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Macroeconomic and Financial Effects of Natural Disasters

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climate change, natural disasters, transmission, local projections

JEL Classification

C22, E31, E32, E44, E52, E62, Q54

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Macroeconomic and Financial Effects of Natural Disasters*

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Abstract

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1 Introduction

As climate change intensifies, its impacts become increasingly undeniable. July 2023 stands out as the hottest month ever recorded on Earth (Thompson 2023). Projections indicate that the frequency and severity of extreme weather events, including natural disasters, will continue to escalate with advancing climate change (IPCC 2014, 2022). As the bulk of the social and economic costs are yet to fully materialize, discussions among economists and policymakers regarding the economic and political ramifications of climate change are gaining momentum (e.g., Carney 2015, Batten 2018, Olovsson 2018, Rudebusch 2019, Batten et al. 2020, Lagarde 2020, ECB 2021).

Indeed, the repercussions of climate change inevitably intersect with the primary objectives of central banks and fiscal authorities, despite climate change mitigation not being their primary mandate. For instance, central banks must deepen their understanding of how natural disasters and broader climate change phenomena impact economic activity, inflation, and financial stability along with comprehending the transmission mechanisms underlying these impacts. For fiscal authorities, understanding these impacts is essential as well. Climate change could strain public debt levels, complicating their management and potentially heightening the vulnerability of public finances. Anticipating and accommodating the impact of climate change is thus crucial for the policy decisions of central banks and fiscal authorities and, more broadly, for their support of the broader societal transition to a carbon-neutral economy.

In this paper, we examine the dynamic transmission of natural disasters to the US aggregate economy. We focus on those disasters that are expected to intensify due to climate change, i.e. severe floods, storms, and extreme temperature events. We rely on local projections using monthly data since 2000. Our impulse variable reflects the number of natural disaster events in the US in a given month. We project the effects over a horizon of up to three years. Over these horizons, we can maintain the assumption that the disasters are predetermined with respect to the macroeconomy and financial markets (Baker & Bloom 2013, Ludvigson et al. 2021).[1]

We find that natural disasters trigger significant and enduring negative aggregate impacts on the real economy. These effects are broad-based, as they manifest across various sectors, including labor and housing markets, production, consumption, and investment. The adverse real effects can be attributed to a widespread decline in confidence, an increase in uncertainty, heightened awareness of climate change and a tightening of broad financial conditions, en-

[1] This does not preclude that there is feedback from the economy to the climate in the long term (Nordhaus 1991, 1994, 2007). These are, however, longer-run processes with climate change slowly progressing due to carbon emissions which does not render our estimation invalid. Eickmeier et al. (2023) argue along similar lines in their analysis of the effects of bank capital regulation on the economy.

compassing financial risk perceptions. We also observe a widespread rise in bank risk and the economy's susceptibility to future bank risk following the disasters, coupled with a decrease in holdings of (comparatively secure) treasury securities. Conversely, banks appear to be adjusting their portfolios toward safer business and real estate loans, potentially to mitigate the heightened risk.

Furthermore, our analysis reveals that disasters temporarily elevate consumer prices, likely driven by transient increases in energy and food costs. Monetary and fiscal policy variables move in the direction that could contain negative macroeconomic impacts. Furthermore, anchored inflation expectations appear to help contain price pressures. However, we find a persistent increase in public debt relative to GDP, exposing the US government to heightened vulnerability in future adverse scenarios. Furthermore, our results suggest a long-lasting decline of r-star, limiting future space to manoeuver for monetary policy as well.

Our results are robust against a large variety of alterations. For instance, we consider individual disaster types, i.e. storms, floods, extreme temperature events, separately; we exclude hurricane Katrina and the subsequent months from the analysis; we also account for persistence of the impulse variable; and we vary the lag structure of our local-projections setup. In a complementary analysis, we analyse the impact of media attention toward climate change on the macroeconomy and find effects on the unemployment rate and consumer prices that are comparable to those following natural disasters. Furthermore, we demonstrate that the effects of natural disasters at the aggregate level differ markedly from their local impacts, reconciling studies which consider local effects of local disasters and those which examine aggregate effects. Overall, our findings highlight significant negative impacts across the real economy, financial markets, and key policy variables, emphasizing the critical importance of taking immediate action against climate change and enhancing economic and financial resilience.

We contribute to the growing empirical literature on the dynamic aggregate macroeconomic effects of (local) natural disasters in developed countries (see Section 2). Our paper extends the scope of existing research by conducting a comprehensive analysis of the impact of natural disasters on a large array of 61 variables, capturing real activity; prices; interest rates; confidence, uncertainty and media attention toward climate change; risk; as well as bank balance sheet measures. This allows us to meticulously unravel the intricate transmission channels through which natural disasters influence the aggregate economy. This granular approach not only enhances our understanding of the immediate effects of such calamities but also sheds light on their broader implications relevant for key objectives of central banks and fiscal authorities. Indeed, we examine the repercussions of disasters on numerous monetary and fiscal policy variables, making a significant contribution to the literature on the interrelatedness of climate change and macroeconomic policies.

As a caveat, just as previous empirical papers, our analysis captures past adjustments. Yet, most of the costs and adjustments are yet to materialize as natural disasters are projected to intensify and occur more frequently. Furthermore, as people increasingly associate these events with climate change, the manner in which the economy adjusts will critically hinge upon individual and collective behavioral responses, making their duration, sign, or size challenging to predict. Despite these uncertainties, we feel confident that our research contributes to a better understanding of the aggregate effects of natural disasters and informs policymakers on possible interventions which could lead to better outcomes.

The remainder of this paper is structured as follows. In Section 2 we give an overview of how natural disasters can theoretically impact the aggregate economy as well as of the related empirical literature. In Section 3, we present the data on natural disasters. Section 4 introduces our local projections approach, while Section 5 presents the effects of the natural disasters on our key variables, i.e. the unemployment rate and consumer prices. In Section 6, we analyze the transmission mechanism in detail. Robustness checks are provided in Section 7 and Section 8 concludes.

2 Related literature

2.1 Theory

Local natural disasters will directly damage local infrastructure, harvest, houses, human health and possibly even lead to death. The (indirect) effects on the real economy are, however, ambiguous. Models based on neoclassical growth theory predict natural disasters (just as any shocks to capital and labor supply) to affect economic activity only temporarily because the marginal product of capital increases as capital and labor become scarcer.[2] These models keep basic factors fixed, which can otherwise change the steady state such as savings, depreciation, or productivity growth (Botzen et al. 2020). Models with endogenous productivity suggest lasting effects on economic activity after natural disasters. These can be either positive because technology will be updated and productivity growth increases as a consequence of capital depreciation ('building-back-better') or negative, for example in AK models which imply a decline in labor productivity as a consequence of negative capital shocks.

[2]See Akao & Managi (2007), Felbermayr & Gröschl (2014), Onuma et al. (2021).

Local effects may, through simple accounting, have aggregate (national) effects, and the larger the region the larger is likely its contribution to the overall aggregate effect. Furthermore, effects at the local level may spill over to the aggregate economy through (trade or financial) linkages between economic actors across regions.[3] One channel that we will be particularly interested in is that local disasters may also affect nation-wide or global financial intermediaries, which may choose to adjust their risk and re-balance their portfolios in response to disasters and to actual or possible future loan default losses.

Furthermore, economic agents may associate natural disasters with climate change, something that has been emphasized explicitly in Natoli (2023) and Choi et al. (2020), for example. Choi et al. (2020) explains that "local weather conditions are people's first-hand experience. The impact of local weather also can be amplified through communication channel and the media [...]. Extreme local temperatures therefore serve as "wake-up calls" that alert investors to climate change". As a consequence, households, non-financial firms, the financial sector, as well as policymakers may adapt their behaviour. There is a lot of uncertainty involved with respect to the future path of the economy admidst climate change. Scenarios range from very negative to bright (in case we manage to adapt). Hence, there may be effects on uncertainty, confidence, and the expected economic outlook.

The effects of natural disasters on prices are theoretically also ambiguous (see the discussions in Beirne et al. 2021, Parker 2018, Faccia et al. 2021). On the one hand, disasters destroy harvest, housing, infrastructure, and can lead to a rise in food prices as well as production and transportation costs. Reconstruction efforts after disasters can lead to positive demand effects that additionally increase prices. Moreover, responding to climate change by transitioning to zero carbon emissions will likely raise carbon and energy prices (even though the overall effect of consumer prices can be negative due to aggregate demand effects dominating aggregate supply effects, as suggested by Meinerding et al. 2023). There may also be indirect effects through higher production costs. Higher temperatures can also lead to a decline in labor productivity through higher mortality, morbidity, and lower efficiency and, hence, lead to negative supply and positive price effects. On the other hand, prices may also decline due to negative wealth and demand effects or an increase in loan default risk and a rise in capital costs. Some, but not all of the effects can be expected to be local.

[3] Botzen et al. (2020) in their overview paper explain that I-O models emphasize trade flows and interdependencies between sectors. CGE models allow for relative price and quantity changes and substitution possibilities that balance supply and demand. Some of the applied models have a spatial dimension included. There are also global (but regionally differentiated) IAMs, which are based on simplified neoclassical economic growth theory. They are used to estimate global costs of climate change and natural disasters and effects of policy measures.

2.2 Related empirical literature

Our analysis is closely related to earlier empirical studies which investigate the dynamic aggregate macroeconomic consequences of (local) natural disasters in the US and other developed economies.[4] Kim et al. (2022) assess the impact of severe weather events on a few US macroeconomic variables. They use a smooth-transition vector-autoregressive (VAR) model estimated over 1963-2019, and capture severe weather events through shocks to an index summarizing events related to extreme temperature, heavy rainfall, droughts, high winds, and the sea level. They find severe weather events to have no significant impact on real activity at the start of their sample. Toward the end of their sample (which our sample comprises), their model reveals a significant instantaneous temporary decline in the growth rates of industrial production and consumption, a very persistent rise in the unemployment rate, and a temporary rise in consumer price inflation (which, they argue, is likely driven by changes in energy and food prices after the shock). In general, less than 2% (median estimate) of the forecast error variation of inflation is explained by the shocks. The short-term interest rate does not change significantly.

