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# Measuring the Financial Shocks of Natural Disasters: A Panel Study of U.S. States

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## Abstract

This paper employs panel vector autoregression to examine the dynamic fiscal response to disaster shocks. With 50-state, 1970-2013 panel data of state government finance and disaster damage, we estimate disaster impacts on revenue, expenditure, debt issuance, and intergovernmental transfers. We find that following a disaster, states increase program expenditure, but receive more federal transfers. Disasters have limited impact on total tax revenues but amplify fluctuations in sales, income, and property tax revenues. Our findings suggest that disaster-induced additional spending is largely financed through federal transfers, which include not only disaster relief funds but also non-disaster-related public welfare aids.

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## I. INTRODUCTION

Natural disasters cause tremendous mortalities and economic damages, often resulting in significant economic disruptions for the affected regions (e.g., lower output, lost jobs). Disasters also pose severe shocks to public budgets and finance (Benson and Clay, 2004). They may dent the existing tax base and reduce government revenue as a result of business interruptions; they also incur considerable costs in disaster response, relief, and recovery, thereby increasing public expenditure and inducing mid-year budgetary adjustments. These follow-on consequences raise a series of questions regarding the relationship between public finance and natural disasters. Specifically, how should we evaluate the fiscal costs of natural disasters and their welfare implications? How is this burden shared across different levels of government and distributed inter-temporally (over multiple budget cycles)? All these questions become increasingly important to both policymakers and researchers, given that natural disaster damages keep growing and climate change is expected to increase the frequency and intensity of extreme weather events (Intergovernmental Panel on Climate Change, 2012).

Although there is a vast literature on the short- and long-run economic impacts of natural disasters, far fewer studies have examined the fiscal dimension and almost all are cross-country studies using aggregate national fiscal accounts (Noy and Nualsri, 2011; Ouattara and Strobl, 2013; Melecky and Raddatz, 2011) so that little is known about disaster-induced fiscal consequences for subnational governments and the intergovernmental dynamics in responding to these shocks. These issues demand attention because natural disasters typically occur at the local/regional level and large-scale shocks that exceed local responding capacity often necessitate intergovernmental responses and coordination. This paper examines how natural disasters affect American state government finances with regard to their expenditures, tax

revenues, intergovernmental transfers, and use of debt, using the panel vector autoregression (VAR) model on a panel of 50 states from 1970 through 2013. Our research presents one of the few initial attempts to empirically investigate how states interact with the federal government in their fiscal responses to natural disasters.

This paper contributes to the extant literature of public finance and natural disasters in several important ways. First, several recent studies have investigated state fiscal responses to economic crisis and output fluctuations (e.g., Poterba, 1994; Sorensen et al., 2001), whereas little attention has been paid to the financial shocks triggered by natural disasters. Our research fills this gap by focusing on the fiscal implications, which not only aids the estimation of the entire economic costs of natural disasters (e.g., Kousky, 2012; Hallegatte, 2015), but also assists governments in better projecting future disaster costs and budgeting for natural hazards and disaster risk management (Noy and Nualsri, 2011; Phaup and Kirschner, 2010).

Second, almost all extant studies on this subject looked into the fiscal impacts at aggregated national level and inevitably ignored the within-country intergovernmental transfers of disaster costs. Our study makes a unique contribution by investigating how intergovernmental relations shape the cost distribution of natural disasters between the central and subnational governments. The U.S. federalist system provides a particularly interesting context for studying these questions. The Stafford Disaster Relief and Emergency Assistance Act of 1988 and its antecedents from the Disaster Relief Act of 1950 authorize the President to issue disaster declarations which trigger federal aid in the form of various assistance and recovery programs to state, local, and tribal governments.[1] The past few decades have seen an expanded federal role in

[1] When a natural disaster strikes and overwhelms the resources and capabilities of state and local governments, the state's governor may submit a request for federal assistance. After the request and disaster damages are evaluated by FEMA, the President can either approve the request and issue Presidential Disaster Declaration (PDD) or deny the request. The FEMA's Disaster Relief Fund (DRF) is the primary funding source for disaster response and recovery.

disaster assistance as well as a rapidly growing federal budget on disaster relief and recovery.[2] Motivated by this fact, this paper not only delves into the federal and states' financial exposure to natural disaster risks, but also sheds light on the cost distribution and welfare implications.

Finally, this paper goes beyond the traditional estimation of aggregate revenue and expenditure responses to decompose the disaster impact on a variety of state fiscal components. This helps us better understand the mechanism through which natural disasters may affect government finances, and also provides additional insights into the determinants of fiscal resilience to external disaster shocks.

To preview our results, we find that after experiencing a disaster, state governments increase their total expenditure while receiving more federal transfers. Despite their seemingly limited impact on total own-source revenues, natural disasters cause substantial fluctuation of the general sales, income- and property-tax revenues collected by state governments. On the expenditure side, state governments respond to natural disasters by increasing capital outlays, state-to-local transfers, and social welfare outlays. Our results suggest that a considerable portion of the disaster-induced governmental spending at the state level is financed through federal transfers, which include not only post-disaster relief and recovery assistance but also non-disaster-related expenditure of the existing social safety net programs. Additionally, we use historic data on annualized disaster losses and federal disaster relief expenditures to estimate the direct damage-spending relationship. Overall, our study suggests substantial disaster-induced re-

When a catastrophic incident threatens to deplete the DRF, the President typically submits a request to Congress for supplemental appropriation.

[2] According to the President's Office of Management and Budget (OMB), in the 2004-2013 period the federal government incurred over $300 billion in direct costs associated with extreme weather and fire alone, more than half of which ($176 billion) was for direct disaster responses and relief, and the remaining were spent on flood and crop insurance, and wildland fire management. Other research findings (e.g., NDRC, 2014) provide even high estimates.

distributional effects and significant financial exposure of the federal government to disaster risks.

The remainder of the paper is organized as follows. The next section briefly reviews the relevant literature; Section III describes our data sources; Section IV presents our empirical methodological framework and the main results on aggregate and disaggregate fiscal responses. Section V discusses our results and concludes.

## II. RELEVANT LITERATURE

There is an extensive literature documenting the economic effects of natural disaster events in both multi-country and single-country contexts, mostly linking disaster damage and frequency data with macroeconomic variables, including gross domestic product and economic growth (for a more recent review see Kousky, 2012). From a theoretical point of view, natural disasters cause business interruptions and output losses by destroying properties, capital stock and workforces (endogenous growth models); but on the other hand, neoclassical models suggest that disasters may serve as a "creative destruction" by providing the opportunity to update capital stocks and adopt new technologies (Schumpeter, 1942; Cuaresma et al., 2008), which may counterbalance the negative disaster impacts. The unsettled theoretical propositions resonate with the mixed empirical evidence: some studies (e.g., Raddatz, 2007; Noy, 2009; Hochrainer, 2009; Strobl, 2011) find natural disasters exert a negative effect on output growth, whereas others show a positive impact from disasters (e.g., Skidmore and Toya, 2002). Also worth noting is that these studies vary substantially on the time horizon (short term *versus* long term), types of natural hazards, sample of countries or regions, and sectors affected by disasters (e.g., Loayza et al., 2009; Hornbeck, 2012).

Despite the growing disaster economics literature, little research has looked into the fiscal impact of natural disasters, which can often operate through multiple channels. On the public expenditure side, disasters usually result in considerable costs of emergency responses, relief, and recovery. The additional disaster spending may postpone planned investment, lead to a reallocation of budgetary resources (e.g., decreases in other non-disaster-related expenditures) and affect the general provision of public services (Benson and Clay, 2004).[3] On the revenue side, the effect of natural disasters is associated with the direct physical damages and disaster-induced macroeconomic impacts. Business interruptions and lower output could shrink the tax base, which means less revenues at a time of increased governmental spending. The revenue impact also depends on the structure of taxation and other forms of government revenues (Noy and Nualsri, 2011). It is possible that government may adjust its taxation policy in response to large disaster shocks, which can include either providing tax reductions to stimulate economic recovery or increasing taxation to cover the additional disaster-induced spending (Benson and Clay, 2004). From the perspective of subnational governments, their responses to disaster shocks can be affected by the amount of aid received from the central government, as well as the availability of their financial resources, administrative capacity, and overall fiscal institutions.

As we mentioned earlier, the extant empirical evidence on the fiscal impacts of natural disasters is largely limited to cross-country comparisons. Melecky and Raddatz (2011, 2014) estimate the impact of different types of disasters (geological, climatic, and others) on government expenditures, revenues, and deficit by using a panel data set of high- and middle-income countries over the years of 1975 through 2008. Using the panel VAR model, they find that natural disasters, particularly climate hazards, affect a country's fiscal stances by increasing

[3] However, Fengler et al. (2008) notes the other possibility of lower reconstruction costs because the destroyed capital or infrastructure may already be obsolete and required replacement.

budget deficits, and this effect is particularly pronounced in lower-middle-income countries. Lis and Nickel (2010) examine the impacts of large extreme weather events on country-level public budgets, based on a country fixed effect model. Their findings are similar to Melecky and Raddatz (2011) in that developing countries experience much larger budgetary impacts compared to developed countries. Noy and Nualsri (2011) use quarterly fiscal data for a panel of 42 countries for the period of 1990 through 2005 to examine how fiscal responses to large-scale natural disasters differ between developed and developing countries. Also employing the Panel VAR model, they find a response of increased spending and decreased revenues in developed countries but of decreased spending and increased revenues in developing counties. Finally, Ouattara and Strobl (2013) focus on the impact of hurricanes on a sample of Caribbean countries. Their study shows that hurricane strikes only significantly increase government spending, with no obvious effects on public investment, tax revenue, and debt.

