DISCUSSION PAPER SERIES

DP17655

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MONETARY ECONOMICS AND FLUCTUATIONS

CEPR

ISSN 0265-8003

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Discussion Paper DP17655
Published 09 November 2022
Submitted 01 November 2022

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www.cepr.org

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Keywords: Natural disasters

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Acknowledgements
Pappa acknowledges financial support from the Spanish Ministry of Education and Science, project PGC2018-094321-B-I00.

Costly disasters, energy consumption, and the role of fiscal policy *

Fabio Canova† Evi Pappa‡

5th November 2022

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*The Project benefited from a DG ECFIN's Research Fellowship 2020-2021 (Shifting paradigms: The quest for new modes of sustainable growth and convergence). We are grateful to the DG ECFIN team, the participants to the 2021 Winter meetings of the EMES, the 2022 T2M conference, London, the XXIII Conference in International economics, the EMAEF 2022 conference and seminars at BI, Norges Bank, DNB, and Cleveland Fed for useful discussions and suggestions. Pappa acknowledges financial support from the Spanish Ministry of Education and Science, project PGC2018-094321-B-I00. First Draft, January 2021.

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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, earthquakes, floods, and wildfires, or extreme weather events, like droughts, torrential rain, and winter storms, are increasing in frequency and becoming more damaging due to climate change. According to a UN Office for Disaster Risk Reduction report (UNDRR (2020)), reported natural disasters have almost doubled since 2010, affecting a larger portion of the world population, and inducing almost twice as large damages. In fact, from 2000 to 2019, there were 7,348 major recorded disaster events, claiming 1.23 million lives, affecting 4.2 billion people, and costing approximately 2.97 trillion US dollars. China (557) and the US (467) suffered the largest number of incidents and paid the largest costs.

These trends raise important concerns about the price climate change will bring about in the future and the appropriate public policy reaction. The rising costs and the intensification of the events, however, puts pressure on public budgets and has led policymakers to revise their strategies to prepare for and to respond to natural disasters. The COVID-19 pandemic, although not a natural disaster, has brought about similar issues and additional discussions about the design of the fiscal response when unexpected catastrophic events occur. For example, Guerrieri et al. (2020) highlight that government transfers, rather than government expenditure, may be the key in counteracting a pandemic crisis. A EU Commission's Public Finances report (ECFIN (2021)) dedicates a chapter to this topic, emphasizing (i) the need of strengthening disaster risk management and (ii) developing disaster risk financing.

To design the best policy response and to understand how and to what extent preemptive measures are desirable, it is essential to know how disasters dynamically affect the macroeconomy and to assess how past policy actions impacted on the ability of economies to recover and on the fiscal position of the affected states.

Contribution This paper analyzes how natural disasters affect production, income and the unemployment rate of US state economies. Disasters generate direct costs, involving the destruction of residences, business structures, productive capital, infrastructures, crops and livestock; and indirect costs, altering or shutting down economic activity. This indirect effect, often referred as the "macroeconomic resilience" in the literature, has an impact and a dynamic component, and it is the focus of our investigation. Contrary to most of the literature, which has looked for evidence across countries, we focus attention on US states since natural disasters are frequent; there is information about their nature and their direct costs; and long enough data allows us to use formal methods to analyze their dynamic repercussions.

We investigate how the fiscal framework shapes macroeconomic resilience. We examine whether flexible state level constraints, such as loose budget and debt restrictions, or budget stabilization provisions, such as rainy day funds (henceforth, RDFs) mitigate the real consequences of natural disasters and evaluate the sustainability of debt accumulation following catastrophic events. We also study the role of state and federal fiscal policy. In particular, we study whether federal aid differs from state expenditure as far as shaping the dynamics after a disaster, and whether it undoes state restrictions or exacerbates existing constraints.

We use two different methodologies in the investigation. In the first one (event study approach), we construct the cross-sectional distribution of dynamic effects in a number of macroeconomic variables around disaster dates. In the second (local projection approach), we construct the cross-sectional distribution of dynamic responses following a *disaster cost shock*, conditional on a number of controls. Thus, rather than examining the unconditional correlation between the fiscal and the macroeconomic variables around disaster dates, we compute such a correlation, conditional on a disaster shock, taking important macroeconomic features into account.

Relationship with the literature Our investigation brings together different strands of literature. The first studies the effects of disasters on economic performance. Cavallo et al. (2021) using cross country data conclude that disasters produce real cost primarily for small and poor countries. Rich or large countries seem more resilient to the events. Deryugina (2017) analyzes how hurricanes affect US counties' economies taking into account both direct (through the disaster aid channel) and indirect (through other social safety net programs) costs. She shows that they cause real damages and produce a fiscal drag, as they lead to a persistent increase in non-disaster government transfers, such as unemployment insurance and public health payments. Relative to her work, we consider all major natural disasters, not just hurricanes, and focus on US states; we also account for the fact that disaster costs are serially and cross sectionally correlated; look at the dynamics disasters induce for a broader spectrum of variables; and study the interaction between state and federal fiscal policies.

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. (2021). Relative to this literature, we take a spatial perspective and use state rather than aggregate US data; and evaluate the role of fiscal policy in mitigating the consequences of disasters on the macroeconomy.

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. Ramey and Zubairy (2018) and Alloza (2017) argue that this conclusion is sensitive to the specification of the empirical model, the sample period, and the methodology used. Barnichon et al. (2022) reconcile the two views by arguing that the sign of the fiscal shocks matters. Since, certain disasters induce recessions, studying whether discretionary fiscal policy can avoid a slump is an important related question.

Our work is also related to the large literature studying the desirability of counter cyclical fiscal policy and the use of contingency public funds for emergency situations. 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 prescriptions do not generally hold in the data of many countries. By studying fiscal responses to disaster cost shocks in states facing different disaster risks and different public policy profiles, we can evaluate whether countercyclical fiscal policy is important for containing the negative effects of natural disasters on the state economy and assess whether such actions affect the dynamics of state debt.

In complementary work Grosse-Steffen et al. (2021) looked at the effects of disasters across countries and investigate the role of the fiscal stance in shaping outcomes. We differ as we examine US states, where a wealth of information reduces the risk of econometric misspecification; we take into consideration the presence of a two-layer fiscal system; and use an empirical methodology that explicitly accounts for the presence of predictability in costs and dynamic heterogeneity in the responses.

The results We demonstrate that, contrary to a large portion of the literature, on average over the cross section, disasters do not imply significant output or fiscal costs; and that this is true regardless of the methodology employed, the type of disasters considered, and the frequency of the data used. We obtain this surprising outcome because macroeconomic variables respond to disasters in a very heterogeneous way across states. We highlight that standard factors, such as the geographic location, the cost magnitude, or the event frequency do not account for the cross-sectional heterogeneity we discover. Similarly, adding conditioning variables, using finer sampled data, and eliminating the predictable component in disasters costs does not change the conclusions.

We find that the cross-sectional dynamics of energy usage is useful to account for this heterogeneity. In fact, only in states where disasters negatively impact on energy consumption have significant negative output and income effects and important unemployment consequences. Quantitatively, the fall in energy usage persistently decreases output and personal income: four years after the disaster the typical cumulative loss is around 0.4 percent. In addition, unemployment increases by up to 1.5 percentage points on average reaching its peak three years after the event.

For states displaying negative energy responses, fiscal policy is clearly counter cyclical, debt persistently increases, and the federal government is generally more proactive than the state government. Importantly, once we condition on energy consumption responses, the type of disaster affecting the state economy is irrelevant.

Negative energy responses are typically significantly associated to three state characteristics: the vulnerability and the maintenance of power facilities; the share of home ownership; and the participation in the National Flood Insurance Policy (NFIP) and special state insurance programs. Since energy is an upstream sector for many US state economies, the vulnerability and the poor maintenance of, e.g. power plants or electric grids, may have important consequences on the state production and income, see also Lee et al. (2021) for the effects of natural disasters on oil, renewables, and nuclear energy consumption across countries. The share of home ownership matters because home owners take a better prevention measures against residential destruction and have incentives to do so because their disaster insurance premiums depend on the presence of features that make a home safer. Furthermore, disaster insurance is compulsory only for homeowners and cross sectional differences in state home ownership is important. Private disaster insurance however does not cover certain events such as flooding or earthquake. Thus, differential participation in federal public insurance programs (such as the National Flood Insurance Program (NFIP)) or in specific state programs (such as the Florida Hurricane Catastrophe Fund (FHCF), the California Earthquake Authority (CAE) Program) may change the real consequences of disasters. Interestingly, we find that states where local governments spend more on average on protection policies are those with the smallest negative energy responses. Thus, preemptive public provisions matter for the way disasters affect the local economies.