Natoli (2023) uses local projections to estimate the effects of temperature surprises on the US macroeconomy over 1975-2019. He finds temporary declines in all examined variables: GDP, production, consumption, investment, employment, prices, and short- and long-term interest rates. Negative effects on durable consumption exceed those on non-durable consumption. He further finds a decline in non-residential investment, but no significant response of residential investment. He also shows that temperature shocks raise attention of the FOMC which more frequently mention the word "temperatures" or "natural disasters" after the shocks. The increase after the events is, however, very short-lived. "Climate change" is rarely mentioned in FOMC transcripts over most of his sample period.

Ludvigson et al. (2021) investigate the effects of costly disasters on the US economy estimating a VAR model over the sample 1980-2020. Their disasters are taken from the National Oceanic and Atmospheric Administration, and they are more broadly defined than ours. They include wildfires, hurricanes, flooding, earthquakes, droughts, tornadoes, freezes, and winter storms. The authors further add 9/11 and the Covid pandemic events. Costly disasters temporarily raise (financial, macroeconomic, and economic policy) uncertainty and depresses industrial production and employment.

[4]There is a large literature also on the economic effects of natural disasters studying local effects within countries (e.g. Boustan et al. 2020, Canova & Pappa 2023, Roth Tran & Wilson 2023), in small open developing economies (e.g. Heger et al. 2008, Cavallo & Noy (2010)), or aggregated over a large sample of countries including developed and developing countries (e.g. Kalkuhl & Wenz 2020, Kahn et al. 2021). We later try to reconcile local with aggregate effects, but otherwise do not mention this literature further.

Another study, which is closely related to ours is De Winne & Peersman (2016). The authors analyze the effects of global food disruptions (which can occur due to natural disasters) on the US economy. The authors use VAR models and, alternatively, local projections. They find that between 2003 and 2014 (which is the sample with the largest overlap with our sample) negative shocks to food production temporarily increase global food prices, persistently lower US GDP and consumption, and temporarily increase US consumer as well as energy prices. For their longer baseline sample, they also analyze more disaggregated effects and find a much larger decline in durable consumption compared to non-durable consumption, accompanied by a short-term drop in consumer sentiment, and a decline in investment. In a more recent paper (De Winne & Peersman 2021), the same authors investigate the effects of an increase in global agricultural commodity prices due to harvest and weather disruptions on a large number of countries. They find a decline in real GDP in middle- and high-income countries and a temporary increase in consumer prices across the world.

Stock (2022), in a preliminary paper presentation, investigates the effects of climate change news on the US macroeconomy using a VAR model for the post-1984 period. He finds a very persistent rise in the unemployment rate, a decline in industrial production, and an increase in producer prices.

Finally, using a European version of the G-Cubed multisector model, McKibbin et al. (2021) simulate the effects of a global physical climate shock comprising both extreme climate events and chronic climate change on central euro-area macroeconomic variables. They find permanent negative effects on GDP, consumption and investment and lasting positive ones on the price level.

Other papers focus specifically on the effects of natural disasters on prices. Faccia et al. (2021) illustrate, based on panel regressions, that hot summer extreme temperatures lead to a temporary rise in food prices in advanced economies - the effects on emerging economies are much larger, and there is no significant effect on non-food prices in advanced economies. The rise in food prices is confirmed by a DSGE model. Parker (2018) finds a temporary rise on headline consumer price inflation as well as food price inflation of severe disasters in high-income countries. Significance depends on the impulse measure and horizon. Mukherjee & Ouattara (2021) discover a short-lived rise in inflation in developed countries after temperature rises. Beirne et al. (2021) find significant, positive, temporary effects on euro-area headline inflation of natural disasters. The effect on core inflation is barely significant, whereas food as well as housing and energy price inflation rise significantly. The authors also find a difference across countries: headline and food price inflation does not change significantly in the large euro-area countries.

3 Natural disaster data

We study the short- to medium-run effects of natural disasters on the US economy in order to proxy for the aggregate effects of climate change. We obtain information on natural disasters from the Emergency Disasters Database (EM-DAT) of the Centre of Research on the Epidemiology of Disasters (CRED).[5] The database documents hydrological, meteorological, and geophysical disasters for a large set of countries. For a disaster to be recorded, it must meet at least one of the four criteria: i. 10 or more people were killed, ii. 100 or more people were affected, iii. a state of emergency was declared, and iv. international assistance was called for.[6]

Given our aim to proxy the effects of climate change, we specifically focus on disasters that are closely linked to climate change and global warming: extreme temperature events, floods, and storms. Specifically, clear linkages between extreme weather-related events - especially extreme temperature events and floods, but also increasingly so storms - , and climate change have been established through attribution science, an area in climate research (see, for instance, Coumou & Rahmstorf 2012, Otto 2015, 2016, Stott 2016, Stott et al. 2016). Furthermore, the Intergovernmental Panel on Climate Change (IPCC) repeatedly predicts that climate change will very likely increase the frequency with which natural disasters, especially floods and hurricanes, will occur as global warming intensifies. With that, associated economic damages are projected to increase as well (IPCC 2014, 2022).

Our monthly sample period is from 2000M01 until 2019M12. We choose the beginning of the sample because the EM-DAT data are more reliable from 2000 onward. And we end our analysis before the pandemic, which represents a major structural break we do not aim at investigating here. For this period, EM-DAT reports 44 extreme temperature events, 209 floods, and 320 storms. Multiple disasters (also of the same category) can occur within a given month in different regions. In addition, a storm can occur together with a flood and / or an extreme temperature event in the same region.

In our baseline setup, we use an impulse variable that reflects the number of natural disasters (all three types) that have occurred in the US within a given month, which we show in Figure

[5] Information on natural disasters from EM-DAT has been used in many international and US specific studies (see, among others, Noy 2009, Cavallo & Noy 2010, Noy & Vu 2010, Strobl 2011, Loayza et al. 2012, Strobl 2012, Von Dahlen & Peter 2012, Cavallo et al. 2013, 2014).

[6] Note that the vast majority of US events enters because criteria (i) and/or (ii) are met, so that criterion (iii) and (iv) do not drive US entries. This could be different for other countries.

1.[7] In the robustness section, we later explore effects of disasters of different types separately. The count variable has a standard deviation of 1.7 disasters. On average (mean), there are 2.4 disasters per month. An advantage of our baseline approach is its simplicity. Another is that the count variable is more likely to be exogenous with respect to the macroeconomy than a variable that accounts for intensities which often depends on the local economic and political conditions (see, e.g., Kahn 2005, Hsiang & Narita 2012, Hsiang & Jina 2014, Kim et al. 2022).

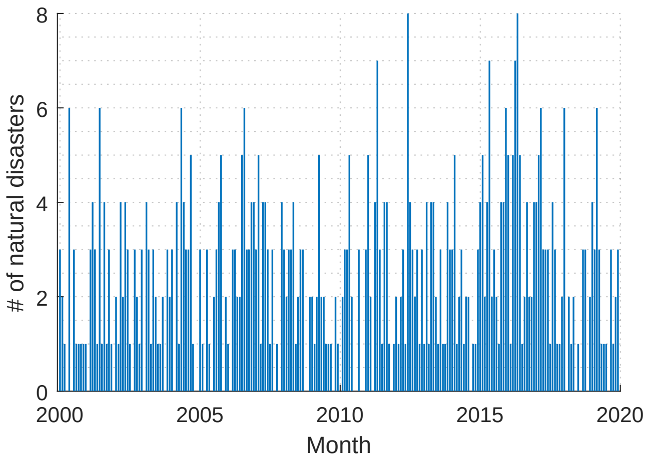

Figure 1: Baseline natural disaster variable

Notes: Number of extreme temperature events, floods, and storms as reported by EM-DAT in a given month.

Note that our count variable accounts for some differences in intensity over time: when several disasters (both storms and floods, for example) hit at the same time, this is reflected in higher values adopted by our count variable.[8]

[7] McDermott et al. (2014) adopts a similar approach.

[8] The EM-DAT database also contains information on the number of deaths, number of people affected, or economic loss after a disaster, which is potentially informative. We decided, however, not to use these intensities in our econometric analysis. The data quality is quite poor. For example, there are many missing values, or numbers are not consistent across events. Statistics partially rely on official or self-reported direct disaster damages. Data quality (and completeness), therefore, depends on local and nation-specific data collection standards (Kahn 2005, Hsiang & Narita 2012, Hsiang & Jina 2014). For a recent discussion on the reliability of the database, see Kim et al. (2022). To still get a rough sense of direct damages of our disasters as reported by the EM-DAT, we note that the median extreme temperature / flood / storm event caused 33 / 10 / 16 deaths, affected 220 / 1558 / 401 people, and yielded an estimated economic loss of 579.520 / 1.086.341 / 1.426.678 USD over our sample period.

4 Modelling approach

To investigate the dynamic transmission of natural disasters, we follow Jordà (2005) and specify the following local projection:

$$y_{t+h} - y_t = c^h + \beta^h(L)\Delta x_t + \delta^h(L) z_t + \varepsilon_{t+h}. \tag{1}$$

$y_{t+h} - y_t$ is our response variable of interest. Δx_t are control variables. In our baseline setup, z_t denotes the natural disaster count variable. c^h is the deterministic component and comprises a constant and a linear time trend.

In our baseline model, we include 3 lags of controls. The impulse variable enters contemporaneously and with 9 lags. We later check for robustness with respect to the lag lengths. Controls are the unemployment rate (our key measure for economic activity), consumer prices, house prices, the VIX, the Federal Funds rate, stock prices, and a dummy variable which captures the global financial crisis (GFC) (i.e. equals to one between 2007M12 and 2009M6 and to zero otherwise) as well as the response variable, if not already among the controls. These are variables that are commonly included in small-scale empirical macro-financial models. All controls enter in log differences, except for the unemployment rate and the Federal Funds rate, which enter in differences, and the GFC dummy, which is not transformed. House and stock prices are converted into real by dividing them with the consumer price index.

We show impulse responses over a projection horizon of up to 36 months. Natural disasters due to climate change may be endogenous with respect to economic activity in the long run, but not in the short to medium run. The projection horizons of 36 months, hence, allows us to consider the impulse variable as exogenous with respect to the macroeconomy. Since we are interested in the effects after a "typical" disaster shock, we consider a one standard deviation increase in the disaster count variable. Below, we provide point estimates and 68% as well as 90% confidence bands using HAC standard errors.

