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Costly Disasters & the Role of Fiscal Policy: Evidence from US States

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DG ECFIN's Fellowship Initiative 2020-2021 "Shifting paradigms: The quest for new modes of sustainable growth and convergence" sought contributions exploring underlying and emerging trends in the quest for new growth models that respect the limitations of natural resources while ensuring job creation and lasting prosperity in Europe. Achieving a successful transition to become the world's first climate-neutral, resource efficient continent, fit for the digital age, while ensuring social fairness requires identifying evolving trends and challenges to success stemming from ageing and inherent to both environmentally sustainable development and the transition to a digital society. The fellowships were awarded to prominent scholars in the field to interact with staff in ECFIN and other Commission colleagues, and to prepare final reports on specific research questions brought by these shifting paradigms.

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Abstract

We examine the dynamic effects of natural disasters in US states and relate them to state and federal fiscal policy. Disasters have significant negative output but less severe unemployment consequences. Real effects vary spatially: coastal and poor states recover more slowly. States with less stringent budgetary requirements and/or rainy day funds have insignificant real costs and negligible debt consequences. Countercyclical fiscal policy reduces the severity of the real downfall. Both federal and state governments respond to the disaster shock and aid by the former helps to lower the short run costs on state debt. The ability of states to run deficits and temporarily increase debt is a key factor in the recovery.

JEL Classification: C32, E27, E32, H30.

Keywords: natural disasters, recessions, federal transfers, state fiscal policy, debt accumulation, rainy day funds.

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1. INTRODUCTION

To many observers, planet earth has become a more uncertain and dangerous place to live. Natural disasters, such as hurricanes, cyclones, earthquakes, wildfires, floods, or extreme weather events, like droughts and snow storms, are increasing in frequency, due to climate changes, and becoming more damaging. According to a UN Office for Disaster Risk Reduction report (UNDRR (2020)), the number of reported natural disasters has almost doubled since 2010, affecting a larger portion of the world population and inducing almost twice as large economic costs. From 2000 to 2019, there were 7,348 major recorded disaster events, claiming 1.23 million lives, affecting 4.2 billion people, and resulting in approximately 2.97 trillion US dollars of economic losses. According to the report, China (557) and the US (467) are the countries suffering the largest number of incidents.

These trends raise important concerns about the price one should expect to pay in the years to come and about the appropriate public policy reaction in these situations. A central issue in the discussion is to ensure that enough public funding is available to prepare for, respond to, mitigate against, and recover from natural disasters. The rising costs and the intensification of disasters, however, is putting pressure on public budgets and has induced policymakers to revise existing strategies. The Covid-19 pandemic has brought about similar issues and additional discussions about the design of the fiscal response to better deal with catastrophic events. For example, Guerrieri et al. (2020) highlight that government transfers, rather than government expenditure, may be key in counteracting a pandemic crisis. The Commission's Report on Public Finances in EMU 2020 (ECFIN (2021)) dedicates a full chapter to this topic, emphasising the need of strengthening disaster risk management and of developing disaster risk financing. In particular, the European Commission's overview highlights the need to pursue and deepen national assessment coverage of the effects of climate change on disaster risks. It also underscores that financial resilience, in particular, from a budgetary perspective, is key for governments to be able to appropriately respond to future disaster events.

To evaluate what is the best policy response design and to understand how and to what extent preemptive measures could matter, it is essential to examine the dynamic macroeconomic effects induced by disasters.

Contribution

This paper analyses how natural disasters affect production and employment and the role active fiscal policies may have in moderating their effects. We look at US states since natural disasters are quite frequent; there is sufficient information about their nature and their costs; and long enough macroeconomic data allows us to use statistical methods to analyse the dynamic repercussions of these events.

We analyse the role of fiscal policy at the state level and examine how federal responses can shape macroeconomic dynamics after natural disasters. From the state point of view, we examine whether flexible constraints, such as loose balance budget and debt restrictions, or special budget provisions, such as the existence of rainy day funds (henceforth, RDFs) can help dealing with the consequences of natural disasters. In the process, we study the sustainability of debt accumulation in reaction to catastrophic events at the state level. From the federal point of view, we evaluate whether federal transfers have different impacts and whether they undo state fiscal restrictions or exacerbate existing constraints.

We use annual data from 1980 to 2018 and measure the macroeconomic effects of disasters in two ways. First, we employ an event-study methodology and examine the dynamics of macroeconomic and fiscal variables around "costly" disasters' events. We calculate disaster losses using different cost measures and concentrate on those events with severe costs to provide a clear cut view of their real effects and of the role of fiscal aid. Because event studies only provide evidence on the correlation between

macroeconomic activity and fiscal variables, they have little to say about the causal role that fiscal policy may have in reducing the economic disruptions. Furthermore, because other events may occur in the year of the disaster, and because some states are more likely to suffer certain types of disasters than others, an event-study analysis is unable to tell us what drives the correlation between economic activity and fiscal variables around disaster dates.

To address this latter issue we examine the dynamic effects of disaster shocks. Thus, rather than computing unconditional correlations between the fiscal and the macroeconomic variables around disaster dates, we compute such a correlation, conditional on a disaster shock. Once dynamic responses are obtained, state by state, we explain the heterogeneity we found clustering outcomes using state characteristics.

We examine the role of fiscal policy in reducing the recessionary effects of disaster shocks by clustering responses in states with different federal transfer or state expenditure responses. Intergovernmental transfers are a major source of finance to local and state governments. Overall, they are a surprisingly stable and persistent component of the complex system of intergovernmental regulatory and fiscal relations. Transfers facilitate local fiscal adjustment to shocks arising from natural disasters and from demographic and economic shocks. The real effects of these transfers, and their real role in the fiscal system, are far less obvious. Indeed, understanding the role of intergovernmental transfers in a complex federation presents deep analytical challenges. The fiscal systems of the Federal, state, and local governments are intertwined in a multitude of ways. Policy decisions made by the Federal and state governments affect local economic conditions and the effective costs and burdens of local government expenditures and revenues. The economic effects of those transfers and their interaction with local and state fiscal policy has been extensively studied in the literature (See, e.g. Buettner and Wildasin (2006)). Here we focus on their role in stimulating state conditions in response to a disaster shock.

Relationship with the literature

Our investigation brings together four different strands of literature. The first studies the effect of calamities. Kuralbayeva et al. (2019) examine how earthquakes affect the rate of time preferences and Deryugina (2017) estimates the fiscal consequences of hurricanes, taking into account both direct (through the disaster aid channel) and indirect (through other social safety net programs) costs. She shows that hurricanes not only cause real damages but also produce a fiscal drag, as they lead to a substantial increase for a number of years in non-disaster government transfers, such as unemployment insurance and public medical payments. Relative to this work, we consider all disasters, not just hurricanes; we account for the fact that disaster costs are serially correlated and, thus, avoid the upward bias likely to be present in her estimates; and look at a broader spectrum of variables. The second strand quantifies the macroeconomic impact of disasters in recent US history in order to estimate the likely impact of Covid-19 on the US economy, see e.g. Ludvigson et al. (2020). Relative to this work, we take a spatial perspective and use state rather than aggregate US data; and evaluate the role of fiscal policy in mitigating disasters. The third strand of literature investigates the role of fiscal policy in stimulating the economy. Auerbach and Gorodnichenko (2012) find that expenditure increases are more expansionary in recessions than on average. Ramey and Zubairy (2018) and Alloza (2017) question this conclusion, as it turns out to be sensitive to the specification the empirical model, the sample period, and to the methodology used for computing the multipliers. Barnichon and Matthes (2020) reconcile the two views by arguing that the sign of the fiscal shocks matters. In particular, they stress that only the multiplier associated with negative government spending shocks is greater than one, and that this multiplier becomes larger in times of economic slack. Since, natural disasters induce recessions, studying whether discretionary expansionary fiscal policy can lift the affected economies from the slump is an important related question. Finally, our work is also related to the large literature studying the desirability of countercyclical fiscal policy and of contingency public funds for emergency situations, see Alesina and Passalacqua (2016) for a review. It is well known that higher government spending or lower taxes may help to speed up the recovery by stimulating demand; and many economic models prescribe that deficits should be countercyclical, but should not lead to a secular increase in the debt-to-

GDP ratio. Alesina and Passalacqua (2016) document that these insights do not generally hold for many countries. By studying fiscal responses to disaster shocks in states facing different disaster risks and different public policy profiles, we evaluate whether countercyclical fiscal policy is important for mending the negative effects produced by natural disasters on the state economy and assess whether such actions affect the dynamics of state debt.

The results

Costly disasters are typically associated with negative although short-lived effects on gross state product (GSP) and the unemployment rate, relative to the US average. Relative welfare aid increases on impact, relative state expenditure increases persistently, but relative state debt dynamics are generally moderate and convergent. Relative federal state transfers also increase to sustain the state economy. Thus, fiscal policy is countercyclical with the federal government generally being more proactive than the state government. Nevertheless, the magnitude and the scope of both reactions is far from overwhelming.

We demonstrate that the geographical position and the level of income matter for the comovements between real macroeconomic and fiscal variables with coastal and poor states experiencing higher output losses and lower comovement with fiscal variables. Moreover, in states with strict budgetary restrictions the recovery is slower and these states heavily rely on federal aid to counteract the negative effect of the disaster shock. Finally, the presence of rainy days funds makes an important difference and, in states without such provisions, output and employment losses are larger in the medium run.

The dynamic responses to the identified disaster shocks reveal that a disaster shock typically generates a fall in relative GSP, significant up to four years after the disturbance, but no measurable effects on relative unemployment. Relative state expenditure increases on impact, mainly because of the increase in welfare expenditure programs, while relative state revenues fall significantly two years after the shock. As a result, relative state debt rises, reaching its peak two years after the shock. However, there is a medium term reversal: relative government expenditure falls (and relative revenue increases) bringing relative state debt back on track. Relative federal transfers increase significantly one year after the shock, reach their maximum two years after the disaster, and return back to the US average within four years. Thus, while both state and federal policies countercyclically respond to the disaster shock. State expenditure increases on impact while federal expenditure is slower to reach the beneficiary states, possibly due to red tape for individual assistance and delays in the official declaration of disaster.

