The Welfare Economics of Catastrophic Loss

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"Yesterday, all my troubles seemed so far away. Now it looks as though they're here to stay."
Lennon/McCartney

1. Introduction

There have been four major trends in the economic environment of catastrophic loss in the U.S. since World War II:

1) The number and severity of catastrophic events appear to be steadily rising; see Figure 1 and Kunreuther and Michel-Kerjan (2009).

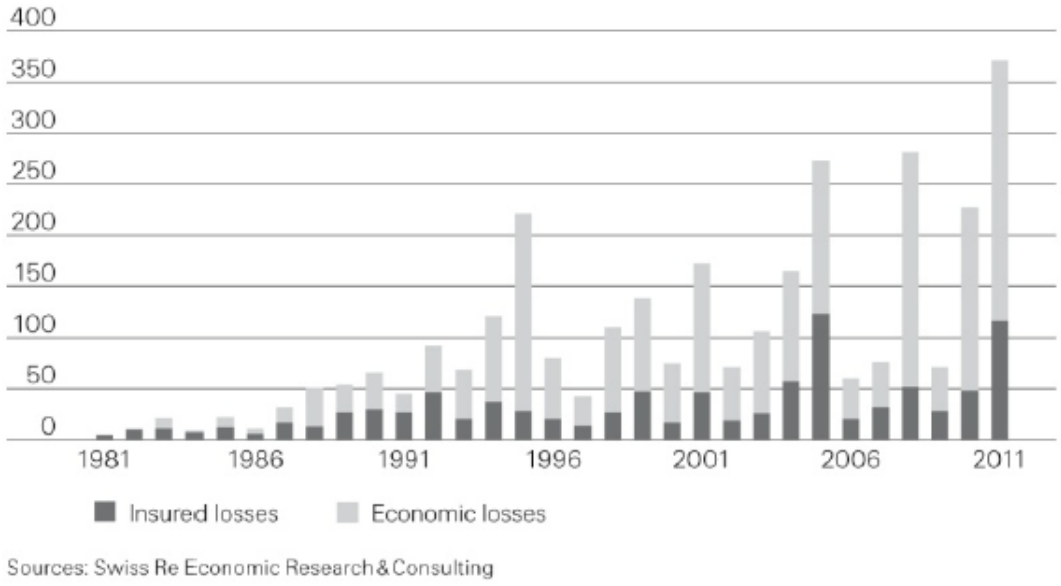
2) Private catastrophe insurance markets that could cover these risks have steadily disappeared, spawning government insurance programs as replacements; [1] see Jaffee and Russell (1997). The government programs have serious drawbacks including subsidies, lack of risk-based premiums, and low takeup rates; see Priest 2003. Figure 1 shows that the economic losses far exceed the insured losses.

3) Federal disaster relief has expanded significantly based on the activities carried out by the Federal Emergency Management Agency (FEMA) and other agencies; see Michel-Kerjan and Volkman-Wise (2011). As shown in Figure 2, Cummins, Suher, and Zanjani (2010) compute an average FEMA aid ratio of just over one-third, but with ratios over 60 percent for many recent catastrophes. Most recently, 2011 saw 99 federal disaster declarations, an all-time record; see Insurance Information Institute (2012).

4) Both public and private sector actions to mitigate the underlying risks, including avoiding development in risky areas and physically reinforcing structures, have been limited; see for example Kunreuther (1996, 2006) and Comerio (1998).

[1] These include state and federal insurance programs for earthquakes, floods, terrorism, and wind damage.

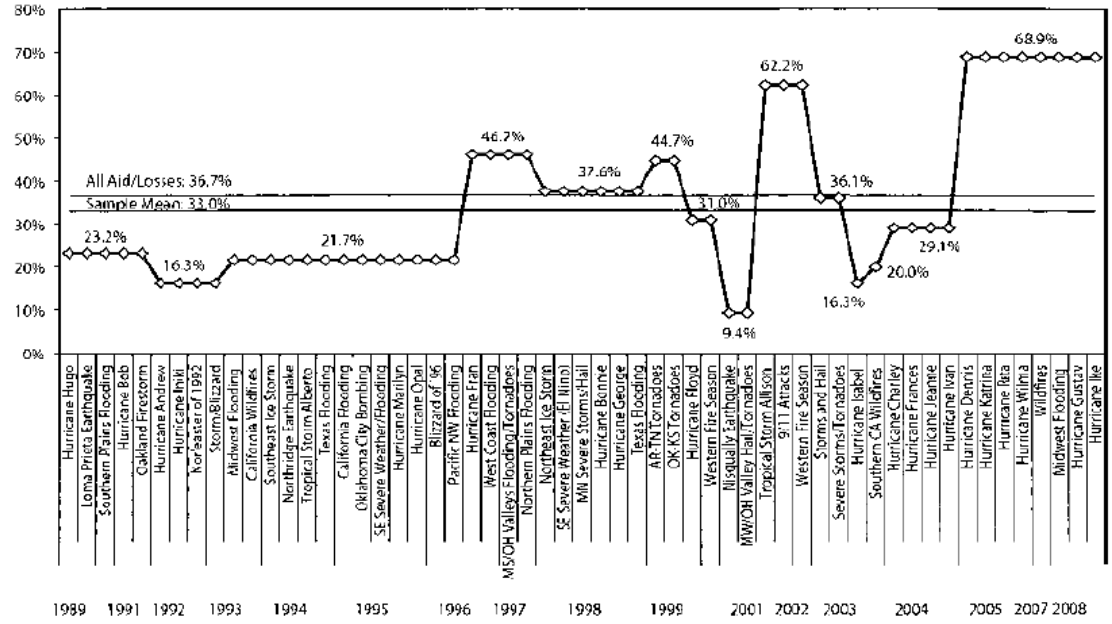
Figure 1: Economic Losses Versus Insured Catastrophe Losses, 1981 to 2011



Sources: Swiss Re Economic Research & Consulting

Recent major events include: 1992 Hurricane Andrew; 1994 Northridge Earthquake; 1999 Winter Storm Lothar; 2001 9/11 Attacks; 2004 Hurricanes Ivan, Charley, and Frances; 2005 Hurricanes Katrina, Rita and Wilma; 2008 Hurricanes Ike and Gustav, 2010 Chile and New Zealand Earthquakes; 2011Japan and New Zealand Earthquakes, Thailand Flood.

Figure 2: Federal FEMA Aid Ratios, 1989 to 2008
Source: Figure 4.3.A, Cummins, Suher, and Zanjani (2010)



The ratio is adjusted for both price-level changes and changes in the size of the housing stock.

