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On the Optimal Design of Disaster Insurance in a Federation

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On the Optimal Design of Disaster Insurance in a Federation

Abstract

Recent experience with disasters and terrorist attacks in the US indicates that state and local governments rely on the federal sector for support after disasters occur. But these same governments are responsible for investing in infrastructure designed to reduce vulnerability to natural and man-made hazards. This division of responsibilities – state governments providing protection from disasters and federal government providing insurance against their occurrence – leads to the tension that is at the heart of our analysis. We explore these tensions building on the model of Persson and Tabellini (1996). We show that when the federal government is committed to full insurance against disasters, states will have incentives to underinvest in costly protective measures. We then show that when the central government cannot verify state investment choices, the optimal insurance system would be designed to reward states that succeed in avoiding disasters and punish those that do not, thereby giving states an incentive to increase investment in protective infrastructure. However, this raises the question of whether the central government can credibly commit to such a scheme, and we find in a simple political model that it cannot. In our political model, the central government will decrease transfers ex-post if a state provides protective infrastructure that increases its expected uncertain income, generating a soft-budget constraint for states. This provides an additional incentive for states to underinvest in protective infrastructure. We discuss these results in light of disaster policy in the US.

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I. Introduction

Chaos in New Orleans in the wake of Hurricane Katrina and the controversy that continues to swirl around the public sector response have led to a broad discussion of the appropriate roles of various levels of government in disaster management and preparedness. A central theme in press and pundit accounts of what went wrong in New Orleans was conflict between those who argued that the disaster was attributable to local officials' failure to adequately prepare for an easily predictable set of events and those who blamed a slow and inadequate response by federal officials (Walter and Kettl 2006).[1]

While recent events have brought these questions to the forefront of public debate, many of the same issues have arisen in previous disasters, including the earthquakes, hurricanes and floods that irregularly strike particular geographic areas of the US. Clearly, a combination of preparedness and effective response are crucial to minimizing the overall welfare losses from these region-specific shocks. Yet policy design must confront a tradeoff between efficiently allocating resources ex ante to minimize potential losses, and dealing equitably with residents of regions that experience significant losses ex post. This tradeoff and its implications for the design of public disaster insurance are the subject of the current study.

The problem of the public sector's role in preparing for and responding to disasters has been the subject of considerable recent scholarly interest. In part, this work has stemmed from a belief that natural hazards have increased in their frequency and intensity in recent years, a belief that appears to be largely consistent with at least a

[1] Thomas (2005) provides an overview of events in the period immediately surrounding the breach of New Orleans' levees; neither federal nor state and local officials come out looking very good. See http://www.msnbc.msn.com/id/9287434.

cursory review of the data on disaster declarations in the US.[2] In addition to their increased frequency, Richard Zeckhauser (2006) has argued that the distribution of disaster losses exhibits "fat tails" – losses experienced in the worst disasters are many times worse than those experienced in the second worst – implying that the most serious events may be expected to be extraordinarily costly.[3]

Our paper is related to several strands of literature. The existence of natural hazards produces risks to income flows in particular places. One strand examines the role that federalist institutions can play in insuring residents of a federation against income loss (von Hagen 1998 provides a useful review). When shocks to regional incomes are independent or negatively correlated, an insurance contract can be derived that transfers resources from regions that realize high income to those that sustain a negative shock. One example is when regional business cycles are not completely in phase. In such circumstances, a policy institution that provides a transfer to regions with strong growth fundamentals that are experiencing a downturn can enhance both aggregate stability and equity (see, for example, Bayoumi and Masson 1995). An empirical literature has sought to quantify the actual size of such transfers, an effort which is complicated by correlations in shocks across regions, by difficulty in distinguishing temporary from permanent shocks, and by the distinction between aggregate income and aggregate output. Melitz and Zumer (2002) summarize previous results and provide a well-founded estimate that central government redistribution offsets about 20% of shocks

[2] See, for example, data on Presidentially declared disasters on the FEMA website http://www.fema.gov/news/disaster_totals_annual.fema; last accessed August 28, 2006. Note, however, that these declarations reflect losses, which are jointly determined by hazards and vulnerability.

[3] When the subject is broadened to include potential losses from terrorism - disasters planned and executed by intelligent opponents as compared to a relatively passive natural environment - the complexity and need for serious attention become even more pronounced.

to personal income in four countries.[4] Within economically developed federations, central government insurance is thus an important resource for regions experiencing negative shocks.

