishment of such a reserve and the prospect of its loss in the event of a disaster. Following standard insurance principles, the (credible) establishment of "deductibles" and "co-pays" can affect *ex ante* decisionmaking by insurees (subnational governments, in this case) even when their actions are not directly observable or controllable by insurers (the Federal government).

Expanded involvement by the Federal government in areas of policy traditionally reserved for subnational governments raises a host of further legal (including constitutional), fiscal, and economic issues. In the federalism context, the term "mandate" often is preceded by "unfunded," emphasizing the fact that regulations can impose significant costs on those subject to regulation, and direct Federal control of private agents and subnational governments might thus be accompanied by compensatory fiscal transfers that would require the Federal government (and thus the rest of society) to absorb the costs of precautionary actions. Exactly this issue has been the subject of considerable policy debate already in the context of homeland security, with representatives of subnational governments lobbying for added resources to offset the costs of public safety, public health, transportation, and many other types of emergency preparedness efforts. Whether "mandates" should or should not be funded, and if so, in what manner, remains an under-researched question. Viewed within the context of the theory of optimal insurance contracts, insurees might well be required to undertake specific actions *ex ante* in order to limit the magnitude or probability of future losses. At the same time, limits on central government powers are necessary in any system that allows effective decentralization of decisionmaking and the exercise of subnational government autonomy. Striking a balance that allows effective subnational autonomy without giving rise to adverse subnational incentives will be a most challenging problem for the American federation.

4. Conclusion: Policy and Research Issues on the Horizon

Complete centralization of responsibility for all disaster-related policies, including public safety, land use control, public health, transportation, and economic development policies, would constitute a radical departure from historical practice in the US and would indeed necessitate a major overhaul of the constitutional structure of the nation. Short of such an extreme outcome, the intergovernmental aspects of disaster relief, preparedness, and avoidance will continue to present major policy challenges. One major analytical task is to examine the incentives embedded in alternative institutional structures as a basis for understanding the outcomes that they generate. A rapidly-developing theoretical and empirical literature[11] addresses the issue of "bailouts" and "soft budget constraints," exploring the conditions under which transfers to subnational governments may destabilize overall fiscal balances and, ultimately, produce inefficient or inequitable policy outcomes. As suggested by the discussion in Section 3, however, many issues remain to be investigated.

Take for example, the issue of coastal development during the next half-century. As noted earlier, there is still significant debate about the extent to which recent hurricane activity may or may not be related to global warming and, if so, whether this global warming is anthropogenic. Whether or not hurricane intensity or frequency is anthropogenic, however, there is no doubt that human actions affect the probability and magnitude of *damage* from hurricanes and other climatic events (Pielke and Landsea 1998). If global warming (anthropogenic or otherwise) results in significantly rising sea levels over the coming decades, as some now predict, the extent of coastal flood damage, whether from hurricanes or otherwise, is sure to increase. Public policy decisions taken now, by Federal, state, and local governments, will affect locational choices and development patterns for decades to come. A fundamental issue is whether public policies will or should encourage or discourage population and investment from “going coastal". It remains to be seen – and future research can help to determine -- whether the existing system of intergovernmental fiscal and regulatory relations, in its current or some alternative form, is up to the task of producing the correct incentives for efficient policymaking.[12] The combined Federal, state, and local responses to the recent Gulf Coast hurricanes provide analysts with early indications of the direction of institutional response to the closely-connected problems of disaster relief, avoidance, and preparedness.

ENDNOTES

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[1] Disasters are of certainly of critical importance in other countries. See, e.g., Anbarci et al. (2005) and Toya and Skidmore (2005) for international comparative analyses and Kreimer (2002) for discussion of flood damages in Argentina. The present discussion focuses on the US, but the fundamental issues are global in nature.

[2] As a typical instance, a Swedish insurance group (Rootzen and Tajvidi (1997)) experienced claims from 46 major wind storm events over an 11-year period, just one of which accounted for more than a fourth of total losses over the period; the four largest storms accounted for about half of total losses. (See also McNeil and Saladin (2000).) Embrechts et al. (2000) analyze the probability of failure for a dike along the Dutch seacoast, which requires estimation of the probability of "extreme" waves, a typical extreme value problem.

[3] Since only a fraction of total damages from floods are absorbed by the state's fiscal system, the magnitude of damages relative to PSI overstates the fiscal burden of disasters. The object of the following analysis, however, is to gauge the *potential* fiscal impact of disasters, recognizing that a host of public policies and private behavior interact to produce the *observed* fiscal impact. The mapping (observed as well as optimal) from the former to the latter is the subject of much of the discussion of Section 3.

[4] More generally, the rth moment does not exist if $\xi > 1/r$.