Table 1: Federal Allocations in Response to Hurricanes Katrina, Rita, and Wilma
as of August 21, 2006, Source: Fellowes, Matt and Amy Liu (2006)

Major Issue Area	Funding Available *(in billions)*	Sub-Issue Area	Funding Available *(in billions)*	Description
I. Spending				
1. Temporary and Long Term Housing	$52.0			Grant and loan programs in FEMA, HUD, and USDA for temporary and long-term housing, flood insurance
		Flood Insurance Program	$19.3	Money available for premium payouts
		CDBG	$16.7	Community Development Block Grants for home and infrastructure repairs
		Temporary Manufactured Housing	$7.5	Trailers and mobile homes
		Temporary Housing and Home Repair	$5.9	Rental assistance to households and grants for repairing damaged homes
		Other	$2.6	Loan programs in FEMA, HUD, &USDA, and HUD, USDA grants
2. Emergency Response and DOD Spending	$28.8			Response by FEMA, DOD, and other agencies, as well as restoration of Federal facilities.
3. State and Local Response, Infrastructure Rebuilding	$18.2			FEMA, Transportation, and Corps of Engineers funding to restore Gulf Coast infrastructure, including levees, highways, and federal facilities.
		Levee repair and restoration	$4.3	Restore the existing federal levee system to its previous condition
		Coastal restoration	$.3	A federal-state coastal restoration plan to help weaken future storm surge
		Other	$13.6	All other FEMA, Transportation, and Corps of Engineers funding to restore Gulf Coast infrastructure
4. Health, Social Services, and Job Training	$3.6			Programs in HHS, Labor, and other agencies to address health, social services, and economic needs. Includes $2 billion from Reconciliation
5. Non-housing Cash Assistance	$3.2			FEMA grants and SBA loans covering needs beyond housing. Does not include the full $10.3 billion in loans made by the SBA to date.
6. Education	$1.9			Education assistance for impact of displaced students and higher education needs.
7. Agriculture	$1.2			USDA funding for agriculture and timber losses, recovery, and conservation.
Allocated Spending Total:	*$108.9*			
II. Tax Relief				
1. Tax Relief	$8 billion			Gulf Opportunity Zones, charitable giving incentives, full deductibility of personal losses, and extended periods for replacing damaged property. Ten-year total is $11 billion.

Sources: Department of Homeland Security, Office of the Federal Coordinator of Gulf Coast Rebuilding (OFCGCR); Katrina Hurricane Disaster Weekly Report (FEMA), March 2, 2006; The White House, Press Briefing, March 6, 2006; Bruce Katz, Matt Fellowes, and Mia Mabanta. 2006. "The Katrina Index." Brookings Institution.
Note: Allocated funds in each spending categories were estimated based on categories provided by the OFCGCR.

While Figure 2 shows FEMA post-disaster aid rising significantly, other agencies have also played large and expanding roles in the federal government's post disaster response. To illustrate this, Table 1 reproduces a tabulation from Fellowes and Liu (2006), at the Brookings Institution, of the many government programs that participated in the federal response to the 2005 hurricanes of Katrina, Rita, and Wilma. In addition to FEMA, the government's post-disaster aid included key roles for the Small Business Administration (SBA), the Housing and Urban Development (HUD) department, and the U.S. Department of Agriculture (USDA). The various federal agencies also provide substantially different forms of post-disaster aid. FEMA focuses on immediate emergency relief, the provision of temporary housing, and grants to rebuild damaged government infrastructure (both federal and local). The SBA primarily provides low-cost loans to help the recovery of small businesses and the rebuilding of homes. HUD provides support for the longer-term relocation of individuals and for the rebuilding of homes. The USDA aid is to help the agricultural sector recover from a disaster.

Table 2 provides a summary total of the $117 billion for all the government aid detailed in Table 1 for the 2005 hurricanes. Insurance payments for the 2005 hurricanes totaled $72 billion, so the government aid represented about 62 percent of the total payments from the federal government and insurance for the 2005 Hurricanes.

Table 2: Government Expenditures vs. Insurance for the 9/11 Attacks and 2005 Hurricanes

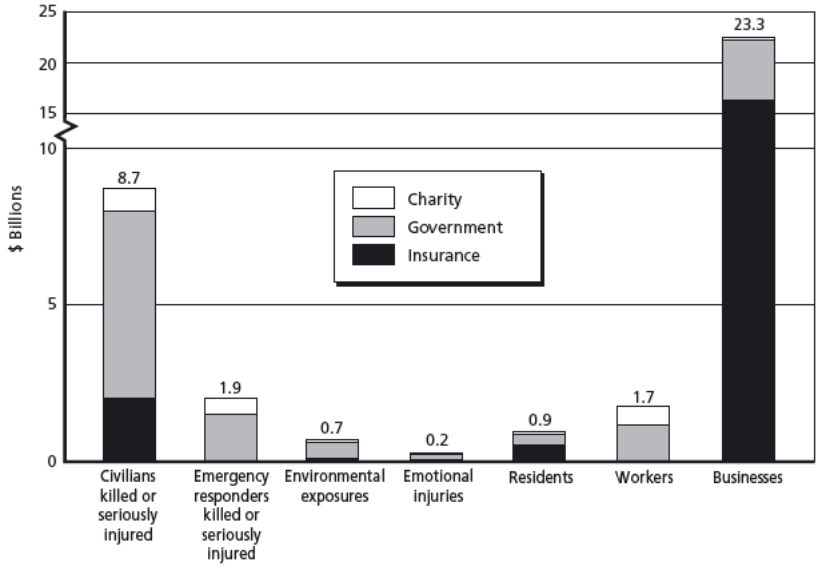
	Katrina, Rita, and Wilma Hurricanes		**9/11 Attacks**	
Payment Source	$ Billion	Percent of Total	$ Billion	Percent of Total
Government	$117	62%	$15.8	42%
Insurance	$72	38%	$19.6	51%
Charity	n/a	n/a	$2.7	7%
Total	$189	100%	$38.1	100%

Sources:
Fellowes and Liu (2006) for 2005 hurricanes, Rand (2004) for the 9/11 attacks, Reinsurance Association of America for 2005 insured losses at http://www.natcatus.org/print_all.php .

Dixon and Stern (2004), at the RAND Corporation, provide details of the payments made in response to the 9/11 terrorist attacks that parallel the Table 1's tabulation for the 2005 hurricanes. As shown in Figure 3, the largest category was insurance payments to business, covering payments for property damage and business interruption among others. Next largest is the government's payments for individual injuries and deaths, a large component of which is the Victims Compensation Fund a government response that is unique to the 9/11 event. It is important to note that the "quantified" payments explicitly exclude payments made for public infrastructure (including public buildings and the transportation system), cleaning of the sites, and airline assistance. The report also acknowledges that the charitable payments and environmental expenditures are surely understated.

The total payments by government, insurance, and charities for the 9/11 attacks are aggregated in Table 2, showing that 42% of the quantified payments came from government, 51% from insurance, and 7% from charities. Table 2 thus shows the total payments for the more recent 2005 hurricanes far outpaced those for the 9/11 attacks ($189 billion versus $38) and with a substantially higher government share as well (62% versus 42%). It should also be recognized that the total economic losses from such catastrophic events may far exceed the total of the tabulated payments.