A second strand emphasizes asymmetric information and the moral hazard aspects of intranational insurance as in Persson and Tabellini (1996).[5] We adapt many features of Persson and Tabellini's (1996) model to the study of natural disasters. Persson and Tabellini study the institutions of federalism in an economy characterized by uncertainty about future income in distinct regions of a federation, a situation that well describes the natural disaster setting. In Persson and Tabellini, as in our model, we abstract from household mobility and focus on immobile governments. Our focus does not imply that mobility is an unimportant feature of disasters. Indeed, location choice is a fundamental part of the process that determines vulnerability and is relevant to designing appropriate disaster response. Nonetheless, while residents may choose to relocate either before or after a disaster strikes, governments are defined by particular geographic areas and are thus fixed in place. We thus interpret our model as shedding light on the interplay between disaster risk and the institutions of federalism, not on the relationship between a central government and individuals. The latter interaction is considered by Kunreuther's (2006) work on public disaster insurance for individual households and firms and Wildasin's (2006) work on federal disaster insurance with mobile households.

A third strand of literature relates to "second generation" models of federalism as reviewed by Oates (2005). This emerging literature is often characterized by models in

[4] France, the UK, the US and Canada

[5] Other papers that study various aspects of asymmetric information and insurance in a federation include Bordignon, Manasse, and Tabellini (2001), Caplan, Cornes, and Silva (2000), Raff and Wilson (1997), and Lockwood (1999).

which information, politics, and strategic decisions play important roles. Our paper fits into this emerging body of literature.

Hazards policy in the United States is a complex interplay between the federal and state-local sectors. Broadly speaking, state and local officials bear primary responsibility for minimizing vulnerability to natural hazards through policies such as land use regulation, investment in protective infrastructure and providing resources designed to enhance emergency response.

While the federal government is involved in these activities to a limited extent (Corps of Engineers flood control grants are a prominent example), the bulk of federal resources are devoted to providing assistance to individuals and governments after disasters occur. Between fiscal years 1974 and 2005, Presidents declared over 1,200 disasters in the United States, and the federal government appropriated over $80 billion (constant FY 2005 dollars) for disaster relief. As indicated in the figure, as the annual number of declared disasters has risen, the average cost per year has risen above $3 billion.

While much of this relief was provided to individuals and businesses, a substantial portion takes the form of grants-in-aid to state and local governments. Since 1998, the Federal Emergency Management Agency (FEMA) has obligated an average of over $2 billion per year to public sector disaster assistance. Roughly three quarters of these expenditures have been designated for ex post emergency response and repair of public facilities.[6] This division of responsibilities – state governments providing protection from disasters and federal government providing insurance against their

[6] These figures exclude the response to the September 11, 2001 terrorist attack. That event alone resulted in a $7 billion Congressional appropriation.

occurrence – leads to the tension that is at the heart of our analysis. When the federal government is committed to full insurance against disasters, states will have incentives to underinvest in costly protective measures.

A second tension we highlight results from the timing of insurance commitments by the federal government. As indicated in the figure, more than half of the federal funds provided for disaster relief since 1990 have been the result of supplemental appropriations. That is, Congress has elected to appropriate large amounts of additional federal compensation to victims *after disasters occur*, raising questions about commitment that we explore in Section IV.

The paper is organized as follows. Section II describes the economy we study, and lays out the basic model of federalism with uncertain incomes. In this section we also derive the optimal insurance scheme and level of investment in protective infrastructure for the federation and demonstrate that when individual states act non-cooperatively, they will underinvest relative to this optimum. In section III, we describe the structure of the optimal insurance system when state governments choose investment levels independently and the central government cannot verify state investment choices. This system is designed to reward states that succeed in avoiding disasters and punish those that do not, thereby giving states an incentive to increase investment in protective infrastructure. This goes some way towards internalizing the externality produced by central government insurance by in effect reducing the completeness of the insurance. Section IV contains an analysis of a distinct aspect of the problem. If the central government is unable to credibly commit to the constrained-optimal insurance plan of section III, as we show will likely be the case in a simple political model, then states will

recognize a soft budget constraint and will again underinvest in protective infrastructure. Section V concludes with a discussion of what the model can teach us about the federal response to recent disasters and those yet to come.