We demonstrate that the fiscal framework is not crucial in determining macroeconomic outcomes. In particular, when an energy induced recession occurs, the presence of loose or tight state budget restrictions is irrelevant for the dynamics of state macroeconomic variables, because federal transfers are significantly larger in states with tighter budget restrictions and because welfare transfer are cut to allow expenditure increases. Similarly, the presence of budget stabilization funds do not significantly alter the dynamics of output, personal income, or the unemployment rate. Thus, fiscal flexibility does not seem crucial for moderating the output and income effects, provided that the federal government steps in to take care of the economic disruptions.

Consistent with this observation, we also find that having a high or a low state government expenditure in response to disaster cost shocks is irrelevant to determine macroeconomic outcomes. The only significant difference across groups is that state debt is higher in the medium run when the state expenditure response is high.

On the contrary, federal transfer aid matters for the way the state economy recovers. States enjoying larger federal transfers at the onset of the disaster typically display no output or personal income recessions. Still federal aid has little effect on the local labor markets. Hence, a timely reaction of federal spending increases the likelihood of a soft landing, even though may interfere with the labor market transformations that the disasters bring about.

The plan of the paper The rest of the paper is organized as follows. The next section describes the data and the econometric procedure. Section 3 studies the dynamics around disaster dates unconditionally, or conditioning on certain disaster characteristics. Section 4 examines the effects of disaster cost shocks. Section 5 investigates the role of the fiscal framework. Section 6 studies the role of state and federal fiscal policy and Section 7 concludes. The appendix contains a data description and additional figures and tables.

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 US 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 Smith and Katz (2013) there are 249 disasters causing damages of at least a billion US dollars in our sample: 16 were wildfires, 27 droughts, 43 tropical cyclones (hurricanes), 107 severe storms, 17 winter storms, 30 floods, and 9 freezes. The death toll was large (14179 fatalities) 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. Katrina in 2005, caused 1833 deaths and 170 billions US dollars in damages. The next most extreme event is Harvey in 2017; although it caused "only" 89 deaths, it generated 131.3 billion dollars of damages. At the other end, Maria 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 in 2012 was also severe, costing 75 billion dollars and 159 fatalities. NOAA does not provide exact damage measures each disaster generates. Instead, it reports range estimates [1] and measures total yearly costs by summing the upper limit of the ranges for each disaster in each state. We

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

follow the same approach to compute state annual costs.

Table 1 summarizes the main features of the data. For each state, we report the number of natural disasters in the sample, the mean per-capita estimated cost, the major event experienced and the year it occurred. The number and the type of episodes affecting a state varies with the location, given that different geographic regions face a unique combination of weather and climate. Tropical cyclones and droughts are the most recurrent events and they also more often produce the largest costs. The southeastern, central and gulf regions experienced a higher number of billion-dollar events.

Table 1: **Billion dollars Natural Disasters summary, 1980-2018**

State	Number of disasters	Mean costs per-capita	Major event	State	Number of disasters	Mean costs per-capita	Major event
Alabama	80	411.6	Hurricane Katrina (2005)	Nebraska	39	712.6	Drought/Heatwave (2012)
Arizona	23	549.2	Severe Storm (2010)	Nevada	18	170.2	Flood (1997)
Arkansas	62	104.8	Tornadoes (2011)	New Hampshire	16	307.6	Winter Storm (1998)
California	36	140.9	Wildfire (2018)	New Jersey	44	327.1	Hurricane Sandy (2012)
Colorado	47	285.5	Severe Storm (2018)	New Mexico	27	223.6	Hurricane Dolly (2008)
Connecticut	31	162.0	Hurricane Sandy (2012)	New York	59	140.8	Hurricane Sandy (2012)
Delaware	26	415.5	Drought/Heatwave (2011)	North Carolina	78	307.3	Hurricanes Florence/Michael (20118)
Florida	56	686.9	Several Hurricanes (2004)	North Dakota	17	3707	Drought/Heatwave (1988)
Georgia	80	149.2	Hurricanes Florence/Michael (2018)	Ohio	62	83.6	Hurricane Ike (2008)
Hawaii	1	8696	Hurricanes Iniki (1992)	Oklahoma	75	387.8	Severe Storms (2013)
Idaho	25	365.7	Drought/Heatwave (1988)	Oregon	30	132.7	No major event
Illinois	76	154.8	Drought/Heatwave (2012)	Pennsylvania	66	76.4	Hurricanes Ivan/Jeanne (2004)
Indiana	62	241.6	Flood (2008)	Rhode Island	23	320.9	Hurricane Sandy (2012)
Iowa	50	798.7	Flood (1993)	South Carolina	66	432.4	Hurricane Hugo (1989)
Kansas	68	507.2	Drought/Heatwave (2012)	South Dakota	24	1317	Drought (2006)
Kentucky	62	231.1	Drought/Heatwave (2012)	Tennessee	72	218.6	Severe Storm (2003)
Louisiana	63	2063.2	Hurricane Katrina (2005)	Texas	106	514.0	Hurricane Harvey (2017)
Maine	14	267.7	Winter Storm (1998)	Utah	18	248.8	Flood (1983)
Maryland	54	158.3	Hurricane Ivan (2003)	Vermont	15	731.7	Hurricane Irene (2011)
Massachusetts	27	91.4	Hurricane Bob (1991)	Virginia	71	142.5	Hurricane Isabel (2003)
Michigan	34	55.4	Drought/Heatwave (1988)	Washington	25	67.6	Drought/Heatwave (2015)
Minnesota	33	390.2	Flood (2008)	West Virginia	34	294.4	Flood(1988)
Mississippi	72	1013	Hurricane Katrina (2005)	Wisconsin	31	159.7	Flood (1993)
Missouri	71	344.8	Severe Storm (2011)	Wyoming	21	94.9	Drought/Heatwave (1988)
Montana	27	1363	Drought/Heatwave (1988)				

Texas has the largest incidence of episodes (106), followed by several southern states (Alabama, Georgia, Mississippi and North Carolina) and by states in the tornado alley (Illinois, Oklahoma, Missouri). At the other extreme, Hawaii faced only one catastrophic event, while New England states experience less than 20 disasters in the sample. Per-capita costs also vary considerably with the state and the type of calamity. Tropical cyclone Iniki costed to the average person in Hawaii 8696 US dollars; tropical cyclone Harvey costed 7254 US dollars per-capita in Texas; tropical cyclone Katrina was devastating for Louisiana: it produced costs estimated at 370000 dollars per-capita, close to one year of state per-capita income. On the other hand, the drought suffered in North Dakota in 1988 costed 15282 dollars per-capita. On average, the damages vary from below 100 US dollars per-capita, with the minimum in Michigan and Washington, to over 1000 US dollars per-capita, with the maximum in Mississippi, Louisiana, North Dakota, and Hawaii.

Macroeconomic and fiscal data State macroeconomic data is also annual and goes from 1980 to 2017. The BEA provides data for state real GSP. Because it currently publishes only data from 1993, we splice the data with the one used in Canova and Pappa (2006) to have a longer time series. State unemployment rate, state personal income, and state population are from the FRED database. For state and local government finances we employ U.S. Census Bureau information and retrieve series for state government expenditure, revenues, welfare transfers, and debt, and federal state transfers. Details of what each series measures are in the appendix. We deflate all nominal variables by the GSP deflator, and use the state population to convert them in per-capita terms. To control for aggregate 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 are in deviations from national averages.

The empirical methodology We employ two different methodologies. First, we use an event-study approach and characterize the cross-sectional dynamics of state variables around disaster dates. The idea is to examine whether there is an important pattern in the dynamic evolution of the economy after a disaster event and a relevant correlation in the patterns of macroeconomic and fiscal variables. The approach is equivalent to running a univariate projection at t+h, h=-1,0,1,2,3 and t is a disaster date, of each variable on a dummy which is equal to 1 when a disaster occurs and zero otherwise, event by event and state by state, without a constant or controls. Thus, each event is treated as identical from the point of view of the exercise, there is no account for the fact that certain states are more prone to natural disasters, nor that state characteristics or the type of events may matter [2].