Almost no research has systematically examined the fiscal implication of natural disasters at the subnational level. The only exception might be Yang et al. (2012). In a recent working paper using U.S. state-level fiscal and macroeconomic data, they find that natural disasters have increased both state government spending and revenues, with a large portion of the increased expenditures driven by federal intergovernmental transfers. Our research further improves their work by using higher quality disaster data and a more rigorous estimation methodology, and moreover, examining the disaster impacts on disaggregate fiscal outcomes (e.g., tax revenues by type, separating federal disaster-related aid from non-disaster-related transfers).

## III. Data

We create a balanced panel with measures of state government financial outcomes at both the aggregate and disaggregate levels, and total damages states experienced from natural disasters each fiscal year. Our sample includes all 50 states over the period of 1970 through 2013. Table 1 presents the descriptive statistics of the main variables used.

## A. State Government Finance

Our fiscal variables are from the U.S. Census Bureau's *State Government Finances Survey*, which contains the annual statistics on government revenue by source, expenditure by object and function, indebtedness by term, and assets by purpose. At the aggregate level, we include each state government's total own-source revenues (including taxes, current charges, and other types of revenue), total expenditures (including intergovernmental and direct expenditures), total intergovernmental revenue from the federal government, and long-term debt issued. In addition, we divide these aggregate accounts into their main components to measure the disaggregate fiscal outcomes: own tax revenues by source (general sales tax, individual income tax, corporate net income tax, property tax); expenditures on current operations, capital outlay, intergovernmental expenditures to the local level, and social welfare payment;[4] and federal transfers by function (housing and community development, natural resources and agriculture, and public welfare). To complement the data on total federal transfers, we also collect data on the disaster relief aid provided by the Federal Emergency Management Agency (FEMA) from the Census Bureau's *Federal Aid to State reports*, which documented federal government aid to state and local governments by agency and program.[5] The FEMA data are available for the fiscal

[4] It includes insurance benefits and repayments, and assistance and subsidies.
[5] FEMA's reported disaster relief aid is comprised of primarily Disaster Relief Funding, disaster assistance direct loan financing account, and flood mitigation assistance. It should be noted that FEMA's disaster relief represents a large proportion of the federal disaster relief, although there are other federal agencies, including United State Department

years from 1981 to 2010. All the fiscal variables are deflated using the Bureau of Labor Statistics' consumer price index for urban consumers (year 2000 = 100), and divided by the real state gross product (GSP) in the previous year, with the data retrieved from the U.S. Bureau of Economic Analysis.

[Table 1 about here]

**B. Natural Disaster Severity**

Given that public finance statistics are reported on a fiscal-year annual basis, we collect monthly disaster damage data from the Spatial Hazard Events and Losses Database for the United States (SHELDUS)[6] to match state-specific fiscal years.[7] SHELDUS is a county-level hazard loss data set of 18 different types of natural disaster events including hurricanes, floods, earthquakes, and tornados.[8] To measure the severity of natural disasters, we calculate state-level total economic losses (including direct crop and property damages) from all types of natural hazards recorded in SHELDUS. Although using the sum of disaster losses may mask the heterogeneity in states' risk profiles and disaster-specific effects, the aggregate term can better capture the overall severity of extreme events hitting a state within a certain time period and

of Agriculture and Department of Housing and Urban Development, which are engaged in providing assistance and direct relief to disaster-stricken states and localities.

[6] The database is maintained by the Hazards and Vulnerability Research Institute at the University of South Carolina. SHELDUS DATA are assembled from public sources such as the National Climatic Data Center's monthly publications.

[7] According the Census Bureau, most state government fiscal years end on June 30 except for four states with other ending dates: Alabama and Michigan (September 30), New York (March 31), and Texas (August 31).

[8] The 18 types of hazards recorded in SHELDUS include hurricanes, flooding, earthquakes, droughts, tornadoes, winter weather, severe storm/ thunder storms, hail, wind, wildfires, landslide, volcano, heat, lightning, coastal events (e.g., storm surges, coastal erosions), tsunami, fog and avalanche, as seen in Table 2 panel A. The main data sources for SHELDUS was hard copy versions of "Storm Data and Unusual Weather Phenomena" by the National Climatic Data Center. It should be noted that SHELDUS data have a number of limitations in losses estimation (Gall et al., 2008), for example, using the lower bound of the range of the estimated losses and only include events causing at $50,000 in property damages or causing at least one fatality may underreport losses for low-damage events. The dataset also equally distributes loss information across counties when multiple counties are involved in an event. But the latter is less of a concern for our study because we aggregate disaster damages at the state level.

minimize the possible omitted variable bias resulting from excluded some disaster damages.[9] All disaster-induced damages are adjusted for inflation and normalized as a ratio of the previous year's GSP to facilitate cross-state comparisons.

To provide a better sense of the scale of natural disasters, Table 2, Panel A reports the average disaster damages by hazard types. These summary statistics show that hurricanes and tropical storms have caused the most damage ($81 million per year) in the United States across the 1970-2013 period; nearly 70 percent higher than the average costs of flooding, which represents the second most damaging event type in the country. The amount of damage is more or less similar among earthquakes, droughts, tornados, winter weather, and severe storms.

Panel B reports state-specific annual average disaster damages (ranked by adjusted dollar amounts) over the sample period to compare their overall exposure and vulnerability to natural hazards. The table shows that the Gulf coast (e.g., Florida, Louisiana, Texas, and Mississippi) states have experienced highest disaster damages (0.8 to 1.7 billion); this is presumably because they are at higher risk of hurricanes, the costliest natural hazard in the U.S. as seen in Panel A. These statistics also hint that larger states are more likely to be hit by natural disasters and incur tremendous disaster losses. However, when we take into account the size of state economies (disaster damage as the ratio of GSP), the relative disaster impact becomes less significant for larger and higher-income states. Among all, Mississippi, North Dakota, Louisiana, and Iowa stand out as the four states with the highest proportion (over 0.8 percent of GSP) of their statewide wealth destroyed annually by natural hazards in the past.

We compose Figure 1 using a longer time series, 1960 through 2013, to exhibit the gradual increasing trend in annual natural disaster damages the United States. The figure

[9] For example, focusing merely on droughts may lead us to ignore the potential influence of floods, which might more likely occur in the absence of droughts and likewise affect the economy and governmental finance.

highlights 2005 as the worst year because of Hurricane Katrina, which is ranked as the most expensive disaster event in the U.S. history.

[Table 2 about here]

[Figure 1 about here]

## IV. Methods and Results

In this section, we describe the empirical model we employ to trace the dynamic fiscal response to natural disasters. We first consider the disaster impact on aggregate-level state government finances, including total spending, total own-source revenues, intergovernmental revenues from the federal government, and long-term debt issuance. Next, we break the revenue and spending totals into smaller categories and study how disasters affected different state tax revenue sources (e.g., sales and income taxes), major spending categories (e.g., current operation, capital outlays), and various types of federal transfer by functions (e.g., disaster relief, public welfare, housing and community development), respectively. We also use the data on FEMA's Disaster Relief Fund (DRF) to estimate the federal financial exposures to significant natural disaster damages.

### A. Empirical Methodology

Drawing upon previous research, we estimate a panel VAR model and the corresponding impulse-response functions (IRFs). This methodology combines the traditional VAR model which allows for endogenous interactions between variables in the system, with the panel-data structure which allows for controlling unobserved individual heterogeneity (Holtz-Eakin et al.,

1988; Love and Ziccino, 2006).[10] Based on the model selection criteria proposed by Andrews and Lu (2001),[11] we specify a first-order reduced-form panel VAR model with a five-year distributed lag of disaster damages as follows:

(1) $$\boldsymbol{Y_{it}} = \boldsymbol{A_0} + \boldsymbol{A_1 Y_{it-1}} + \sum_{j=0}^{5} \boldsymbol{B_j D_{it-j}} + \boldsymbol{\theta_i} + \boldsymbol{\gamma_t} + \boldsymbol{e_{it}}, \quad i \in \{1,2,\ldots,50\}, t \in \{1,2,\ldots,43\}$$

where $\boldsymbol{Y_{it}}$ is a vector of k fiscal variables of interest for state $i$ in fiscal year $t$ ($\boldsymbol{Y_{it}}$ = {$revenue_{it}$, $spending_{it}$, $transfer_{it}$, $debt_{it}$} in the aggregate fiscal response model). $D_{it-j}$ denotes the contemporaneous and lagged natural disaster damages ($j$ = 0, 1…5,) allowing for the delayed effect of disaster shocks on government finances, $\boldsymbol{\theta_i}$ is a vector of state fixed effects, $\boldsymbol{\gamma_t}$ is a vector of fiscal-year fixed effects, and $\boldsymbol{e_{it}}$ is a vector of independently and identically distributed disturbance term. $\mathbf{A_0}$, $\mathbf{A_1}$, and $\mathbf{B_j}$ are estimated coefficient matrices.[12]

Following Holtz-Eakin et al. (1988), we remove the state-fixed effects by first-differencing, and estimate the rest of the parameters using the generalized method of moments (GMM) as implemented in Abrigo and Love (2015). Differencing out the fixed effects in this dynamic model introduces potential bias in our estimate (Nickell, 1981), which we correct for by instrumenting the differenced lagged dependent variables with lags of $\boldsymbol{Y}$ and $\boldsymbol{D}$ in levels, following the approach in Holtz-Eakin et al. (1988). We test our instrumental variables for overidentifying restriction using Hansen's J-statistic, and check the eigenvalue stability condition

[10] VAR treats all variables in the system as endogenous by allowing each of them to be influenced by its own lagged values, and lagged values of other endogenous variables, and exogenous variables. All the endogenous variables are simultaneously estimated in a system of equations.