II. Underinvestment with Moral Hazard

We begin with a simple model of a federation with two state-level governments. To differentiate the two states, variables for one of the states are denoted with asterisks. Each state's income has certain and uncertain components. The uncertainty results from i.i.d. shocks. Uncertain income can be high with probability P or low with probability (1 – P). A state can use some of its certain income ($\overline{Y}$) to invest in protective infrastructure, I, (e.g. levies or police) and this investment increases the probability of ending up with high income, so P is a function of I. There are thus four joint possibilities for uncertain income:

i. (Y_H, Y^*_H) with probability P(I)P(I*)

ii. (Y_H, Y^*_L) with probability P(I)(1-P(I*))

iii. (Y_L, Y^*_H) with probability (1-P(I))P(I*)

iv. (Y_L, Y^*_L) with probability (1-P(I))(1-P(I*))

First-best optimal transfers for given investment levels

States are assumed to be risk averse and risk sharing in the federation is accomplished through a set of transfers. The central government wants to choose

transfers T_{ij} and T^*_{ij} for i=L,H and j=L*,H* to maximize the sum of expected utilities subject to the constraint that the transfers are self-funding, i.e. $T_{ij}^* = -T_{ij}$:

$$\begin{aligned}
&\underset{T}{\text{Max}}\ \bar{Y} - I + \bar{Y}^* - I^* \\
&+ P(I)P(I^*)u\,(Y_H + T_{HH^*}) \\
&+ P(I)(1-P(I^*)u(Y_H + T_{HL^*}) \\
&+ (1-P(I))P(I^*)\,u(Y_L + T_{LH^*}) \\
&+ (1-P(I))(1-P(I^*))\,u(Y_L + T_{LL^*}) \\
&+ P(I)P(I^*)u\,(Y^*_H - T_{HH^*}) \\
&+ P(I)(1-P(I^*)u(Y^*_L - T_{HL^*}) \\
&+ (1-P(I))P(I^*)\,u(Y^*_H - T_{LH^*}) \\
&+ (1-P(I))(1-P(I^*))\,u(Y^*_L - T_{LL^*})
\end{aligned}$$

This yields the FOC:

$$E(\frac{\partial u}{\partial T_{ij}}) = E(\frac{\partial u^*}{\partial T_{ij}}) \quad i = L,H;\ j = L^*,H^*$$

where u* henceforth denotes utility given the value of the starred state's arguments. This first order condition says that transfers should be set to equalize the expected marginal utility of transfers across the two states. Hence, optimal transfers for a given state investment level in the first-best results in full risk-sharing. For cases (i) and (iv) above no transfers occur. For cases (ii) and (iii), income is transferred from the state that realizes high income to the state that realizes low income. With symmetric states (that is, identical utility functions, $Y_L = Y_{L^*}$, and $Y_H = Y_{H^*}$), optimal transfers will equalize the expected value of the uncertain component of income.

First-best state investment levels

Now consider the level of state investment that maximizes the sum of expected utilities. In the first-best, we assume that the central government commits to full risk-sharing grants that depend on the joint incomes of the two states, and that transfers will be unrelated to investment in protective infrastructure; this assumption will be relaxed later. Here there is no information problem since the central government is able to choose investment levels directly. In this case, the first-best optimal investment solves:

$$\begin{aligned}
&\underset{I}{\text{Max}}\ \bar{Y} - I + \bar{Y}^* - I^* \\
&+ P(I)P(I^*)u\,(Y_H + T_{HH^*}) \\
&+ P(I)(1-P(I^*)u(Y_H + T_{HL^*}) \\
&+ (1-P(I))P(I^*)\,u(Y_L + T_{LH^*}) \\
&+ (1-P(I))(1-P(I^*))\,u(Y_L + T_{LL^*}) \\
&+ P(I)P(I^*)u\,(Y^*_H - T_{HH^*}) \\
&+ P(I)(1-P(I^*)u(Y^*_L - T_{HL^*}) \\
&+ (1-P(I))P(I^*)\,u(Y^*_H - T_{LH^*}) \\
&+ (1-P(I))(1-P(I^*))\,u(Y^*_L - T_{LL^*})
\end{aligned}$$

and the FOC is:

$$\begin{aligned}
&\frac{\partial P}{\partial I}\left[P^*\{u(Y_H) + u(Y_H^*)\} - (1-P^*)\{u(Y_L) + u(Y_L^*)\}\right] \\
&+ \frac{\partial P}{\partial I}(1-P^*)\left[\{u(Y_H + T_{HL^*})\} + \{u(Y^*_L - T_{HL^*})\}\right] \\
&- \frac{\partial P}{\partial I}P^*\left[\{u(Y_L + T_{LH^*})\} + \{u(Y^*_H - T_{LH^*})\}\right] = 1
\end{aligned}$$