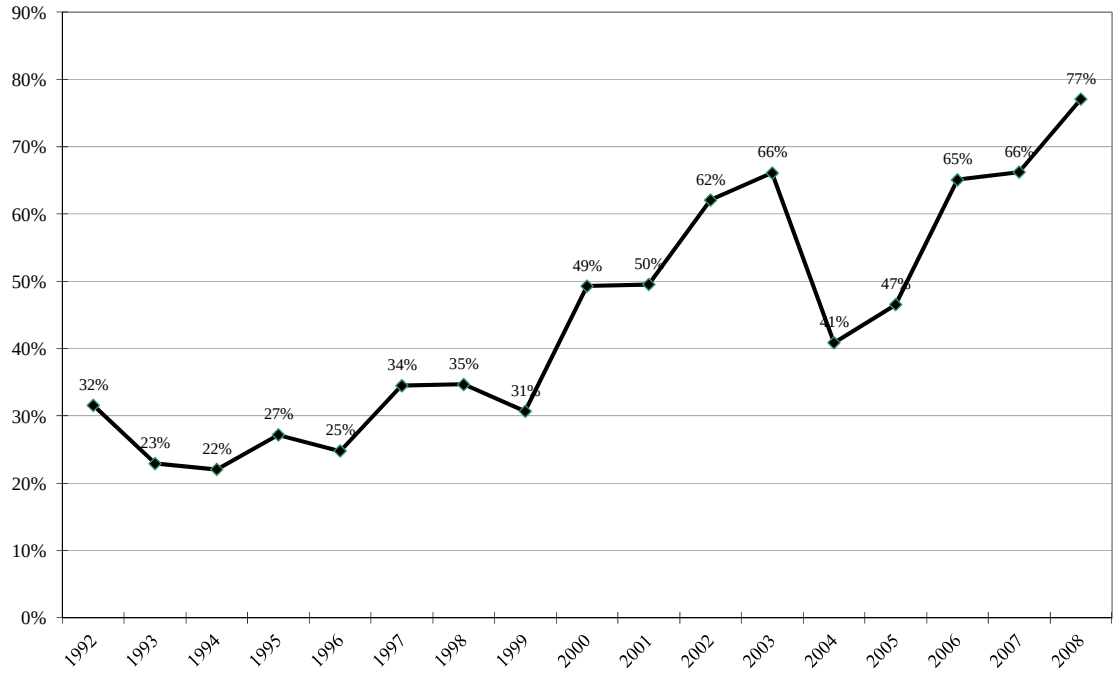
Figure 3: Quantified Benefits by Victim Group and Source of Benefits
Source: Table S.2 in Dixon and Stern (2004)



Detailed tabulations of government aid for the earlier natural disasters--1989 Loma Prieta earthquake, 1992 Andrew Hurricane, and 1994 Northridge earthquake—are available from Comerio (1998) with a focus on aid directed to the provision of temporary housing and permanent rebuilding. She notes that the programs providing housing aid generally cover only uninsured losses and she documents the sequential process that requires property owners to document their rejection by certain government programs in order to become eligible for other programs. As a result, a substantial part of the lost housing stock is not rebuilt or the reconstruction is privately funded.

By way of summary, Figure 4 shows the ratio of aggregated federal government aid to measured total losses based on data from Cummins, Suher, and Zanjani (2010). In contrast to Figure 2, the government aid covers all of the primary agencies including FEMA, SBA, HUD, and USAD and is shown on an annual fiscal year basis. Due to the lags in the expenditures for several years after a disaster, we use 4-year moving averages to illustrate the basic trend. Figure 4 provides firm evidence of a rising trend in the ratio. With the disasters themselves arriving more frequently, the dollar expenditures are rising even more rapidly.

Figure 4: Ratio of Total Federal Government Disaster Expenditures to Measured Losses
Source: Cummins, Suher, and Zanjani (2010)[2]



[2] We thank the authors for providing us with their data.

Figure 5: Reference Losses for the U.S. and Japan, as of 2007, $ Billions
Source: Swiss Re, Sigma, No. 2, 2007



Going forward, future terrorism/Katrina style mega catastrophes cannot be ruled out. Figure 5, for example, shows estimates of "reference losses" projected by Swiss Re in 2007. Reference losses are Swiss Re's estimates of catastrophes with return periods between 200 and 1,000 years. They projected a Japanese earthquake could create $500 billion in total losses, a value that, interestingly, equals some current estimates of the total from the 2011 Japanese earthquake. They also total project losses in the range of $300 billion for both future California earthquakes and U.S. hurricanes.

A major earthquake centered on the San Francisco Bay Area Hayward Fault presents an interesting case study (and one close to home for the authors). Consistent with the Swiss Re projection, Holden, Bahls, and Real (2007) state "an earthquake of this magnitude in the San Francisco Bay Area could have an even greater impact on businesses, employees, and payrolls in the area than Hurricane Katrina had in Louisiana and Mississippi." Indeed, in the last 25 years, California had two major earthquakes, Loma Prieta in 1989 and Northridge of 1994.

The Northridge earthquake also provides an excellent case study of how government insurance replaced private insurance following a major event. Prior to the Northridge earthquake, earthquake coverage was available as a rider to all California homeowner policies, and the general perception was that the premium cost was reasonable. Insurance payments on Northridge claims offset approximately the previous 10-years of premium payments received by the insurers, an amount far exceeding the insurers' estimates of the claims from such an event; see Risk Management Systems (2004). As a result, soon after Northridge, most insurers decided to

no longer offer earthquake coverage. After a protracted negotiation with the state legislature, a public/private earthquake insurance plan (the California Earthquake Authority) was established. This plan, however, has experienced a very low take-up rate; starting with an initial coverage ratio of about 30%, it now covers only about 12% of California homeowners.

It is an open question to what degree the uninsured California homeowners anticipate state and federal governments will help fund the reconstruction of their homes after a major earthquake. There was a time in which such government aid would surely not have been anticipated. Moss (1999) provides the example of President Grover Cleveland who in 1887 vetoed a bill to assist the victims of a severe drought in Texas, declaring, "I do not believe that the power and duty of the General Government ought to be extended to the relief of individual suffering. ... Though the people support the Government, the Government should not support the people." More recently, both Kunreuther (1978) and Comerio (1998) cite evidence that many homeowners do not anticipate government aid to rebuild their homes. Self insurance may also be a sensible economic decision for California homeowners to the extent that wood-frame single-family homes can be protected against most earthquake damage at a cost that may well be less than the present value of future insurance premiums.[3] On the other hand, these homeowners are surely aware of the rising trend in government post-disaster aid that has been documented in this section, and it would be reasonable for them to expect government generosity in response to a large earthquake.

This is the setting for the focus of this paper, namely to analyze the welfare implications of alternative pre and post-disaster responses by the private sector and the federal government. The significant and rising dollar amounts of government disaster aid has already received recent scrutiny in Cummins, Suher, and Zanjani (2010) and Michel-Kerjan and Volkman-Wise (2011). In these papers, the primary question is whether and how the government's largesse in providing post-disaster aid can be constrained given the overall fiscal crisis facing the country. Answers to this question must also recognize the political process whereby disaster aid creates a chain of political benefits, starting with the President who designates a federal disaster, through the

[3] In particular, the standard policy of the California Earthquake Authority (CEA) has a 15 percent deductible, and with standard mitigation actions (bolting homes to their foundations and using plywood to create shear walls), it is unlikely a house will suffer damages above 15% of the insured value. The CEA has also introduced a policy with a 10% deductible, but few California homeowners have been attracted to it, presumably because the premiums are substantially higher.

sequence of state governors and local mayors who help distribute the aid, and finally to the business and individual beneficiaries.

However, there has been little systematic analysis of the fundamental welfare economic principles underlying the public provision of post-disaster aid (but see Shavell (2011)). The purpose of this paper is to attempt to fill this gap by applying ideas from the welfare economics of uncertainty to the problem of the design of public catastrophe loss programs. We begin in the following Part 2 by taking up the fundamental question whether welfare decisions by the government should focus on providing citizens with the ex ante opportunities to insure against the evident risks, or whether there is also a fundamental role from welfare economics for ex post disaster relief. We will propose that welfare economics provides a fundamental role for ex post disaster relief that has not been previously integrated into the discussions involving disaster aid, insurance, and mitigation.