While the typical pattern of responses conforms with economic intuition and theoretical prescriptions, there is considerable heterogeneity in the way states react to the shocks. By selecting a few representative states, we show that there are measurable differences in the real costs of disasters, in the way fiscal policy reacts, and in the conditional correlation between federal and state spending and local economic activity. The geographical position of the state, the level of income, the tightness of the budget restrictions and the presence of RDFs account for some of the heterogeneity we uncover. In particular, states with tighter fiscal constraints or no RDFs tend to have inferior macroeconomic performance. Which level of the government runs countercyclical policies seems to matter and states using more proactively their own fiscal lever face the calamity better. Still, even in states with looser budgetary restrictions, debt dynamics are modest and state debt returns to the mean level fast.

The amount of federal transfers a state receives also matters for the way the state economy develops along the adjustment path. States enjoying larger federal transfers on the onset of the disaster display much more positive medium term output responses and reductions in their relative unemployment rates. Interestingly, states receiving larger federal support after the shock are not those which have tighter budget restrictions.

Fiscal flexibility at the state level is important for moderating the effects of natural disasters on relative unemployment. States that can increase spending on impact recover better with increases in relative GSP and reduction in relative unemployment. This superior macroeconomic performance comes at the

cost of temporarily higher but moderate relative state debt along the recovery path. Thus, a timely reaction of state spending increases the likelihood of a faster and more vigorous recovery from natural disasters, and limits the fiscal costs associated with a spending increase. On the other hand, states that react by decreasing relative government spending, albeit the fact that they experience increases in relative federal transfers and maintain the debt level at low levels, suffer a considerable increase in their relative unemployment and output losses in the medium run. Hence, the ability of states to run deficits and temporarily increase debt is also an important factor in the recovery.

The plan of the paper

The rest of the paper is organised as follows. The next section describes the data and the econometric procedure. Section 3 examines the dynamics of macro and fiscal variables from an event-study point of view. Section 4 studies the dynamic effects of a disaster shock on average, zooms-in on selected states, and clusters results along relevant dimensions. Section 5 investigates the causal role of fiscal policy and Section 6 concludes.

2. THE DATA AND THE ECONOMETRIC APPROACH

National Oceanic and Atmosphere Administration, (NOAA) disaster data

Natural disasters cost data spans the sample period 1980-2018, it is state specific, annual, and comes from NOAA (2020). The damages are reported in real 2019 billions of dollars and based on insurance data; information obtained from federal programs such as the Flood and crop insurance program, the Property claims program; as well as from risk management agencies, such as the Federal Emergency Management Agency (FEMA), the U.S. Department of Agriculture (USDA), and the US Army Corps of Engineers (USACE).

According to the updated database of the Billion-Dollar Weather and Climate Disasters of Smith and Katz (2013), 249 disasters costing at least a billion dollars are present in our sample: 16 were wildfires, 27 droughts, 43 tropical cyclones, 107 severe storms, 17 winter storms, 30 floods, and 9 freezes. The death toll was large (14179 human lives lost) and the total cost amounted to 1736.4 billion dollars. Different states have been exposed differently to disasters; and there is a geographical pattern in the type of events affecting certain regions. Western states suffer from wildfires, South-east states from hurricanes, Central states from droughts and tornadoes, and Northern states from severe weather and snowstorms. Hurricanes are the most severe disasters. Hurricane Katrina, occurred in 2005, caused 1833 deaths and 170 billions US dollars in damages. The next most extreme event is Hurricane Harvey, occurred in 2017; although it caused “only” 89 deaths, it generated 131.3 billion dollars of damages; at the other end, Hurricane Maria, which also occurred in 2017, was one of the deadliest storms, with numerous indirect fatalities in the wake of the storm’s devastation (2981 deaths) but with more contained financial damages (94.5 billion dollars). Hurricane Sandy which occurred in 2012 was also severe, costing 75 billion dollars and taking 159 human lives.

Unfortunately, NOAA does not provide exact measures for the damages each disaster generates. Instead, it reports range estimates [1] and measures total costs by summing the upper limit of the ranges for each

1 In constant 2019 million of dollars they are: [1-5], [5-250], [250-500],[500-1000], [1000-2000], [2000-5000], [5000-10000], [10000-20000], [20000-50000], [50000-100000], and [100000-200000].

disaster in a given year and a given state. We follow the same methodology to compute state annual costs. Tables 1 and 2 present a summary of the features of the data.

The first column has the name of the state and the second the number of natural disasters experienced during the sample period. The third reports the per-capita costs of disasters and the fourth the major event experienced and the year it occurred.

Table 1: **Natural Disasters by State 1980-2018: Part I, Alabama-Nebraska**

State	Disasters	Mean per capita	Major event
Alabama	80	411.6	Hurricane Katrina (2005)
Arizona	23	549.2	Severe Storm (2010)
Arkansas	62	104.8	Tornadoes (2011)
California	36	140.9	Wildfire (2018)
Colorado	47	285.5	Severe Storm (2018)
Connecticut	31	162.0	Hurricane Sandy (2012)
Delaware	26	415.5	Drought/Heatwave (2011)
Florida	56	686.9	Several Hurricanes (2004)
Georgia	80	149.2	Hurricanes Florence/Michael (2018)
Hawaii	1	8696	Hurricanes Iniki (1992)
Idaho	25	365.7	Drought/Heatwave (1988)
Illinois	76	154.8	Drought/Heatwave (2012)
Indiana	62	241.6	Flood (2008)
Iowa	50	798.7	Flood (1993)
Kansas	68	507.2	Drought/Heatwave (2012)
Kentucky	62	231.1	Drought/Heatwave (2012)
Louisiana	63	2063.2	Hurricane Katrina (2005)
Maine	14	267.7	Winter Storm (1998)
Maryland	54	158.3	Hurricane Ivan (2003)
Massachusetts	27	91.4	Hurricane Bob (1991)
Michigan	34	55.4	Drought/Heatwave (1988)
Minnesota	33	390.2	Flood (2008)
Mississippi	72	1013	Hurricane Katrina (2005)
Missouri	71	344.8	Severe Storm (2011)
Montana	27	1363	Drought/Heatwave (1988)
Nebraska	39	712.6	Drought/Heatwave (2012)

Table 2: **Natural Disasters by State 1980-2018: Part II, Nevada-Wyoming**

State	Disasters	Mean per capita	Major event
Nevada	18	170.2	Flood (1997)
New Hampshire	16	307.6	Winter Storm (1998)
New Jersey	44	327.1	Hurricane Sandy (2012)
New Mexico	27	223.6	Hurricane Dolly (2008)
New York	59	140.8	Hurricane Sandy (2012)
North Carolina	78	307.3	Hurricanes Florence/Michael (20118)
North Dakota	17	3707	Drought/Heatwave (1988)

Ohio	62	83.6	Hurricane Ike (2008)
Oklahoma	75	387.8	Severe Storms (2013)
Oregon	30	132.7	no major event
Pennsylvania	66	76.4	Hurricanes Ivan/Jeanne (2004)
Rhode Island	23	320.9	Hurricane Sandy (2012)
South Carolina	66	432.4	Hurricane Hugo (1989)
South Dakota	24	1317	Drought (2006)
Tennessee	72	218.6	Severe Storm (2003)
Texas	106	514.0	Hurricane Harvey (2017)
Utah	18	248.8	Flood (1983)
Vermont	15	731.7	Hurricane Irene (2011)
Virginia	71	142.5	Hurricane Isabel (2003)
Washington	25	67.6	Drought/Heatwave (2015)
West Virginia	34	294.4	Flood(1988)
Wisconsin	31	159.7	Flood (1993)
Wyoming	21	94.9	Drought/Heatwave (1988)

There are considerable variations in the number and the types of episodes occurring in different states, given that different geographic regions face a unique combination of weather and climate. Still, at least one natural disaster occurred in all states. The Southern, the Central and the South-east regions experienced a higher number of billion-dollar disaster events. Texas is the state with the largest incidence of disasters (106). On average, the damages amounted to 514 dollars per-capita with the most severe disaster (Hurricane Harvey in 2017) producing damages estimated at 7254 dollars per-capita. At the other extreme, Hawaii was affected only once, by Hurricane Iniki in 1992, which caused costs whose upper bound was estimated at 8696 dollars per-capita. Although North Dakota suffered less disasters than Texas, it experienced 17 very costly disasters, with the drought of 1988 costing 15282 dollars per-capita. Hurricane Katrina was devastating for the state of Louisiana. According to our database, it induced damages of roughly 37000 dollars per-capita. Alabama and Georgia have also experienced a large number of disasters but they were generally moderate in terms of economic costs. Finally, Washington is the state were disasters happen less frequently and are also relatively less damaging in per-capita terms.

Note that total estimated damages do not necessarily give a good overview of economic consequences of disasters. For a given cost, states with large gross state product (GSP) or larger population may dilute the pain better than states with smaller GSP or less densely populated. For this reason, our analysis examines the effect of disasters, when measured in per-capita terms. Given that it generally makes little difference if disasters are measured in per-GSP terms, we comment on results obtained with the latter in robustness sections.

Macroeconomic data

State macroeconomic data is also annual and goes from 1980 to 2017. The U.S. Bureau of Economic Analysis (BEA) provides data for state real GSP. Because it currently publishes only data from 1993, we splice the data with the one used by Canova and Pappa (2006) to have a longer time series. State unemployment rate and population are from the database of the Federal Reserve Bank of Sant Louis (FRED). For state and local government finances we employ the information available from the U.S. Census Bureau. We obtain series for state government expenditure, revenues, welfare transfers, and debt,

and federal state transfers. Details of what each series measures are in the appendix A. We deflate all nominal series with the GSP deflator, and use the state population series to compute per-capita variables. To control for aggregate business cycle conditions, which may cause state variables to fluctuate even in the absence of natural disasters, all macroeconomic variables are scaled by national averages. Thus, the dynamics we report have to be interpreted as deviations from national conditions.

The econometric methodology

We employ two different methodologies in our investigation. First, we use an event-study approach and characterise the dynamics of scaled state variables around disaster dates. The idea of the exercise is to check whether there are interesting unconditional correlation patterns between macroeconomic and fiscal variables around disaster dates and to assess whether they could be linked to observable state characteristics, such as the geographical position, the income level, or features of the state fiscal framework, such as the tightness of budget restrictions, or the existence of rainy days funds. We consider macroeconomic dynamics from one year before up to three years after the disaster. We analyse only very costly disasters, which we define as those with losses larger than 2700 dollars per-capita or larger than six percent per-GSP losses. While there are some differences, the main events are present regardless of the definition used [2].