Next, we illustrate the effects of the natural disasters on the unemployment rate and on consumer prices, which we estimate from our baseline model. Thereafter, we analyze the transmission mechanism in more detail, by incorporating a broad variety of further measures (such as various proxies for activity, prices, and financial variables) one by one as left-hand-side variable and in the set of controls in our model. Details on all series can be found in Appendix A.

5 Key results

Figure 2 shows the impulse responses of the unemployment rate and consumer prices after a typical, i.e. one standard deviation, disaster shock (see Equation (1)).

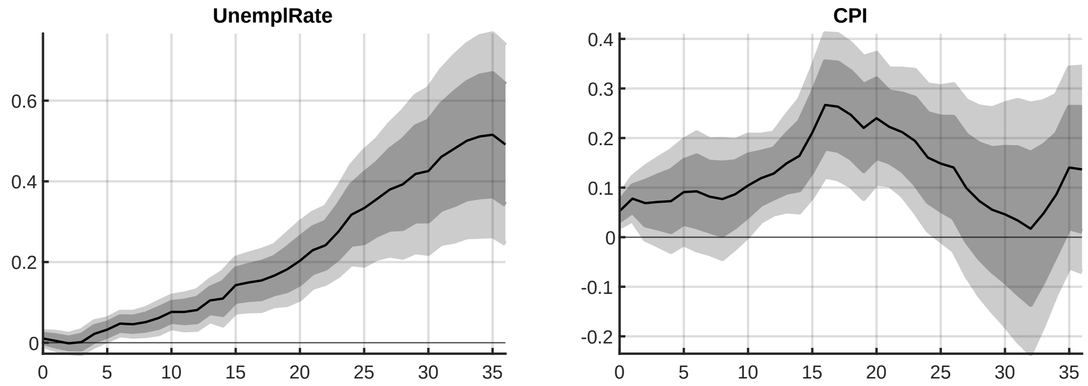

Figure 2: Impulse responses of the unemployment rate and consumer prices

Notes: In pp for the unemployment rate, in % for consumer prices. Gray areas indicate 68% and 90% confidence bands. x-axis: months. For further details on data, please see Appendix A.

Following the disasters, the unemployment rate shows a gradual increase, becoming statistically significant around five months later. Over a period exceeding two years, it rises by approximately 0.5 percentage points before stabilizing.[9] Hence, we find a very persistent effect of natural disasters on our core activity measure, which is our first key result.

Consumer prices increase, with a delay, to around 0.3% after the disasters. They turn insignificant after about two years. Summing up, supply channels seem to dominate demand channels in the transmission of natural disasters to the aqggregate macroeconomy. In the next section we investigate the transmission mechanism in detail.

6 Understanding the transmission mechanism

6.1 Additional real economic variables

We first examine the effects of natural disasters on a range of real activity variables. In line with the unemployment rate response, industrial production, employment, consumption, and investment decline gradually and persistently, up to roughly -1.2%, -0.5%, -0.4% and -2.9%, respectively (see Figure 3).

[9] We computed impulse responses for longer horizons to gauge the persistence of the effects. Following a prolonged increase in the unemployment rate post-disasters, it gradually returns to baseline levels from year five onward. However, even after eight years, it remains significantly positive.

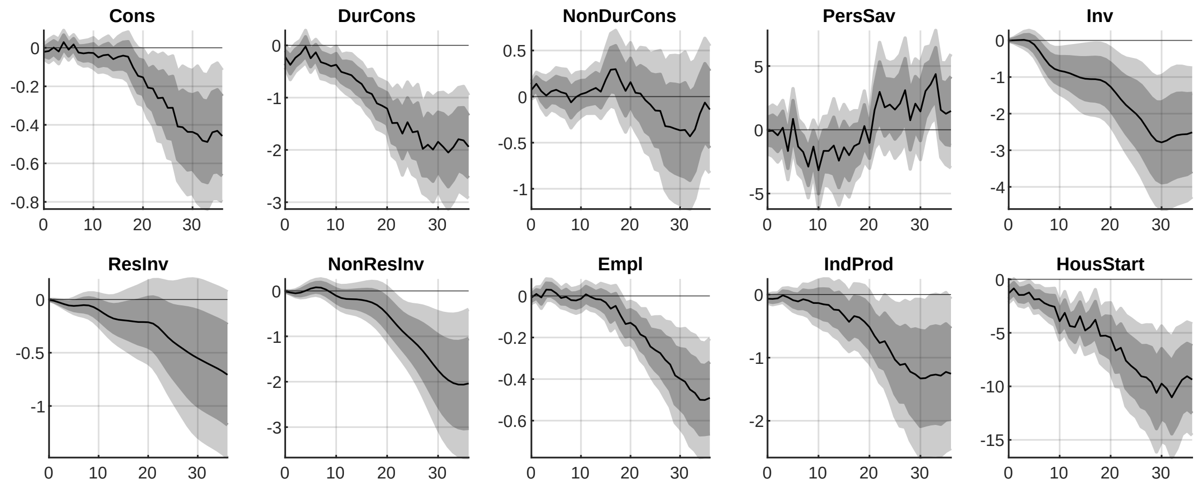

Figure 3: Impulse responses of a broad set of real activity variables

Notes: In %. Gray areas indicate 68% and 90% confidence bands. Abbreviations: Cons: personal consumption expenditure, DurCons: durable consumption, NonDurCons: non-durable consumption, PersSav: personal savings, Inv: private investment, ResInv: residential investment, NonResInv: nonresidential investment, LabProd: labor productivity index, defined as output per hour, Empl: employment, IndProd: industrial production, HousStart: housing starts. x-axis: months. For further details on data, please see Appendix A.

The persistent drop in aggregate consumption is driven by lower durable consumption (in line with Natoli 2023 and De Winne & Peersman 2016), whereas the response of non-durable consumption is not significantly different from zero. The decline in durable consumption is accompanied by a delayed, persistent increase in personal savings at longer horizons. The confidence bands of the savings' response are, however, wide. When we decompose the investment response further, we find a larger negative response of nonresidential compared to residential investment, again, consistent with Natoli (2023). Other housing activity measures, i.e. housing starts and housing permits (not shown here), drop on impact significantly and persistently.

De Winne & Peersman (2016) discuss reasons for the significant impacts on consumption and nonresidential investment resulting from increases in food (and energy) prices, as highlighted in the literature, with some findings potentially applicable here. Heightened uncertainty regarding future climate change and its repercussions may lead to postponed purchases of investment and durable consumption goods, or an increased perceived likelihood of future unemployment or income loss. We will later evaluate responses of uncertainty and confidence measures to the natural disasters. Frictions in reallocating capital and labor across sectors, differently influenced by climate change, could also contribute. The stronger impact on durable consumption compared to nondurable consumption imply sectoral changes amplifying overall macroeconomic consequences, as also emphasized by the authors.

As to the magnitudes of the effects, results previously reported in the literature are quite dispersed. Our estimated effects are at the upper end (in absolute terms) of what has been found so far.[10]

Summing up, natural disasters affect real activity negatively, broadly, and persistently.

6.2 Disaggregated price measures, wages, and inflation expectations

After observing temporary increases in consumer prices following natural disasters, we will now examine the response of other price measures to obtain a more comprehensive understanding.

The impulse response shapes of energy, food, and producer prices resemble those of overall consumer prices, albeit with varying magnitudes (Figure 4). Energy prices surge tenfold, food prices double, and producer prices increase fivefold compared to consumer prices. Conversely, core consumer prices rise by only one-third of the increase in headline consumer prices, but the positive effect persists significantly. The substantial increases in energy and producer prices may be attributed to disruptions in production, transportation, and delivery of energy resources, or possibly linked to heightened demand resulting from business restarts or cleanup and rebuilding endeavors. Finally, our findings indicate a decline in wages, which mitigates the increase in consumer prices.

Anchored inflation expectations likely play a role in containing more pronounced price effects. The lower graphs in Figure 4 display the Federal Reserve Bank of Cleveland's estimates of expected inflation rates over various time horizons. These estimates are derived from a model incorporating Treasury yields, inflation data, inflation swaps, and survey-based measures of inflation expectations.[11] Following the natural disasters, inflation expectations show a slight

[10] Kim et al. (2022) find a 0.02 percentage point rise of the unemployment rate after a one standard deviation shock to their disaster index at their sample end (2019). Consumption and industrial production growth are found by them to drop on impact by more than 0.1%. Ludvigson et al. (2021) also find a small effect of a one standard deviation disaster shock on industrial production, which temporarily drops by about 0.05% (and the effect is largest on impact). Their interpretation of the small effect is that large disasters may have not had a large impact on regions where most of production takes place. We recall that their disaster measure includes the Covid pandemic and 9/11 as well. In Stock (2022), a one standard deviation unexpected shock to climate news raises the unemployment rate and lower industrial production permanently by between 0.05 and 0.15 percentage points and between 0.2 and 0.5 percent, depending on the climate news measure. De Winne & Peersman (2016) do not show effects on the unemployment rate, but on personal consumption and investment (as well as GDP). A one standard deviation shock to global food supply lowers US consumption by 0.2%-0.3%, depending on the specification, and investment by 1%, and these magnitudes are similar to those reported by Natoli (2023). Consumption and investment responses are weaker than our estimates of -0.4% and -2.5%, respectively. Natoli (2023) focuses on extreme temperature, and we show in Section 7 that the effect of extreme temperature events on the unemployment rate is also about half the size of the effects of combined disaster events. Moreover, he relies on a longer sample than we do, and we find it plausible that effects may have changed over time. A global food disruption shock such as the one emphasized in De Winne & Peersman (2021), of course, does not fully overlap with our natural disaster shock.

[11] One-year ahead inflation expectations, drawn from the Michigan University Survey of Consumers, exhibit similar reactions to those from the Cleveland Fed, albeit not depicted here.