[11] We determine the appropriate lag length by minimizing the criteria proposed by Andrews and Lu (2001) based on the Hansen's J-statistic, which are analogous to likelihood-based model selection criteria.

[12] The time fixed effects captures national shocks common to all state government finances in the same period. We removed the time fixed effects prior to estimation by subtracting the cross-sectional mean from each variable in the model.

for our panel VAR specifications and estimates.[13] Finally, we cluster standard errors at the state level to allow for potential heteroscedasticity and autocorrelation.

Several things are important to note here. First, the major advantage of using the panel VAR in this study is we are able to treat all fiscal variables as endogenously determined and inter-related in the system (based on the VAR approach). This is particularly important considering that fiscal decisions are often highly interdependent and can be simultaneously affected by external shocks.[14] Additionally, using this model also allows the exogenous impact on one endogenous variable to spillover on other endogenous variables in succeeding periods.[15]

Second, this paper follows previous work (Cunado and Ferreira, 2014; Lis and Nickel, 2010) and assumes that natural disasters are exogenous, wherein past or present economic conditions are irrelevant in explaining the timing and level of natural disasters after controlling for state fixed effects. Because the panel VAR model regresses each endogenous variable on lagged values of other endogenous variables, treating natural disasters as endogenous excludes the estimation of the contemporaneous disaster effect on government finances and may generate misspecification bias (Srithongrung and Kriz, 2014). However, one might worry that a state's direct losses from natural disasters can be significantly affected by its socioeconomic characteristics (e.g., property losses directly depend on the values of properties; therefore, wealthy states are subject to larger monetary damages from natural disasters because they have more capital stocks to lose). We address this issue by normalizing disaster losses by GSP; furthermore, we conduct of the granger causality tests on the normalized disaster variables and

[13] For the Hansen J test, we do not reject the null hypothesis that instruments are uncorrelated with the error terms. As for the stability test (Lutkepohl, 2005; Hamilton, 1994), we checked the modulus of each eigenvalue of the estimated model and show that all moduli of the companion matrix are strictly less than one.
[14] Note that almost all states have a balanced budget requirement, which could lead to joint decisions on government revenues and spending. Likewise, a state's receipts of federal transfers may also affect its spending behaviors.
[15] For example, if natural disasters cause a change in federal transfers which later have an effect on spending, the panel VAR model can pick up the indirect effect of disasters on spending.

show that a state's pre-existing fiscal conditions are overall insignificant in predicting (do not granger cause) its later disaster damages (see Appendix A).

Third, because the VAR estimated coefficients are difficult to interpret, the impulse response functions (IRFs) are often calculated using the estimated coefficients and their variance-covariance matrix, which show the isolated impact of a shock in one variable of interest on each dependent variable in the system one period at a time, while holding other shocks equal to zero. Assuming natural disasters as exogenous shocks, we estimate their impact on state government finances by calculating dynamic multiplier functions (i.e., the IRFs specifically for exogenous variables) using Abrigo and Love's (2015) PVAR program.[16] Because of the distributed lag structure of disaster damages, we compute the dynamic multipliers $\boldsymbol{\vartheta_t}$ at period *t* by using the estimated coefficients $\mathbf{A_1}$ and $\boldsymbol{B_j}$ in the following equation,

$$\vartheta_t = \sum_{j=0}^{5} A_1^{t-j} M B_j \tag{2}$$

where the *kxk M* matrix having elements $M[r, c]$ Equals one if $r = c$ and $j \geq t$, and zero if otherwise. We perform Monte Carlo simulations with 500 iterations to the estimated standard errors to generate the 95% confidence interval for the dynamic multiplier functions. The dynamic multiplier captures the effect of a unit increase in our disaster damage measure on the temporal trajectory of state fiscal variables in the model, which not only portrays the dynamics of fiscal responses to shocks over the short term and intermediate term, and but also identifies the duration through which a disaster shock persists for various fiscal outcomes.

Finally, as a prerequisite for estimating panel VAR, we test each endogenous fiscal variables for the presence of panel unit root, which may have a bearing on the relevance of the

[16] This approach has not yet been used in other studies because the dynamic multiplier function of estimating the effect of exogenous variables has been added very recently in the updated PVAR version.

instruments. In Table 3, we show that each series is stationary based on the test proposed by Im, Pesaran and Shin (2003) for heterogeneous panels (with and without time trends).[17]

[Table 3 about here]

## B. Aggregate Fiscal Responses

First, we employ the panel VAR model to estimate the disaster shock on state aggregate fiscal outcomes. The calculated IRFs, as shown in Figure 2, present our simulated estimates of various state fiscal responses to disaster shocks in FY *t* (i.e., instantaneous response) through FY *t*+10.

[Figure 2 about here]

Table 4, Panel A presents the point estimates of the fiscal impact resulting from one unit increase in natural disaster damages in each FY as well as the cumulative effects through FY *t*+5. Overall, we find that natural disasters exert a significant and positive impact on state total spending and intergovernmental revenues from the federal government. The effect on spending becomes statistically significant at the 1% level in year *t*+2 and peaks in the year *t*+3 (0.06 percent of GSP with respect to one percentage point increase in the experienced disaster damages as the ratio of GSP), and decline thereafter. The five-year cumulative effect is roughly 0.2 percent of GSP. The federal-to-state transfer ratio increases more than state total spending in each period; it remains statistically significant through year *t*+5 and accumulates to 0.27 percent of GSP over the 5-year post-shock period. The positive response of government spending to disaster shocks is consistent with the findings from previous cross-country studies (e.g., Melecky

[17] We use the IPS test in this case because we have moderate T and moderate N. Note that we cannot reject the unit root hypothesis when the federal welfare transfer variables when time trend is not included. But this should not be a big concern because our model includes fiscal year fixed effects.

and Raddatz, 2011; Ouattara and Strobl, 2013). In tandem, these two variables suggest that the disaster-induced increase in state expenditure is largely financed through federal transfers. In some sense, states could be ensured that the federal government fully covers their costs of disaster response and recovery, which suggests a considerable re-distributional effect of natural disasters under fiscal federalism: the financial burden of the disaster affected areas is shifted to the rest of the nation, and the federal government plays a leading role in reallocating resources to address subnational post-disaster needs.

In comparison, the effect of natural disasters on state issuance of long-term debt is statistically insignificant, though positive, through the *t* to *t*+5 window, implying that states rely on federal assistance for the post-shock outlays and therefore have no need for additional borrowing. Furthermore, if disasters generally leave states in a neutral fiscal stance, they may have lower incentives to budget for disaster shocks *ex ante*. On the revenue side, disaster shocks do not exert any statistically significant effect on states' total own-source revenues. While similar results are also reported for national fiscal accounts in previous studies (e.g., Ouattara and Strol, 2013), this finding could be linked with federal post-disaster aid that contributes to rebuilding the tax base and lessen the adverse impact of natural disasters on revenue. It could also be linked with the state tax structure and composition, which necessitates a nuanced examination of disaster impacts on different types of tax revenues as we discuss next.

[Table 4 about here]

Based on the same empirical model, we have performed additional tests to examine the robustness of our main results. For example, we use the direct damages only from the Presidential Declared Disasters instead of total disaster damages, and obtain similar and consistent estimates (see Appendix B). In Appendix C, we exclude the Hurricane Katrina-

affected state-year observations and show that the results are qualitatively the same except that state governments are more likely to engage in borrowing following a major disaster shock (i.e., significant and positive impact on long-term debt issuance). To further investigate the heterogeneity across states in their disaster-induced responses, we divide our sample into higher-income and lower-income groups depending on whether a state's GSP per capita (mean value over the study period) is above or below the median. As shown in appendix D, we find that both state groups increase their total expenditures after natural disasters and also receive more federal transfers. Moreover, richer states spend slightly more during the post-disaster period, compared to lower-income states, and they also borrow more to finance disaster responses and recovery.