Because event-studies make a number of strong assumptions, which may be violated in practice, the second methodology we employ avoids some of their shortcomings. With a local projection exercise we examine the dynamics of state macroeconomic and fiscal variables induced by disaster costs shocks, conditional on state and US variables. Shocks are computed as innovations in the disasters costs series, accounting for the fact that disasters display time and spatial patterns. The projections equation controls for observable characteristics; thus the results provide evidence on the *conditional* correlation of macro and fiscal variables in response to disaster cost shocks. Given the short sample, we employ a Bayesian approach to compute response dynamics. As long as the disaster cost shocks are exogenous to state macroeconomic activity, the approach is statistically valid and can be though as a Bayesian variant of a LP-IV methodology, where disaster cost shocks are used as instruments in the

[2] The methodology differs from a difference-in-difference exercise where one considers the states experiencing a disaster as the treated group and the states escaping them as the control group. Such an approach is unsuitable in our case for four reasons. First, disasters do not typically occur only once and states could belong to control and treated groups at different points in time. Thus, the post-treatment dynamics are polluted by events occurring in subsequent years. Second, as showed in Sun and Abraham (2021) when units are treated at different times, it is difficult to consistently estimate the average treatment. Third, while disasters are random, the probability that a state experiences a catastrophic event differs by location. Fourth, the effects of disasters are likely to be heterogeneous. Thus, treating states as if they were homogeneous is likely to induce biases in the average estimates.

projection equation. More details on the specification are in section 4.

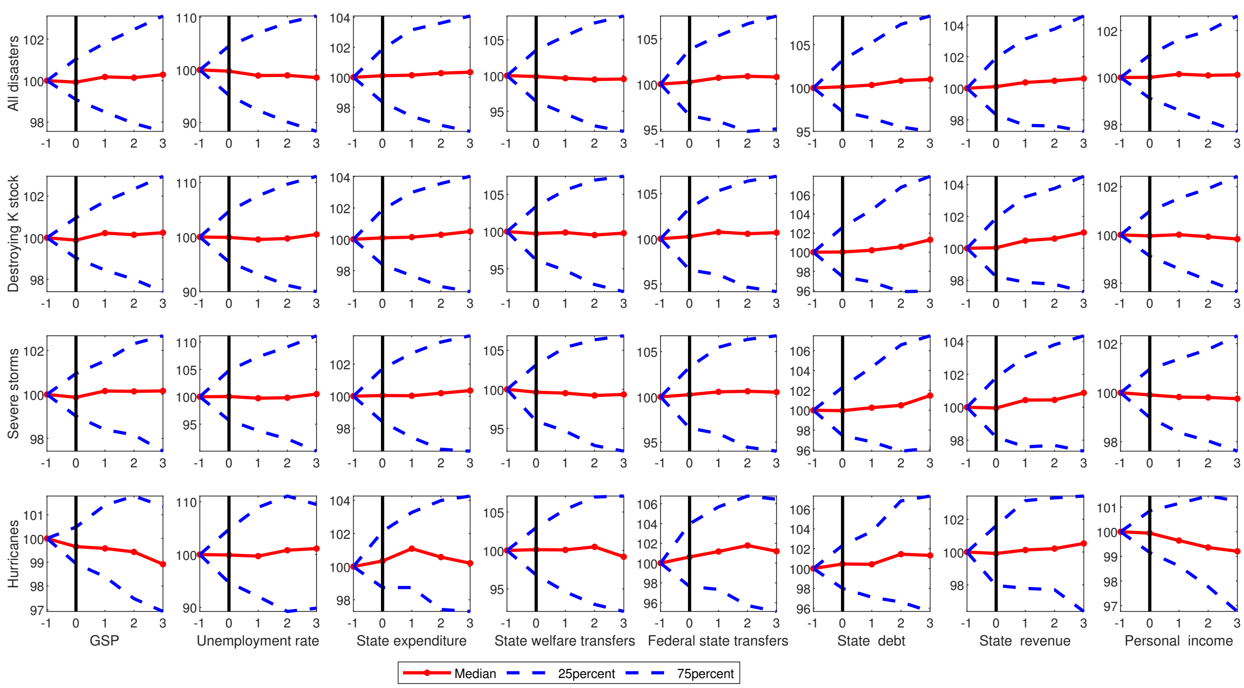
In both cases, we construct the dynamics of macro and fiscal variables, state by state, to allow for a different state propagation mechanism; and summarize the cross-sectional distribution at each horizon via a "typical" state dynamics and a measure of dispersion.

3 Event study approach

Figure 1 presents the median and the interquartile range of the cross-sectional distribution of state output, unemployment, personal income; state expenditure, state welfare transfers, state revenues, state debt, and federal transfers dynamics around disaster dates. We consider the evolution from one year before up to three years after the disaster occurred for each variable scaled by the national average. To control for local business cycle conditions, the figure is normalized so that any variable in any state starts with a value of 100, one year prior to the disaster. Thus, deviations from 100 in years t=0,1,2,3 represent cumulative percent change from year -1 relative to the average. For example, a value of 98 at t=2 means a two-year cumulative fall by 2 percent from year -1. The first row considers all events. The next row considers disasters that are likely to destroy the capital stock (tropical cyclones, severe storms, floods). The last two rows separately analyze the effects of severe storms and tropical cyclones.

When all 985 events present in our database are considered, there is not much that can be said about the macroeconomic effects of disasters nor about the correlation between macroeconomic and fiscal variables around these episodes. The median of the cross sectional dynamic distribution hoovers around 100 at all horizons and the interquartile ranges are large. Many factors could drive macroeconomic and fiscal variables around disaster dates and this may account for the ample interquartile ranges we detect. The rest of the figure tries to understand whether the nature of the event makes a difference. Splitting disasters by type could be useful since events destroying production capabilities are expected to have output, income, and unemployment effects that are more important than disasters primarily affecting, say, the agricultural sector unless, of course, state economic activity is dominated by agriculture. Thus, one would expect the dynamics of state macroeconomic variables to become more homogeneous in the last three rows of Figure 1.

Figure 1: Cross sectional dynamics around disaster dates, event study



Unfortunately this is not the case: for any classifications considered, the heterogeneity in the dynamics around disaster dates is massive When only tropical cyclones are consider the median dynamics conform with economic intuition: output and personal income are declining and the unemployment rate is increasing while state expenditure and federal transfers have humped shaped patterns. Still, contrary to what is claimed in the literature, one can not confidently claim that a recession is generated nor that fiscal policy is counter cyclical.

We have investigated whether other features of the disaster data can help us to reach some useful conclusion. In particular, we have considered only very costly disasters; disasters occurring in years when a large number of events occur; or focus on a region where they more frequently hit. Although the database we use records only events with insurance costs exceeding a billion US dollars, very costly events may produce larger and more persistent macroeconomic consequences than others, if we are willing to assume that the distribution of costs is independent of location and time. In addition, since the frequency of disasters is time varying, one may conjecture that state finances will be more strained when multiple catastrophic events occur, given that costs are only partially covered by federal insurance agencies. Considering those years when, say, a large number of events occur, may thus help to obtain a cleaner picture of the dynamics around disaster dates. Finally, some regions are more prone to natural disasters than others. Thus, they may have better capabilities to deal with their consequences than regions which are less frequently hit, regardless of the costs.

Figure 8 in the appendix presents dynamics around "costly" disasters. These are disasters with losses exceeding 2200 dollars per-capita or five percent per-GSP. Figure 9 presents the dynamics for disasters occurring in years featuring, for the US as a whole, at least 10 billion dollars events (1998, 2008, 2011-2013, 2015-2017) ; and for disasters affecting the South east of the US (Alabama, Florida, Georgia, North and South Carolina and Virginia) [3].

The dynamic heterogeneity present in Figure 1 has not much to do with the costs, the year in which they occur, or their geographical location; in fact the same inconclusive evidence obtained considering all disasters emerges in all cases. When we analyde costly disasters measured in per-capita terms, the median output and the median personal income fall while the median unemployment increases in the disaster year. Furthermore, the median state expenditure variables and federal transfers increase. However, the interquartile range of the dynamic distribution at each horizon is large and no firm statistical conclusions can be reached. Even focusing on south-east regions, where severe storms and tropical cyclones are prevalent, a more homogeneous pattern of dynamics around disaster dates is hard to find.

[3]Using Gulf states or Tornado alley states produces a very similar picture. Also using the last 10 years of data (2008-2017) does not change the conclusions.

Time aggregation is also not responsible for the results either. As Figure 10 shows when quarterly data on real GSP, the unemployment rate, manufacturing GVA and state expenditure are used and disasters information are assigned to the quarter they occur, the same inconclusive evidence emerge. Factors unrelated to disaster characteristics, such as the level of income, the openness to trade, etc, may also account for dynamic heterogeneity. However, in all cases examined, a large cross sectional dispersion around disaster dates remains.