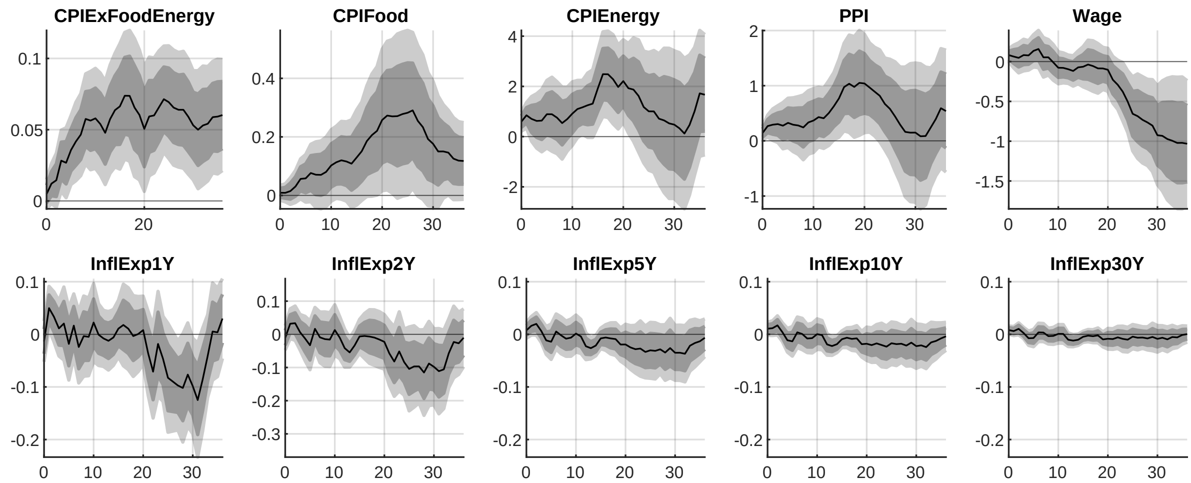

Figure 4: Impulse responses of core consumer prices, energy and food prices, producer prices, wages and inflation expectations

Notes: Inflation expectations in percentage points, all else in %. Gray areas indicate 68% and 90% confidence bands. Abbreviations: CPIExFoodENergy: consumer price index excluding food and energy prices, CPIFood: food-specific consumer price index, CPIEnergy: energy-specific consumer price index, PPI: producer price index. InflExpxY: Inflation expectations x-years ahead as obtained from the Federal Reserve Bank of Cleveland. x-axis: months. For further details on data, please see Appendix A.

uptick initially, followed by a temporary decline. However, these responses are only marginally significant. We observe some evidence of anchoring, as the impact on inflation expectations diminishes as the forecast horizon lengthens.

Our findings are, by and large, consistent with the literature on the effects of natural disasters on prices and inflation expectations in advanced countries and the US more specifically (Faccia et al. 2021, Parker 2018, Mukherjee & Ouattara 2021, Kim et al. 2022, Beirne et al. 2021, De Winne & Peersman 2016). Magnitudes are overall comparable with those from the literature.[12]

In summary, energy price fluctuations contribute significantly to the temporary increase in consumer prices, with food price dynamics also playing a notable role. Anchored inflation expectations likely contribute to moderating price changes in the medium term.

[12]They are, again, larger than those found by Kim et al. (2022) where CPI inflation increases at the end of their sample by 0.04 percentage points on impact. The authors show that this is not driven by core inflation. Our magnitudes are, however, in the ballpark of De Winne & Peersman (2016). Consumer prices rise temporarily in their paper between 2003 and 2014 by 0.1%, energy prices by 1%. When they rely on local projections, effects are larger: for consumer prices at 0.4%, compared with almost 0.2% when they use a VAR model for the longer sample 1963-2013. In contrast, Natoli (2023) find that consumer prices decrease by 0.2%, with food prices showing no immediate response and energy prices dropping by over 2%. One explanation for this disparity is that the author examines the effects of extreme temperatures exclusively, while our disaster measure encompasses a broader range of events. In Section 7 we explore effects of extreme temperature events in isolation as well, which allows us to reconcile our results for prices with Natoli's.

6.3 Macroeconomic uncertainty, confidence, recession prospects, and media attention toward climate change

Next, we show impulse responses of macroeconomic uncertainty, consumer sentiment, and business confidence in Figure 5. We also display reactions of two measures capturing recession prospects: the Anxious Index taken from the Federal Reserve of Philadelphia, which is the probability of a decline in real GDP in the quarter after a survey is taken, and the inverted yield curve. The slope of the yield curve has historically been a good predictor of economic activity. Furthermore, we consider two news indices that capture public attention given to climate change. One is television coverage of "climate change" or "global warming", taken from the Media and Climate Change Observatory (MeCCO) derived from ABS, CBS, CNN, FOX, MSNBC, NBC, PBS. The other is newspaper coverage of climate change, constructed from Factiva data. We count the number of articles containing "climate change" in the ten largest US newspapers (Los Angeles Times, USA Today, Chicago Tribune, Washington Post, Boston Globe, Wall Street Journal, Miami Herald, Dallas Morning News, Houston Chronicle, and San Francisco Chronicle) and divide it by the number of all articles, similar to Baker et al. (2016).

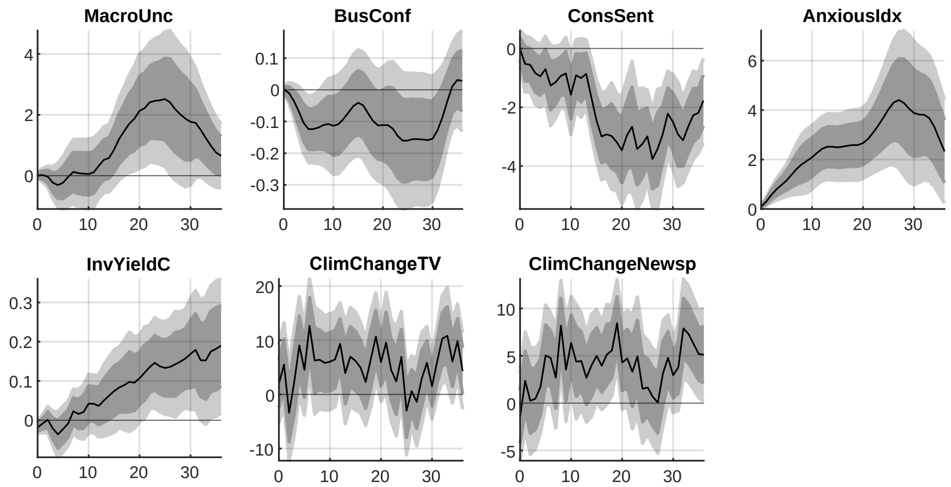

Figure 5: Impulse responses of macroeconomic uncertainty, confidence / sentiment, recession probabilities and median attention toward climate change

Notes: In %, except for InvYieldC: inverted yield curve, in pp. Gray areas indicate 68% and 90% confidence bands. Abbreviations: MacroUnc: macroeconomic uncertainty, BusConf: business confidence index, AnxiousIdx: anxious index, ConsSent: consumer sentiment, ClimChangeTV: television coverage on climate change, ClimChangeNewsp: newspaper coverage on climate change. x-axis: months. For further details on data, see Appendix A.

The impulse response analysis reveals that macroeconomic uncertainty rises and confidence declines after the disasters, consistent with Ludvigson et al. (2021) and De Winne & Peersman (2021), respectively. Consumer confidence, the Anxious Index, and the inverted yield curve are significantly different from zero at the end of the forecast horizon and, hence, likely contribute to the negative persistent consumption and investment responses shown before, as firms may postpone investment and consumers may save more (ECB 2021). The Anxious Index rises immediately, pointing towards a direct effect on the probability for an economic downturn in the near future.

We next examine the influence of natural disasters on media coverage. Climate attention can serve as an additional channel of transmission. How individuals connect natural disasters with climate change likely shapes their adaptation strategies. For instance, acknowledging that a particular disaster is projected to increase in frequency or severity may prompt adjustments in consumption or investment behaviors. Consequently, natural disasters affect the macroeconomy not only through direct effects like physical damage or financial linkages but also via individuals' perceptions of their relationship to climate change.

We find that the two measures of attention remain unchanged upon impact, indicating not an immediate association of natural disasters with climate change by the media. However, we note a subsequent increase, amounting to approximately 10%. While the effects are marginally significant, they suggest that the media gradually link natural disasters with climate change, possibly influenced by their repercussions on financial markets and the economy.

6.4 Financial sector

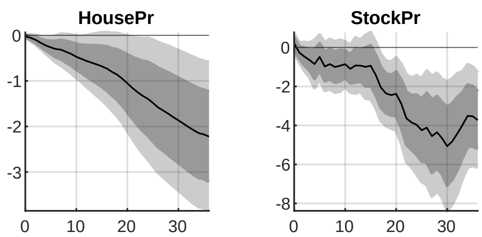

Figure 6: Impulse responses of asset prices

Notes: In %. Gray areas indicate 68% and 90% confidence bands. Abbreviations: HousePr: house prices, StockPr: stock prices. x-axis: months. For further details on data, please see Appendix A.

Asset prices Figure 6 shows that both, real stock and house prices, decline gradually and persistently. Negative wealth effects, hence, may have contributed to the negative consumption and investment responses (see Figure 3). A drop in house prices may weaken households' borrowing capacity, leading to diminished demand for durable goods. The reduction in wealth could also be one of the factors driving the increase in personal savings.

The negative wealth effect is also consistent with the theoretical discussions presented by ECB (2021), which argue that escalating physical risks reduce the value of residential properties and capital assets. These reductions may be due to both expected direct effects (e.g. destruction of capital) and indirect effects. The latter may include increased insurance premiums and reduced availability of insurance coverage as insurers adjust their risk assessments and pricing models in response to heightened disaster risks.

Furthermore, the decline in asset prices is relevant for financial stability. It can harm household and non-financial firm balance sheets, increasing the risk of loan defaults and stress within the financial system. Next, we delve into the implications of these disasters on financial stability.

Financial uncertainty, broad financial conditions, and risk Figure 7 indicates that financial uncertainty rises shortly following a disaster event, in contrast to macroeconomic uncertainty, which does not exhibit the same immediate increase (see Figure 5). The early jump in financial uncertainty is accompanied by the concurrent tightening of broad financial conditions, as evidenced by the immediate upticks in both the Financial Stress Index of the St. Louis Fed and the NFCI.