### C. Disaggregate Fiscal Responses

To better understand the mechanisms through which natural disasters affect states' fiscal stance, we look into the major components of state expenditures, own-source revenues and federal transfers, and estimate separate sets of panel VARs for each category. With respect to states' own tax revenues, we consider general sales tax, personal income tax, corporate income tax, and local property taxes. On the expenditure side, we distinguish among current operational spending, capital outlays, state-to-local transfers, and welfare spending (the sum of a state's insurance benefits and repayments, assistance and subsidy spending).[18] Regarding federal-to-state transfers, we consider four types of federal aid – direct disaster relief (distributed by FEMA), housing and community development aid, natural resources and agriculture-related aid,

[18] Both categories are listed as stand-alone items under state government direct expenditure, involving direct payments to individuals. Specifically, insurance benefits and repayments include social insurance payments to beneficiaries, employee-retirement annuities and other benefits, and withdrawals of insurance or employee retirement contributions. Assistance and subsidies comprise direct cash assistance payments to public welfare recipients as well as veteran's bonuses, direct cash grants for tuition, scholarships.

and transfers on public welfare programs.[19] It is important to note that although FEMA is responsible for the bulk of the federal disaster-related expenditures, many other federal agencies (e.g., the U.S. Department of Agriculture, Department of Housing and Urban Development, Department of Commerce, and the Department of Health and Human Service) also operate programs involving disaster relief and assistance (Healy and Malhotra, 2009). The complex and diverse nature of federal disaster funding programs makes it extremely difficult for us to capture the full scope of federal direct expenditure on disasters; therefore, we focus on identifying the disaster effect on major related federal transfer categories. We present the IRFs portraying the dynamic responses of disaggregate fiscal variables in Figure 3, and Table 4 Panels B through D report the IRFs for each fiscal year and the cumulative effects over a five-year horizon.

[Figure 3 about here]

*1. Tax Revenue Components*

Regarding tax revenues (Table 4, Panel B; Figure 3.1), sales tax revenue rises following a disaster and peaks (0.01 percent of GSP, statistically significant at the 5 % level) one year later. This one-year increase can be attributed to the activities in replacing the assets and capital stocks damaged by natural disasters. However, this response declines and turns negative (0.01 percent of GSP, significant at the 5 % level in year $t$+5), which might be associated with the negative macroeconomic impacts posed by disasters on output and consumption. The negative response offsets the initial increase and results in an insignificant cumulative overall effect.

Natural disasters cause an immediate decline in property tax collections, which accumulates to -0.016 percent of GSP with respect to one percent of GSP total disaster damages

[19] The reason for collecting FEMA disaster aid data from another source is because the Census data do not specifically identify disaster assistance but rather categorize it under "all other" federal transfers.

(statistically significant at the 1 % level) in the next five years, though collections appear to return to the original level over time according to the IRFs figure. This negative response is expected because natural disasters usually damage and destroy properties, which diminishes the tax base. It could also be attributed to local policies on disaster relief for properties. For example, some California counties allow immediate reappraisal of property values to reflect the damaged conditions and property owners are allowed to postpone their property tax installment. Moreover, the lower tax base may also be associated with the decline in housing values in the affected regions. As the disaster economics literature suggests, natural hazards like floods and earthquakes raise public awareness of local risks, thereby imposing a negative effect on the price of properties located in the hazardous areas (e.g., Kousky, 2010; Atreya et al., 2013).

While natural disasters appear to exert little impact on personal and corporate income tax revenues in individual years *ex post*, the cumulative responses are both statistically significant which merit special attention. Specifically, disasters on average pose a negative shock to personal income tax revenues over the five-year horizon. This response could be driven by a combination of several factors: first, disasters impose negative shocks on individual and household wealth (e.g., lost jobs and reduced wages); second, post-disaster migration lowers the tax base (Strobl, 2011); and finally, states provide income tax relief for the disaster-affected populations. In contrast, the cumulative response to corporate income tax revenues is positive (0.015 percent of GSP). One possible driving factor is the additional market transactions and investment triggered by disasters to replace destroyed physical infrastructure and capital stocks, which are sufficiently large to offset the potential negative macroeconomic effects of natural disasters. Meanwhile, the overall increase in corporate income tax revenues, as opposed to the later decline in sales tax revenues, may suggest that natural disasters pose larger negative shocks

to local consumption rather than to production in the affected regions. Furthermore, the federal and state governments often employ a variety of incentive policies to mitigate the adverse disaster effect on local businesses (e.g., subsidized disaster loans provided by the Small Business Administration).

Overall, we find that while natural disasters have little impact on state total own-source revenues, they can cause different patterns of fluctuations to various taxes. Our findings are particularly useful for policymakers to understand how states' tax structure may influence their fiscal vulnerability to natural disaster shocks.

*2. Expenditure Components*

Regarding disaggregate state expenditure variables (Table 4, Panel C; Figure 3.2), we find that natural disasters increase major spending components in the short term, although the impact on current operational spending is overall insignificant (except the positive response of 0.019 percent in year *t*+2), evidenced by the wide confidence interval band. This finding is somewhat counter-intuitive because operational spending usually accounts for the bulk of a state's total direct expenditure. Given that disaster destruction induces the need for reconstruction, as expected, states increase their capital spending immediately following a shock (0.012 percent of GSP) in year *t*+1, and experience a cumulative increase of 0.036 percent of GSP (statistically significant at 1% level) through year *t*+5.

After experiencing a disaster shock, states also increase their intergovernmental spending on local governments,[20] which peaks (0.015 percent of GSP) in year *t*+1 and accumulates to 0.04

[20] Local expenditure includes amounts paid to local governments as fiscal aid in the form of shared revenues and grants-in-aid, as reimbursements for performance of general government activities and for specific services for the statement government, or in lieu of taxes. It excludes amounts paid for purchase of commodities, property, or utility services, any tax imposed and paid as such, and employer contributions for social insurance.

percent of GSP (statistically significant at 1% level). Given that large disaster events are normally declared at the county level which trigger federal disaster assistance, we presume a large proportion of the increased state-to-local transfers is financed with federal transfers. In other words, state governments redistribute federal aid to lower-level governments.

Additionally, natural disasters cause an immediate and persistent increase in state welfare spending, which peaks in year *t*+1 (0.01 percent of GSP) and accumulate to 0.037 percent (statistically significant at the 1 % level) over the five-year post-shock period. Note that the expenditure of this category is primarily comprised of direct payment to individual beneficiaries, and it contains both disaster-related direct relief and non-disaster-related welfare spending (e.g., unemployment insurance). Nonetheless, here we could not separate the disaster-related payment from the general welfare payment due to the absence of such information in the Census data.

*3. Federal Transfer Components*

Figure 3.3 along with Panel D of Table 4 presents the dynamic responses of various types of federal transfers to natural disasters. Consistent with our expectation, states see an immediate and significant increase in FEMA's disaster relief following disasters. This effect remains positive and significant from year *t*+1 through *t*+5, accumulating to 0.072 percent of GSP. The persistence of relief funding is also expected because it usually takes a relatively long time for FEMA to evaluate disaster damages, approve claims, and distribute the relief funds.

In addition to direct disaster aid, we also observe significant increases in federal transfers on public welfare programs as well as housing and community development aid in the post-disaster period. Specifically, the housing and community development aid, primarily administered by the Department of Housing and Urban Development (HUD), has a proportion of

funding used to assist in disaster response and long-term recovery activities. Therefore, it is not surprising to see an increased transfer of this category (0.042 percent of GSP over 5-year horizon).

The public welfare transfers include cash assistance paid directly to needy persons under the categorical program or under other welfare programs, and for other welfare purposes (e.g., health services). They are not specifically related to disaster relief, but natural disasters can have implications for such expenditure by affecting individual income, health and employment status and therefore their eligibility for entitlement programs. Noticeably, the magnitude of the cumulative increase in public welfare transfers (0.077 percent of GSP) is slightly larger than the increase of the FEMA disaster relief, suggesting disasters also affect federal expenditure on existing welfare programs as a means to mitigate the adverse welfare shocks. This finding resonates with the results in Deryugina (2013) that natural disasters not only increase direct disaster relief but also cause a no-smaller increase in non-disaster-related governmental transfers on social safety net programs. It also suggests that the actual fiscal costs of disasters should not be confined to disaster-related programs. The increased federal welfare transfers may partially help explain the increase in states' own spending on welfare following disaster shocks.

Finally, we find that states receive less federal transfers in the natural resources and agriculture category (-0.001 in year *t* and -0.002 over five years) after a disaster. Despite the relatively small magnitude of the estimate, this finding may suggest that disaster-induced federal expenditure on some categories could crowd out other types of federal transfers.

### B. Federal Financial Exposure to Natural Disaster Risks

As our results on the aggregate fiscal responses indicate that natural disasters increase state government expenditures at the cost of federal transfers, we take a further step to examine the federal exposure to disaster shocks based on the historic relationship between nationwide disaster damages and federal disaster expenditures. While the aforementioned analysis uses the percentage measure of disaster damages and fiscal outcomes (normalized by GSP), making it difficult to put the figures into perspective, in this section we provide direct estimates in dollar amounts given certain scope of disaster shocks, as a way to inform projection of future federal spending.