In Part 3, we turn to the policy implications that arise from combining the fundamental welfare role for governmental ex post disaster aid with the incentive conflicts it creates for individuals to purchase insurance and/or mitigate the underlying risks. The issue is complex. A major complication is the interactions that exist among the four factors we identified at the outset: the increasing severity of the catastrophes, the substitution of government insurance for private insurance, the rising trend of government aid, and the incentive of homeowners and even the government itself not to mitigate the underlying risks. For example, while the increasing number and size of the catastrophes no doubt was a major factor leading to the substitution of government insurance and post-disaster aid for private insurance, it is also clear that subsidized government insurance and free post-disaster aid has encouraged greater development in risky areas, thereby expanding the dollar magnitude of the resulting losses.

In the Appendix, we discuss issues raised by the Samaritan's Dilemma that may interfere with the ex ante incentives of the victims to help themselves by mitigating the risks or purchasing insurance; see Buchanan (1975). This gives rise to a problem of time inconsistency. As Kunreuther and Pauly (2004) note, time inconsistency arises in a number of economic areas, and indeed was originally illustrated by Kydland and Prescott (1977) as a problem in the design of a program of flood relief, although their focus was the design of macroeconomic policy.

2. Welfare Economics of Catastrophes: Ex Post versus Ex Ante Criteria

The following theorem is well known.

Theorem 1: When a population of n identical risk averse individuals face a common risk of fixed size, each individual's expected utility is maximized by having each of them bear 1/n th of the risk.

This theorem is just an application of Samuelson's well known theorem that it pays to diversify, Samuelson (1967). It can also be viewed as an application of the earlier fundamental risk sharing theorem of Borch (1962).

To first order, this theorem is neutral with regard to the question of how this risk sharing is to be financed. It can be financed ex ante through an insurance market in which premiums are paid into a common pool. But it can also be financed by ex post relief paid for by a poll tax levied on each citizen. At this level, as compared with ex ante insurance, ex post relief has nothing to commend it or impugn it.

Of course, second order effects may be important. Competitive insurance markets may have lower administrative costs of claims settlement and may be better at targeting loss compensation, and a poll tax may not be politically feasible, but under the assumptions of the theorem, there is no reason not to provide ex post relief.

Systemic differences appear, however, when we relax the theorem's assumptions. If individuals differ in their beliefs, the Pareto criterion based on expected utility loses its consensus welfare appeal. For broader measures of welfare, even when they are based on solely on individual well being, , there can be tension between the evaluation of welfare before an event occurs (ex-ante optimality) and the evaluation once the outcome is revealed (ex post optimality). In choosing among policies to deal with catastrophe loss we would like to use the framework of established welfare economics. Unfortunately under the conditions of uncertainty inherent to catastrophic events, there is as yet no consensus on how to do this.

One set of issues has recently received a great deal of attention. If individuals make systematic errors in judgment, the usual principle of consumer sovereignty will clash with the desire to

protect individuals from themselves. This tension is the basis of the desire to "nudge", Thaler and Sunstein (2008). The problems of welfare measurement which arise under uncertainty go beyond those which arise in behavioral economics, however, and behavioral issues will not be the focus of this section.

Instead we will focus on the problem generally described as the question of ex ante versus ex post optimality.[4] This dilemma arises even when individual behavior is assumed to satisfy the traditional Von Neumann Savage axioms. The fundamental problem is that under these axioms subjective probabilities can differ across individuals in the same way that preferences may differ, and when this is true, insurance contracts will be written which serve only to exploit the difference in opinion. Once it is known which state has occurred, however, differences of opinion disappear, and payments under these insurance contracts may no longer be welfare enhancing.[5]

The question then arises as to which measure of individual welfare to respect. Should it be individual well being, as measured by expected utility (subjective probabilities being taken at face value) i.e. individual welfare ex ante before it is revealed whether or not a catastrophe has occurred? Or should it be ex post individual welfare as measured by the (probability free) utility after it is known whether or not a catastrophe took place? [6] Until this question is settled, the definition of social well-being as determined by a (Bergson) social welfare function will also be open to debate.

This dilemma makes for difficulties in interpreting the standard Arrow-Debreu formulation of welfare under uncertainty, Arrow (1953,1964,1971), Debreu (1959). Recall that in the case in

[4] This problem is discussed in the papers of Diamond (1967), Dreze (1970), Feiger (1976), Guesnerie and de Montbrial (1974), Hammond (1981), Harris (1978), Mirrlees (1974) and Starr (1973) among others. More recently it has been discussed by Adler and Sanchirico (2006) and Fleurbaey (2010).

[5] The use of credit default swaps (CDS) by certain investors to profit if the subprime housing boom were to collapse provides a good example of using insurance contracts to exploit a difference in opinion (and not to hedge an insurable interest). Further, some argue that this use of the CDS contracts deepened the crisis and thereby enlarged the size of the required government bailouts. In a 2003 newsletter to Berkshire Hathaway shareholders, Warren Buffett referred to such derivatives as "financial weapons of mass destruction".

[6] Note that these terms risk confusion as to when the welfare comparison is undertaken. In both cases the welfare comparisons and choices with respect to policy are made before it is known if a catastrophe has occurred. It is the level of individual welfare which is measured ex ante or ex post, not the time at which the evaluation takes place.

which individuals satisfy the Von Neumann Savage axioms, the preferences of individual i over state contingent consumption bundles x_j can be represented by a function of the form

$$V^i = \sum_j p_j u^i(x_j)$$

where j is the index of the state, p_j is the probability of state j, and u is a cardinal utility function assumed to be state independent.

A feasible allocation is Arrow-Debreu efficient if there is no alternative feasible allocation which is Pareto superior in terms of the V^i. But, as Mirrlees (op.cit.) notes: "The Arrow-Debreu formulation of welfare accepts each household's beliefs –possibly expressible by means of subjective utilities- in the same way that it accepts the household's tastes. If a man strongly but wrongly believes that the end of the world is at hand, he will be given his wealth and allowed to spend it all at once. He will then starve, in circumstances he believed would not occur, but an Arrow-Debreu welfare function does not care."

The concept of efficiency implied by applying the Pareto criterion to the functions V^i is known as "ex ante" efficiency. An allocation of resources is said to be ex ante efficient if it provides an "optimal allocation of risk bearing", Arrow (1964). Under general conditions, insurance markets can be expected to guarantee this. But, as Starr (1973) points out, if we consider the allocation of resources which results from the trading of insurance contracts not before but after the outcome of the insured event is known, (i.e. ex post) there may be for all realized states a feasible redistribution of resources within that state which increases some agent's (actual) utility without lowering the realized utility of anyone else. As Starr states " If we are interested in satisfactions actually realized rather than those which are merely anticipated, the appropriate quality to seek is that there be no redistribution that will increase some trader's realized utility while decreasing no trader's realized utility. Such a situation will be termed an ex post Pareto optimum."

In this paper we do not add to the continuing debate on the relative normative merits of the ex ante versus (several) ex post viewpoints. A clear statement of the deep issues involved may be

found in Kolm (1998). For recent contributions supporting the ex post viewpoint see Adler and Sanchirico (op.cit.) and Fleurbaey (op.cit). Our goal, instead, is to explore the implications of the ex ante versus ex post debate for the design of programs to deal with the risk of catastrophe loss. We would note, however, that to the extent that welfare economics exists to guide government policy, a government election campaign based on the "ex-ante optimality" slogan, "you bought the optimal amount of insurance, why are you complaining?" will not gain much traction in a post-Katrina political environment.

2.1 Insurance and Ex Post Pareto Efficiency: The Starr Case

We now assume that policy makers have adopted the ex post Pareto efficiency criterion. Then the question arises of how best to deal with the risk of catastrophic loss, particularly as compared with policies which adopt the ex ante criterion. We begin by examining the insurance/relief implications of an ex post efficiency criterion due to Starr (op.cit.)