In the second exercise we examine the dynamics of scaled state macroeconomic and fiscal variables and of federal transfers induced by disaster shocks. We perform the exercise, state by state, to allow for different spatial propagation of the shocks; then we average the responses and report the dynamic effects in a "typical" state. Because spatial heterogeneity is important, we cluster the responses along interesting geographical, economic and political economy dimensions, and examine differences in the typical state of each group. Finally, we study whether typical states where responses in federal or state fiscal variables differ also display differences in macroeconomic responses.

To trace out dynamic responses we employ a Bayesian local projection (LP) technique. The prior we employ shirks coefficient estimates toward zero, as it would be the case in a classical ridge regression setup, while allowing for the prior precision on the restriction to be sufficiently loose. The prior helps to reduce biases in point estimates due to the short available sample. To compute a disaster shock we filter the disaster costs series of each state using a constant and one lag of the disaster cost variable. Because disasters occur repeatedly and costs are often spread over a number of years, disaster damages are highly serially correlated. Thus, an exercise performed without a preliminary filtering the series would overestimate the effect of the shock. Note that, as long as disaster shocks are exogenous to state macroeconomic activity, the approach can be though as a Bayesian variant of a LP-IV methodology, where shocks are used as instruments in the projection equation. Given that we have annual data, we estimate projections equations for horizons up to four years.

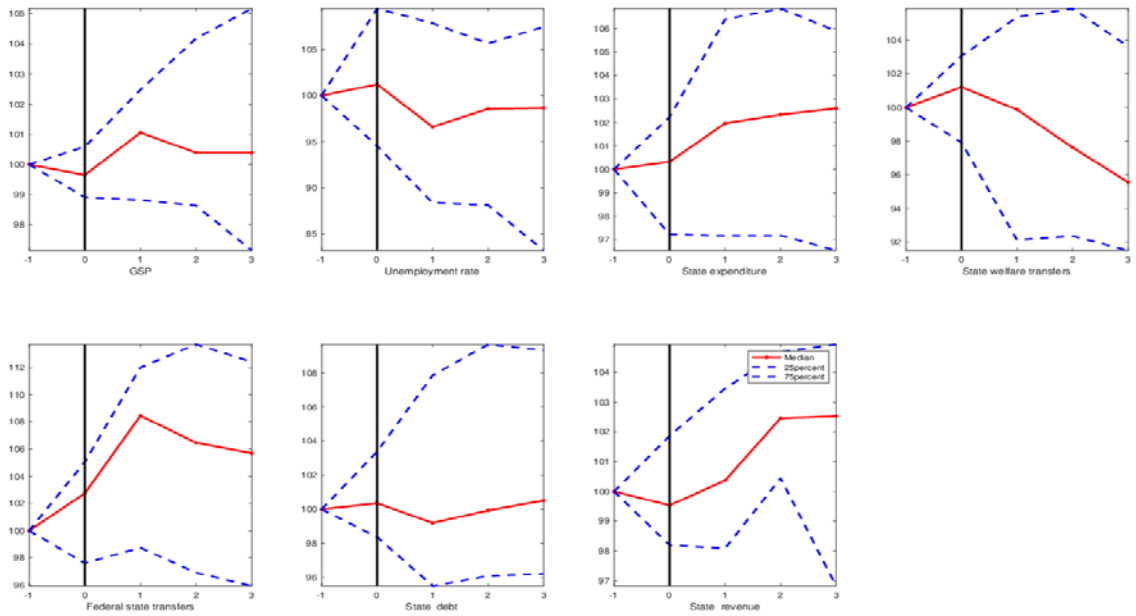
2 When costs are measured in per-capita terms, large disasters are: the 1988 heat wave/drought for ND, SD, MT and WY; the 1989 hurricane Hugo for SC; the 1992 hurricane Iniki for HI; the 1992 hurricane Andrew for FL; the 1993 blizzard for SD; the 1993 floods for IA and ND; the 1995 flood in LA; the 1997 flood in ND; hurricanes Ivan, Francey, and Charley in 2004 for FL; the 2005 hurricane Katrina for AL, FL, LA, and MS; the 2006 wildfires for SD; the 2008 hurricanes Gustav and Ike for LA; the 2008 tornadoes for IA; the 2012 drought in SD and the 2012 hurricane Sandy affecting KS, NE, NJ and NY. When the costs are measured in per-GSP terms, large disasters are: the 1983 floods for MS; the 1983 storm for UT; 1988 heat wave for ID, IA, MT, ND, SD, WY; the 1989 drought for ND, SD; the 1989 hurricane Hugo for SC; the 1992 hurricane Andrew for FL; hurricane Iniki in 1992 for HI; the 1993 blizzard for SD; the 1993 floods in IA, ND; the 1994 ice storm for MS; the 1997 flood for ND; the 1998 blizzard for Vermont; the 2004 hurricanes Ivan, Francey, and Charley in 2004 for FL; the 2004 hurricane Ivan for AL, the 2005 hurricane Katrina for AL, FL, LA, MS; the 2006 wildfires for SD; the 2008 tornadoes for IA; the 2011 tornadoes in AL, and the 2012 hurricane Sandy for NJ.

3. EVENT STUDY APPROACH

We present median and the interquartile range of dynamics across states for the seven variables of interest around large per-capita disaster dates in Figure 1. To help visualise the results, the dynamics are normalised so that, for any given variable, all states start with an index equal to 100, one year prior to the disaster.

In the median, relative GSP falls by about 0.5 percent in the disaster year; it rebounds the year after, and converges to the US average from above. Relative unemployment increases by 1.3 percent in the disaster year and then persistently falls for three years to return to the US average from below. The impact of the disaster is clearly reflected in the response of regional fiscal variables: relative state expenditure persistently increases after the disaster, while relative state welfare transfers increase on impact and then fall one year after the disaster. Since the relative state revenue temporarily falls, relative state debt dynamics are moderately increasing on impact. This pattern is however reversed one year after the disaster: relative revenue increases and state debt falls and converge to the US average from below. Relative federal transfers also increase in the disaster year and continue to increase also in the second year[3]. At the peak, one year after the disaster, relative federal state transfers increase by about eight percent, remaining six percent above average three years after the shock.

Figure 1: **Dynamics around disasters, event study**



Thus, costly disasters generate mild and temporary recessions in the real side of a typical state affected by the event. Federal aid is strongly countercyclical and persistent. On the other hand, state expenditure and transfers do not react much when compared to federal state transfers, perhaps due to limited fiscal capacity or to already high level of debt. Interestingly, the persistent increase in state expenditure is not due to a persistent increase in welfare transfers. In fact, three years after the disaster, expenditure is

3 Federal transfers increase persistently in Figure 1. In exercises we do not present here for economy of space we show that after big disasters federal debt also increases but only moderately. Hence, it does not seem that the impact of natural disasters is absorbed at federal level.

above their pre-disaster level by about 2.5 percent. Note also that, while the typical relative state debt increases the year of the disaster, there is no evidence of persistent or explosive dynamics. Even for states where the increases are considerable, relative debt peaks at most at nine percent.

3.1. WHAT DRIVES THE HETEROGENEITY?

While the effects in the typical state are broadly in line with the expectations and support the predictions of many theoretical models, there is considerable heterogeneity in the dynamics of variables around the disaster dates and the interquartile ranges reported in Figure 1 include 100 at all horizons and for all variables. Thus, there are states in which costly disasters do not create a relative contraction in real activity and others in which state expenditure and federal transfers fall relative to the US average. To try to understand why this is the case, we link these patterns to observable states' characteristics.

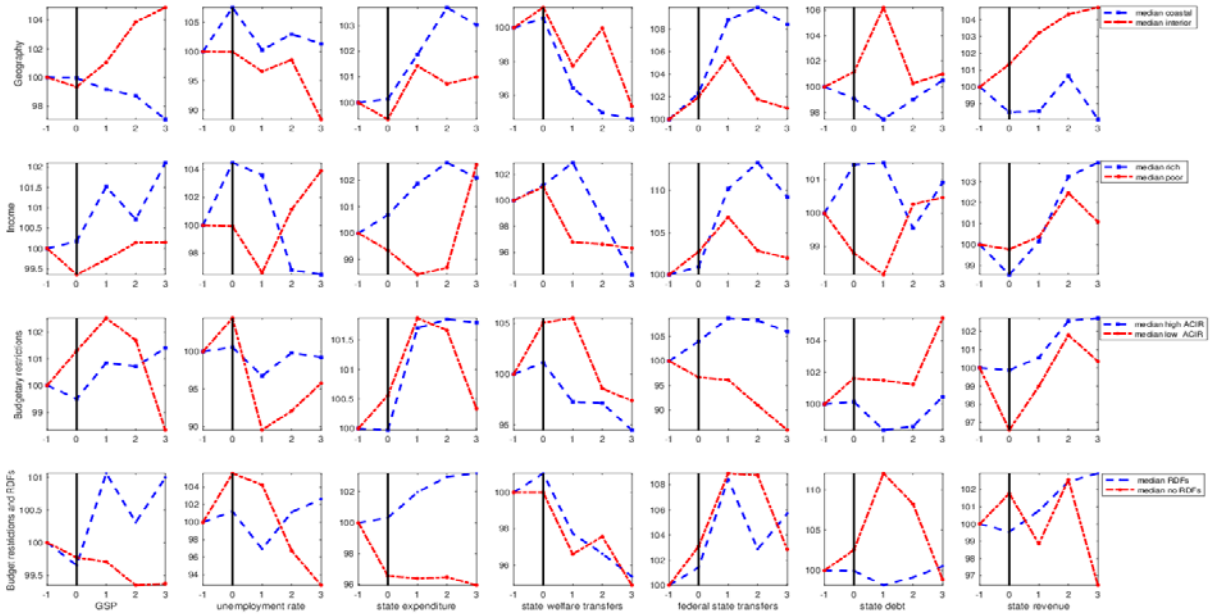
Coastal versus interior states

We first examine whether the geographical position matters for the dynamics of the variables of interest. Hurricanes have dealt hundreds of millions of dollars in damages to Atlantic states, while floods, droughts, heat waves, and tornadoes have mostly affected interior states. For that reason we cluster costly episodes into two groups: those affecting interior states and those affecting coastal states. Because geography and type of disasters are correlated, this grouping implicitly analyses the macroeconomic consequences of hurricanes versus other natural calamities. Note that the magnitude of costs differs in the two groups and, on average, coastal disasters are almost three times as costly in per-capita terms (8109 versus 3056 US dollars). Thus, the classification we present can also be interpreted as due to extreme vs. less severe damaging disasters. The first row of Figure 2 plots the typical response of the relative variables separately for coastal and interior states.