We combine the data from presidential declared disasters with the sum of regular appropriations and emergency supplemental appropriations for FEMA's DRF, and use these as measure of federal disaster fund. For the former variable, we match the Presidential Disaster Declaration (PDD) data retrieved from FEMA with the loss data from SHELDUS based on hazard type,[21] and compute rough estimates of PDD-related disaster damages by the federal-fiscal year. For the appropriations, we use the statistics provided by the Congressional Research Service (Lindsay, 2014; Lindsay and Murray, 2014), which are depicted in Figure 4. Due to the different time spans for the two variables, we construct a time-series dataset over FY 1989-2013.

[Figure 4 about here]

Table 5 reports the ordinary least squares (OLS) estimation results on the relationship between federal disaster aid and direct disaster losses, both adjusted to year 2000 constant dollars. We include both the contemporaneous and one-year lagged disaster damage to allow for the possible delayed effect on spending, with and without a linear time trend. The results suggest

[21] It is important to note that the raw SHELDUS data does not have a PDD identifier or include all PDD events (e.g., human-caused emergencies). Therefore, we restrict our attention to the types of natural hazards that are included both in FEMA's data and SHELDUS. We include a state's disaster damage for a specific disaster category (e.g., floods) in the national statistics if the state is declared for the presidential disaster for this hazard type in a given year.

that one dollar direct disaster losses is associated with 0.34-0.37 dollar immediate federal spending on post-disaster response and recovery. However, one caveat is that our data of FEMA's DRF flows only captures a proportion of total federal disaster expenditures, which should also include disaster supplemental appropriations to other agencies (e.g., HUD, Department of Defense, Department of Transportation), agriculture disaster assistance (operated by the U.S. Department of Agriculture), and federal insurance programs such as the National Flood Insurance Program and Federal Crop Insurance Program. Also worth noting is that natural disasters may increase the federal social welfare expenditures (as suggested in earlier tables) which should also be accounted for as part of the federal financial exposure. Therefore, our estimates tend to underestimate ted the actual federal costs of PDD-related natural disaster events.

[Table 5 about here]

## V. DISCUSSION AND CONCLUSION

In this paper, we have employed the panel VAR model to empirically investigate the dynamic fiscal responses of U.S. state governments to natural disasters in the last three decades. In sum, we show that states respond to natural disasters by substantially increasing their public expenditures, including capital outlays, transfer to localities, and welfare spending. After natural disasters, states also receive more federal transfers which appear to offset the increased portion of their spending. Our results suggest that disaster-induced increase in federal transfers outsizes the increase in state spending, which suggests that in most cases, the federal government acts as a full insurer for subnational natural disaster costs. This finding highlights the significant re-distributional effects of natural disasters in the U.S. federal system. That is, a considerable

portion of local disaster costs is shifted to all taxpayers in the nation. As pointed out in previous research (e.g., Burby, 2006; Wildasin, 2008; Cummins et al., 2010; Cohen and Werker, 2008; Donahue and Joyce, 2001), while these transfers alleviate the burden on the disaster-affected regions, the *ex post* disaster relief from the central government creates the problematic incentive for subnational governments to under-invest in *ex ante* disaster mitigation and preparedness, and to continue development in hazard-prone areas, which in turn increases the risk of catastrophic losses. The generosity of federal aid also raises the question of how efficiently and effectively state governments spend the federal money in post-disaster recovery.

Our investigation of disaggregate fiscal responses provides additional insights into the post-disaster dynamics. We find that although natural disasters exert little impact on states' total own-source revenues, they result in different levels of fluctuations in the sales, income, and property tax revenues, which appear to offset each other, thus leaving states tax-revenue neutral. While we do not possess evidence to conclusively explain the reasons behind all these changes, they could be closely associated with the macroeconomic effects and behavioral implications of natural disasters as well as tax policy responses. Overall, this finding is beneficial for policy makers to understand the link between fiscal sustainability and tax structure in the context of natural disasters.

Another important finding of this study is natural disasters not only increase disaster-related spending and transfers but also significantly increase non-disaster-related transfers (e.g., public welfare and safety net programs). This suggests the actual fiscal costs of natural disasters could be much larger than the current estimates because the increased welfare spending and transfers have not yet been incorporated in any of the existing studies. Therefore, it is critical for policy makers to account for this portion of expenditure in gauging their financial exposure to

natural hazards. In future research, it is also important to separate different types of welfare payments and assess how they are affected by natural disaster events and to what extent they could mitigate the adverse disaster shocks on various socioeconomic outcomes such as income, health, consumption and employment.

In addition, our study could be further extended in several ways. First, to fully understand the distribution of natural disaster costs would necessitate another study focused on the local level, examining intergovernmental transfers among federal, state and local governments. Second, in this paper we use aggregate disaster damages to measure the severity of disaster shocks. To better capture the exogeneity of environmental shocks, it is worth using objective data (e.g., temperature and precipitation data) to construct the physical magnitude of natural hazards and examine their impact on fiscal behaviors and governmental financial exposure. Future research may also distinguish among different types of natural hazards, and link them with more specific economic/ fiscal outcomes and aid programs (e.g., droughts and agricultural-related disaster assistance). Third, since our research suggests that natural disasters substantially increase government welfare spending and transfer payments, it would be interesting to further examine to what extent the existing social safety net programs can lessen the negative shocks of disasters to the local economy. Finally, this study could also be extended by including the private and nonprofit sector investments and expenditures to provide a more comprehensive understanding of the financial dynamics in the post-disaster period.

**DISCLOSURES:**

The authors have no financial arrangements that might give rise to conflicts of interest with respect to the research reported in this paper.

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**Table 1**
**Summary Statistics of Main Variables (1970-2013)**

| **Variables** | N | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| *Natural Disaster Damage* (% of GSP) | | | | | |
| *Total disaster damages* | 2200 | 0.19 | 1.20 | 0.00 | 32.55 |
| *Aggregate Fiscal Variables (% of GSP)* | | | | | |
| *Total own-source revenues* | 2200 | 3.07 | 1.22 | -0.12 | 40.95 |
| *Total revenues from federal transfers* | 2200 | 2.83 | 1.21 | 0.95 | 10.12 |
| *Total Spending* | 2200 | 11.08 | 3.28 | 4.84 | 32.80 |
| *Long-term debt issued* | 2200 | 1.01 | 0.81 | 0.00 | 6.34 |
| *Disaggregate Fiscal Variables (% of GSP)* | | | | | |
| *Sales tax revenues* | 2200 | 1.58 | 0.79 | 0.00 | 4.15 |
| *Personal income tax revenues* | 2200 | 1.44 | 0.90 | 0.00 | 3.66 |
| *Corporate net income tax revenues* | 2200 | 0.33 | 0.26 | 0.00 | 4.73 |
| *Property tax revenues* | 2200 | 0.13 | 0.34 | 0.00 | 4.22 |
| *Current operational spending* | 2200 | 5.48 | 2.18 | 1.71 | 23.10 |
| *Capital Outlays* | 2200 | 1.01 | 0.48 | 0.26 | 5.81 |
| *Intergovernmental Spending on local governments* | 2200 | 2.77 | 0.96 | 0.09 | 6.20 |
| *Welfare spend (insurance, subsidies, assistance)* | 2200 | 1.45 | 0.64 | 0.17 | 4.57 |
| *FEMA's disaster relief (1981-2010)* | 1500 | 0.03 | 0.10 | -0.04 | 1.70 |
| *Federal transfer - housing and community development* | 2200 | 0.04 | 0.08 | 0.00 | 2.01 |
| *Federal transfer - agriculture and natural resources* | 2200 | 0.06 | 0.06 | 0.00 | 0.80 |
| *Federal transfer - public welfares* | 2200 | 1.33 | 0.78 | 0.16 | 5.12 |