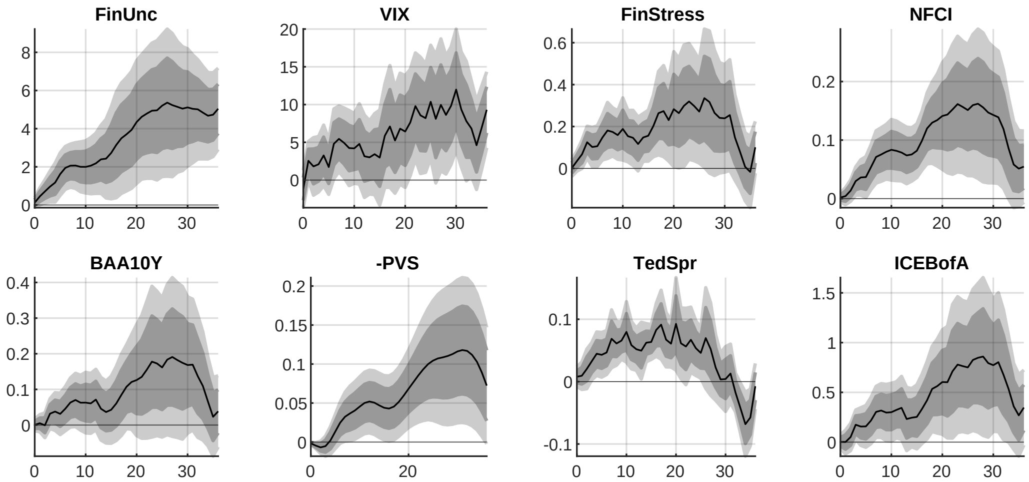

Figure 7: Impulse responses of broad financial risk and conditions

Notes: Financial uncertainty (Jurado et al. 2015) in %; VIX in %; FinStress (in ordinary units): St. Louis Fed financial stress index; NFCI (in ordinary units): Chicago Fed national financial conditions index; Spreads in pp; BAA10Y: Moody's seasoned Baa corporate bond yield to 10-year treasury yield; TedSpr: TED spread, which is the spread between the 3-month LIBOR and the yield on the 3-month Treasury bill, which captures riskiness of banks as borrowers relative to the US Treasury; ICEBofA: ICE BofA US high yield index option-adjusted spread, which is an option-adjusted high-yield Treasury spread; -PVS (in ordinary units): financial market risk perceptions. It is the negative of the PVS as defined by Pflueger et al. (2020) (high values: high perceived risk, directly measured from surveys and option prices). Gray areas indicate 68% and 90% confidence bands. x-axis: months. For further details on data, please see Appendix A.

Other risk measures also show a rise soon after the disasters, with these effects demonstrating persistence over time. The fact that these financial shifts precede the downturn in economic activity – and also the rise in macroeconomic uncertainty – suggests that heightened financial uncertainty, tighter financial conditions, and increased financial risk could have been catalysts for the economic contraction. These financial factors may have also played a role in the observed reduction in consumption and investment, as well as the elevation in personal savings, which might be attributed to precautionary motives. Our findings are consistent with studies reporting a surge in financial risk aversion following disaster events (Cameron & Shah 2015, Bourdeau-Brien & Kryzanowski 2020).

Banks We next analyse the way commercial bank risk and activity are affected by natural disasters. Figure 8 illustrates that bank risk rises consistently across measures. Bank stock market volatility and the nonperforming loans ratio increase, bank profitability captured by the return on equity and the bank capital ratio decline. The loan deposit ratio rises, leaving banks more vulnerable to future loan default. All variables are back to zero at the end of our projection horizon. An exception is the non-performing loans ratio which still increases three years after the disaster shock. Our impulse responses are consistent with evidence provided by Klomp (2014), Noth & Schüwer (2023), and Do et al. (2023) who find bank stability to decrease and bank defaults to become more likely after natural disasters.

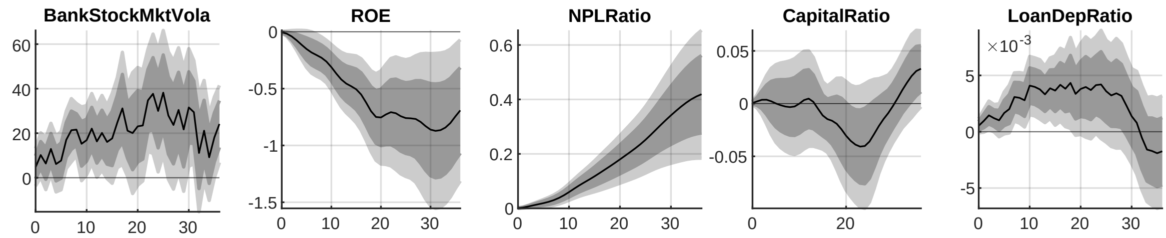

Figure 8: Impulse responses of bank risk

Notes: In pp (ratios); Bank stock market volatility in %. Abbreviations: BankStockMktVola: bank stock market volatility; ROE: return on equity; NPLRatio: ratio of non-performing loans; LoanDepRatio: loan to deposit ratio. Gray areas indicate 68% and 90% confidence bands. x-axis: months. For further details on data, please see Appendix A.

We next assess effects of disasters on bank loan supply and demand, which are important factors driving economic activity. While prior studies report consistent evidence that natural disasters increase loan demand (see Bos et al. 2022 and references therein), the natural disasters' impact on credit supply is more complex. Specifically, on the aggregate level, there is mixed evidence. Choudhary & Jain (2022) and Nguyen & Wilson (2020) find a reduction, whereas Bos et al. (2022) find an increase of credit supply after disasters.

In Figure 9, we observe a hump-shaped rise in both mortgage and business loans. The latter response is, however, only marginally significant. Consumer loans do not change significantly. At the same time mortgage and business loan spreads decline persistently, whereas personal loan spreads rise. This suggests positive bank loan supply effects that dominate possible demand effects in the business and real estate loan sector, and predominantly negative loan supply effects (via prices only) in the personal consumer loan sector. Hence, it seems that banks adjust their portfolio in response to the rise in uncertainty, risk, and risk perceptions by increasing lending to safer borrowers (e.g. Eickmeier et al. 2023).

To more directly assess loan supply versus demand effects, we also look at the effects on survey measures. The surveys suggest negative consumer and business loan supply effects, as the net percentage of banks reporting increased willingness to make consumer installment loans declines and business loan standards tighten, as well as negative business loan demand effects.[13] Surveys for consumer loans, hence, yield results that are consistent with actual data. This is, however, not the case for surveys for business loans. Survey data rely on the subjective assessment of senior loan officers, which may differ from actual loan supply and demand (Lown & Morgan 2006). Arguably, what is most relevant for policymakers is actual data, but it is still interesting to document that surveys may yield different conclusions.[14]

We next turn to additional items of bank assets. We observe a decline in treasury security holdings post-disasters, possibly indicating a continued search for yield by banks rather than a limitation of their portfolio risk. Schüwer et al. (2019) show that highly capitalized independent banks increase their holdings in (safer) treasury securities, suggesting a risk-averse strategy in the face of disasters. We do not distinguish between types of banks, but our finding together with that by Schüwer et al. (2019) suggests that the adaptation of treasury security holdings may not be uniform across banks.

Figure 9 reveals that total bank assets increase (because of the business and real estate loan increase and despite the fall in treasury security holdings). The expansion of bank balance sheets suggests an increase in the exposure of the real economy to the banking sector. A further rise in bank risk due to climate change may therefore, in the future, more easily translate into economic turmoil. Turning to the liability side, we find that bank deposits rise, marginally significantly and to a smaller extent than loans, which explains the increase in the loan deposit ratio. This suggests at least no withdrawal of funds by depositors after the increase in bank risk.

[13] While we use here the survey answers for commercial and industry loans to small firms, the results for large firms are qualitatively and even quantitatively similar.

[14] Differences in actual data and survey cannot be driven by U.S. Small Business Administration (SBA) disaster loans granted through commercial banks. We received this information from the SBA: "The Small Business Act includes three disaster loan programs administered through private banks, including the Intermediate Disaster Assistance Program (IDAP), Expedited Disaster Assistance Program (EDAP), and Private Disaster Assistance Program (PDAP). More than 10 years ago, SBA wrote regulations and attempted implementation of these guaranteed disaster loan programs. [...] Due to the lack of lender interest and participation, Congress did not re-authorize these guaranteed disaster loan programs and they are not active." Hence, the SBA grants disaster loans directly to homeowners, renters, businesses, and non-profit organizations rather than through commercial banks. See also Lindsay et al. (2021). We also investigated into another potential explanations for the discrepancy between results based on survey data and those based on actual data. Specifically, we looked separately at business loans granted by foreign, large, and small banks (not shown). We found the largest and most persistent positive effect on business lending by small banks, followed by large banks. Business lending by foreign banks is not significantly altered. But no loan volume aggregate declines over the first year after the disasters. Hence, differences in the coverage between the survey and actual data cannot fully explain the differences in the findings.