The dynamics of macroeconomic variables differ in the two groups: In interior states (dashed red line), relative GSP falls on impact, recovers after one year, and expands thereafter; relative unemployment persistently falls after the disaster and, after three years, the fall exceeds 10 percent relative to the US average. In coastal states (dotted blue line), on the other hand, relative GSP remains unchanged on impact but it persistently falls thereafter; and relative unemployment increases by six percent on impact and remains higher than the US average for a number of periods. One reason for this differential pattern may have to do with the timing of the disasters: hurricanes tend to happen in the fall, while droughts, heat waves and tornadoes are more common in the summer. Thus, for coastal states, the largest real effects tend to be lagged at least one year. Still, the costs are spread over consecutive years for coastal states and this should be due to the nature of the disasters heating those states.

The two groups of states also differ along other dimensions. State fiscal policy in coastal states is more countercyclical after disasters; relative state expenditure increases and relative state revenues fall on impact, while the opposite occurs for interior states. Notice that in both groups relative welfare transfers follow a similar path, increasing on impact and falling afterwards. The dynamics of relative federal transfers are also similar in the two groups; however relative federal transfers increase more strongly and more persistently in coastal states. The differential response of federal transfers could explain the dynamics of debt, since federal state transfers count as revenues in the state budget.

Figure 2: **Dynamics around disasters, event study: different groupings**



Rich versus poor states

An alternative reason for why the dynamics around disaster dates may differ may be related with the level of income. One can envision different reasons for why poor states may be more severely hit by the catastrophic events. For example, richer states may be less affected because only a smaller portion of their economic activity is damaged by the disaster; alternatively, because richer states have developed private and public insurance schemes, implemented at the individual and firm level. The second row of Figure 2 plots the dynamics of the seven variables separately for the typical rich (dotted blue line) and the typical poor states (dashed red line), where we use 40,000US$ per-capita on average over the sample as a threshold to define rich states.

Disasters produce different dynamics in the two groups. In poorer states (dashed red line) relative GSP falls in the disaster year and takes some time to return to the pre-disaster level. In rich states (dotted blue line), instead, it increases at all horizons. Job destruction rises in rich states the year of the disaster but then falls below the pre-disaster level, while poor states feature a temporary fall in relative unemployment, perhaps due to the fact that people search less for a job, followed by a sharp increase. The dynamics of relative state expenditure also differ, with poor states reducing, while rich states increasing expenditure persistently after the disaster. The dynamics of government expenditure in the two groups reflect the dynamics of relative state debt. Tax revenues fall on impact in both groups of states and the fall is larger in rich states; but they persistently increase in both states afterwards. Another important difference between the two groups of states is in the behavior of relative welfare transfers, which increase more persistently in rich states. Finally, although poor states receive more federal transfers in the year of the disaster and in the following one, relative federal state transfers increases last longer for richer states. This may be due to the fact that, in rich states, unemployment increases for a few years.

Fiscal rules and rainy day funds

The state fiscal rules may also affect the dynamics of real variables after a disaster. For example, if budget restrictions are present, one should expect state expenditure to be quite unresponsive, state debt to be roughly unchanged, and the dynamics of relative GSP and relative unemployment to be shaped almost entirely by the dynamics of federal transfers. Similarly, given a set of budget restrictions, one would expect states with rainy day funds to be in a better position to contrast the negative real effects of disasters than states without.

The third row of Figure 2 displays the typical dynamics of the relative variables around disaster dates, separately for states with tight (dotted blue line) or loose (red dashed line) budget restrictions; the fourth row has the same information for states with tight budget restrictions states that also have (dotted blue line) or do not have (red dashed line) RDFs available. We measure the severity of the budget restrictions using the Advisory Council on Intergovernmental Relations (hereafter ACIR) index, which runs from 1 (lax) to 10 (stringent) and combines two types of information: whether the state budget should be balanced ex-ante, ex-post, or never; whether deficits can be carried over two consecutive fiscal years. Details on these indicators are in Canova and Pappa (2006). We define as states with tight budget restrictions states that score 10 on the ACIR scale, as those states require a balanced budget at the end of the fiscal year. States with score below five have softer requirements and do not have stricter rules and for that reason we consider states with score below five as states with loose restrictions.

In the typical state with loose fiscal restrictions there is no downfall of economic activity: relative GSP grows the year of the disaster and continues to grow the following years; relative unemployment rate increases on impact but falls drastically subsequently. On the other hand, in the median state with tight budget constraints, relative output falls by 0.5 percent the year of the disaster while the relative unemployment falls the year after the disaster and stays persistently below the US average. These dynamics seem to be due to the fact that in states with tight budget restrictions state government expenditure reacts with a lag and that state revenues remain unchanged and increase after the disaster. Knight (2005) examines the short-run effects of tax and expenditure constraints by looking at state responses to fiscal crisis. He focuses on unexpected deficits, measured by the difference between actual and forecasted deficits, and finds that states with constraints respond to unexpected deficits through tax increases. This seems to be true also in response to exceptional events like disasters. Notice that the fall in real activity occurs in states with tight constraints despite the fact that federal transfers respond instantaneously, persistently, and significantly. The typical state with loose budget restrictions accumulates relative state debt in order to finance the increase in relative expenditure. Moreover relative welfare transfers persistently increase after the disasters. Thus, fiscal restrictions constrain state expenditures in response to natural disasters, impose limits on state debt dynamics, but tend to imply larger output and unemployment costs, at least in the first few years after the disaster.

Over time, states have found themselves increasingly constrained in their ability to quickly raise taxes or to run fiscal deficits whenever they experience an unexpected revenue shortfall. Partly in response to these budget limitations, states began employing budget stabilisation funds, often called " rainy day funds," that allow them to store surpluses to be spent during revenue shortfalls. RDFs are a relatively new addition to the set of stabilisation tools state governments have at their disposal. They help to smooth state consumption expenditure by serving as receptacles for savings in good times to be used in bad times and situations of economic distress. They did not become common until the mid-eighties, although dates of adoption vary substantially (see Table 3 for RDFs adoption dates in appendix A). As of today, there are five states without RDFs: Alabama, Arkansas, Colorado, Montana and Oregon; and states such

as Hawaii and Illinois have adopted them only late in the 2000s. At the opposite end, New York in 1945 and Florida in 1959 where the first making procurement for RDFs in the state budgets.

It is still largely unexplored how RDFs interact with budget restrictions. For example, balanced budget restrictions should matter less for states with sizable stock of rainy day funds. The last row of Figure 2 shows that the typical state with stringent budget restrictions and no RDFs displays a persistent decrease in relative GSP and a persistent increase in the relative unemployment rate after the disaster. In the typical state of the other group the recession is instead very mild and short-lived: relative state output turns positive and the relative unemployment rate falls into negative territory after one year. This seems related to the ability of the state government to spend. In fact, in the wake of the disaster, relative state expenditure increases persistently in the typical state with RDFs and falls in the typical state with no RDFs. Also note that the typical state with RDFs manages to maintain relative debt dynamics almost unchanged, while relative debt persistently increases in the typical state with no RDFs. Finally, as expected, both types of states rely on federal state transfers on the year of the disaster, but the reliance persists for several years in states with no RDFs.

Robustness

The results we have presented tend to give relative more importance to disasters occurring in less densely populated states, since for a given magnitude of the disaster, per-capita costs are larger. One may also be interested in examining whether conclusions differ when we give relative more importance to disaster occurring in poorer states, since in this case the per-GSP costs will be larger.

It turns out that the dynamics around disaster dates are broadly consistent across the two classifications. As appendix B shows, the typical responses around costly disaster dates for large disasters measured as events where costs have exceeded six percent of GSP are quite similar in shape. There are, however, a few relevant differences in the magnitudes: the impact effect on relative GSP is now null; the medium term dynamics of relative state expenditure are now larger and relative federal state transfers significantly increase in the majority of the states hit by a disaster one and two years after the event.

Summary

Costly disasters have temporary negative effects on relative production and the relative unemployment rate of the typical state. Relative state government expenditure generally rises to make up for the fall in output and to contain job losses, but the dynamics of relative state debt are subdued, thanks also to the fact that relative state revenues do not drastically fall. Federal aid helps to contain the real consequences of a natural disaster.

US states are far from homogeneous in their reaction to disasters, both along the macroeconomic and the fiscal dimensions. The state geographical position (and thus, the type of disasters affecting a state) account for some of the cross sectional variations, as does the level of state income, with richer states doing slightly better than poorer states, but neither of the two fully account for the dynamic cross-state heterogeneity. The fiscal framework also explains some of the differences. In particular, less stringent budgetary restrictions and the presence of RDFs provisions help to better contain the real effects of costly disasters. In response to disasters, fiscal policy is generally countercyclical, with the federal government being more proactive than the state governments.

Still, neither the magnitude nor the scope of the reactions of both levels of the government is overwhelming, especially when one takes into account that the analysis considers disasters producing severe damages.

There are a number of reasons for why the analysis does not deliver sharper insights. First, it could be that certain states are better equipped than others to face disasters. Coastal states may have already protocols which may be quickly activated when tropical storms are expected to hit the region, which might contain the real economic costs. Similarly, California may be better equipped than Minnesota when fighting wildfires and, vice versa, Minnesota may be better equipped when dealing with freezes. States that have a low probability of being affected by minor or major disasters may invest less in prevention or set aside smaller amounts of RDFs and these may not be enough to cope with catastrophic events. For these reasons, grouping of states into binary cells may be insufficient to bring out the correlation we care about and, because of the large amount of heterogeneity, a finer taxonomy is needed. Second, different states have different economic structure and a disaster that hits the rust belt or an oil state may have very different macroeconomic implications of a disaster hitting more service oriented states. Third, individuals and private firms may have private insurance schemes, which can help them to cope with the damages disasters create and this may come in addition to state or federal fiscal aid. Finally, event study evidence only characterises the unconditional correlation of macroeconomic and fiscal variables around disaster dates. Since other events may occur in the same year, and since both macroeconomic and fiscal variables endogenously respond to the state of the regional economy, the correlations we present do not provide evidence that disasters "cause" fiscal policy to react when the state economy is in disarray.