## Table 2
## Statistics on Natural Disaster Damages in the U.S.

**Panel A. Total annual damage by disaster type 1970-2013**

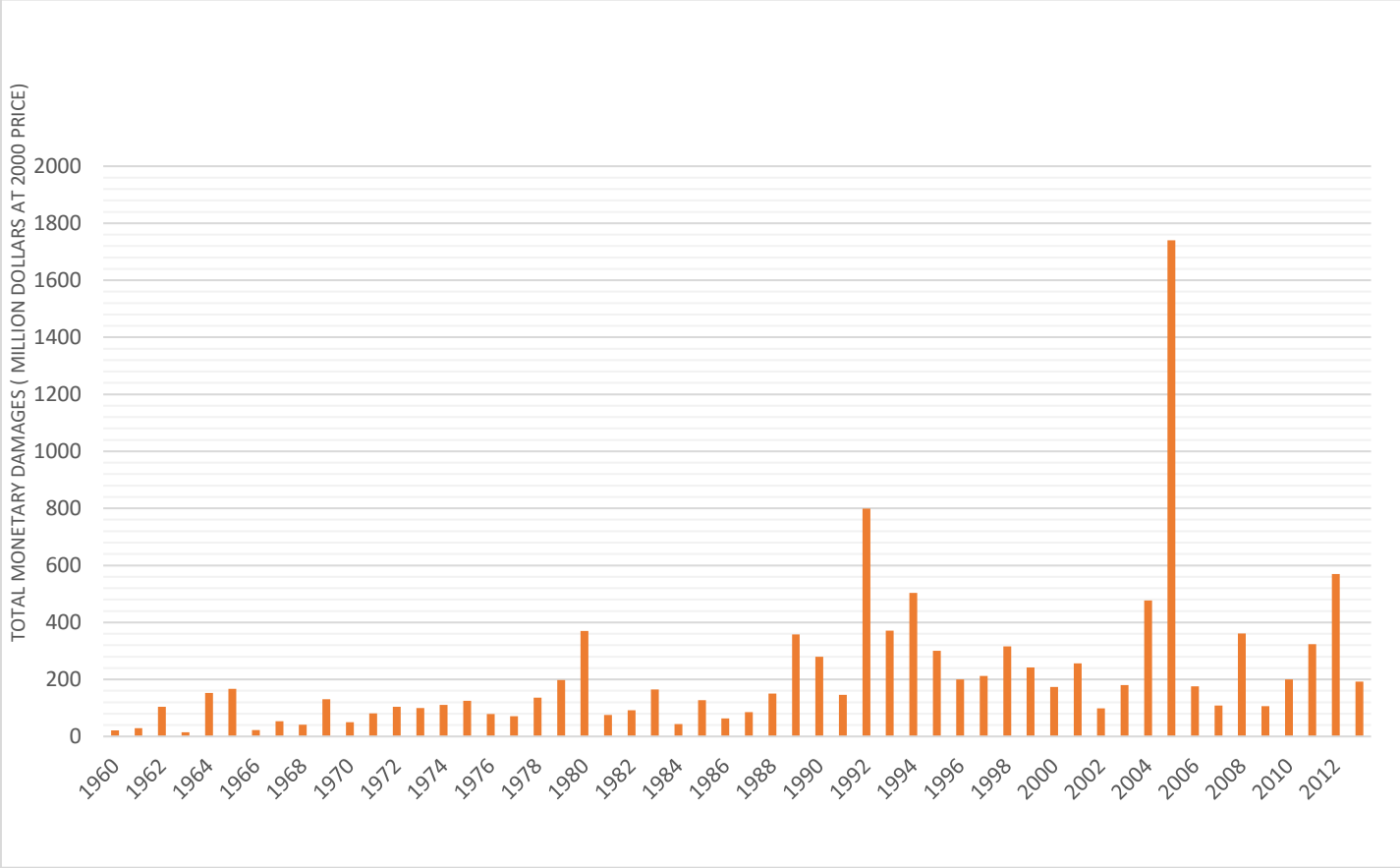
| *Rank* | *Natural Hazard* | *Total Annual Damage (thousand dollars at 2000 price)* | *Rank* | *Natural Hazard* | *Total Annual Damage (thousand dollars at 2000 price)* |
|---|---|---|---|---|---|
| *1* | Hurricane/Tropical Storm | 81,469 | *10* | Wildfire | 6808 |
| *2* | Flooding | 49,109 | *11* | Landslide | 2832 |
| *3* | Earthquake | 18,383 | *12* | Volcano | 2165 |
| *4* | Drought | 17,185 | *13* | Heat | 1308 |
| *5* | Tornado | 16,042 | *14* | Lightning | 850 |
| *6* | Winter Weather | 14,142 | *15* | Coastal | 805 |
| *7* | Severe Storm/Thunder Storm | 13,652 | *16* | Tsunami | 48 |
| *8* | Hail | 11,955 | *17* | Fog | 16 |
| *9* | Wind | 11,437 | *18* | Avalanche | 6 |

**Panel B. Total annual damage by state 1970-2013**

| *State* | *Damage as % of GSP* | *Total annual disaster damage (thousand dollars at 2000 price)* | *State* | *Damage as % of GSP* | *Total annual disaster damage (thousand dollars at 2000 price)* |
|---|---|---|---|---|---|
| Florida | 0.42 | 1,727,744 | Kansas | 0.18 | 134,632 |
| California | 0.16 | 1,536,719 | Tennessee | 0.08 | 131,221 |
| Louisiana | 0.89 | 1,353,967 | Michigan | 0.04 | 116,878 |
| Texas | 0.18 | 1,084,391 | Georgia | 0.05 | 91,432 |
| Mississippi | 1.26 | 798,956 | Arizona | 0.07 | 90,206 |
| Iowa | 0.81 | 702,304 | Kentucky | 0.09 | 86,275 |
| New Jersey | 0.14 | 501,475 | Hawaii | 0.16 | 64,158 |
| Washington | 0.28 | 352,474 | Massachusetts | 0.03 | 54,170 |
| Alabama | 0.29 | 322,022 | New Mexico | 0.10 | 50,102 |
| North Carolina | 0.12 | 273,979 | West Virginia | 0.12 | 49,393 |
| New York | 0.04 | 256,168 | Vermont | 0.27 | 41,693 |
| Missouri | 0.15 | 237,460 | Utah | 0.10 | 41,599 |
| Illinois | 0.06 | 222,229 | South Dakota | 0.24 | 38,071 |
| Oklahoma | 0.23 | 215,593 | Maine | 0.12 | 35,105 |
| Wisconsin | 0.15 | 211,421 | Maryland | 0.03 | 34,514 |
| South Carolina | 0.25 | 207,111 | Idaho | 0.13 | 33,759 |
| Pennsylvania | 0.06 | 195,738 | Oregon | 0.03 | 24,357 |
| North Dakota | 1.06 | 185,841 | Nevada | 0.04 | 23,653 |
| Ohio | 0.05 | 175,044 | Connecticut | 0.02 | 20,422 |
| Nebraska | 0.32 | 157,995 | Alaska | 0.07 | 19,532 |
| Minnesota | 0.12 | 155,317 | Montana | 0.06 | 12,471 |
| Arkansas | 0.25 | 147,294 | Wyoming | 0.06 | 11,614 |
| Colorado | 0.10 | 136,708 | Rhode Island | 0.03 | 8,587 |
| Virginia | 0.09 | 136,644 | New Hampshire | 0.02 | 6,815 |
| Indiana | 0.09 | 136,224 | Delaware | 0.02 | 5,955 |

**Figure 1**

**Trend in annual natural disaster damages in the United States (1960-2013)**



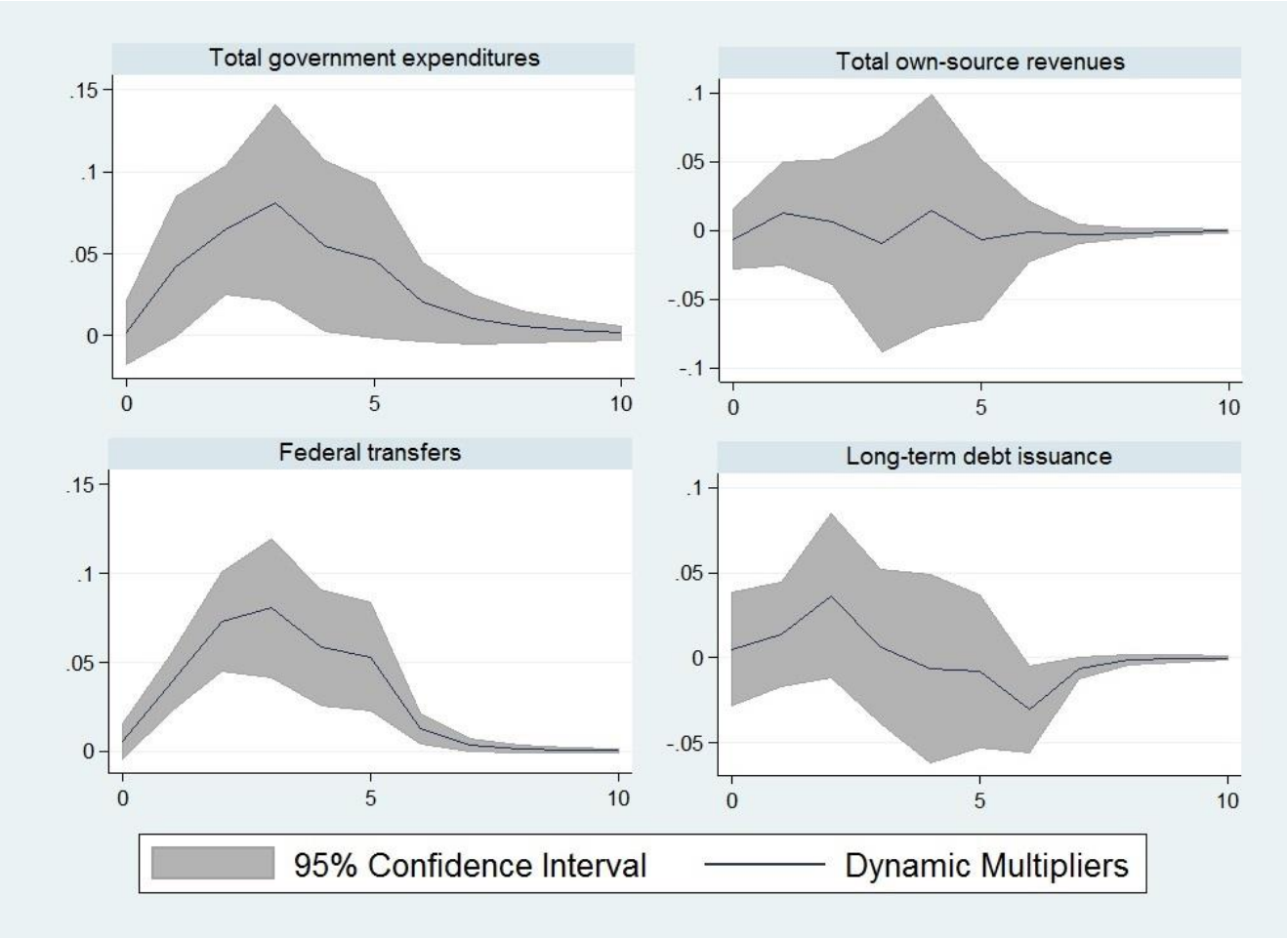
## Table 3
## Unit Root Tests (Im, Pesaran and Shin, 2003)