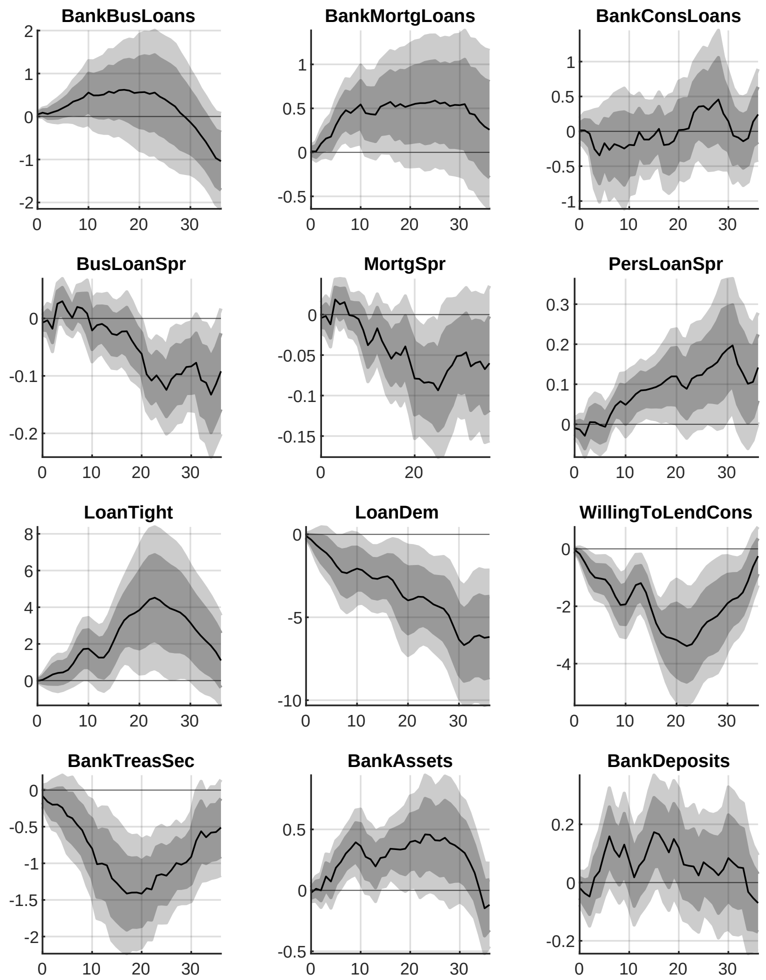

Figure 9: Impulse responses of bank lending activity and balance sheets

Notes: In %. Spreads are in p.p. Gray areas indicate 68% and 90% confidence bands. Abbreviations: BankAssets: total assets of commercial banks (CBs); BankBusLoans: commercial and industrial loans (CBs); BankMortgLoans: mortgage loans (CBs), BankConsLoans; consumer loans (CBs); BankTreasSec: treasury and securities (CBs); BankDeposits: depostis (CBs); BusLoanSpr: business loan spread; MortgSpr: mortgage spread; PersLoanSpr: personal loan spread; LoanTight: share of domestic banks tightening lending standards for commercial and industrial loans to small firms, LoanDem: share of domestic banks reporting stronger demand for commercial and industrial loans from small firms, WillingToLendCons: share of domestic banks reporting increasing willingness to lend to consumers. Business and personal loan spreads are defined as the difference between the bank prime loan rate or the finance rate on personal loans at commercial banks for 2-year loans, respectively, and the market yield of US treasury securities at 2-year constant maturity. Mortgage spreads reflect the difference between the 30-year fixed-rate mortgage average and the market yield of US treasury securities at 10-year constant maturity. x-axis: months. For further details on data, please see Appendix A.

Overall, we find that banks are negatively affected by the natural disasters, and this may have repercussions on the macroeconomy in the future. We see a broad-based increase in bank risk and in the exposure of the economy to future bank risk after the disasters and a decline in (relatively safe) treasury security holdings. On the other hand, banks seem to re-balance their portfolios towards safer business and real estate loans, likely in an effort to counteract the increase in risk.

6.5 Macroeconomic policy

Climate change and the increasing frequency and intensity of natural disasters will present additional challenges for macroeconomic policy making. This is not least because these shocks often first manifest as supply disruptions that can then also trigger demand-side fluctuations (ECB 2021). The significant uncertainties surrounding the effects, including their magnitudes and persistence, as well as individuals' behavioral responses, further contribute to heightened uncertainty.

Figure 10 shows responses of monetary and fiscal policy variables to the disasters. We find a long-lasting decline of short rates, measured by the Federal Funds rate and the shadow rate taken from Wu & Xia (2016), likely aimed at counteracting the decrease in economic activity.

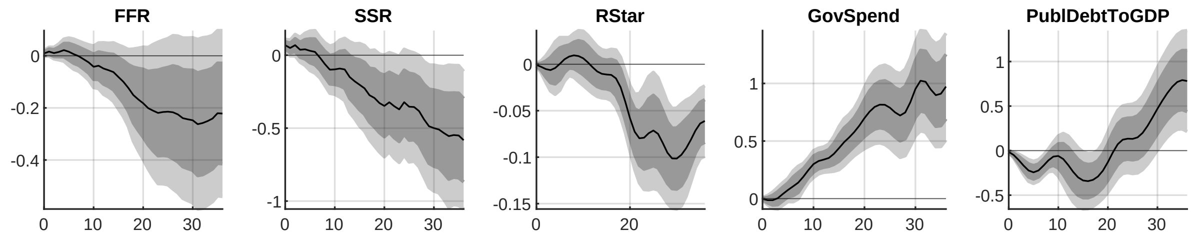

Figure 10: Impulse responses of monetary policy and fiscal measures

Notes: In % for government spending, in pp for all other variables. Gray areas indicate 68% and 90% confidence bands. FFR: federal funds rate. SSR: shadow short rate provided by Wu & Xia (2016). RStar: one-sided estimate for r-Star by Laubach & Williams (2003). Remaining abbreviations: PublDebtToGDP: total public debt in % of GDP, GovSpend: government total expenditures. x-axis: months. For further details on data, please see Appendix A.

In addition, r-star, the real neutral interest rate expected to prevail when the economy is operating at its full sustainable level, declines.[15] Several channels through which climate change might add downward pressure on r-star have been emphasized in the literature. One is through physical damage and lower total factor productivity and production (Seppänen et al. 2006). Further, both physical and transition risks likely put a dint into the capital stock: the former through shifting resources from innovation to reconstruction when recurring physical risks intensify, the latter through formerly productive assets becoming stranded assets (ECB 2021). Moreover, as also underlined by our results, elevated economy-wide uncertainty and risk aversion may put downward pressure on r-star. There is increasing evidence that higher (perceived) climate-change-related risk translates into higher risk premia (e.g. Bansal et al. 2019, Nguyen et al. 2022, Battiston & Monasterolo 2020, Cevik & Jalles 2022). In consequence, demand for save assets as well as the propensity to save may increase.[16] Combined with a

[15] https://www.newyorkfed.org/research/policy/rstar.

[16] Jordà et al. (2022) shows that pandemics (another type of natural disaster) negatively affect r-star as well, through an increase in personal savings, which the authors attribute to either precautionary savings or rebuilding of depleted wealth effects.

reduced willingness to invest by firms, this likely induces downward pressure on r-star (ECB 2021). Our results support these hypotheses as we find investment activities to decrease after disasters, whereas private saving tends to increase. One word of caution: r-star is estimated from data on actual interest rates and, hence, it is not totally surprising that r-star declines, given our finding of a decline of the nominal short interest rate.

Furthermore, our results suggest a strong increase in government spending, similarly counteracting the decline in economic activity. Public debt first declines relative to GDP and then increases. Its impulse response is significantly positive at the end of the projection horizon. Natural disasters, hence, have a medium-run effect on the public debt ratio, leaving the US government more vulnerable.

In summary, this subsection provided further evidence, beyond the long-term effects of disasters on real activity and certain risk or uncertainty measures, indicating that natural disasters have enduring negative impacts. Given the assumption that ongoing climate change exacerbates further downward pressure on r-star and upward pressure on the public debt-to-GDP ratio, the space to maneuver monetary and fiscal policy may become constrained (ECB 2021).

7 Robustness

In this section, we conduct sensitivity analyses to examine the robustness of our baseline results. Specifically, we investigate robustness with respect to the set of control variables, we differentiate between extreme temperatures, storms, and floods, incorporate persistence in the impulse variable. We further compare effects of natural disasters with effects of media attention toward climate change, and examine the local effects of disasters. To ensure comparability, we maintain the scale of one standard deviation for each impulse. Figures 11 and 12 show all results for our core variables, the unemployment rate and consumer prices, respectively.

Controls and disasters without hurricane Katrina Our findings are robust when we control for more lags of the control variables and of the impulse dummy in our econometric analysis. We further replace the dummy variable that captures the global financial crisis with a dummy variable that equals 1 in recessions and 0 otherwise. We use recessions as defined by the NBER. Our key findings are barely altered. We next set the month of Hurricane Katrina (August 2005) and the two subsequent ones to zero in our natural disaster count series. Our results are robust to this check.

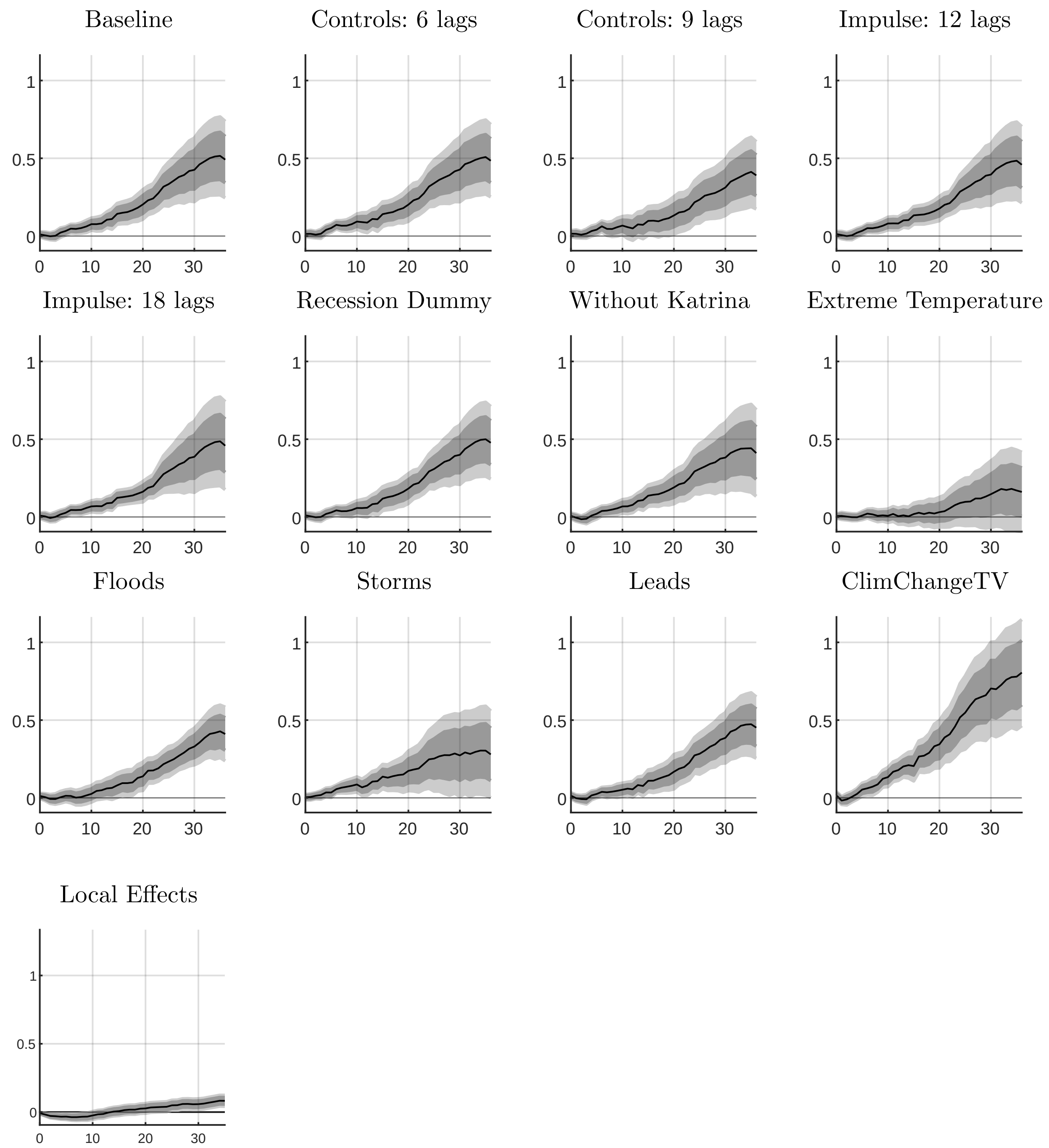

Figure 11: Impulse responses of the unemployment rate from the robustness analysis

Notes: In pp. Gray areas indicate 68% and 90% confidence bands. x-axis: months.