4. CAUSAL ANALYSIS: THE EFFECTS OF DISASTER SHOCKS

To control for events other than disasters that may affect the correlation between macroeconomic and fiscal variables, and to give a causal interpretation to the results, we examine the dynamic propagation of disaster shocks. Given that in some states calamities are recurrent and the damages persistent, we use disaster cost innovations as instruments in the projection equations. Had we not done so, the estimated coefficients in the projection equation would be upward biased, as they would capture the cumulative effect of shocks from t up to $t+h, h = 1,2,3, ...$, see Canova (2020). The dependent variable in the local projection equations is the relative value of the macroeconomic variable j, for state i, at time t and horizon h, i.e, $y_{j,i,t+h} = \frac{Y_{j,i,t+h}}{\overline{Y}_{j,t+h}}$, where $\overline{Y}_{j,t+h}$ is the cross-sectional average of $Y_{j,t+h}$. The independent variable $x_{i,t}$ is the disaster per-capita cost at time t for unit i and the controls are a constant and the value of a vector of $t-1$ variables which includes, at least, state output, state unemployment, and the dependent variable in the projection equation. While additional controls could be employed, degrees of freedom are scarce and small sample bias may not be negligible, see e.g. Herbst and Johannsen (2021). We take a Bayesian approach to deal with small sample problems. Formally, for each variable, the estimated equation is

$$y_{j,i,t+h} = a_{j,i,h} + \sum_{j} b_{j,i,h} y_{j,i,t-1} + d_{j,i,h} x_{i,t} + e_{j,i,t+h} \quad h = 0,1,2,3,4 \tag{1}$$

where $e_{j,i,t+h}$ is a MA(h-1) process, while the instrumental variable regression is

$$x_{i,t} = \alpha_i + \beta_i x_{i,t-1} + u_{i,t} \tag{2}$$

To reduce small sample problems, we estimate equation (1) using a normal prior for $(a_{j,i,h}, b_{j,i,h}, d_{j,i,h})$ with zero mean and fixed variance; thus, the estimates we construct smoothly shrink IV projection

coefficients to zero and are the same as those obtained with an IV ridge estimator. The prior on the coefficients and on the covariance matrix of the error term of equation (2) are conjugate but loosely specified.

Our interest is in the cross-sectional distribution of $d_{j,i,h}$ estimates, which we obtain estimating equations (1)-(2) separately for each i. Once the distribution is obtained, we compute a location and a dispersion measure for each j, h. The typical responses we present are weighted averages, with weights reflecting the precision of unit i sample information.

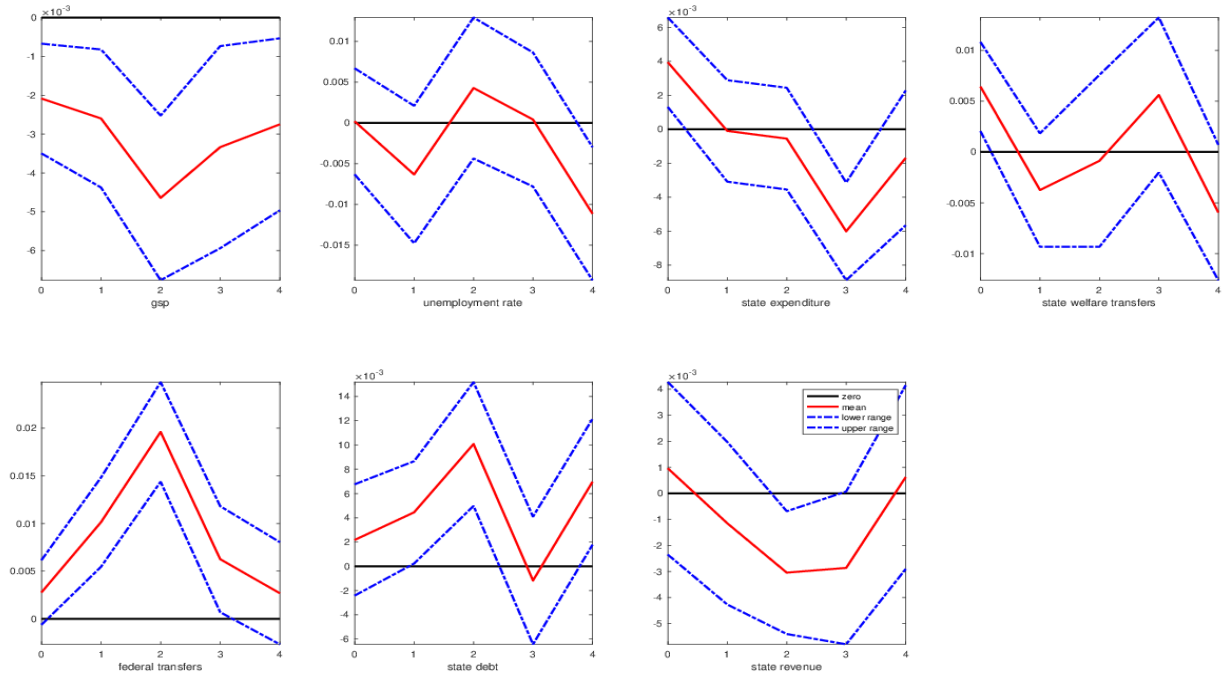
Typical dynamic responses

Figure 3 traces out the dynamic responses in our typical state. Disasters create production recessions: relative GSP significantly falls relative to the US average and the minimum occurs two years after the shock. The fall is persistent, and GSP is still lower than the average four years after the shock. Unemployment, instead, does not seem to react significantly. As we shall see, while there are similarities in the GSP responses across states, the dynamics of the unemployment rate are quite idiosyncratic and this may explain why typical unemployment responses fluctuate around the US average.

Relative state expenditure and relative state welfare transfers are positive and significant on impact. However, the positive response of both variables is quickly reversed and it takes time for state expenditure to return to the pre-disaster level. Relative state debt increases with a lag, primarily because the fall in revenues from own sources becomes significant two years after the shock. The response of the federal government is in line with expectations: relative federal transfers significantly increase on impact, peak after two years and then return to their pre-shock level after four years. This dynamic pattern differs from the one discussed in Deryugina (2017). She suggests that a hurricane produces a persistent increase in federal aid and in non-disaster government transfers, such as unemployment insurance. In contrast, we find that welfare transfers returns quickly to their pre-disaster level, perhaps because the typical unemployment rate is hardly affected by the shock. While the two studies are not strictly comparable, as we consider all natural catastrophes, there is an important econometric reason to question the validity of her estimates. As we have mentioned earlier, estimates of $d_{j,i,h}$ are upward biased whenever disaster costs are positively serially correlated, as they are here. Hence, the persistent response of both federal aid and welfare transfers she finds, might be due to the fact that shocks are not used as instruments in her regressions.

Overall, taking into account the potential presence of other events the year disasters occur and the fact that macroeconomic and fiscal variables endogenously respond to the state of the local economy, qualifies somewhat the event study conclusions. Disaster shocks create persistent output recessions, but no significant dynamic responses in the relative unemployment rate. Relative state and federal fiscal policy appear to be countercyclical, as they both attempt to counteract the negative real effects that disasters generate in the typical state economy. However, the typical state expansionary effort is relatively small, quite temporary and federal aid bears the burden of supporting the local economy along the adjustment path. Relative state debt temporarily increases, but the increase is due more to a fall in revenues than to prolonged state government efforts to contain the real consequences of the shock.

Figure 3: **Typical dynamics in response to disaster shocks**



When disaster shocks are constructed with per-GSP damages, the patterns are similar. The main differences are in the responses of relative state expenditure, which positively rebounds after two years, and relative state revenues, now insignificantly hovering around the US average. Because of these changes, relative state debt dynamics also differ (see appendix B).

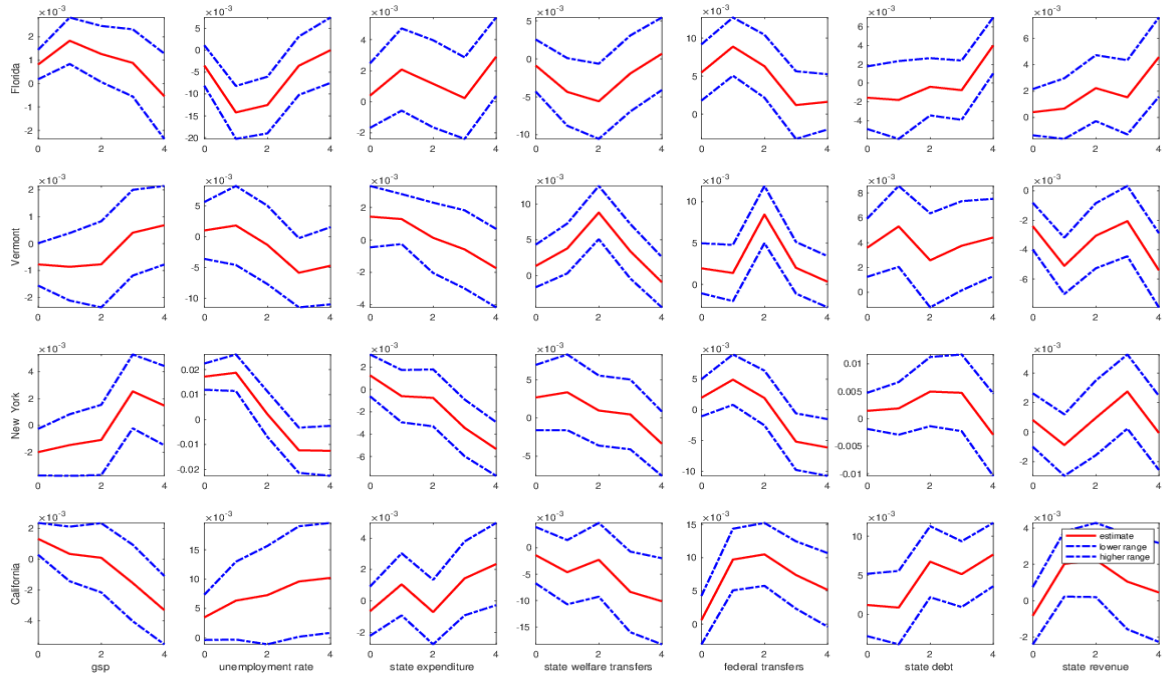
Zooming in on selected states

As in the event-study analysis, the typical effects reported in Figure 3 hide a very heterogeneous pattern of spatial dynamics. To illustrate the differences, Figure 4 presents the responses in Florida, Vermont, New York, and California, which we select as they characterise well the range of outcomes we obtain.