| | Without time trend | | With time trend | |
|---|---|---|---|---|
| *Variable* | $W_{tbar}$ - Stat | p-value | $W_{tbar}$ - Stat | p-value |
| *total disaster damage* | -27.8431 | 0.0000 | -28.4296 | 0.0000 |
| *total own-source revenues* | -3.7618 | 0.0035 | -4.5039 | 0.0000 |
| *total spend* | -3.5797 | 0.0002 | -8.6177 | 0.0000 |
| *federal intergovernmental revenue* | -2.5075 | 0.0061 | -8.7491 | 0.0000 |
| *long-term debt issued* | -20.9415 | 0.0000 | -22.7882 | 0.0000 |
| *sale tax revenue* | -3.2719 | 0.0005 | -5.4534 | 0.0000 |
| *personal income tax revenue* | -4.7447 | 0.0000 | -7.7299 | 0.0000 |
| *corporate income tax revenue* | -8.9559 | 0.0000 | -11.6544 | 0.0000 |
| *property tax revenue* | -1.3850 | 0.0830 | -10.0456 | 0.0000 |
| *current operational spending* | -1.7288 | 0.0419 | -7.5887 | 0.0000 |
| *capital outlay* | -11.5351 | 0.0000 | -13.4006 | 0.0000 |
| *intergovernmental local spending* | -4.1567 | 0.0000 | -4.7050 | 0.0000 |
| *welfare spending* | -4.1708 | 0.0000 | -7.4843 | 0.0000 |
| *FEMA disaster relief* | -9.1548 | 0.0000 | -12.8031 | 0.0000 |
| *federal transfer (housing & community)* | -3.1532 | 0.0008 | -7.1634 | 0.0000 |
| *federal transfer (natural resource& agriculture)* | -5.8601 | 0.0000 | -6.8780 | 0.0000 |
| *federal transfer (public welfares)* | 0.3758 | 0.6465 | -7.9114 | 0.0000 |

Note: All unit root tests have subtracted the cross-sectional means for consistency with the specification of our PVAR model.

## Figure 2

## Impulse-Response Functions: Aggregate Fiscal Responses to Natural Disaster Shocks



## Table 4
## Impulse Response functions: Fiscal responses to one unit increase in disaster damages

| | t | t+1 | t+2 | t+3 | t+4 | t+5 | Cumulative through t+5 |
|---|---|---|---|---|---|---|---|
| *Panel A: Aggregate Fiscal variables* | | | | | | | |
| *Total own-source revenues* | -0.005 | 0.010 | 0.004 | -0.013 | 0.014 | -0.008 | 0.002 |
| *Total governmental spending* | 0.000 | 0.035 | 0.051*** | 0.061** | 0.027 | 0.015 | 0.190*** |
| *Total revenues from federal transfers* | 0.005 | 0.038*** | 0.068*** | 0.071** | 0.044*** | 0.038*** | 0.266*** |
| *Long-term debt issued* | 0.006 | 0.010 | 0.036 | 0.009 | 0.003 | 0.004 | 0.069 |
| *Panel B: Disaggregate Tax Revenues* | | | | | | | |
| *Sales tax* | 0.000 | 0.009** | 0.005 | 0.001 | -0.004 | -0.0099* | 0.002 |
| *Personal income tax* | -0.002 | -0.004 | -0.004 | -0.006 | -0.004 | -0.005 | -0.024** |
| *Corporate net income tax* | 0.000 | 0.001 | 0.004 | 0.003 | 0.004 | 0.003 | 0.015*** |
| *Property tax* | -0.002** | 0.002** | 0.003 | 0.002 | -0.003 | -0.004* | -0.016*** |
| *Panel C: Disaggregate Spending Categories* | | | | | | | |
| *Capital outlay* | 0.000 | 0.012*** | 0.008* | 0.010* | 0.005 | 0.001 | 0.036* |
| *Current operational spending* | -0.005 | -0.003 | 0.019* | 0.019 | 0.008 | 0.007 | 0.043 |
| *Welfare (assistance, subsidies, insurance benefits)* | 0.004* | 0.010*** | 0.006* | 0.006* | 0.008* | 0.003 | 0.037*** |
| *Intergovernmental Spending (local)* | -0.001 | 0.015*** | 0.012*** | 0.007 | 0.004 | 0.004 | 0.040*** |
| *Panel D: Disaggregate Federal Transfers* | | | | | | | |
| *FEMA's disaster relief* | 0.005 | 0.024*** | 0.014*** | 0.009** | 0.008** | 0.012*** | 0.072*** |
| *Housing and community development* | 0.000 | -0.0001 | 0.012** | 0.017** | 0.009 | 0.005 | 0.042*** |
| *Agriculture and natural resources* | -0.001* | -0.0003 | -0.0004 | -0.0002 | 0.0002 | -0.0005 | -0.0023** |
| *Public welfare* | 0.005*** | 0.005 | 0.013*** | 0.014*** | 0.020*** | 0.020*** | 0.077*** |

Notes: Asterisks denote significance at the 1% (***), 5% (**), and 10% (*) levels. For Monte Carlo simulations, 500 replications were used in the computation of error bands.