[5] Since the damage assessments for Katrina and Rita are still being compiled at the time of writing, this estimate is obviously very crude. Louisiana gross state product for 2005 was approximately $112 billion, and so 50% of PSI corresponds to a loss of about $55B. It may be worth noting here that the quality of flood damage data is generally poor, especially for *small* floods (Pielke et al. 2002): "When damage in a state is estimated to be greater than $500 million (1995$), disagreement between estimates from NWS and other sources are relatively small (40% or less)." Superior data are to be welcomed, as emphasized by Downton et al. (2005).

[6] Aside from purely statistical questions, a proper analysis of flood damages should recognize that these damages are highly dependent economic and demographic conditions which in turn depend on public policy (see n. 2 and Section 3 below).

[7] To quote Schirmacher et al. (2005, p. 344) in the context of reinsurance, "In the past very large losses would be labeled as outlier observations, rationalized as extremely improbable, and sometimes even removed from the data set. For the reinsurance actuary these observations are likely to be the most important observations in the data set."

[8] See Chernick (2001) and Chernick and Haughwout (2006) for careful analysis of the fiscal impact of the 9/11 terrorist attacks on New York City.

[9] As usual, there is a wide range of project options, at widely-varying costs. According to a *Washington Post* report (Whoriskey and Hau 2006), one part of a recently-proposed project would protect a region containing 2% of the population at a cost $2.9B, while another part of the project would protect an area containing 13% of the population at a cost of only $129M.

[10] Flooding in the Gulf Coast counties of Louisiana and Texas during the period 1983-1997 resulted in numerous Presidential disaster declarations (Downton and Pielke (2001, Fig. 2 and Table 3), as state and local policymakers, analysts, private insurers, and others have always been well aware. New Orleans flood project options have been analyzed and debated for decades; see, e.g., GAO (1976, 1982). Numerous pre-Katrina studies drew attention to the potential impact of a major hurricane strike on New Orleans, with findings that were widely reported in the popular press for many years. See, e.g., a major report in the New Orleans *Times Picayune* (2002), "Washing Away," containing many details of the history of hurricanes in the region and of past efforts to control flooding, maps and charts showing areas that would be flooded in a major hurricane, and information about evacuation plans and their limitations. Information about hurricane hazards in New Orleans had widely been disseminated even well beyond purely local media, e.g., Berger (2001), Fischetti (2001), and Wilson (2001).)

[11] See, e.g., Inman (2003), Wildasin (2004), Oates (2005, 2006) for partial surveys, and Besfamille and Lockwood (2005) for a recent theoretical analysis. Buettner and Wildasin (2006) examine empirically the dynamic fiscal adjustment process of US municipal governments, including in particular the role of intergovernmental grants in maintaining municipal fiscal balance.

[12] See Wildasin (2006) for one initial attempt to shed analytical light on this issue.

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TABLE 1

Flood Damage as % of SPI, Louisiana, 1955-2003

Generalized Pareto		Lognormal	
Modified Scale	Shape	Mean (of log)	Standard Deviation (of log)
24601	1.02	5.28	2.68
(1500)	(0.618)	(0.43)	(0.30)

Notes: Standard errors in parentheses. Data are rescaled by 10^6. Threshold for GPD estimates = 300; number of exceedances = 15. Lognormal estimated using all positive observations (n = 39).

Table 2

Estimated Probability of Large Flood Damages in Louisiana

	Size of loss (% of SPI)			
Probability	1%	3.7%	10%	50%
GPD estimate	.201	.065	.0253	.0027
Lognormal estimate	.072	.026	.0101	.0007
Empirical Frequency	.086	.022	0	0
Empirical (augmented)	.104	.042	.021	.021

Notes: Prob(loss greater than or equal to x% of PSI), GPD and lognormal parameter estimates from Table 1.

TABLE 3

Flood Damage as % of SPI, Louisiana, 1955-2005

Generalized Pareto		Lognormal	
Modified Scale	Shape	Mean (of log)	Standard Deviation (of log)
2118	1.66	6.33	2.47
(1341)	(0.708)	(0.43)	(0.30)

Notes: Standard errors in parentheses. Data are rescaled by 10^6. Threshold for GPD estimates = 300; number of exceedances = 16. Lognormal estimated using all positive observations (n = 40).

Table 4

Re-Estimated Probability of Large Flood Damages in Louisiana

	Size of loss (% of SPI)			
Probability	1%	3.7%	10%	50%
GPD estimate	.269	.129	.0716	.0180
Lognormal estimate	.122	.045	.0180	.0030
Empirical (augmented)	.104	.042	.021	.021

Notes: Prob(loss greater than or equal to x% of SPI), GPD and lognormal parameter estimates from Table 3.

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