Individual disaster types Next, we show results separately for the three disaster types that compose our baseline impulse variable: extreme temperature events, floods, and storms. While the impulse responses of the unemployment rate and consumer prices are very similar to the baseline impulse responses after floods and storms (confidence bands are wider for the unemployment rate reaction after storms), the results for extreme temperatures show some noticeable difference. Most importantly, estimation uncertainty is much larger. Effects on the unemployment rate are even only significant at the 68% confidence level, and they are the

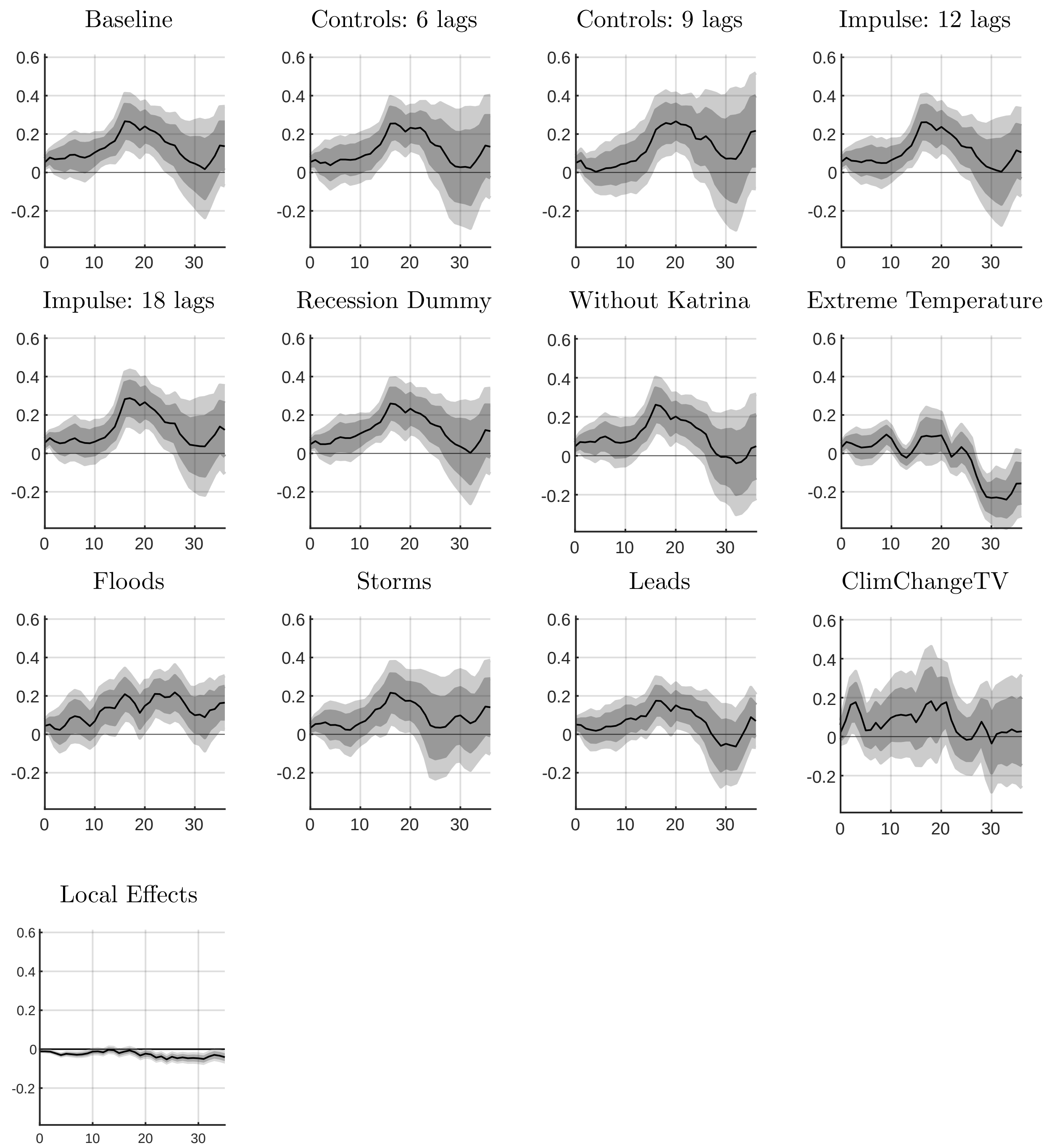

Figure 12: Impulse responses of consumer prices from the robustness analysis

Notes: In pp. Gray areas indicate 68% and 90% confidence bands. x-axis: months.

smallest among the three disaster types, in line with Natoli (2023). Moreover, consumer prices decline significantly over the medium run. This robustness analysis reveals that, overall, our choice to aggregate the three natural disasters types in our baseline analysis is sensible, beyond their relation to climate change and their interdependence. Specifically, by doing so, we gain precision in our estimates.

Persistence in the impulse variable Alloza et al. (2021) highlight possible implications for estimating local-projections as in Jordà (2005) when the impulse is persistent. Impulse responses that are estimated from local projections are "the most likely dynamic response [...] to a shock based on historical data" (Alloza et al. 2021, p. 3). Hence, some of the shock persistence may get carried over to the estimated impulse responses because local projections do not account for the shock evolution between t and the $t+h$. Estimated impulse responses may, thus, reflect the effects we are after as well as persistence effects. To see whether these considerations are relevant in our application, we follow Alloza et al. (2021) and control for shock leads over the entire projection horizon.[17] Results are almost identical to our baseline findings.

Effects of media attention toward climate change We proceed by substituting our baseline disaster measure with the climate attention measure, which tracks TV coverage of "climate change" or "global warming", sourced from MeCCO. This measure is presented in Figure 13 (and was previously used in Figure 5). This analysis mirrors that of Stock (2022). Our aim is to discern the responses of our key variables to natural disasters and media attention to climate change. We observe remarkably similar effects on the unemployment rate and consumer prices. If anything, the impact on the unemployment rate appears slightly more pronounced following a one standard deviation increase in median attention. This suggests that the effects of natural disasters and media attention focused on climate change yield comparable outcomes. It is still interesting to recall that we found not immediate association of the disasters with climate change by the media.

Local effects Our aggregate effects appear to be very different from the local effects reported in the literature, e.g. by Deryugina et al. (2018), Groen et al. (2020), or Roth Tran & Wilson (2023). Roth Tran & Wilson (2023), for example, find temporarily positive local employment effects after disasters that last over a year before becoming insignificant. To reconcile the findings, we next estimate state-level panel local projections, similar to Roth Tran & Wilson (2023) (see Buch et al. (2022) for an application of panel local projections and details). We include the state-level unemployment rate, regional consumer prices, and state-level house prices as control variables. More specifically, we use monthly state-specific all-transactions house price indices as published by the US Federal Housing Finance Agency as well as unemployment rates and consumer prices as published by the US Bureau of Labor Statistics. Consumer prices are not

[17]Following Alloza et al. (2021), we check for persistence in our baseline impulse variable as well as in the individual natural disaster series. We do so by implementing Ljung-Box Q-tests for residual autocorrelation (Box & Pierce 1970, Ljung & Box 1978). Statistically, we find evidence for persistence in both, our baseline impulse variable as well as the series capturing individual disaster types, when we check for autocorrelation for up to 36 periods.

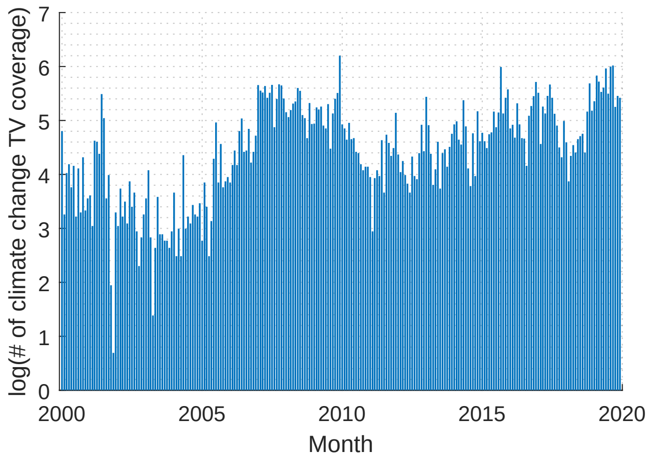

Figure 13: Climate change TV coverage (climate attention)
Notes: Logarithm of number of TV coverage of "climate change" or "global warming" across seven stations: ABS, CBS, CNN, FOX, MSNBC, NBC, PBS, taken from MeCCO.

available at the state level at a monthly frequency, but only at a regional level (West, Midwest, South, and Northeast). Following Buch et al. (2022), we, therefore, use the same consumer price for all states in a region.