We use the following simple example from Harris and Olewiler (op.cit.). An economy lasts for two periods. In period 0, there is no uncertainty. In period 1 there are two possible states of nature. In state C a catastrophic loss occurs, and in state N there is no loss. The economy is endowed with a single commodity, X . In period 0, the endowment is $\bar{X}_0$. If a catastrophic event occurs (in period 1), the endowment is $\bar{X}_C$ and if not, the endowment is $\bar{X}_N$, with $\bar{X}_C < \bar{X}_N$

The economy has two citizens, A and B. They have the same endowment, $\bar{X}_j/2$ j=0,C,N. At time 0, the preferences of both citizens can be represented by a time separable state independent expected utility function, identical in all respects except one. Individual A believes that the probability of a catastrophic event is low, p_L, whereas individual B thinks it is high, p_H .

The expected utility of each citizen is thus given by

$$V^A = U(X_0^A) + p_L U(X_C^A) + (1-p_L)\, U(X_N^A)$$

$$V^B = U(X_0^B) + p_H U(X_C^B) + (1-p_H)\, U(X_N^B)$$

where X_j^i is the consumption of X by individual i, i=A,B in time/state j, j=0, C, N.

Assuming differentiability, the consumption bundle $\hat{X}_j^i$, i= A,B, j=0, C, N is ex ante Pareto efficient if it is feasible, $\Sigma_i \hat{X}_j^i = \bar{X}_j$ i= A,B, j= 0, C, N, and if the marginal rate of substitution of period 0 consumption for contingent state j consumption, j=C,N, is the same for each individual. That is we must have

$$p_L \frac{U'(\hat{X}_j^A)}{U'(\hat{X}_0^A)} = p_H \frac{U'(\hat{X}_j^B)}{U'(\hat{X}_0^B)} \quad j = C,N. \qquad (1)$$

The equality in equation 1 can be achieved by competitive trading. Since there are 3 goods in this model (i.e. one good indexed by 3 indices (time 0, state C, and state N), we will need 3 prices. Normalizing by setting the price of X in period 0 =1, we may interpret the two other prices as insurance premia paid for delivery of 1 unit of the good if there is catastrophe (in state C) or not (in state N). Individual A (the optimist) will write a policy of insurance to individual B (the pessimist) for a premium to be paid in period 0, such that A will increase the endowment of B in the state in which the catastrophe occurs.

More generally, for m periods, n states and k consumers and l commodities, under standard assumptions, any allocation which is competitive in spot markets and contingent claims (insurance markets) is ex ante efficient. Conversely, any allocation that is ex ante efficient will be a competitive outcome for spot markets and insurance arrangements, given suitable lump sum transfers.

This is the basis of the standard welfare argument in favor of markets of insurance. Suppose, however, that in defining Pareto efficiency we use ex post preferences i.e. efficiency once the outcome is known. This can be done in more than one way. Here we use the approach of Starr (op.cit.).

Definition: Starr ex post efficiency. An allocation $\hat{X}_j^i$, i= A,B, is ex post Pareto efficient in state j if it is feasible, $\Sigma_i \hat{X}_j^i = \bar{X}_j$ i= A,B, and there is no other feasible allocation X_j^i for which $U(X_j^i) \geq U(\hat{X}_j^i)$ i=A,B with strict inequality for at least one i.

An allocation is (universally) ex post Starr efficient if it is ex post Starr efficient for each state j=C,N.

By Starr's criterion, for each state j = C, N, ex post Pareto efficiency requires that the marginal rate of substitution of period 0 consumption for actual (not contingent) state j consumption in that state be equal for each individual. That is we must have

$$\frac{U'(\hat{X}_j^A)}{U'(\hat{X}_0^A)} = \frac{U'(\hat{X}_j^B)}{U'(\hat{X}_0^B)} \quad \text{j=C,N.} \qquad (2)$$

Now looking at (1) and (2) it is clear, as Dreze (op. cit) and Starr (op.cit.) noted, that unless the subjective probabilities p_L , p_H are equal for each citizen, the ex ante and (Starr) ex post Pareto efficient allocations will not coincide.

How likely is it that subjective probabilities of catastrophic loss will vary across individuals? In Kunreuther and Pauly (2004), a theoretical explanation is given for why individuals may not seek information on the probabilities of low frequency events. In this case subjective probabilities are likely to differ. The role of heterogeneous beliefs in financial markets, such as equity markets, is also receiving more attention, in part due to the evident differences in beliefs that were revealed during the subprime crisis.[7]

But even if they seek information, say by trying to infer probabilities from market prices, difficulties will arise.[8] Catastrophe bonds, for example, offer interest spreads which are far higher than expected losses, in some cases surpassing a 5% spread over LIBOR. Bantwal and Kunreuther (2000) and Froot (2001) have offered several explanations for this risk premium

[7] For recent papers, see Brunnermeier and Xiong (2011) and Fedyk, Heyerdahl-Larsen, and Walden (2012).

[8] For a recent contribution on this topic in the finance literature, see Albagi, Hellwig, and Tsyvinski (2011).

ranging from non-standard preferences to capital market imperfections. Since it is difficult to know what is causing the premium to far exceed the expected loss, it is clearly not possible for agents to infer the underlying probabilities just from the catastrophe bond's price. Moreover, although there is not a large empirical literature on this question, Botzen et al (2009) show that in Holland, risk perceptions for the probability of floods do differ, and they provide empirical correlates for the differing subjective utilities. It seems reasonable therefore to suppose that the preconditions for equality between ex ante and ex post optimality will not be met.

What does this imply for the choice between insurance and ex post (state dependent) transfers? Since individuals are identical, ex post Starr efficiency requires that each individual simply consume his or her endowment in each state; i.e. no trade takes place. Each agent attains the same level of utility. But, given that individuals differ in their subjective probabilities, they will write contracts of insurance based on their differing views of the likelihood of loss. Then in the event of a catastrophe, settlements will take place. The optimist suffers a loss of endowment, (offset by her gain in period 0), the pessimist experiencing the reverse. This is ex post Pareto inefficient in the catastrophe state. By adapting the same argument, it is also ex post inefficient in the state in which a catastrophe does not occur. Thus it is ex post inefficient in the Starr sense.

How could a government achieve ex post efficiency? Suppose a catastrophe occurs. Then since $p_H > p_L$, ex ante trading in insurance markets to satisfy equation (1) will force $\frac{U'(X_C^A)}{U'(X_0^A)} > \frac{U'(X_C^B)}{U'(X_0^B)}$. Thus ex post relief in which the government redistributes resources from B to A will lead to an ex post Pareto improvement. Here then is an example in which by one welfare measure (Starr ex post Pareto efficiency) government relief is efficient, but insurance is not. Indeed the government relief is simply undoing the misallocation caused by the insurance, so a policy which banned insurance would work as well.