In sum, an event-study methodology has a hard time to identify any association between natural disasters, macroeconomic activity, and fiscal responses. Even refining the approach, by conditioning on event or state characteristics, does not produce a clear and significant pattern of correlations. Why does the methodology fail to deliver clear cut conclusions? Several reasons may account for the poor outcomes. First, disasters are treated as dummy variables, each disaster receives the same weight in the exercise, and the recurrent and spatial features of the phenomena is disregarded. Weighting events by disaster characteristics, such as type or costs, is not enough to generate informative results, given that the recurrent nature and the spatial features of the events are disregarded. Disasters are not i.i.d. events and certain states may be better equipped than others to face their economic consequences. For instance, coastal states may invest more in prevention, set aside budget funds to deal with disasters, or set protocols which may be quickly activated when tropical cyclones or severe storms hit the region. These protocols might make, other things equal, the costs smaller than in other states less prone to such events. Similarly, California may be better equipped than Minnesota when fighting wildfires and, vice versa, Minnesota may be better equipped when dealing with freezes. None of these considerations matter in an event-study methodology.

Events may also hit in different months of the year - the effect of winter storms may show up in the data of the year they occur while the effect of tropical cyclones or severe storms, which tend to occur in the summer or the fall, may be delayed. It is well known, see Sun and Abraham (2021) that typical effects may not be meaningful when the timing of the treatment differs across units. Finally, different states have different economic structure and different production networks, and a disaster hitting, say, the rust belt or an oil state, may have very different macroeconomic implications from a disaster hitting more service oriented states. For all these reasons, an event-study methodology seems incapable of highlighting the multidimensional of conditional correlation patterns we are looking for.

4 The effects of disaster cost shocks

To take into account part of these shortcomings, we use a local projection approach. First, rather than considering disaster dummies, we examine the dynamic effects of disaster cost *shocks*. As mentioned, natural disasters are serially and spatially correlated and some states may be more used than others to deal with them. Disregarding serial correlation makes the estimated coefficients upward biased, as they would capture the cumulative effect of a disaster from t up to $t+h, \forall h$, see Canova (2020). It is also important to account for regional correlation, as otherwise there would be a common predictable component to the shocks, which would make dispersion measure biased.

Second, we include controls in the projection equation to interpret the results in a causal sense. Even if the event study evidence was more informative, it would identify only unconditional correlation patterns. Since other events may occur in the same year, and since both macroeconomic and fiscal variables endogenously respond to the state of the economy, unconditional correlations do not provide evidence that disasters "cause" fiscal policy to react when the state economy is in disarray.

We employ disaster cost shocks as instruments in the projection equations. 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 $Y_{j,t+h}$. Thus, the effect we report refers to the dynamics of a variable in a state *relative* to its US average counterpart. 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 a vector variables $w_{j,i,t}$ which includes lagged state output, lagged state unemployment, and the lagged dependent variable. Additional controls could be employed but, due to the relatively small sample, degrees of freedom are scarce and small sample bias may be important, see e.g. Herbst and Johannsen (2020). Formally, the estimated equation is

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

where $e_{j,i,t+h}$ is a MA(h-1) process, The instrument vector is $z_{i,j,t} = [1, y_{j,i,t-1}, \hat{u}_{i,t}, w_{j,i,t}]$ where $\hat{u}_{i,t}$ is obtained from

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

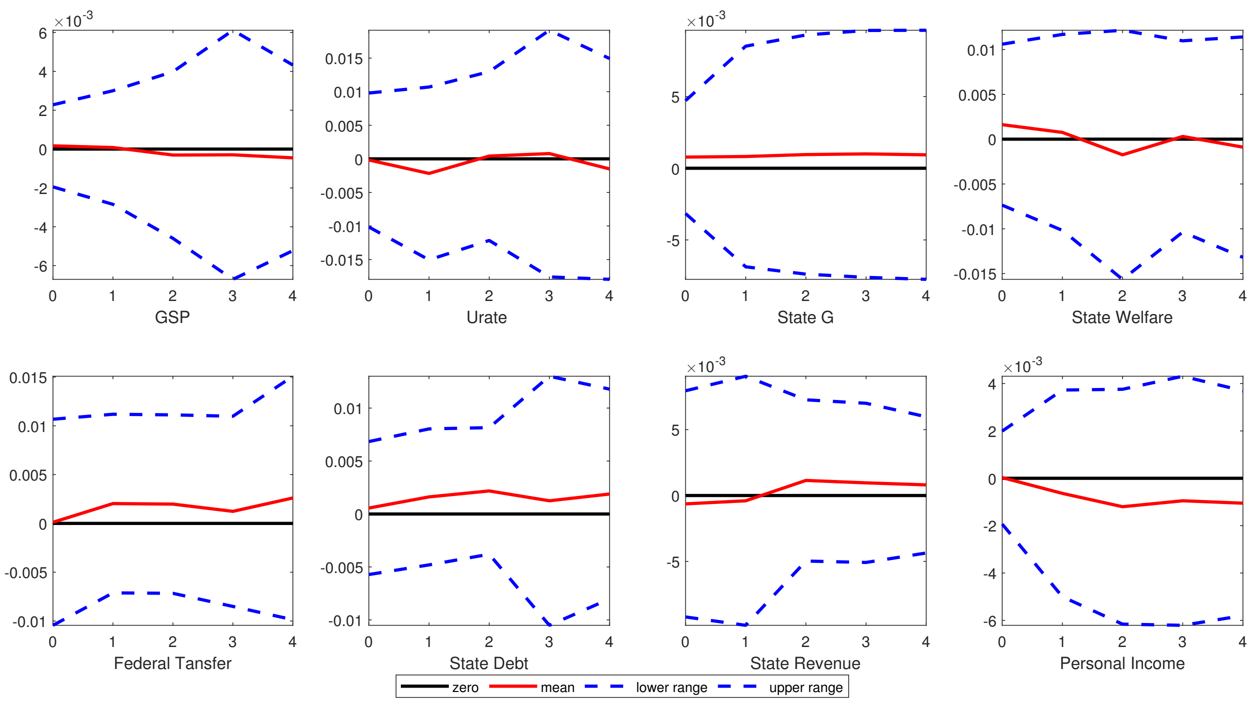
and $\bar{x}_{i,t-1}$ is a regional cost factor.

To reduce small sample problems, we employ a Bayesian approach: we estimate equation (1) using a normal prior for $(a_{j,i,h}, b_{j,i,h}, d_{j,i,h}, f_{j,i,h})$ with zero mean and fixed variance; thus, the estimates we construct smoothly shrink 2SLS 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.

As (1)-(2) make it clear, estimates are obtained for each (j,i)-pair separately. We do so because we are interested in tracing out for a given j, the cross-sectional distribution of $d_{j,i,h}$, for different h, not just an average measure. We summarize the estimated distribution for each h with a location and a dispersion measure. The typical responses we present are cross-sectional averages and the uncertainty bands represent interquartile ranges.

Typical dynamic responses Figure 2, which traces out the cumulative cross-sectional distribution of dynamic responses to a disaster cost shock, indicates that no statistically significant effect is obtained. Thus, the shortcomings of the event-study methodology we have highlighted in the previous section, including lack of controls, failure to account for the endogeneity of disaster costs, and equal weighting of events, are not responsible for the results. Even disregarding the large dispersion measure, the typical effect of real variables hardly conforms with intuition: GSP increases for a year, unemployment falls and only personal income shows any evidence of a decline. It is only two years after the shock that a recession seems to set- in.