**Figure 3.1**

**Impulse-Response Functions: Disaggregate Fiscal Responses to Natural Disaster Shocks (Tax Revenues)**

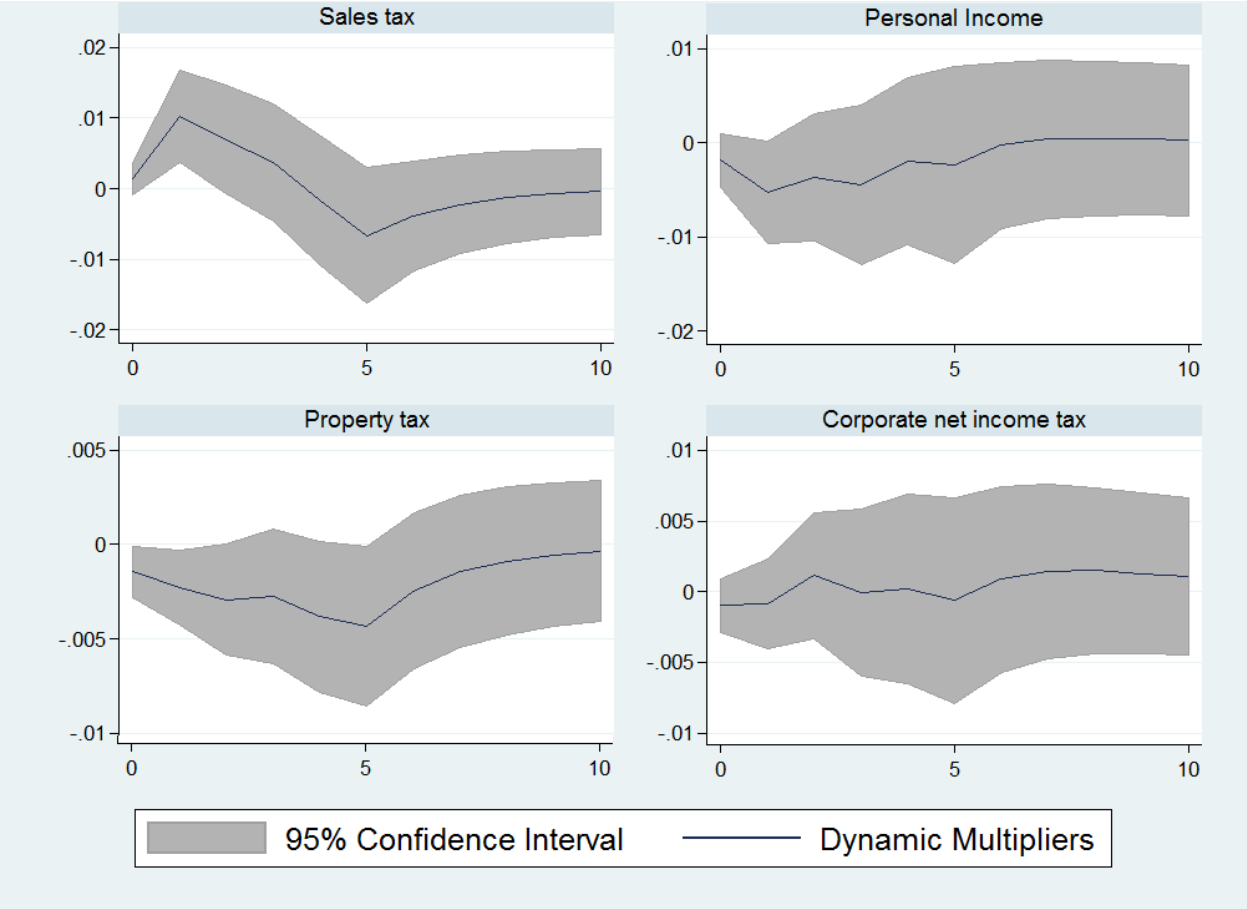
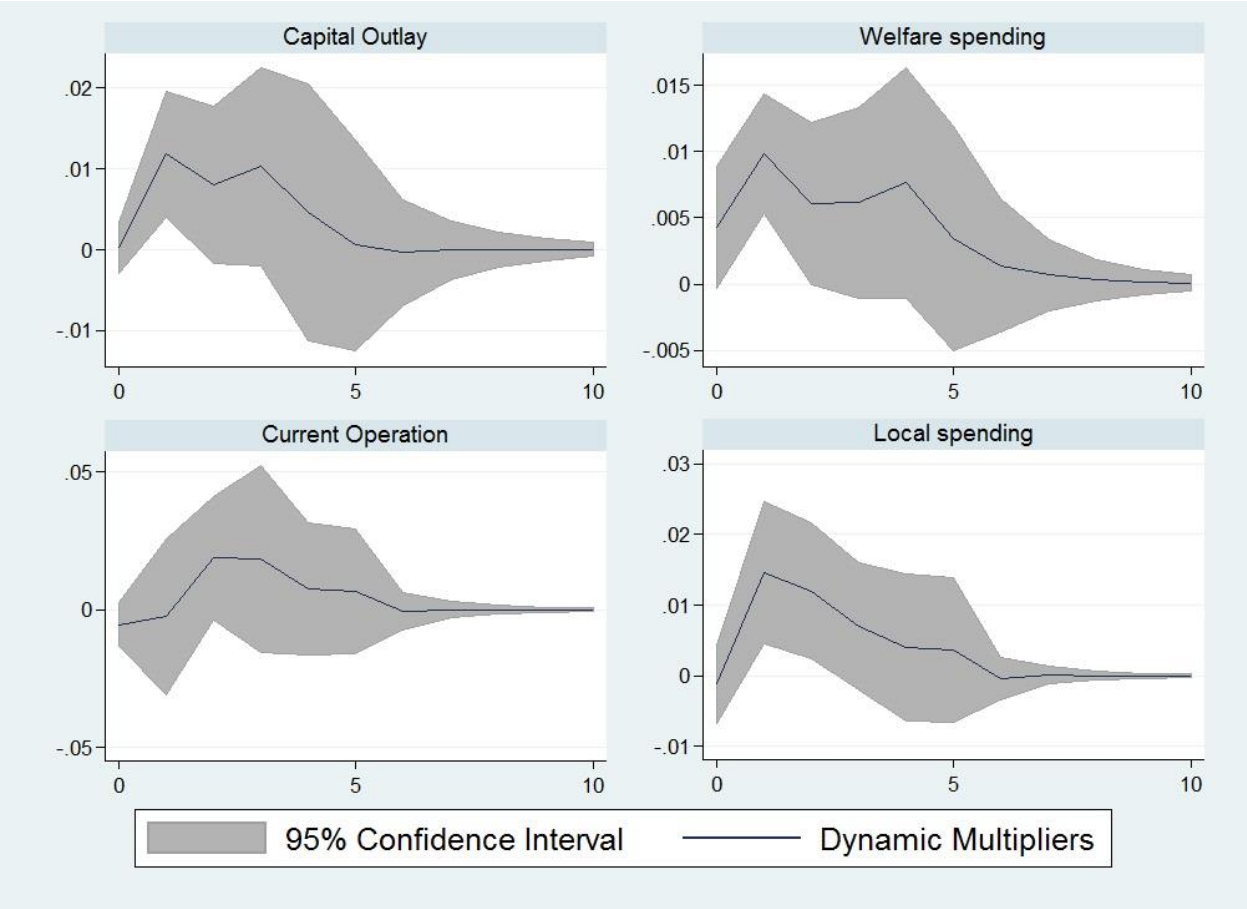


**Figure 3.2**

**Impulse-Response Functions: Disaggregate Fiscal Responses to Natural Disaster Shocks (Expenditure)**



## Figure 3.3

## Impulse-Response Functions: Disaggregate Fiscal Responses to Natural Disaster Shocks (Federal Transfers)

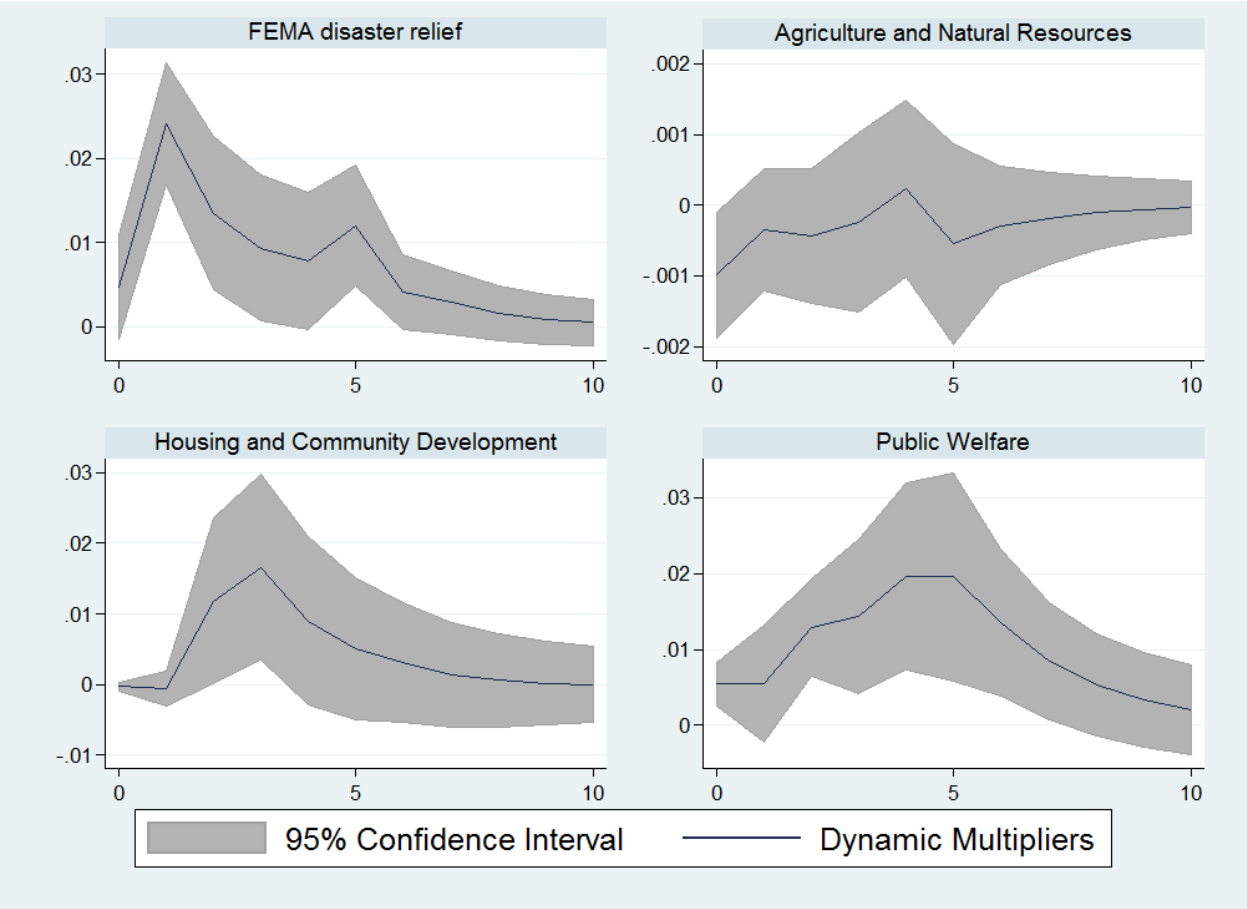


**Table 5**
**Response of the Federal DRF appropriations to PDD direct disaster losses (OLS 1989-2013 time series)**

| | (1) | (2) |
|---|---|---|
| *PDD disaster dollar losses(t)* | 0.340*** | 0.370*** |
| | (0.0627) | (0.0493) |
| *PDD disaster dollar losses(t-1)* | 0.00651 | 0.0197 |
| | (0.0626) | (0.0487) |
| *Fiscal year time trend* | | 0.4242*** |
| | | (0.1078) |
| Constant | 1.522 | -847.7818*** |
| | (1.3047) | (215.9245) |
| Observations | 25 | 25 |
| R2 | 0.581 | 0.759 |

Notes: Standard errors in parentheses. Asterisks denote significance at the 1% (***), 5% (**), and 10% (*) levels. Unit of analysis is federal government.

**Figure 4**

**U.S. Congress Regular and Supplementary Appropriations for the Disaster Relief Fund (FY1989-FY2013)**