where we use the fact that $T_{HH^*} = T_{LL^*} = 0$. With symmetric states (defined above) and transfers that exhibit full risk-sharing as derived above (so that $Y_H + T_{HL^*} = Y^*_L - T_{HL^*}$) this reduces to:

$$2\frac{\partial P}{\partial I}P*\left[u(Y_H\ )-u(Y_L\ +T_{LH*})\right]-2\frac{\partial P}{\partial I}(1-P*)\left[u(Y_L\ )-u(Y_H\ +T_{HL*})\right]=1$$

For future reference, notice that if there were no transfers the first order condition would reduce to:

$$\frac{\partial P}{\partial I}\left[u(Y_H\ )-u(Y_L)\ \right]=1$$

The presence of the transfers has inserted an externality into the problem because they make it so that one state's investment affects the utility of the other state.

Non-cooperative state investment levels given transfers

We now want to explore the investment decision of an individual state that acts non-cooperatively. How much protective infrastructure will a state provide? An individual state's maximization problem is:

$$\begin{aligned}&\underset{I}{\text{Max}}\ \overline{Y}-I\\&+P(I)P(I*)u\ (Y_H\ +T_{HH*})\\&+\ P(I)(1-P(I*)u(Y_H\ +T_{HL*})\\&+(1-P(I))P(I*)\ u(Y_L\ +T_{LH*})\\&+(1-P(I))(1-P(I*))\ u(Y_L\ +T_{LL*})\end{aligned}$$

The first order condition is:

$$\frac{\partial P}{\partial I}P*\left[u(Y_H\ )-u(Y_L\ +T_{LH*})\right]-\frac{\partial P}{\partial I}(1-P*)\left[u(Y_L\ )-u(Y_H\ +T_{HL*})\right]=1$$

The right hand side is the direct marginal cost of greater investment which results in lower certain income and consumption. The left hand side is the marginal expected

increase in utility resulting from the fact that an increase in investment increases the probability of ending up with Y_H and decreases the probability of ending up with Y_L. Comparing to the above problem, the first order conditions are the same except that the two left hand side terms are multiplied by two in the previous problem. This is because one state's investment decision affects the probability of ending up in each of the four joint income possibilities. The state takes into account the effect of its investment on its own utility, but does not take into account the effect on the utility of the other state. In other words, state 2 benefits from an increase in state 1's probability of ending up with Y_H (holding state 2's probabilities constant). State 1 ignores this benefit in its investment decision and invests too little in protective infrastructure from a social point of view.

Notice that if there were no transfer system, an individual state's FOC reduces to:

$$\frac{\partial P}{\partial I}\left[u(Y_H) - u(Y_L)\right] = 1$$

and the state would undertake the first-best level of investment. The transfers have inserted an externality into the investment problem of the state.

To summarize, the central government can offer full risk-sharing, which would be first-best optimal if the central government could also choose state investment levels. However, if states choose their own investment levels while the central government offers full risk-sharing transfers, states acting non-cooperatively will underinvest in protective infrastructure. If there were no transfer system, states would choose investment levels optimally.

III. Transfers that Increase Investment by Trading-off Risk Sharing

We have thus far shown that if the central government commits and offers first-best optimal transfers with full risk-sharing while states choose their investment levels and act non-cooperatively, states will tend to underinvest in protective infrastructure from a national perspective. Thus, first-best investment and first-best risk-sharing transfers cannot be achieved under these circumstances.

We next consider whether the central government can design a transfer system to increase state investment in protective infrastructure by trading-off the risk-sharing benefit of transfers. One aspect of this is how the central government can get the states to voluntarily invest in a high level of protective infrastructure at the lowest cost in terms of transfers. If the central government cannot verify state investment levels, transfers cannot be set to depend on investment levels directly. Rather, the central government must depend instead on the observed income of the two states. The problem is to find the minimum transfer necessary to induce a certain level of protective infrastructure subject to (i) the participation constraint that utility of the state given the transfer is greater than a reservation utility level, and (ii) the incentive compatibility constraint that the level of utility of the state given that it chooses a high level of protective investment is greater than or equal to its level of utility if it chooses a low level of investment. The participation constraint is included here because we are interested in a constitution in which states voluntarily agree to the transfers rather than opting out of the federation altogether.