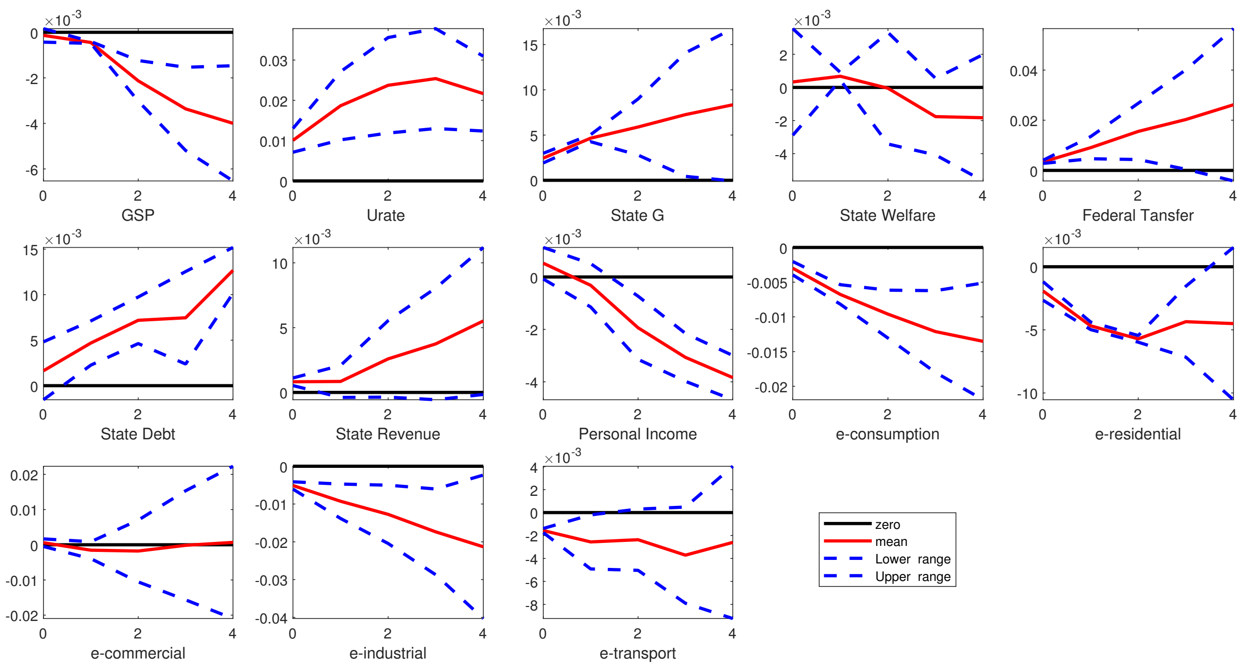
Figure 2: Cross sectional dynamics in response to disaster cost shocks



We interpret this evidence as suggesting that there is an important source of unaccounted heterogeneity. Among all possible factors one may consider, we found that energy usage is key to understand the differential effects of disaster cost shocks. In particular, only disasters cost shocks which affect energy consumption have significantly negative effects on real activity. This finding seems intuitive as the energy sector is upstream relative to many sectors in US state economies and disruptions of energy usage may have important and persistent consequences on the state macroeconomies. However, as we show later, the drop in energy usage after a natural disaster might proxy for other important state characteristics.

Figure 3 shows the dynamics obtained, conditioning on total energy consumption falling in response to the disaster cost shock. Notice that the fall in total energy consumption is equally shared by the industrial, residential and transport sectors; but it is in the industrial sector where the energy consumption disruption is larger.

Figure 3: Cross-sectional dynamics in response to disaster costs shocks, conditional on energy usage



When energy usage falls, output of the typical state remains unchanged on impact and significantly and persistently falls subsequently, the typical unemployment rate increases significantly on impact and its increase persists, and the typical personal income significantly and persistently falls with a lag. The magnitudes of the typical effects are economically important: output and personal income fall by 0.4 percentage points cumulatively after four years and relative unemployment increases cumulatively by two percentage points after three years. Hence, it is not the disruption of the capital stock induced by natural disasters that triggers a recession. It is the destruction of energy related infrastructures that persistently cripples the supply side of the state economy.

The fact that energy consumption and GDP growth correlate is well known. Still, the direction of causation is debatable and may vary over time. As a result, one might think that the fact that GSP falls in states where energy consumption falls is mechanical. However, as it is clear from Figure 3, energy consumption falls significantly on impact in response to disaster cost shocks (and especially so for industrial usage) and the fall leads the fall in GSP. Hence, the pattern of impulse responses suggests that energy disruptions induce a supply driven recessions.

This interpretation is consistent with Lee et al. (2021), who argue that natural disasters have first a significant negative impact on oil, renewable and nuclear energy consumption in a cross section of low-middle income countries. Our results show that such result is not driven by the choice of countries and also occurs in developed states belonging to a monetary union. Figure 3 is also consistent with many pieces of less formal, narrative type of evidence presented in the literature. For example, Wanik et al. (2018), claims that Hurricane Sandy (2012) was among the most devastating storms to impact Connecticut' s overhead electric distribution network, resulting in over 15,000 outage locations that affected more than 500,000 customers. The damage to the energy infrastructure was so significant that it caused power outages for months after the storm. In Puerto Rico Hurricane Maria in 2017 devastated the electric grid in the island and many households remained without electricity for over a year and the recent fire at a newly constructed power plant (April 2022) has caused concerns that the island energy infrastructure will not be able to stand the hurricane season [4]. Also, the hurricane Inaki in Hawai in 1992 destroyed most of electricity distribution and transmission infrastructure of the island and one month after the disaster utility companies were able to restore power only in 20 percent of the island. Furthermore in Kauai, half of the electricity

[4]See https://www.businessinsider.com/fire-causes-major-blackout-in-puerto-rico-before-hurricane-season-2022-4?r=US&IR=T.

poles where not up 6 months after the disaster [5].

Another piece of supporting evidence comes from the tornado hitting Western Kentucky in December 2021, the deadliest tornado ever occurring in the month of December. The power infrastructure of the state was severely damaged, leaving ten thousands of households without electricity. Furthermore, there were concerns that it might have taken months to restore the electric grid to full capacity[6]. This prediction came true in April 2022 when a new storm hit the area further damaging the power infrastructure and causing generalized power outages [7].

Figure 4: States where energy consumption falls in response to a disaster cost shock.

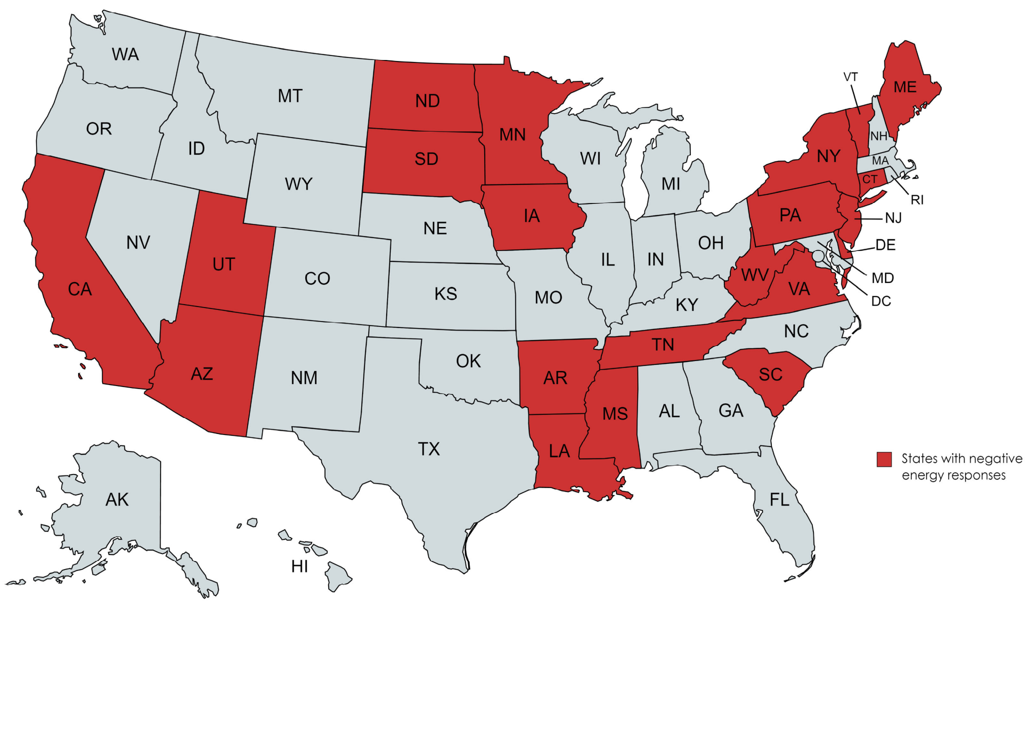


Figure 4 maps the states where disasters typically induce a fall in energy consumption.

[5]See https://www.swissre.com/dam/jcr:7b49faa1-ddf5-4e11-93a2-5ae17c0105cd/lights-out-the-risks-of-climate-and-natural-disaster.pdf.

[6]See https://edition.cnn.com/2021/12/15/weather/kentucky-tornadoes-storm-wednesday/index.html.

[7]see https://www.kentucky.com/news/weather-news/article260408177.html) and in August 2022 when a major flood caused by torrential rains occurred.

Clearly, location is not key to understand the responses of energy consumption; thus, the type of disaster disrupting the local economy is irrelevant, as is the intensity or the frequency of the event. Then, why do these states display a recession?