For instance, compare Florida and California. Relative federal transfers positively respond in both states with a lag, while relative state expenditure dynamics are insignificant. Thus, these states rely on federal aid to counteract the real consequences of a disaster shock. However, the dynamic responses of relative GSP and the relative unemployment are quite different: GSP falls and unemployment increases, although not significantly so, in California in the medium run; GSP persistently increases while unemployment persistently falls in Florida.

Now compare New York and Vermont. The dynamics of relative GSP and relative unemployment are similar: GSP falls on impact and recovers after two years; the unemployment rate increases for two years (insignificantly in Vermont) and then gradually falls. Note that, in both states, relative government expenditure increases on impact and then falls. Thus, these are states which use their own fiscal lever to counteract the negative consequences of disaster shocks. However, relative state debt responses are insignificant in New York, while they increase on impact and become insignificant after two years in Vermont. Moreover, relative federal transfers behave differently: they increase on impact in New York, while they display a saw-tooth pattern in Vermont and the reaction is significant only after two years.

Figure 4: **Dynamics in response to disaster shocks, selected states**



How does one interpret these very heterogeneous patterns of state dynamics? One explanation is that the responses of both fiscal and macroeconomic variables to a calamity shock depend on unaccounted factors that shape the effects of the shock differently in different states. We have already analysed some of these factors in the previous section: the location (or type of disaster); the level of income, the existence of balance budget restrictions, and the presence of RDFs in the state budget. We next study whether they also account for the heterogeneity we uncover in the dynamic responses to disaster shocks.

Heterogeneity

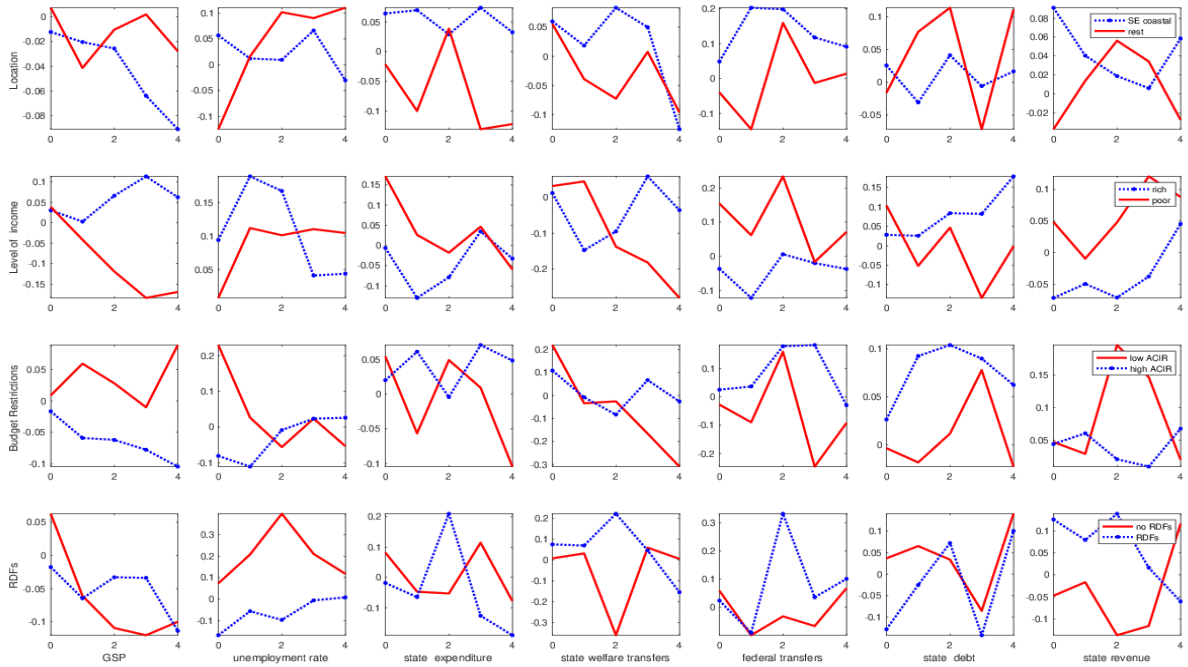
We first look at whether the geographical position makes a difference for the pattern of dynamic responses. The first row of Figure 5 plots the typical responses in two groups: South-east coastal states (dotted blue line) and the rest (continuous red line).

South-east states experience a larger and more persistent relative GSP decline and a moderately high relative unemployment rate after the shock; in the rest of the states, instead, relative GSP falls moderately and relative unemployment rate insignificantly fluctuates around the US average. Note that state spending increases in South-east states, while it falls in the rest. Also, a typical South-east state provides more persistent welfare transfers in response to the disturbance. More importantly, in the South-east relative federal transfers increase more persistently after a disaster shock than in the other group. Despite the increase in relative state spending, the increase in relative debt in South-east states is contained since those states increase own revenues following a disaster shock. Instead, the delayed increase in state federal transfers and the fall in state revenues imply highly fluctuating dynamics around the US average for relative state debt of the other group.

As we have stressed, because of individual insurance programs or better hazard mitigation measures, richer states should be able to handle disaster shocks better than poor states. Thus, one may expect them to rely less on state expenditure and federal transfers to respond to unexpected shocks. Confirming the

event study analysis, rich states (dotted blue line in the second row of Figure 5) do not experience a recession after a disaster shock and their relative GSP stays positive throughout the horizon of interest. Instead, the relative GSP of poor states (continuous red line) falls significantly and persistently. The relative unemployment rate increases in both groups of states. However, while for rich states the increase is temporary, for poor states, albeit smaller in magnitude, it is more persistent and relative unemployment rate remains high for a number of years. Probably because of the larger per-capita costs, poor states increase relative state spending and relative welfare transfers more and receive positive federal transfers for a while. The countercyclical responses of federal aid helps them to contain the increase in relative state debt. On the contrary, rich states experience minor real losses at the cost of having their relative debt persistently increasing.

Figure 5: **Typical responses to disaster shocks: different groupings**



The fiscal stance and the fiscal framework could also affect the responses to disasters shocks. In particular, states subject to tighter budget restrictions should be more prone to rely on federal transfers than state expenditure to counteract the negative effects of the shock. Similarly, states with RDFs should be better prepared to face the recession generated by a disaster shock. To make the distinction as stark as possible, we compare top scoring states and states with an ACIR index below five. The third row of Figure 5 presents the typical responses of the variables in these two groups.

Indeed, the responses of macroeconomic variables vary: relative GSP increases in response to a disaster shock in states with loose budget restrictions (continuous red line), while it falls persistently in states with stringent budget restrictions (dotted blue line). Relative unemployment dynamics also differ and states with high ACIR index reduce the relative unemployment rate while in states with low ACIR relative unemployment increases on impact and returns in the pre-shock level after two years. Welfare transfers increase more in states with loose budget restrictions, are roughly comparable in the two groups of states for two years after the shock, but they deviate thereafter with welfare transfers persistently falling in low ACIR states. As expected, relative state expenditure responds more on impact in states

with loose fiscal constraints and this may account for the fact that those states do not experience a recession. Relative federal transfer responses also differ: they are positive on impact and remain high for the high ACIR group of states; they decrease in states with loose budget restrictions on impact and increase only two years after the shock. Note that, unexpectedly, relative debt dynamics are more subdued in states with looser budget restrictions, because of the relative revenue responses. Thus, for a given amount of federal transfers, states that can use state expenditure more freely seem better equipped to shield the state economy from the disaster shock and do not seem to accumulate debt along the adjustment path.

In our sample, there are five states with no RDFs. However, since Hawaii adopted RDFs only in 2000 after its sole 1992 disaster, we consider it a state without RDFs. Moreover since among the states which currently have RDFs, there are many that experienced disasters before including RDFs to the state budget, we restrict attention to states which have adopted RDFs prior to 1985 in the comparison [4]. The forth row of Figure 5 presents the dynamic responses to the shock in the two groups of states.

States with no RDFs (continuous red line) experience an impact increase in economic activity but afterwards a persistent recession ensues. In states with RDFs (dotted blue line), instead, economic activity is reduced but the cumulative relative GSP costs are smaller than in no RDFs states. Also, in RDFs states relative unemployment rate decreases on impact and returns rapidly to the pre-shock level, while relative unemployment increases significantly and persistently in no RDFs states. These differences are related to the differential responses of state fiscal variables. No RDFs states increase their relative government spending on impact, while in states with RDFs relative state spending rises with a lag. Relative federal transfers also display very stark differences. In no RDFs states, transfers increase insignificantly on impact and decrease thereafter relative to the US average; in RDFs states federal transfers turn higher than the US average after two years. Finally, revenues fall in states with no RDFs while they increase in states with RDFs and, as a consequence, relative debt increases in the former and falls in the latter group[5].

Summary

As in the event-study analysis, the geographical position of a state (and, hence, the type of disaster a state typically faces), the level of income, the tightness of the fiscal restrictions, and the presence of rainy days funds matter for the propagation of a disaster shock. States which are richer, have looser fiscal constraints and budget RDFs recover better or faster from the disaster shock without any persistent increase in state debt. Both federal and state governments respond to the disaster shock and aid by the former helps to lower the short run costs on state debt. Federal aid tends to be larger and more persistent in states facing tight budget restrictions and with no funds for rainy days.