2.2 Insurance and Ex Post Pareto Optimality: The General Case

Because the Starr test of efficiency is defined from within a given state and ignores effects across states, it has been argued, see Hammond (1981), that the Starr definition makes the set of

ex post inefficient allocations too large. Hammond analyses the implications of a definition of ex post efficiency which widens the set of efficient states. In his sense a feasible allocation $\hat{X}_j^i$, i= A,B, j=0, C, N is ex post efficient if there is no alternative feasible allocation X_j^i, i= A,B, j=0, C, N which is Pareto superior for all ex post utility functions U() in different states of the world. That is, for which $\{U(X_0^i), U(X_j^i)\} \geq \{U(\hat{X}_0^i), U(\hat{X}_j^i)\}$ i= A,B, j= C, N.[9]

With this definition, Hammond proves the following result. If an allocation is efficient ex ante, it must be efficient ex post, except possibly for states of the world j and consumers i for whom $P_j^i = 0$. Since we know that spot markets with contingent insurance markets are in general ex ante efficient, this definition of welfare reinstates the argument for insurance even when the ex post criterion is used.

The concept of Pareto efficiency, however, provides only rather weak welfare comparisons. If we are prepared to measure welfare outcomes by a (Bergson) social welfare function, the distinction between ex ante and ex post again becomes important. An ex ante Bergson social welfare function is a function W_a of consumers' ex ante expected utility V^i which is increasing in each V^i ; $W_a = W_a(V^i)$ for all i.

An ex post social welfare function, on the other hand, is a function which is increasing in each consumer's ex post utility in state j, $Y^i = U(X_0^i) + U(X_j^i)$

$$W_p = \sum_j \pi_j \; W(Y^i) \text{ i=A,B j=C,N.}$$

[9] Harris (1978) provides a simple comparison of the Starr and Hammond definitions for this example. Since preferences are time separable, it is possible to show all preferences over all feasible allocations by drawing two Edgeworth Bowley boxes with time 0 allocations on the vertical axis and state j, j=C,N allocations respectively on the horizontal axes. These two boxes must be of the same vertical height, since the same feasible quantity of X in time 0 is available regardless of which state occurs. By Starr's criterion, ex post efficient points must lie on the contract curve of each box at the same vertical height. By Hammond's criterion an ex post efficient point could lie on the contract curve of one of the state boxes, say state C, but (at the same vertical height) off the contract curve of the other state N. Any attempt to Pareto improve the welfare of both agents in state N would require a change in the allocation in time 0 which would reduce the welfare of one of the agents in State C, and is thus ex post efficient in the Hammond sense. This reduction in welfare in the other state is ignored by the Starr criterion which looks at efficiency state by state.

Here π_j is the social probability of state j, and may differ from the subjective probability P_j^i. An ex post welfare optimum is a maximum of W_p

Hammond proves the following theorem:

Theorem 2: Every ex post welfare optimum will be ex ante efficient if and only if

a) for all i=A,B and j=C,N $P_j^i = \pi_j$

b) for all j=C,N, $W = \sum_i \mu^i Y^i$ i=A,B.[10]

We have already discussed the likelihood that individuals will differ in their subjective probabilities. The second requirement forces each consumer to display the same individual attitude to risk as the social attitude to risk, see Hammond (op.cit. p 241).

Both requirements are needed to prevent individuals who disagree ex ante (whether in their beliefs or in their attitude to risk) from writing insurance contracts which will move the allocation away from the ex post social optimum.

Suppose that the conditions of Theorem 2 are not satisfied. How can an ex post allocation be decentralized? As Hammond shows, one way to do this is with spot markets and state contingent lump sum transfers. That is to say, if the welfare goal is the maximization of ex post welfare and if individuals differ either in their beliefs or in their attitudes to risk, the appropriate way to deal with catastrophic loss is with a system of ex post lump sum relief. Moreover, because insurance markets potentially interfere with the optimal allocation, they are best closed. If they remain open, ex post relief will need to be changed to undo the risk transfers which occur in these markets.

[10] An intuitive explanation for the need for an additive linear (utilitarian) form for the social welfare function has been given by Adler and Sanchirico (op.cit). Assuming that all subjective probabilities are equal and equal to the social probabilities, the ex ante and ex post welfare functions are assembled from the same ingredients, the probabilities π_j and the utilities $U(X_j^i)$. But ex ante welfare assembles these ingredients by first forming the vector of expected utilities $V^i = \sum_j \pi_j u^i(x_j)\ i = 1,\dots n$ then evaluates, $(W_a(V^i)$, whereas ex post welfare first evaluates the vector of utilities $W_p(u^i(x_j)$ then applies the probabilities. Equality between these two concepts requires that the welfare function be additively linear.

These conclusions of welfare economics are starkly at variance with the standard arguments for using insurance markets to handle catastrophic risk. In a later section we will discuss their practical implications for catastrophe loss policy design.

3. Policy Responses

If we take the implication of ex post welfare economics literally, the following conclusions would emerge: (i) Continue and even expand as necessary the government's post-disaster aid programs; (ii) Prohibit the relevant insurance markets, or at least maintain the catastrophe insurance programs at their currently low levels. The ex post view generally does not consider the role of production, and therefore has no explicit implications for mitigation. Overall, this position is, in effect, a proposal to maintain the status quo.

The ex post view is, however, based on important assumptions, and if these assumptions do not hold, then a range of second-best policies should be considered. We focus on two issues:

1) The ex post view is based on an exchange economy that takes as given the initial endowments. In reality, a relatively wide range of ex ante mitigation actions are available, and it seems relevant to evaluate them either as additions to or as substitutes for government transfers.

2) The ex post view assumes that lump sum transfers can be made without cost. The reality, of course, is that lump sum transfers create dead weight costs since they must be funded with taxes. Given the fiscal crisis currently facing the United States, it seems relevant to evaluate second-best policies that might encourage ex ante insurance as a substitute for government transfers.

We begin by discussing the issue of mitigation.

3.1 Expanding Incentives for Ex Ante Mitigation

The introduction of production into the ex post welfare story is widely understood to create difficulties; see Starr (1973), Harris (1978), Hammond (1981). This literature, however, is silent on one of the major problems of ex post government aid, namely the possibility that government disaster assistance may reduce the incentives of individuals to limit their potential loss through mitigation activities. In the Appendix, we provide a discussion of the Samaritan's Dilemma as a problem of time inconsistency. Here we simply note that to the extent that positive net present

value (NPV) mitigation investment opportunities exist, they would appear to be ex post welfare enhancing even in the presence of lump sum transfers, and all the more so if the transfers are limited.

The main issue for mitigation actions is that many households appear unwilling to carry out the necessary investments, even when they are NPV positive. The basis of the limited mitigation actions is not well understood, and it is quite possible that there are multiple factors, each having its own resolution; see Kunreuther (1996, 2006). One factor, within the scope of this paper, is that individuals may anticipate negative NPV outcomes because they are applying low subjective probabilities for the underlying event. In line with the discussion of Part 2, an ex post welfare criterion might take this as given, and would therefore recommend lump sum transfers for the losses that might result from the failure to mitigate. But, if the lump sum transfers are not available, and if the government itself computes a positive NPV, then it might be sensible to mandate the necessary mitigation actions. Such a mandate would, of course, be in line with the common application of building codes across the United States.

To be clear, there are many plausible explanations for the low observed mitigation rates, including behavioral factors, loan market imperfections, the existence of subsidized insurance, and finally a dependence on disaster relief. It is noteworthy that most U.S. households also do not carry out NPV positive investments in energy efficiency, even though the availability of disaster relief is not a relevant factor; see Jaffee, Stanton, and Wallace (2011). This suggests that disaster relief may not be a primary factor in explaining the failure to mitigate against natural disaster risks.