Three factors may be responsible for the patterns in Figure 4. First, the vulnerability of power facilities and their maintenance differs across states. Second, different states have different share of home ownership and owners may better take care of their houses than renters when it comes to disaster prevention. Third, disaster insurance does not cover flood costs - if a building is destroyed by the winds of a hurricane it is covered but if it is flooded by its torrential rains it is not. The national flood insurance policy (NFIP) is designed to deal with this problem, but participation is by community (not by individual), it is voluntary, and the program is largely unused (e.g. in Louisiana only 25% of households participate). Furthermore, some states, such as Florida and California, have setup insurance programs to deal with the consequences of hurricanes, earthquakes and other natural disasters.

All the three factors appear important. A proxy for the vulnerability of power facilities (power outages in 2018, a year with a few number of disasters), cross sectionally correlates, although marginally, with the two years cumulative magnitude of the energy consumption response (p-value 0.10); and the state average ownership ratio cross sectionally correlates negatively with the two years cumulative magnitude of the energy consumption response (p-value 0.03). Preventive measures are also important. For example, cross sectional differences in state expenditure on fire protection are negatively correlated with the two years cumulative magnitude of the energy consumption response (p-value 0.005) [8].

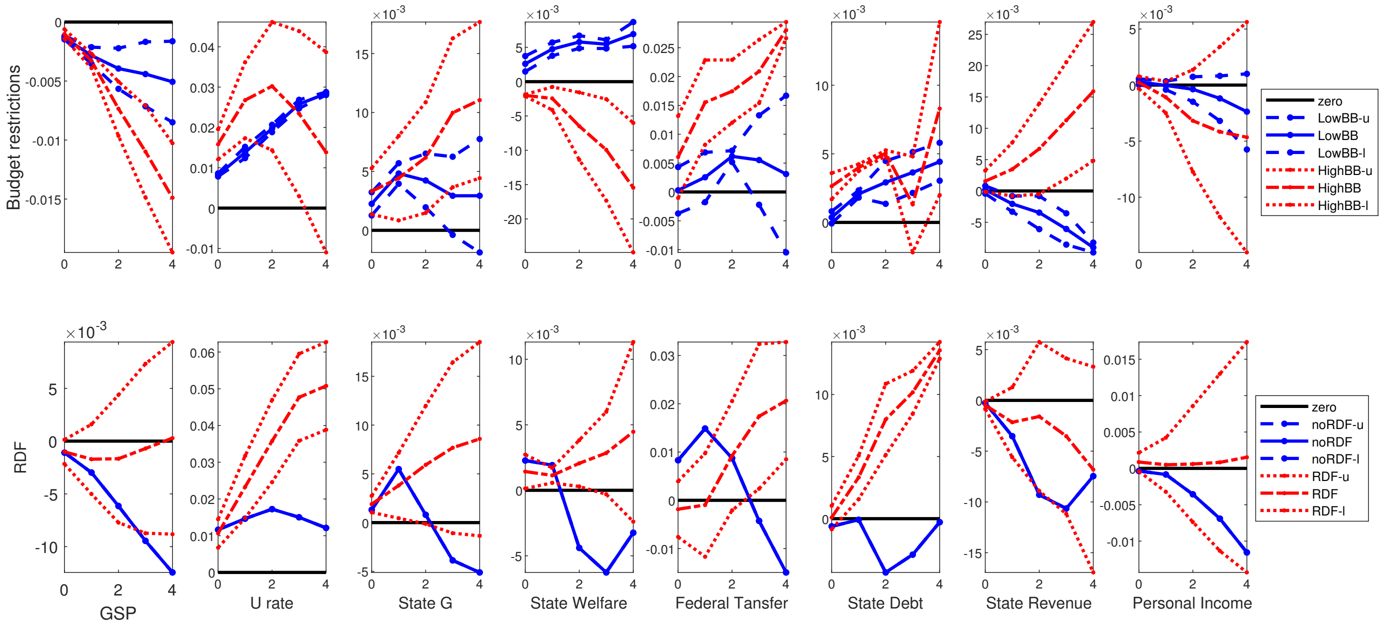
[8] It is worth noting that other standard state characteristics do not significantly correlate with energy consumption responses, For example, the cross sectional distribution of energy consumption responses does not correlate with the cross sectional distribution of state level of income (p-value 0.71), with the geographical location (p-value 0.66), with the political color of the state (p-value 0.82) nor with economic characteristics such as construction activities (the correlation with the average per-capita building permits has a p-value of 0.15), the industrial composition (p-value 0.42), the number (or the type) of foreign migrants (p-value 0.55), the productivity profiles (the correlation with the distribution of average change in earnings per-job has p-value 0.12).

5 The role of the fiscal framework

Conditional on a recession being obtained, one may ask whether the fiscal framework adopted by a state makes a difference as far as the length and depth of the slump are concerned. This interest may stem from a number of preoccupations policymakers may have. For example, following the COVID-19 crisis there has been a call for relaxation of fiscal rules to cope with the unexpected and unprecedented nature of the shock. Is it true that tight budget and debt constraints are detrimental when an unprecedented or large unexpected shock hits the economy? Should one apply the same COVID-19 logic to disaster costs shocks as they cause a large pressure on the local government and may lead to significant negative consequences on the real economy? Is it a good idea to establish contingent funding for disaster relief or establish preventive programs ? Many US states have budget stabilization funds to satisfy balanced budget requirements in face of falling revenues. Is it a good idea to enlarge their scope to include catastrophic events? Would it be more appropriate to have a federally funded program setting aside and accumulating funds for emergencies? While the answers require a specification of policymakers' loss function and constraints, past experience may shed light on the trade-offs various choices imply.

We cluster responses of states displaying declining energy consumption responses to disaster costs shocks using qualitative indicators describing the tightness of the state budget restrictions and the presence of budget stabilization funds. We measure the severity of budget restrictions using the ACIR index, which runs from 1 to 10 (with 10 being the tightest) and combines two types of information: (i) whether the state budget should be balanced ex-ante, ex-post, or never; (ii) whether deficits can be carried over two consecutive fiscal years. The value of the index for each state is in Table 3 and it is taken from Advisory Commission Intergovernmental Relations (1987). We define as states with tight budget restrictions those scoring 10 on the scale, as those states require a balanced budget at the end of the fiscal year and cannot carry over deficit over consecutive years. States with score below five have softer

Figure 5: Cross-sectional distribution of responses to disaster shocks: conditioning on the fiscal framework



requirements, and we consider them as loose restrictions states.

Over the last 40 years, US states have found themselves increasingly constrained in their ability to quickly raise taxes or to run fiscal deficits, whenever an unexpected revenue shortfall occurs. Partly in response to these limitations, states began employing budget stabilization funds, often called " rainy day funds," (RDFs). RDFs are a relatively new addition to the set of stabilization tools state governments have at their disposal and help to smooth state consumption expenditure by serving as receptacles for savings in good times to be used in bad times or situations of economic distress. They did not become common until the mid-eighties, although the dates of adoption vary substantially (see Table 2 in appendix for adoption dates). 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 in the late 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. Other things being equal, balanced budget restrictions should matter less for states with sizable stock of rainy day funds. However, in the case of catastrophic events, the federal government may also step in and undue the limits that budget restrictions induce on state expenditure, regardless of the presence or the absence of RDFs.

The first row of Figure 5 reports the distribution of dynamic responses of macroeconomic variables when energy consumption falls, separately for tight and loose budget restrictions states. Conditionally on a recession being generated, having tighter budget restrictions makes output fall more, and significantly so after 3 years, and unemployment increase more, at least for the first two years. In addition, welfare transfers are substantially cut and federal transfer significantly increased in states with tight budget constraints. However, the dynamics of state debt in the two groups do not differ significantly.

The second row of Figure 5 reports the distribution of dynamic responses for states with and without rainy days funds. Among the states for which energy consumption falls there is only one (Arkansas) without rainy days funds. To make the comparison as stark as possible we plot the responses of the states which had RDFs prior to the beginning of our sample. Cross groups differences in GSP or personal income are insignificant. The unemployment rate increases more in states with rainy days funds but only two years after the shock. Federal transfers increase more for about two years in Arkansas, while state debt increases more in states with rainy days funds as welfare expenditure increases along with state expenditure.

While the evidence is clear, a word of warning may necessary as Arkansas is not only a state without RDFs; it is also a state with tight balanced budget restrictions. Thus, one may be worried that the second row of Figure 5 mixes together two separate effects. It turns out that this is not the case. If, in the RDF group, we only include states with tight balanced budget restrictions, the same insignificant difference obtains. The only change is also that debt in the two groups display a similar pattern in this case.

In sum, the fiscal framework does not seem to be crucial in determining the length and depth of the recession a disaster cost shock generates, provided that the federal government steps in the more restrictive are the budget rules or the less prepared are the states to face the calamities. There is also some substitution process across state budget items, whereas welfare transfers are cut to increase expenditure in response to the disaster costs shock. Whether this substitution is welfare improving is a question our analysis cannot answer.