To investigate the design of transfers that will elicit a high level of state investment in protective infrastructure while minimizing expenditures on transfers, we

modify the problem of the previous section in two ways. First, we will write the problem in indirect form. This will allow us to set up a minimization problem with a well-behaved objective function and linear constraints. To do this we define $t_{LH*} = u(T(Y_L, Y_{H*}))$ as the utility of the transfer T that is based on the state's observed income Y_L and the other state's observed income Y_{H*}. Letting v be the inverse of u, the transfer paid to a state given the observation of income Y_L as a function of t_{LH*} is $T(Y_L, Y_{H*}) = v(t_{LH*})$.

The second modification we make is to generalize the problem to consider the case in which uncertain income is drawn from a finite set $Y = \{Y_1, \ldots, Y_M\}$ for each state. We also simplify somewhat by assuming that a state can choose from a finite set of investment levels $I = \{I_1, \ldots, I_N\}$. Given an investment level I_n, the probability that income level Y_m is produced is P_{nm} where $\sum_m P_{nm} = 1$ for each investment level.

Given these two modifications, the expected transfer the central government must pay if the state undertakes an investment level I_n (the objective function that the central government is trying to minimize) is:

$$\sum_{m^*} \sum_{m} P_{nm} P_{n^*m^*} v(t_{mm^*})$$

For the first constraint, we must be sure that, given the level of investment, the state is at least as well off in expected value terms with the transfers than with no transfers. The first constraint becomes:

$$\sum_{m^*} \sum_{m} P_{nm} P_{n^*m^*} t_{mm^*} \geq 0$$

For the second constraint, we must be sure that the state is better off with its chosen investment level I_n than with some other investment level:

$$\sum_{m^*} \sum_{m} P_{nm} P_{n^*m^*} t_{mm^*} - I_n \geq \sum_{m^*} \sum_{m} P_{n'm} P_{n^*m^*} t_{mm^*} - I_{n'}, n' = 1, \ldots, N$$

The first order condition for t_{mm*} is:

$$\frac{\partial v}{\partial t_{mm*}} = \lambda + \sum_{n'} \Phi_{n'} \left(1 - \frac{P_{n'm} P_{n*m*}}{P_{nm} P_{n*m*}}\right)$$

where λ denotes the Lagrange multiplier on the first constraint and $\Phi_{n'}$ denotes the multiplier on the second constraint for n'.

This first order condition has an interesting interpretation. First, suppose that there are no incentive problems so that none of the relative incentive constraints (the second set of constraints) bind. This would be the case if, for instance, investment were observable. Then the first order condition reduces to

$$\frac{\partial v}{\partial t_{mm*}} = \lambda$$

and the optimal transfer is constant in realized income. Thus, when there are no incentive problems and states are risk-averse, the lowest cost transfer is constant in expected uncertain income. As before, the optimal transfers would equalize the marginal utility of expected transfers and would not be adjusted as ex-post income is realized. Think of this as an initial or base payment.

Now consider what happens when there are incentive problems so that the relative incentive constraints bind. Then the second term on the right hand side of the first-order condition becomes relevant and the optimal transfer will vary with the probability of a particular income level occurring with a particular investment level of the state government.

To be concrete, suppose that the probability of a high income outcome when investment is high is greater than the probability of a high income outcome when investment is low (i.e. $P_{n'm} P_{n*m*} < P_{nm} P_{n*m*}$ where n represents high investment and n'

represents low investment). According to the first-order condition, the optimal transfer would be increased in the event of a high income outcome. This gives the state an incentive to undertake high investment. Conversely, suppose that the probability of a low income outcome when investment is high is less than the probability of a low income outcome when investment is low. In this case, the optimal transfer would penalize the low income outcome by giving less than the base transfer.

The problem for the central government, i.e. the reason that it cannot peg transfers to investment directly, is that a state's investment in protective infrastructure is by assumption unobservable or unverifiable. The central government can only try to infer the investment level of the state by observing the outcome. If greater investment in protective infrastructure reduces the probability of a disaster and the amount of investment is unobservable, the central government should design grants that give states greater transfers when higher income is observed, and this should induce states to increase their investment in protective infrastructure. This, in turn, increases the chances that the state would avoid the disaster or reduces its cost. Thus, there is a trade-off between the risk-sharing insurance provided by transfers and underinvestment in protective infrastructure by states. Incomplete risk-sharing that rewards good outcomes and penalizes bad ones will give incentives to states to invest more in protective infrastructure.