3.2 Expanding Ex Ante Insurance When Post-Disaster Relief Is A Leaky Bucket

In comparing the costs of government relief with ex ante insurance, it is useful to distinguish three classes of government disaster relief: (i) Emergency responses that include immediate medical aid, temporary food and shelter, and rebuilding infrastructure for communications and travel; (ii) Compensation for loss of life or injury as illustrated by the 9/11 Victims Compensation Fund; (iii) Longer-term grants and loan provided to rebuild private property, primarily residential and commercial structures. In our view, the policy issues raised by these categories are quite different and it is best to make our positions explicit at the outset.

We regard the emergency responses as the category where the ex post solution of government aid applies directly. We cannot imagine a situation in which a decision would be made to reduce the government expenditures for medical aid and temporary food and shelter, or not to rebuild the public infrastructure. Indeed, the uniform outcry against FEMA following Katrina was that it did too little, not that it did too much. While insurance might in principle provide financial compensation for the emergency injuries and dislocations created by catastrophic events, it is a physical response, not financial compensation, that is immediately required.[11] Based on data provided by Cummins, Suher, and Zanjani (2010), approximately three-quarters of the total U.S. government disaster provided between 1989 and 2008 was provided by FEMA as emergency aid. So a large part of the government's disaster aid can be motivated by an ex post welfare criterion.

Government compensation for loss of life and injury, as illustrated by the 9/11 Victim's Compensation Fund, appears primarily to arise from losses created by war or war-like attacks on the United State. It is worth noting that free government insurance was also provided during World War II against private losses that would arise from attacks on the U.S. mainland. It seems clear that a sense of national unity in the face of an enemy attack was an important motivation for both the war-time insurance and the 9/11 compensation fund.[12] However, there is no evidence of an expansion of such compensation plans to natural disasters; in particular, no similar compensation was provided to the victims of Katrina. As a result, the following analysis of government disaster relief and insurance does not include victim compensation funds.

This leaves the government disaster programs that provide grants and aid to rebuild structures or reestablish businesses (primarily HUD and SBA) or to aid the agricultural sector (USDA). The Cummins, Suher, and Zanjani (2010) data indicate that approximately one-quarter of the total

[11] Of course, emergency insurance for "roadside assistance" and "MedEvac" is available. However, these policies assume the infrastructure to provide the response remains operational. We know of no insurance lines that cover an infrastructure failure itself.

[12] Hirshleifer (1953, 1955) discusses the World War II and Korean War insurance plans. In line with the discussion in this paper, he compares ex post compensation with an ex ante insurance plan. He favors the insurance plan to the extent that it applies risk-based pricing and thereby provides incentive for citizens to move themselves out of harm's way.

U.S. government disaster aid provided between 1989 and 2008 came from such agencies.[13] For these expenditures, ex ante insurance can be considered a possible substitute for ex post disaster aid. We now discuss the implications for government policy for disaster relief.

3.2.1 Constructive and Destructive Insurance Markets

As discussed in Part 2, the welfare role of insurance ranges from an important and constructive risk-sharing role under an ex ante criterion to a minimal and even negative role under a strict ex post criterion. The ex post view, however, assumes that lump sum transfers can be made without cost. In this section, we take up the second-best question of what might be the proper role of insurance when it is assumed that lump sum transfers are costly—sometimes described as making transfers with a leaky bucket. To simplify the discussion, we assume that the costs of lump sum transfers rise with the amount of the transfers, creating, in effect, a maximum amount for such transfers. Recalling that our discussion here applies primarily to property and business interruption insurance, we will simply assume that this maximum has been reached with the actual government expenditures observed in recent catastrophes. The key question is then whether an active role for insurance markets can be welfare enhancing under this condition.

As a first step in our analysis, we note that the example used in Part 2 in some ways underplays the role of ex ante insurance. In that example, both agents have the same endowments in both states; so if they had the same beliefs and the same attitudes to risk, the ex ante optimal amount of insurance would be zero anyway. But suppose now that individual endowments in the two states are markedly different. Suppose, to take the extreme case, that a catastrophe is bound to occur but we do not know which agent will be affected. For example, suppose that the {state 1, state 2} outcome for agent A is {0, 1}, while the outcome for agent B is {1, 0}. Then as per the Samuelson and Borch theorem stated earlier, if the individuals are otherwise alike including identical beliefs and risk attitudes, then they will both fully insure, possibly through a mutual insurance contract. The insurance outcome would then be {½, ½} for both individuals.

Suppose now that their beliefs differ slightly. They will still insure, just not fully. If ex post lump

[13] Using the Cummins, Suher, and Zanjani (2010) data, we compute that approximately 20 percent of the government's disaster aid has come from the SBA and USAD agencies. We estimate that including expenditures from HUD and other agencies would raise the total to perhaps 25 percent.

sum transfers are costly, then an ex post relief system could easily lead to a worse outcome than the outcome achieved by ex ante insurance. This situation is more likely the more skewed are the state dependent endowments of the agents. Hence, insurance could well improve the ex post welfare, albeit just not to the first best situation available from unlimited lump sum transfers.

On the other hand, it is also easy to generate situations in which insurance moves the agents away from the ex post optimum. Here consider a case in which the {state 1, state 2} endowments are initially {½, ½} for both individuals, and suppose this is an ex post optimum. But now allow an insurance market to exist on an event that does not directly affect either agent. If the agents have differing subjective probabilities of the event, they may well take positions in the insurance market, the optimist (that the event will not occur) being the protection seller and the pessimist being the protection seller. Ex post, there will be a settlement in one direction or the other, and this will necessarily move the agents away from the ex post optimum. And if lump sum transfers are not available, the agents would have been better off on an ex post basis if the insurance market had not existed.

3.2.2 Insurance Contracts With or Without An Insurable Interest

The likelihood that an insurance will provide constructive ex post benefits is enhanced if the market requires an insurance interest. An insurable interest is defined here to mean that the protection buyer is exposed to an underlying risk, and that the insurance protection reduces this risk, ideally to zero. Thus, by definition, insurance that requires an insurable interest can only serve to reduce the ex post exposure of the protection buyer. It appears that most insurance policies purchased from chartered insurers require an insurable interest as a means to protect the insurer against the moral hazard that the insuree might try to profit by intentionally creating the insured event. The conclusion is that insurance markets that require an insurable interest are likely to serve as a good substitute for lump sum government transfers as a mechanism to move the economy toward its ex post social optimum.

On the other hand, financial markets now trade risk transfer instruments, such as credit default swaps (CDS) or indexed catastrophe bonds, that typically do not require an insurable interest. Participants in the markets for these instruments may hold very different subjective probabilities of the likelihood of the underlying event, and may therefore take very large and opposite

positions as protection buyers and sellers. As an example, it appears that by late 2006, there had developed two very different views about the likely collapse of the market for subprime mortgages, with one view believing the subprime market would continue to provide high returns, and the other view believing a major collapse was imminent. The result was a very large open interest in a wide range of CDS contracts, and very large financial transfers to the protection buyers when the collapse did occur; see Stanton and Wallace (2012).The overall conclusion is that, under these circumstances, an insurance market can move the economy to a position of lower ex post welfare.[14]

Indexed catastrophe bonds provide a good example of a risk-transfer instrument that may be either constructive or destructive with respect to the attainment of an ex post optimum. These bonds will represent an insurable interest to the extent they allow insurers or reinsurers to hedge catastrophic risks in their portfolio, and to this extent they should be welfare enhancing. On the other hand, these bonds and similar instruments can allow traders to take speculative positions as protection buyers or sellers where they believe they have more accurate information than the overall market regarding the likelihood of the event.