6 State and federal fiscal policy

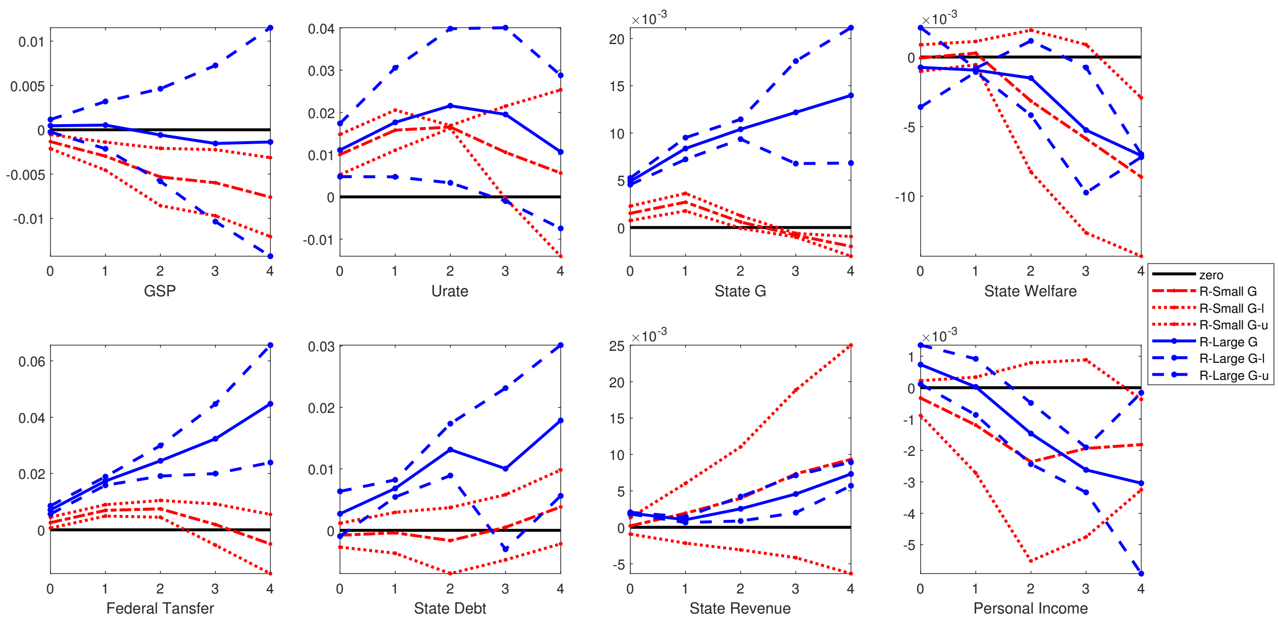
Another important policy question is whether the intensity of fiscal response, at either the state or the federal level, matters as far as containing the negative consequences that disaster costs shocks have on real activity, income, and unemployment.

It is well known that the effects of government spending shocks on the real economy are controversial. The data seems to suggest that the effect is positive, although on average not very large, except when the economy is at the zero lower bound for the nominal rate, in a recession or and when the real rate of interest is sticky (see, Christiano et al. (2011), Barnichon et al. (2022), Canova and Pappa (2011)). Available models seem to provide a different answer, as it is hard to produce multipliers greater than one, unless a special combination of events occurs (see e.g. Leeper et al. (2017)).

The situation we deal with is different from the one considered in the multiplier literature, as we are interested in whether a larger systematic reaction of fiscal policy to the disaster shocks makes the depth and the length of the generated recession smaller. To examine whether it is the case, we cluster responses to disaster cost shocks implying negative energy responses into two groups: those where the reaction of the state expenditure is large and those where the reaction is small; and we do the same for federal transfer responses.

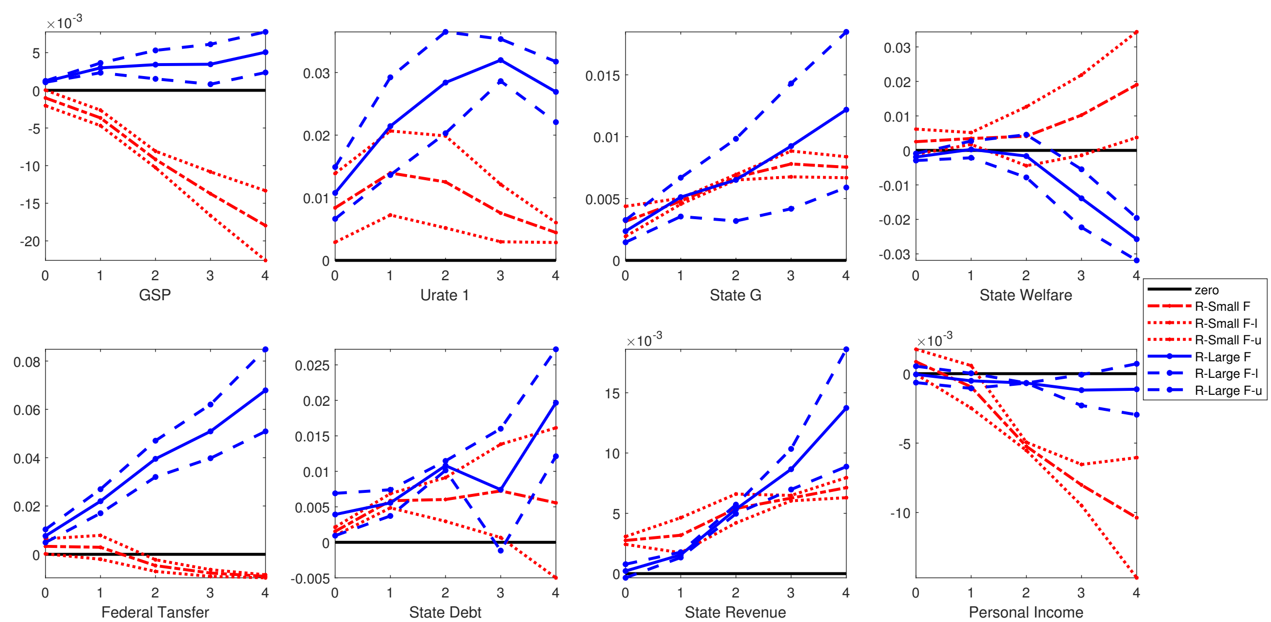
Figure 6 shows the responses in the groups formed by taking high and low state expenditure responses. The response of state expenditure makes little difference for real variables and differences in the dynamics of output, personal income and unemployment are statistically insignificant. If state expenditure is larger, the typical output falls less and the typical personal income goes up temporarily and the unemployment rate goes up less, but uncertainty is large and no firm conclusion can be drawn. Note that there seems to be a high cross-sectional correlation between state expenditure responses and federal transfers, with the latter being three times as large at all horizons as the former. Overall, the response of state expenditure seems irrelevant to determine how the recession evolves and how long it will last.

Figure 6: Cross sectional distribution of responses to disaster cost shocks, large vs small state expenditure reaction



Federal aid instead seems to make an important difference for how real variables evolve and the stronger is the reaction to a disaster cost shock, the easier is the recovery, see Figure 7. In fact, in states where relative federal aid responses are larger, output and personal income do not fall, while the unemployment rate increases more than in the other group only two years after the shock. The increase in the unemployment rate of high federal transfer states correlates with welfare transfers, which fall significantly after three years. On the other hand, state expenditure and state debt similarly respond in states receiving high and low federal transfers. This suggests that federal transfers substitute for both state expenditure and state welfare expenditure and act as counter cyclical safety net in responses to disaster cost shocks.

Figure 7: Cross sectional distribution of responses to disaster cost shocks, large vs small Federal transfer reaction



Combining the content of the two figures one can conclude that states enjoying stronger fiscal support are able to escape output and income losses better. This larger fiscal support does not generally imply larger or more persistent debt dynamics, but positively correlate with unemployment dynamics. Whether this correlation indicates that more federal aid imply less flexible labor markets or whether less resilient labor markets implies larger federal support, is an interesting question which needs to be dealt with in future work.

Comparing across pictures, instead, one can see that federal support does most of the job in limiting the effects of disaster shocks on the real economy. As we have seen in the previous section, federal aid is stronger in states with strict budgetary rules and lacking budget stabilization funds. Thus, it is the federal government that takes the responsibility to stabilize the state economy when disasters hit.

7 Conclusions and policy implications

This paper measures the macroeconomic effects of disasters in US states and evaluates whether the fiscal framework and the reaction of state and of federal fiscal policy matter for how the state economy recovers from the hardships.