IV. Timing and Ex-post Central Government Grants

Up to this point, we have assumed that the central government credibly commits to the ex-ante optimal transfers derived in the previous section. However, the transfers described in the previous section require the central government to effectively ex-ante commit to punish states that end up with a disaster in order to increase the incentive of states to invest in protective infrastructure and thereby lessen the costs of the disaster. But there is a real question concerning the credibility of the central government commitment from a political standpoint. If the central government cannot credibly commit, a different and distinct reason for underinvestment in protective infrastructure will arise: the anticipation by a state that the central government will come to the rescue with transfers if a shock occurs. If this is anticipated by the state government, the state would see a soft budget constraint and would under-invest in protective infrastructure. This soft budget constraint incentive for under-investment results from the timing of decisions and the possibility that the central government is unable to credibly commit to punish a state should a bad outcome occur.

To see this, we consider the central government's choice of transfers from an ex-post perspective and we incorporate a political motivation on the part of the central government to maximize its expected votes, following Goodspeed (2002). In so doing, we move from a normative problem to a positive one. Let p denote the probability that voters in a state vote to re-elect the government where p depends on the utility of voters in the state, $p_u > 0$, and $p_{uu} < 0$. Assuming that the unstarred state is hit by the disaster,

and assuming that state investment has already taken place, the central government chooses transfers to maximize

$$\underset{T}{\text{Max}}\ p(u(Y_L + T_{LH*})) + p*(u(Y*_H - T_{LH*}))$$

The first order conditions are:

$$\frac{\partial p}{\partial u}\frac{\partial u}{\partial T_{LH*}} = \frac{\partial p*}{\partial u*}\frac{\partial u*}{\partial T_{LH*}}$$

Notice that the central government equates the weighted marginal utility across states, with the weights being the change in the probability that the voters of a state vote for the incumbent. Solving implicitly for the politically optimal transfer yields

$$T_{LH*} = \tau_{LH*}\left(\frac{\partial p}{\partial u}(u(Y_L)), \frac{\partial u}{\partial T_{LH*}}(Y_L), \frac{\partial p*}{\partial u*}, \frac{\partial u*}{\partial T_{LH*}}\right)$$

Before we consider a state's ex-ante investment decision, we investigate how the politically optimal transfer τ_{LH*} will change with ex-post realized income of the unstarred state. The unstarred state would want to take this into account in its ex-ante investment decision since greater investment is going to increase the probability of a higher income outcome. Differentiating the politically optimal transfer function yields:

$$\frac{\partial \tau_{LH*}}{\partial Y} = p_{uu}\frac{\partial u}{\partial Y} + u_{TY}\frac{\partial u}{\partial Y} = \frac{\partial u}{\partial Y}[p_{uu} + u_{TY}]$$

The change in utility from an increased Y will be positive so that $\partial u/\partial Y > 0$. p_{uu} is negative indicating that the change in the probability of the voters of a state voting for the incumbent diminishes as utility rises. u_{TY} is also negative since the marginal utility of the transfer will be lower the higher is income. Hence, the higher income of the unstarred

state reduces the politically optimal transfer that it will receive. Through a similar argument, it is easy to show that an increase in the income of the unstarred state increases the politically optimal transfer that it will pay.

Now consider the ex-ante investment decision of the state when it realizes that the central government will implement transfers τ. The state's investment decision will solve:

$$\begin{aligned}\underset{I}{\text{Max}}\ & \overline{Y} - I \\ & + P(I)P(I^*)u\,(Y_H + \tau_{HH^*}) \\ & + P(I)(1-P(I^*)u(Y_H + \tau_{HL^*}) \\ & + (1-P(I))P(I^*)\,u(Y_L + \tau_{LH^*}) \\ & + (1-P(I))(1-P(I^*))\,u(Y_L + \tau_{LL^*})\end{aligned}$$