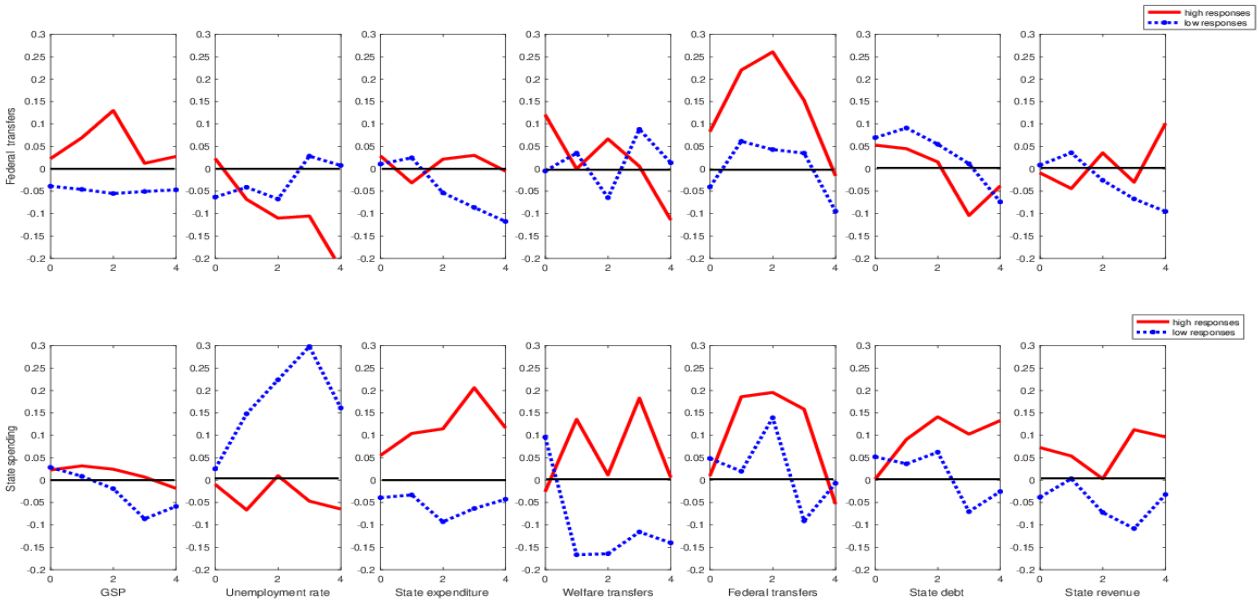
4 Thus, we consider as no-RDFs states Alabama, Arkansas, Colorado, Hawaii, Montana and Oregon, while RDFs states are California, Connecticut, Delaware, Florida, Georgia, Idaho, Indiana, Iowa, Maine, Michigan, Minnesota, Mississippi, Missouri, Nebraska, New Mexico, New York, Ohio, Oklahoma, Pennsylvania, Rhode Island, South Carolina, Tennessee, Washington, Wisconsin and Wyoming. The results are similar if 1981 is employed as cutoff date.

5 The dynamic responses presented in the last row of Figure 5 would be very similar if we would have considered states with tight budgetary restrictions and RDF vs states with tight budgetary restrictions and no RDFs, as we have done in the event study analysis in the previous section. We do not present them here for economy of space.

5. THE ROLE OF FISCAL POLICY

Figures 4 and 5 suggest the presence of a negative correlation between real and fiscal variables, conditional on disaster shocks. Thus, it appears that state and federal governments react to the shocks by increasing expenditure, welfare transfers and intergovernmental transfers. Still, the evidence do not speak directly to the question of interest in this paper, which is the role of fiscal policy in shaping the dynamic adjustment of real variables in response to disasters, because the figures do not single out states where fiscal policy responses are more vigorous than others. To examine this role we cluster responses of states where federal or state responses are more or less pro-active relative to the mean, and compare the differences in the dynamic responses of output and unemployment. The top row of Figure 6 presents the (weighted) average responses obtained in states with larger (continuous red line) vs. smaller (dotted blue line) relative federal transfers responses in the first three years after the shocks.

Figure 6: **Dynamics in response to disaster shocks, federal vs. state intervention**



Federal transfers to the affected states make an important difference for how dynamics responses of real variables evolve and the stronger is their reaction to the disaster shock, the easier is the recovery. In fact, in states where relative responses are larger, relative output expands and the relative unemployment rate falls after the disaster shock without any secular increase in the state relative debt burden.

On the contrary, the relative output responses of states with more subdued transfer dynamics are generally negative in the medium run, while the unemployment rate falls, albeit more moderately compared with the other group. The difference in the macroeconomic responses of the two groups is economically significant: GSP falls persistently in states which receive moderate federal transfers and the gains from the fall in the unemployment rate are short lived. Note that larger relative state transfers do not come together with larger state expenditure. State expenditure responds little in both groups of states. Also welfare aid increases equally with a different timing in both groups of states. Finally, states

that do not receive significant federal transfers accumulate relatively more debt relative to states that do, but differences in debt dynamics are insignificant[6].

We are also interested in knowing whether the dynamic responses of relative output, relative unemployment and relative debt depend on the ability of the state expenditure to react to the shock. This may help us to understand better whether state and federal fiscal policies complement or substitute each other and, in the latter case, which one is more effective. Another issue of particular interest is whether states with fiscal leeway can contain the immediate negative effects of a disaster shock and whether this brings about persistently higher relative debt levels. The second row of Figure 6 presents the average responses for states in which relative state spending are larger (continuous red line) vs. states in which state spending are smaller or negative (dotted blue line) in the first three years after the disaster shock.

In states where relative state expenditure responses are positive and high, relative GSP responses are positive across almost all horizons and the difference with the relative GSP responses of states where state spending response is weak or negative is economically significant in the medium term. Relative unemployment responses are strikingly different: unemployment falls persistently in states where state expenditure reacts countercyclically, while it increases significantly and persistently in states where government spending is weakly procyclical or acyclical.

The favorable relative GSP dynamics and relative unemployment responses in states with larger relative state expenditure responses come at the cost of higher and more persistent responses of relative state debt. Note that debt responses peak two years after the shock but, at the four years horizon, they are still high relative to the US average. Note that relative state debt increases also in the group of states with smaller relative state expenditure reaction, primarily because relative state revenue falls along with relative state GSP. However, the increase in state debt in those states in more moderate and state debt reverses to negative territory two years after the shock. Finally, while relative federal transfers increase in both types of states, they increase more and more persistently relative to the US average for states with positive expenditure reaction.Thus, also in this row, federal and state fiscal policy appear to be complementary.

Comparing the dynamic in the red continuous lines of the two rows of Figure 6, one can conclude that, independently of the source of spending, states enjoying stronger fiscal support are able to escape the output costs of disaster shocks and find themselves in a better position to deal with the larger increase in the relative unemployment rate brought about by the shock. Comparing the blue dotted lines of the first two rows of Figure 6, one can see that states with weak countercyclical state responses, rely more on federal support in the first few years of the adjustment to the shocks and that federal aid alone cannot do the trick. States receiving less relative support from both the federal and the regional government have a harder time to recover and display virtuous relative debt dynamics.

To conclude, fiscal policy has the ability and the power to counteract the negative effects that a disaster shock has on production and employment and to make a significant difference for how output and unemployment responses shape in the medium run. Both federal and state policies can contribute; state actions seem more effective than federal aid in preventing unemployment surges and helping local labor markets to recover. Moreover, states generously using their own resources to counteract the negative effects of a disaster shock and issuing state debt to finance the fiscal expansion suffer moderate fiscal

[6] The difference in the dynamics of debt can be possibly due to the mechanical impact federal transfers have over the state debt level

costs, with no need of a consolidation program to keep their relative debt level under control in the medium run.

6. CONCLUSIONS AND POLICY IMPLICATIONS

This paper measures the macroeconomic effects of US natural disasters for the period 1980-2018 and evaluates the role of state and federal fiscal policy in limiting their costs. Using the costliest events we show that natural disasters typically create temporary recessions accompanied by a mild fiscal reaction, both at the state and the federal level. The real effects are spatially heterogeneous and depend on the geographical position (and, thus, the type of disaster a state faces), the level of income and the rules of the state fiscal design. A natural disaster shock typically induces significant relative output losses but does not have measurable dynamic effects on the relative state unemployment rate. It also induces a countercyclical reaction of the federal and the state governments and moderate but temporary increases in state debt. Again, there is considerable spatial heterogeneity in the dynamic responses to disasters shocks. The geographical position, the level of income, the strictness of budgetary restrictions and the presence of RDFs explain, in part, the differences we observe. Our analysis indicates that, regardless of the source, countercyclical fiscal policy can contain the negative effects of disaster shocks. In addition, states that rely more on local resources recover better and experience only moderate and temporary increases in state debt. Hence, the ability of state governments to react in a timely manner to calamities is fundamental to prevent disasters from having severe and persistent macroeconomic consequences.

Although our analysis focuses on US states, it provides important lessons for the EU and the Euro area. After all, the US is a union of developed states sharing the same monetary policy; and, as in the European continent, some of the states are large and others are small; some are more developed than others, have tighter fiscal rules, and display different economic structure as far as services, manufacturing and agriculture are concerned. The fiscal policy design in the two unions differed up to recently; however, in the most recent budget cycle, an embryo of EU federal fiscal policy was created and the Recovery and Resilience Facility (RRF) (a program part of the Next Generation EU Fund package) has been designed specifically to respond to the downfall created by the COVID-19 pandemic.

Our analysis answers important contemporary policy questions such as: how painful are natural disasters in terms of real costs? Are they long lived? Is the stance of state fiscal policy relevant? Do state budget restrictions or the existence of special funds for rainy days matter? Is it sufficient to rely on federal transfers? Is it a good idea to remove debt constraints over the adjustment path? Which fiscal instrument is more effective?