Regardless of the methodology employed, the type of disasters considered, their costs, their location, or the year when they occur, disasters do not generically imply significant real or fiscal costs. This occurs because macroeconomic variables respond in a very heterogeneous way across states. Adding conditioning variables, using finer sampled data, or eliminating the temporal and spatial component of disasters costs does not affect the conclusions.

We highlight that the dynamics of energy usage are useful to rationalize the large heterogeneity we discover and only disasters that negatively impact on energy consumption have significant negative and persistent output, personal income and unemployment consequences. The effect on total energy consumption is strong on the industrial sector; however, significant declines are evident also in the residential and transportation sectors. State expenditure and debt increase persistently, and federal transfers also rise, making fiscal policy counter cyclical; and the federal government is generally more proactive than the state government. In general, what matters to predict the effects of disasters is not the impact they have on the capital stock, their cost or their location, as emphasized by the previous literature. Instead, what matters is whether the power infrastructure is affected and to what extent. States displaying negative energy responses on impact are also those with low home ownership ratio, and less state expenditure on preemptive measures.

The fiscal framework adopted by a state does not significantly affect real macroeconomic outcomes, primarily because federal transfers partially undo constraints or make up for the lack of stabilization funds. Still, when tight restrictions are in place welfare transfer tend to be persistently cut, while state debt increases significantly.

We also find that having a high or a low government expenditure response to disaster cost shocks is irrelevant to determine macroeconomic outcomes. On the contrary, federal transfer aid matters for the way the state economy recovers along the adjustment path. States enjoying larger federal transfers at the onset of the disaster typically display no output or personal income declines over a four year horizon, at the cost of higher unemployment compared with states that receive less such transfers. Thus, a timely reaction of federal spending increases the likelihood of a soft landing but may also interfere with the economic transformations that the disasters bring about in state labor markets.

Although our analysis focuses on US states, it provides important implications for other regions and the Euro area, in particular. 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 more developed than others, have tighter fiscal rules, more proactive state governments and display different economic structure. 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 with the Recovery and Resilience Facility (RRF) that has been designed specifically to respond to the downfall created by the COVID-19 pandemic. Thus, the insights this work brings about may be relevant also for that area.

Overall, two lessons can be learned from our analysis. First, government preemptive measures are useful and reduce the probability that the real side of the economy falls into a recession when costly disasters hit. Incentives that make households and firms take better care of their properties may also help reduce the likelihood of a slump. Second, provided that a reactive and well funded federal government exists, disasters do not seem to call for suspension of state budget rules or creation of contingency funds to deal with catastrophic events. Because 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 when a natural calamity occurs. Similarly, the lack of budget stabilization funds, accumulated in separate saving accounts, may reduce the ability of state governments to respond to adverse and large shocks. However, the state capacity to increase spending in response to disasters is irrelevant for mitigating their negative real effects, provided that the federal government stands ready to do the job. Thus, in a two-layer fiscal system, the tight predictions of theoretical models need not to hold.

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Appendix: The fiscal data, RDFs adoption dates, and the ACIR index

The state expenditure series are 'General Expenditure' and include all government expenditures other than the 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 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. They cover: cash assistance paid directly to needy persons under the categorical programs Old Age Assistance, Temporary Assistance for Needy Families and under other welfare programs; Vendor payments made directly to private purveyors for medical care, burials, 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, backed by the government's full faith and credit or non-guaranteed, and all interest-bearing short-term credit obligations. Includes judgments, mortgages, revenue bonds, 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 2: **Rainy days fund adoption dates.**

State	RDF dummy	Year of Adoption	State	RDF dummy	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 3: **ACIR index**

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		

Figure 8: Cross sectional dynamics around disaster dates, event study, extreme costs

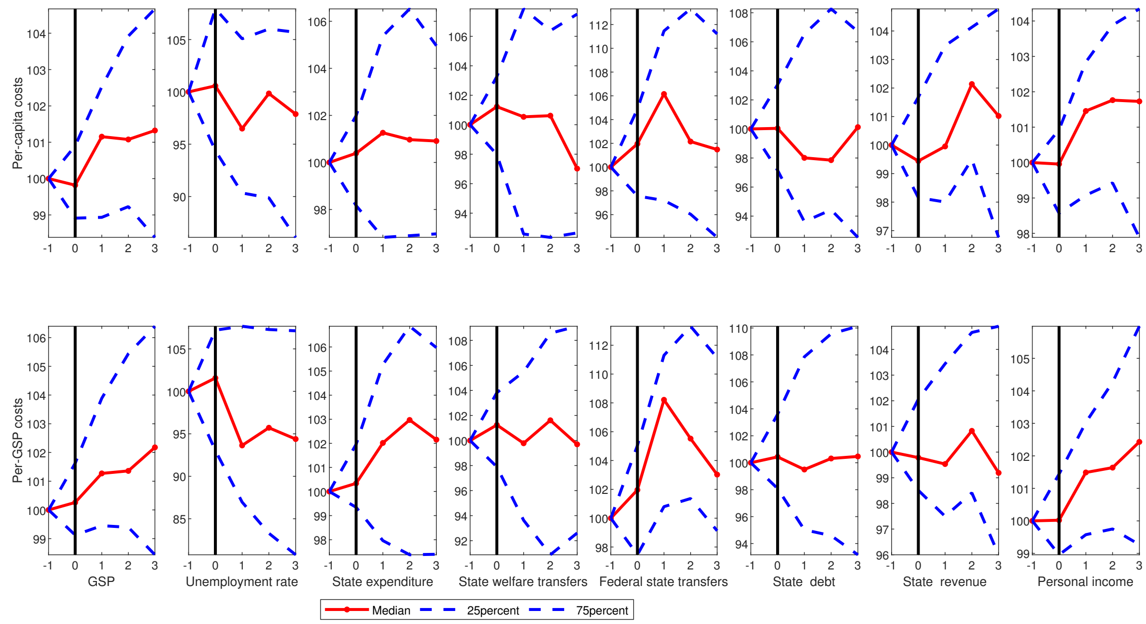

Figure 9: Cross sectional dynamics around disaster dates, event study, special years and location

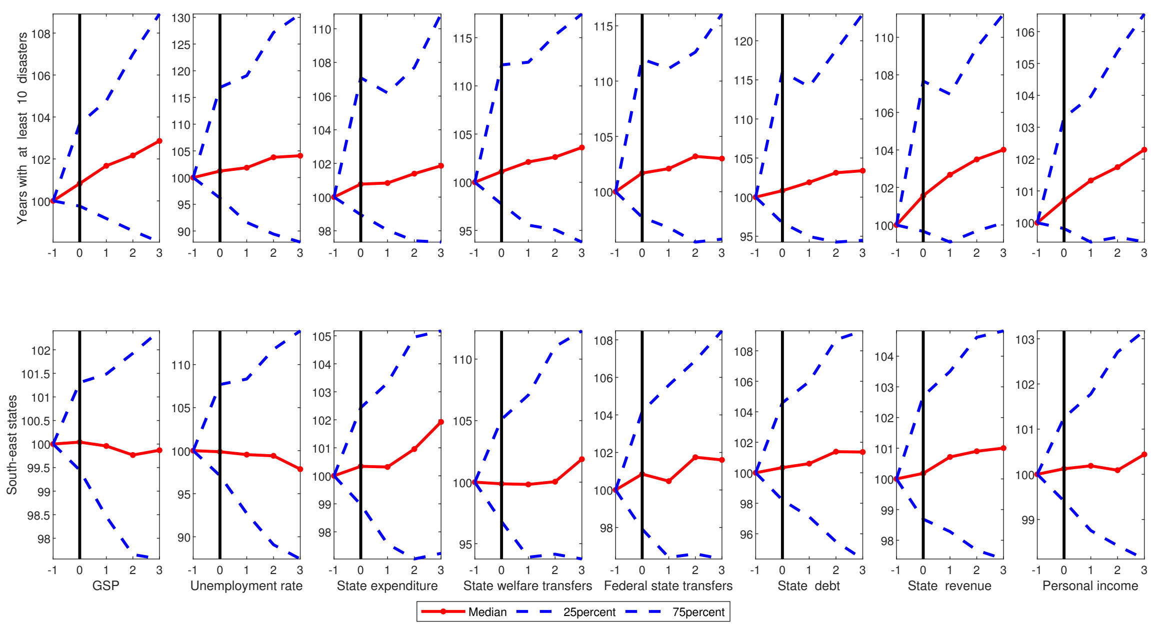

Figure 10: Cross sectional dynamics around disaster dates, event study, quarterly data