The first order condition is:

$$\frac{\partial P}{\partial I}P^*\left[u(Y_H) - u(Y_L + \tau_{LH^*})\right] - \frac{\partial P}{\partial I}(1-P^*)\left[u(Y_L) - u(Y_H + \tau_{HL^*})\right]$$
$$+ \frac{\partial u(Y_H + \tau_{HL^*})}{\partial \tau_{HL^*}}\frac{\partial \tau_{HL^*}}{\partial Y}\frac{\partial Y}{\partial I}P(1-P^*) + \frac{\partial u(Y_L + \tau_{LH^*})}{\partial \tau_{LH^*}}\frac{\partial \tau_{LH^*}}{\partial Y}\frac{\partial Y}{\partial I}(1-P)P^* = 1$$

where we assume for simplicity that $\tau_{HH^*} = \tau_{LL^*} = 0$. The first two terms are the same as before, so from our previous analysis we know that there will be an incentive to under-invest because of the externality. We now have two additional terms to analyze, however. These terms arise from the fact that ex-post transfers will be affected by a state's investment decision. We know that $\partial u/\partial \tau_{HL^*} < 0$, $\partial u/\partial \tau_{LH^*} > 0$, $\partial Y/\partial I > 0$, and we have just shown that $\partial \tau_{HL^*}/\partial Y > 0$ and $\partial \tau_{LH^*}/\partial Y < 0$. Hence these last two terms are negative. This is the effect of the soft budget constraint. As it undertakes its ex-ante investment decision, the state realizes that ex-post the central government will have an

incentive to decrease transfers received and increase transfers paid if the state's investment increases its expected income. Knowing this, the state under-invests in protective infrastructure, anticipating the central government response.

V. Conclusion

This paper has studied a model of federalism which highlights the tradeoff between providing appropriate incentives for protection at the local level and insuring actual losses after a disaster occurs. Our results indicate that when state government efforts to prevent disasters are unobservable, federal disaster insurance will result in underinvestment in pre-disaster protective investment. As in Persson and Tabellini (1996), centralization of the provision of protective infrastructure would eliminate inefficiency by eliminating the moral hazard.

Unfortunately, we believe that current US disaster policies may be susceptible to the dual problems of unverifiable local investment and a federal inability to commit to solutions that would lower the moral hazard problem. In particular, since information about local vulnerability – and which protective investments actually reduce this vulnerability - is likely to be most easily available to state officials, the principal responsibility for protective investment falls on state and local governments. Meanwhile, a large share of post-disaster relief funds come from the federal fisc. Our model suggests that in this institutional environment states have significant incentives to underinvest in protective infrastructure.

Steinberg's (2000, pp 103-111) account of the National Flood Insurance Program (NFIP) is an example of the incentives of unverifiable local investment at work. The

NFIP, adopted in 1968, offered insurance to residents of 100-year floodplains at heavily subsidized rates. In exchange, local officials were to increase protection by requiring that new structures be built above the 100-year flood level. Yet in the interest of economic development, officials in some locations granted numerous variances to these regulations, leading to ever-expanding claims on the flood insurance program.

Federal transfers which reward successful avoidance of disasters would allow achievement of the constrained optimum when local investment is unverifiable. But the effectiveness of such a regime requires credible ex ante commitment by the federal government. This commitment may be difficult to sustain in a political model. Again, the evidence provides some support to this result. In recent years, initial Congressional appropriations to the Disaster Relief Fund have been heavily supplemented after disasters have occurred. When states anticipate an ex post bailout, they will again underinvest, as our analysis of the soft budget constraint problem indicates.

While the model presented here provides preliminary insights into the nature of the problems raised by natural disasters, we see several directions in which this work could be extended. Here we describe two of these. Both of these extensions may add some richness to the findings reported here, but we believe that neither is likely to reverse our main conclusions.

We model state government investment in protective infrastructure, but another major source of risk mitigation by state and local government consists of regulations: building codes, land use restrictions and the like. Such regulations are often seen from the state perspective as diminishing local economic growth, implying that our modeling assumption captures the basic issue. Nonetheless, explicit treatment of the choice

between structural and regulatory mitigation techniques might yield more nuanced insights.

A second possible extension concerns the potential for spillovers from protective investments. In the case of flood control, for example, structures built to prevent flooding in one location can increase their probability in others. A well-known example is levees on the Mississippi River, which force flood waters to other, unprotected, locations. Generalizing the model to account for such externalities in the effects of protective investments will allow a more complete examination of the issues.