In line with the conventional wisdom and the prescriptions of economic models, our investigation indicates that the stance of fiscal policy is important. States with strict budgetary requirements and no RDFs have a harder time to recover from disaster shocks. The state capacity to increase spending in response to disasters is key for mitigating their negative real effects. Although the imposition of tight budgetary requirements is intended to limit the accumulation of short term debt, such limits might curtail the ability of a state to recover, without significant benefit in the dynamics of debt accumulation, at least when a natural calamity occurs. Thus, special escape clauses should be considered to provide states with the flexibility they need to respond to catastrophic events. Policymakers should also put high in their agenda the creation of national budget stabilisation funds, accumulated in separate saving accounts, so as to reduce the impact of adverse disaster shocks. Zhao (2014) indicates that RDFs have become an

increasingly important tool for US states and calculated target RDFs levels for each state, based on expected costs and states' preferences for stable tax rates and expenditure. Similar calculations could be easily performed for any country and may help to underscore the trade-offs involved in ex-ante actions vs. ex-post reactions.

Because countercyclical federal transfers help to stabilise local economies, special provisions for catastrophic events should also be made in federal budgets, employing the same accounting logic used for RDFs. Currently, in the EU the RRF is structured as a combination of grants and loans. Perhaps, targeted transfers for special circumstances, to be accumulated in national accounts held at federal level, could be a more efficient way to make federal policy effective after catastrophic events.

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APPENDIX A: THE DATA AND THE DATES OF ADOPTION OF RAINY DAYS FUNDS

The state expenditure series are 'General Expenditure' and include all government expenditures other than the specifically enumerated kinds of expenditure classified as Utility expenditure, Liquor stores expenditure, and Employee-retirement or other Insurance trust expenditure.

The revenue series are 'General Revenue' and include all government revenues except Liquor Stores Revenue, Employee Retirement, Insurance Trust Revenue, and Utility Revenue. We consider the variable 'Revenue from Own Sources' for our government revenue series which excludes from the general revenues intergovernmental revenues.

For federal transfers we use the series called 'Intergovernmental Revenue From Federal Government', which measures intergovernmental revenue received by a state government directly from the Federal government.

For state welfare transfers we use the series called 'Public welfare' which includes support of and assistance to needy persons contingent upon their need. It excludes pensions to former employees and other benefits not contingent on need. Expenditures under this heading cover: cash assistance paid directly to needy persons under the categorical programs Old Age Assistance, Temporary Assistance for Needy Families (TANF) and under any other welfare programs; Vendor payments made directly to private purveyors for medical care, burials, and other commodities and services provided under welfare programs; and provision and operation by the government of welfare institutions.

The state debt series includes all long-term credit obligations of the state and local government and its agencies whether it is backed by the government's full faith and credit or non-guaranteed, and all interest-bearing short-term credit obligations. Includes judgments, mortgages, and revenue bonds, as well as general obligation bonds, notes, and interest-bearing warrants. It excludes non-interest-bearing short-term obligations, inter-fund obligations, amounts owed in a trust or agency capacity, advances and contingent loans from other state governments, and rights of individuals to benefits from government-administered employee retirement funds.

Table 3: **Rainy days fund adoption date by State**

State	RDF	Year of Adoption	State	RDF	Year of Adoption
Alabama	0	-	Nevada	1	1994
Arizona	1	1990	New Hampshire	1	1987
Arkansas	0	-	New Jersey	1	1990
California	1	1985	New Mexico	1	1976
Colorado	0	-	New York	1	1945
Connecticut	1	1979	North Carolina	1	1991
Delaware	1	1977	North Dakota	1	1987
Florida	1	1959	Ohio	1	1981
Georgia	1	1976	Oklahoma	1	1985
Hawaii	1	2000	Oregon	0	-
Idaho	1	1984	Pennsylvania	1	1985
Illinois	1	2000	Rhode Island	1	1985
Indiana	1	1982	South Carolina	1	1978
Iowa	1	1992	South Dakota	1	1991
Kansas	1	1993	Tennessee	1	1972
Kentucky	1	1983	Texas	1	1987
Louisiana	1	1990	Utah	1	1986
Maine	1	1985	Vermont	1	1988
Maryland	1	1986	Virginia	1	1992
Massachusetts	1	1986	Washington	1	1981
Michigan	1	1977	West Virginia	1	1994
Minnesota	1	1981	Wisconsin	1	1981
Mississippi	1	1982	Wyoming	1	1982
Missouri	1	1982			
Montana	0	-			
Nebraska	1	1983			

Table 4: **ACIR index by State**

State	ACIR	State	ACIR
Alabama	10	Nevada	4
Arizona	10	New Hampshire	2
Arkansas	9	New Jersey	10
California	6	New Mexico	10
Colorado	10	New York	3
Connecticut	5	North Carolina	10
Delaware	10	North Dakota	8
Florida	10	Ohio	10
Georgia	10	Oklahoma	10
Hawaii	-	Oregon	8
Idaho	10	Pennsylvania	6
Illinois	4	Rhode Island	10
Indiana	10	South Carolina	10
Iowa	10	South Dakota	10
Kansas	10	Tennessee	10
Kentucky	10	Texas	8
Louisiana	4	Utah	10
Maine	9	Vermont	0
Maryland	6	Virginia	8
Massachusetts	3	Washington	8
Michigan	6	West Virginia	10
Minnesota	8	Wisconsin	6
Mississippi	9	Wyoming	8
Missouri	10		
Montana	10		
Nebraska	10		

APPENDIX B: EVENT STUDY USING PER-GSP COSTS

Figure 7: **Dynamics around disasters, event study, per-GSP costs.**

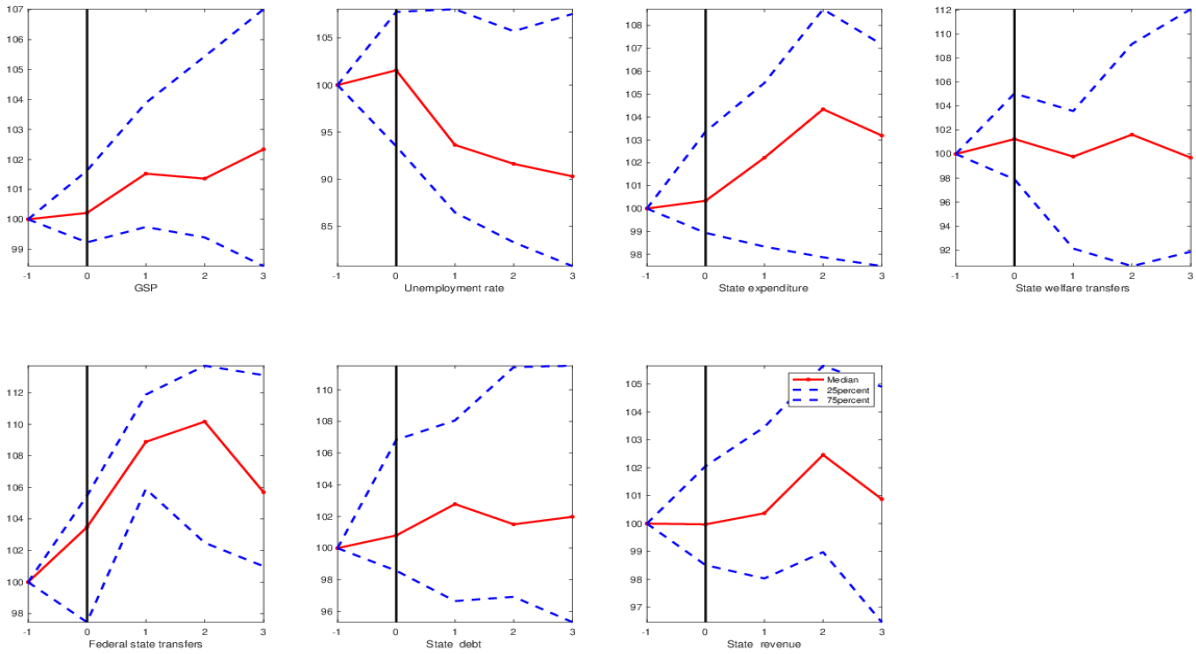
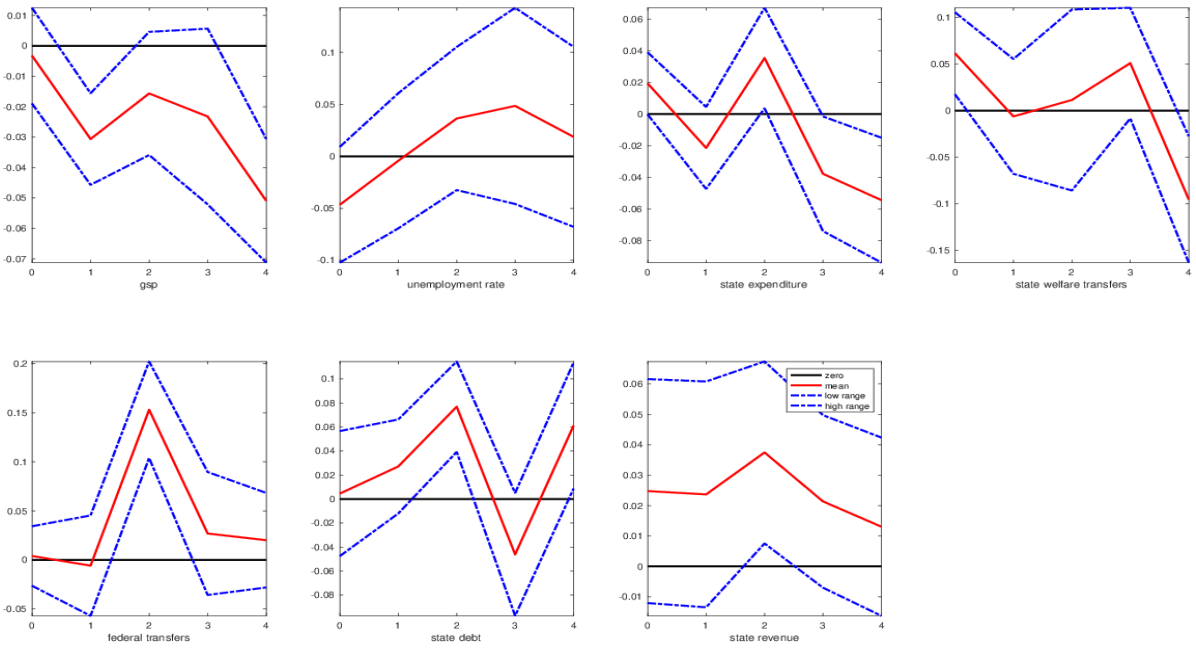


Figure 8: **Typical dynamics in response to disaster shocks, per-GSP costs**



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