The positions of American International Group (AIG) during the subprime boom and crash also appear to provide an example of both constructive and destructive insurance. On the constructive side, AIG owned and still owns a chartered private mortgage insurer subsidiary, United Guaranty. United Guaranty operates as a monoline insurer, offering coverage against the risk of default by single-family mortgages. While United Guaranty suffered significant losses as a result of the subprime crash, it remains solvent and is writing policies today. On the destructive side, AIG also owned a Financial Products subsidiary that wrote credit default swaps against subprime mortgage securities. It was this subsidiary that required a large government bailout when the firm was no longer able to meet the margin calls that were supposed to control its counterparty risk on the swap contracts.

[14] See Stulz (2010) for one of a number of recent papers that discuss the negative welfare consequences of credit default swaps.

3.3 The Special Case of Government Insurance

As noted earlier, the available insurance programs for catastrophic risks are now primarily governmental (National Flood Insurance Program), quasi public (the California Earthquake Authority), or based on government reinsurance (the federal Terrorism Risk Insurance Act and the Florida state Hurricane Catastrophe Fund), and we see no immediate prospects for the re-emergence of private insurance markets for these risks. While an evaluation of these government insurance programs is beyond the scope of this program, we offer several comments on how the government affiliation of these programs affects their impact on the ex post social welfare:

i) These programs all require an insurable interest in the property being insured, and in this sense are in the class of constructive insurance.

ii) The programs vary widely in how the probabilities of the insured event, as embedded in the quoted insurance premiums, compare with the subjective probabilities of the consumers who may purchase the insurance. As one example, the National Flood Insurance Program (NFIP) has offered subsidized premiums on many risks, provide incentive for families to located in risky locations, and with the result that close to a $20 billion transfer was required from the U.S. Treasury to the NFIP to allow it to pay the many claims from Katrina; see Michel-Kerjan (2010). It would thus appear an open question whether the NFIP was on net a positive or negative factor in moving the economy closer to an ex post optimum. On the other side, the California Earthquake Authority currently bases its premiums on the cost of reinsuring the risk, and it appears that the resulting premiums imply event probabilities far higher than the subjective probabilities of most California homeowners. The result is a very low take-up rate. While this may not create significant costs, it clearly limits the impact of the program in moving California homeowners to a better ex post position.

(iii) In view of the low take-up rates observed for both earthquake and flood insurance, there are proposals that would require all homeowners to purchase such insurance; see Kunreuther (2006, 2008). Assuming that the event probabilities embedded in the quoted premiums are no higher than the subjective probabilities held by the consumers, such a mandate could well be ex post welfare enhancing given a limitation on lump sum transfers. On the other hand, if the government insurance premiums are higher than the consumers believe are warranted based on

their subjective probabilities—for example, as appears the case with the California Earthquake Authority--the program may not be ex post welfare enhancing.

4.3 Concluding Comments

The important and expanding role of post-disaster government aid in the U.S. economy results from a broad range of social, political, and economic factors. The social factors primarily reflect the basic human instinct, fortunately still alive and well, to help people who face unexpected disasters. The political factor arises first because government is a natural mechanism to provide the humanitarian response—to control the free rider problem if nothing else—but also because it appears politicians benefit from being seen as the providers of such aid. The economic analysis must respond to the distinction between ex ante and ex post welfare criterion, including the complications introduced by incentive effects on the willingness of citizens to mitigate the risks and/or purchase insurance.

Appendix: <u>The Samaritan's Dilemma and Conflicts with the Ex Post Welfare Criteria</u>

The desire to provide help to victims of disaster is a natural part of the human condition, but unfortunately such Samaritan aid inevitably interferes with the ex ante incentives of the victims to help themselves, Buchanan (1975). This gives rise to a problem of time inconsistency. As Kunreuther and Pauly (2006) note, although this concept was developed by Kydland and Prescott (1977) to deal with the design of macroeconomic policy, time inconsistency is a ubiquitous policy problem; indeed Kydland and Prescott used the problem of the design of a program of flood relief to motivate their treatment of monetary policy.

As originally set out by Buchanan,(op. cit.), the Samaritan's Dilemma can be viewed as a 2 □ 2 simultaneous matrix game with the following payoffs:

Table 3: Samaritan's Dilemma

	B_1 Work	B_2 No Work
Provide Help A_1	4, 3	3, 4
Provide No Help A_2	2, 2	1, 1

Here player A is a potential Samaritan, player B is in need of help. A has two strategies, A_1, "help", say by giving a money transfer and A_2, "do not help". B has two strategies, B_1 "work", and B_2 "don't work". A's payoffs are listed first.

It is easy to see that the game has one Nash Equilibrium in pure strategies, A_1, B_2. Buchanan proposes various versions of the game, but in general the outcome is the same. Thinking strategically, the victim, knowing that help is coming, shirks, thus failing to help himself.

The essence of this game can be transferred to the policy design problem for ex post catastrophe relief. To make the link to the work of Kydland and Prescott (1977), consider the payoffs to a government which is considering A_1 a policy of providing a finite, budget constrained amount of relief, or alternatively A_2 a policy of no relief.

As in the work of Kydland and Prescott (1977), the efficacy of these two policies depends on the expectations of the victims. When the victims expect that the Government will not undertake

relief, expectations B_1, they will themselves mitigate the potential loss. But if they expect the Government to provide relief, expectations B_2, they have no incentive to mitigate, and will not do so. Looking at the payoffs to the government we again have a 2 □ 2 matrix of payoffs. We assume that the government is concerned with the welfare of the victims, with payoffs as in Table 4.

Table 4: Government Relief and Mitigation Efforts

	B_1: Expect No Relief and therefore Mitigate	B_2: Expect Relief and therefore do Not Mitigate
Provide Relief A_1	4	2
Provide No Relief A_2	3	1

The worst outcome (1 on a scale from 1 to 4 where 4 is the best) is A_2 B_2 in which the citizens make no plans for the disaster and the government provides no relief. The best outcome is A_1 B_1 in which the Government provides its budget limited relief to top up the private mitigation efforts to the extent that they did not fully protect against the flood.

The ordering of the other two outcomes, A_2 B_1 (no Government help but private citizens mitigate) and A_1 B_2 (Government help but no private mitigation) depends on the effectiveness of private mitigation versus the amount of relief which a budget constrained Government can afford. The interesting case is the ranking in Table 2 in which private mitigation leads to a better outcome than a Government can provide with limited relief.

This case is an example of a decision-theoretic problem called Newcomb's problem, Broome (1989) . This problem arises when a decision maker must make one of several decisions in such a way that its payoff is affected by whether or not its action was anticipated by another rational agent with good predictive powers. In this case, as here, no one uniquely best rational course of action exists.

To see this, we ask what Government policy should be in this case? If we assume that individuals correctly anticipate government action, then if the Government provides relief, it will have been expected, and no mitigation will have been undertaken. This outcome is worse than the Government doing nothing, since in this case flood losses will have been reduced by the actions of the potential victims. This calls for a rule of “do nothing”.

However, this framework permits another way of reasoning. Before the Government acts, people will have already formed their expectations, and will either have mitigated or not. No matter which, the results of providing relief are better than the results of not providing relief. Therefore the Government should provide relief.

The optimal rule a la Kydland and Prescott is a rule of “no help.” But having adopted such a rule, with the mitigation in place, it would seem appropriate to break the rule and provide relief. As Friedman, O’Driscoll, and Schotter (1982) have argued, the first casualty of this time inconsistency problem is rational expectations itself. Since there is no obvious best course for the Government, it is not possible for the agents to have rational expectations regarding it.

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