The problems raised by geographically-concentrated shocks to income, regardless of their probability and magnitude, are difficult to solve. We study a simple model that we believe captures features of US disaster policy. In our model, underprovision of disaster protection will result from either full federal ex ante insurance or from ex post federal bailouts after disasters. The challenge is to provide appropriate incentives for local protective actions, whether regulatory or structural, while maintaining the benefits of insurance against large shocks. This is a difficulty that has bedeviled disaster policy makers for generations. Rewarding successful *avoidance* of disasters is one path to the constrained optimum. Achieving these benefits, however, requires more post-disaster discipline on the part of Congress than it has historically demonstrated.

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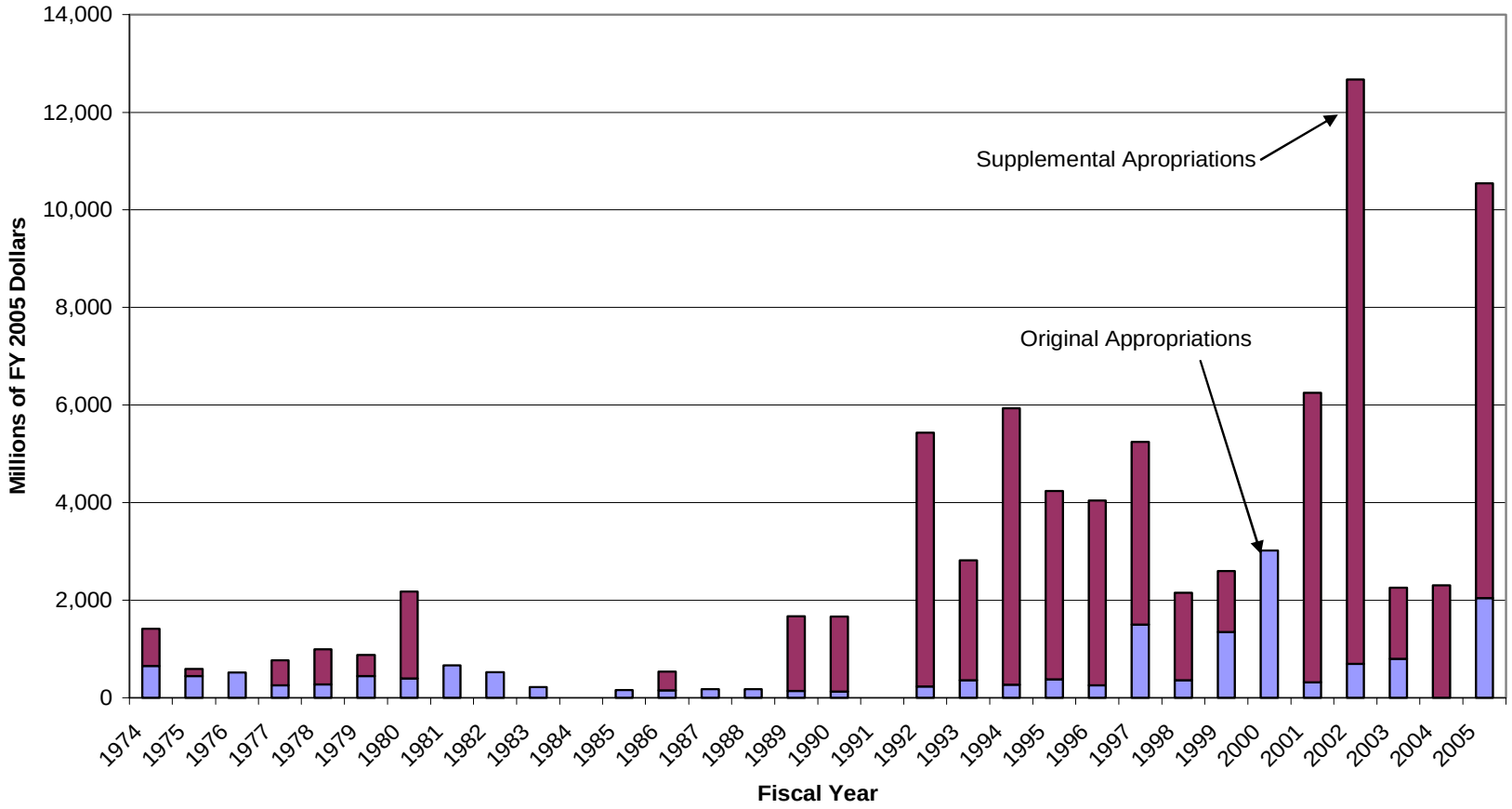

Source: Bea (2005). Note: Data exclude effects of Hurricane Katrina

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