We estimate the effects of our baseline impulse variable that is now based on the disaggregated state-level information provided in EM-DAT from 2000M1 to 2019M12 and find local effects to be much smaller than our aggregate effects. The unemployment rate drops temporarily and then rises persistently to half of the level of the aggregate unemployment rate. We also find a permanent decrease in prices on the state level as opposed to the temporary increase on aggregate prices. This analysis helps reconcile findings on local effects by Roth Tran & Wilson (2023).[18] It, hence, seems that local effects of natural disasters reflect (reconstruction) adjustments to physical damage. In the aggregate and in the medium run also on the local level, financial risk, risk perception, uncertainty, and balance sheet adjustments seem to be most relevant.[19]

[18]Results between their and our study are not fully comparable. Roth Tran & Wilson (2023) use county-level data, which allows them to estimate local effects more precisely. Those data are not publicly available. Given that local effects are not our focus, we decided not to use them. Roth Tran & Wilson (2023) also use state-level data and find insignificant personal income responses, but they discuss findings only very briefly. Moreover, they consider a longer sample period, a different set of controls, and do not report a price response.

[19]Interestingly, Boustan et al. (2020) who compile a county disaster series from 1920 to 2010 for the US and employ a cross-county panel framework find negative effects on local economies in terms of lowered family income and lower house prices after disasters. This also suggests lowered firm productivity. They, however, do not look at the effect through the lens of panel local projections.

8 Conclusion

In this paper, we assess the dynamic transmission of natural disasters on the US aggregate economy and financial markets through the lens of a local-projection-based approach, using monthly series since 2000. We find that natural disasters have large and persistent adverse macro-financial consequences. The decline in economic activity is broad-based and can be traced back to increased risk and risk perceptions, uncertainty and recession prospects, and a decline in confidence. We observe a delayed surge in media attention towards climate change following natural disasters. This trend is expected to intensify in the future, leading to heightened awareness and stronger associations between natural disasters and climate change. Consequently, we anticipate even more significant adjustments in response to these developments. Another finding is that the temporary rise in consumer prices is likely due to a temporary increase in energy and food prices and production costs.

While our analysis suggests that macroeconomic policies may have played a supportive role during natural disasters, indicating potential avenues for mitigating their impacts in the economy, these measures face sustainability challenges amid ongoing climate change. As climate change continues to exert downward pressure on r-star and elevate public debt levels, the effectiveness of monetary and fiscal policies in managing the economic repercussions of natural disasters may be compromised. Enhancing economic and financial resilience against such shocks becomes increasingly paramount, underscoring the need for immediate and strategic actions to combat climate change and its far-reaching effects.

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A Data

Table 1: Aggregate Macro-Financial Series

Category	Variable	Frequency	Source	Transformation	Label in Plots
Economic activity	Unemployment	monthly	FRED	level	UnemplRate
	Personal consumption expenditure	monthly	FRED	log level*	Cons
	Durable consumption	monthly	FRED	log level*	DurCons
	Non-durable consumption	monthly	FRED	log level*	NonDurCons
	Personal savings	monthly	FRED	log level*	PersSav
	Real gross private domestic investment	quarterly	FRED	log level	Inv
	Residential investment	quarterly	FRED	log level	ResInv
	Nonresidential investment	quarterly	FRED	log level	NonResInv
	Employment	monthly	FRED	log level	Empl
	Industrial production	monthly	FRED	log level	IndProd
	Housing starts	monthly	FRED	log level	HousStart
Prices and inflation expectations	Consumer price index	monthly	FRED	log level	CPI
	Consumer price index: all items excluding food and energy	monthly	FRED	log level	CPIExFoodEnergy
	Consumer price index for all urban consumers: food in US city average	monthly	FRED	log level	CPI Food
	Consumer price index for all urban consumers: energy in US city average	monthly	FRED	log level	CPI Energy
	Producer price index	monthly	FRED	log level	PPI
	Received employee compensation: wage and salary disbursements	monthly	FRED	log level	Wage
	Expected inflation: 1Y (FRB of Cleveland	monthly	FRED	level	InflExp1Y
	Expected inflation: 2Y (FRB of Cleveland)	monthly	FRED	level	InflExp2Y
	Expected inflation: 5Y (FRB of Cleveland)	monthly	FRED	level	InflExp5Y
	Expected inflation: 10Y (FRB of Cleveland)	monthly	FRED	level	InflExp10Y
	Expected inflation: 30Y (FRB of Cleveland)	monthly	FRED	level	InflExp30Y
Uncertainty, confidence, and recession probabilities	Macroeconomic uncertainty	monthly	JLN (2015)	log level	MacroUnc
	Business confidence	monthly	OECD	log level	Bus Conf
	Consumer sentiment	monthly	FRED	log level	ConsSent
	Anxious index	quarterly	Philadelphia Fed	log level	AnxiousIdx
	Inverted yield curve: 10Y-2Y	monthly	FRED	level	InvYieldC
	Television coverage climate change	monthly	MeCCO	log level	ClimChangeTV
	Newspaper coverage climate change	monthly	Factiva, own calculations	log level	ClimChangeNewsp
Asset prices	Stock price	monthly	FRED	log level*	HousePr
	House price	monthly	FRED	log level*	StockPr
Financial uncertainty, broad financial conditions and risk	Financial uncertainty	monthly	JLN (2015)	log level	FinUnc
	VIX	daily	FRED	log level	VIX
	BAA credit risk spread	daily	FRED	level	BAA10Y
	Inverted price of volatile stocks (PVS)	quarterly	PSS (2020)	level	-PVS
	Ted spread	daily	FRED	level	TedSpr
	ICE BofA US high yield index option-adjusted spread	daily	FRED	level	ICEBofA
	St. Louis Fed financial stress index	weekly	FRED	level	FinStress
	Chicago Fed national Financial conditions index (NFCI)	weekly	FRED	level	NFCI
Banking sector	Bank stock market volatility	monthly	Ken French$^\diamond$	level	BankStockMktVola
	Return on average equity (all US banks)	quarterly	FRED	level	ROE
	Nonperforming total loans to total loans	quarterly	FRED	level	NPLRatio
	Total equity to total assets	quarterly	FRED	level	CapitalRatio
	Loans and leases in bank credit to deposits (commercial banks)	weekly, monthly	FRED	level	LoanDepRatio

Notes: Series with *: CPI deflated. Daily/weekly series are aggregated to the monthly frequency, while quarterly series are interpolated using cubic spline interpolation. The series on television coverage of "climate change" or "global warming" is taken from the Media and Climate Change Observatory derived from ABS, CBS, CNN, FOX, MSNBC, NBC, PBS. The series on newspaper coverage reflects the number of articles containing "climate change". It is based on own calculations on data taken from Factiva, considering the ten largest US newspapers as in Baker et al. (2016): Los Angeles Times, USA Today, Chicago Tribune, Washington Post, Boston Globe, Wall Street Journal, Miami Herald, Dallas Morning News, Houston Chronicle, and San Francisco Chronicle. This series is standardized by a measure reflecting the number of all articles, similar to Baker et al. (2016). Series for macroeconomic and financial uncertainty come from Jurado et al. (2015) (JLN (2015)). The inverted price of volatile stocks (PVS) series comes from Pflueger et al. (2020) (PSS (2020)). Ken French$^\diamond$: return variances as taken from Ken French's webpage. For bank stock market volatility, the financial industry portfolio is split into subportfolios and the monthly return variance is proxied by the sum of squared daily returns as in Meinerding et al. (2023). Estimates for the shadow short rate are Wu & Xia (2016) estimates and are retrieved from Jing C, Wu's webpage. Estimates for r^* are Laubach & Williams (2003) (LW (2003)) estimates and are retrieved from the Federal Reserve Bank of New York. FRB†: Board of Governors of the Federal Reserve System - H.8 Assets and liabilities of commercial banks in the United States; Federal Reserve Board‡: Senior loan officer opinion survey on bank lending practices.

Table 1: Aggregate Macro-Financial Series – continued

Category	Variable	Frequency	Source	Transformation	Label in Plots
Bank lending activity and balance sheets	Total assets (commercial banks (CBs))	weekly	FRED	log level*	BankAssets
	Commercial & industrial loans (CBs)	monthly	FRB†	log level*	BankBusLoans
	Real estate loans (CBs)	monthly	FRB†	log level*	BankMortgLoans
	Consumer loans (CBs)	monthly	FRB†	log level*	BankConsLoans
	Treasury and agency securities (CBs)	weekly	FRED	log level*	BankTreasSec
	Deposits (CBs)	monthly	FRED	log level*	BankDeposits
	Bank prime loan rate minus US treasury securities market yield (2Y constant maturity)	daily, daily	FRED	level	BusLoanSpr
	30Y mortgage average (fixed rate) minus US treasury securities market yield (10Y constant maturity)	weekly, daily	FRED	level	MorgSpr
	Finance rate on personal loans at BCs (2Y loan) minus US treasury securities market yield (2Y constant maturity)	monthly, daily	FRED	level	PersLoanSpr
	Net percentage of domestic banks tightening standards for commercial and industrial loans to small firms	quarterly	FRB‡	level	LoanTight
	Net percentage of domestic banks reporting stronger demand for commercial and industrial loans from small firms	quarterly	FRB‡	level	LoanDem
	Net percentage of domestic banks reporting increased willingness to make consumer installment loans	quarterly	FRB‡	level	WillingToLenCons
Policy	Federal funds effective rate	daily	FRED	level	FFR
	Shadow rate: Wu/Xia	monthly	WX (2016)	level	SSR
	Rstar: Laubach/Williams	quarterly	LW (2003)	level	RStar
	Federal debt: Total public debt (% of GDP)	quarterly	FRED	level	PublDebtToGDP
	Government total expenditures	quarterly	FRED	log level	GovSpend

Notes: Series with *: CPI deflated. Daily/weekly series are aggregated to the monthly frequency, while quarterly series are interpolated using cubic spline interpolation. Series for macroeconomic and financial uncertainty come from Jurado et al. (2015) (JLN (2015)). The inverted price of volatile stocks (PVS) series comes from Pflueger et al. (2020) (PSS (2020)). Ken French◇: return variances as taken from Ken French's webpage. For bank stock market volatility, the financial industry portfolio is split into subportfolios and the monthly return variance is proxied by the sum of squared daily returns as in Meinerding et al. (2023). Estimates for the shadow short rate are Wu & Xia (2016) estimates and are retrieved from Jing C, Wu's webpage. Estimates for r^* are Laubach & Williams (2003) (LW (2003)) estimates and are retrieved from the Federal Reserve Bank of New York. FRB†: Board of Governors of the Federal Reserve System - H.8 Assets and liabilities of commercial banks in the United States; Federal Reserve Board‡: Senior loan officer opinion survey on bank lending practices.