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NATURAL DISASTERS AND THE EFFECTS OF RECONSTRUCTION EXPENDITURE ON OUTPUT

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ABSTRACT

Using a panel of 116 advanced, emerging market and developing economies over the period 1990-2022, we examine the direct effects of natural disasters on economic activity and public finances and the medium-term effects of post-natural disaster reconstruction, through public spending, on economic activity. As anticipated, we find that natural disasters negatively affect both economic activity and public finances with the output effects being more pronounced in the case of extreme vis-à-vis major natural disasters. Employing a panel local projection methodology combined with an instrumental variable approach, and after conducting a series of robustness checks to address endogeneity concerns, the results reveal that reconstruction spending can serve as an effective driver of medium-term growth. Specifically, a 1% increase in real cyclically adjusted government expenditure following an extreme natural disaster leads to a 2.49% increase in real output five years after the shock. Moreover, the effects of reconstruction spending are found to be stronger in countries with lower public debt, lower trade openness, higher financial development, fixed exchange rate regimes, emerging market rather than advanced or least developed economies, countries with higher old-age dependency ratios, and lower agricultural or tourism dependence.

***JEL**:* E62, F34, O40, Q54, Q58

Keywords: Natural disasters; Government spending; Economic activity; Public finances

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1. Introduction

Climate change causes an increase in the average temperature of the planet and this effect can lead to more frequent and intense natural disasters with serious economic and fiscal consequences (see e.g., Strömberg, 2007; IPCC, 2021; IMF, 2021; Nguyen, 2024; Moshammer, 2024; Mumtaz and Theophilopoulou, 2024). Various studies have examined the effects of natural disasters, concluding that the direct effects of natural disasters have significant economic and fiscal costs (see Kotz et. al. 2022; Fuje et. al., 2023; Canova and Pappa, 2021). In particular, they can reduce potential output, particularly in the agricultural sector which is the dominant sector in emerging market economies and low-income countries. In addition, many times natural disasters due to falling GDP are accompanied by lower revenues and increased expenditures resulting in fiscal deterioration (see e.g. Fuje et. al., 2023). This can lead to fiscal problems if the country already has a bad fiscal situation before the natural disaster.

These adverse macroeconomic and fiscal outcomes arise through several transmission mechanisms that link natural disasters to output dynamics and economic activity. Natural disasters affect output both directly and indirectly through multiple interconnected channels. The immediate effects stem from the destruction of physical capital, infrastructure, and productive assets, which reduces the economy's effective capital stock and disrupts production (Noy, 2009; Cavallo et al., 2013). These shocks can also impair human capital and supply chains, generating short-term contractions in GDP (Nguyen et al., 2025). However, in the medium to long run, reconstruction expenditure can act as a stimulus to aggregate demand and investment, partially offsetting initial losses and even fostering productivity improvements if reconstruction incorporates more resilient or technologically advanced infrastructure, which is called as "*the productivity effect*" (Skidmore and Toya, 2002; Hallegatte and Dumas, 2009). This dynamic implies a dual mechanism; while the disaster shock lowers output through destruction, the reconstruction period can contribute positively to output via public and private investment multipliers, especially when financed efficiently and implemented promptly (Cavallo and Noy, 2011).

Building on Adam and Bevan (2020), Canova and Pappa (2021), Kotz et. al. (2022) and Fuje et al. (2023) our paper makes two key contributions. We first examine the direct effects of natural disasters on output and primary balances across 116 advanced, emerging and developing economies using the panel-event methodology of Freyaldenhoven et al.

(2019), which accounts for pre-trends and unobserved confounds. Our analysis focuses on severe disasters causing substantial economic damage and loss of life, including extreme events involving the former Office of U.S. Foreign Disaster Assistance (OFDA) or the Bureau for Humanitarian Assistance (BHA).

However, a notable gap remains in the literature, as prior studies have not examined whether post-disaster reconstruction spending can stimulate economic activity (see Fidrmuc et al., 2015; Adam and Bevan, 2020; Canova and Pappa, 2021; Fuje et al., 2023). While these studies focus primarily on the direct macroeconomic and fiscal effects of natural disasters at country level, they do not examine the medium-term, indirect effects through reconstruction spending on economic activity. This paper fills that gap by providing the first empirical analysis that examines, over a large set of countries, how reconstruction expenditure influences economic activity in the medium-term, thereby capturing an important transmission channel between natural disasters and output.

Hence, building on the above-mentioned studies, our second contribution examines the medium-term post-disaster reconstruction through cyclically adjusted government spending, by excluding its automatic response to output and disasters (i.e., the amount included in the state budget for unexpected expenses such as immediate compensation for extraordinary events such as natural disasters). This distinction is crucial, since many governments maintain budgetary reserves for such events. We estimate these effects using the local projection method of Jordà (2005) with a two-stage least squares (2SLS) estimator and instrumental variables to address potential endogeneity between cyclically adjusted spending and output.

We find that natural disasters worsen economic activity and primary balances with the effects of real GDP being more pronounced in the case of an extreme rather than a major natural disaster. These results are primarily attributed to developing rather than advanced economies. Regarding the type of disasters, we find that major disasters due to droughts and floods hinder economic activity, while droughts, wildfires, and non-weather-related events negatively impact primary balances. Extreme natural disasters, including floods, storms, and wildfires, significantly affect economic activity, while public finances are particularly affected by floods, wildfires, and high temperatures.

In addition, after conducting a series of robustness checks to address endogeneity concerns, we find that a 1% increase in real cyclically adjusted government spending to

finance reconstruction activities following an extreme natural disaster leads to a rise in real GDP by 2.49% 5 years after the natural disaster. Furthermore, we find that an increase in real spending raises real GDP to a greater extent in low debt countries, in low vis-à-vis high trade openness countries, in more versus less financially developed economies, in fixed versus flexible exchange rate regimes, in emerging relative to advanced and least developed economies, in countries with high versus low old-age dependency ratios and with lower share of agricultural gross value added (GVA) and tourism intensity.

The remainder of this paper is organized as follows. Section 2 reviews the related literature. Section 3 presents the data. Section 4 examines the direct effects of natural disasters on economic activity and public finances. Section 5 investigates the medium-term effects of reconstruction expenditure on output, while Section 6 presents the baseline results and conducts several robustness checks to address potential endogeneity concerns. Section 7 examines the baseline findings under different states of nature, while Section 8 concludes.

2. Related literature

There is growing interest on the economic consequences of natural disasters and climate change, reflected in the expanding literature on their macroeconomic and fiscal implications. Climate change is expected to continue in the coming decades, despite global efforts to reduce greenhouse gas emissions. (IPCC, 2021). As a result, economists and policymakers increasingly seek to understand its diverse effects on economic activity.

One strand of the literature has examined the effects of climate change on output. Several studies such as Nordhaus and Yang (1996) and Christensen et al. (2012) found a nexus between global temperature increases and output losses by reduced-form damage functions. In this context, other studies such as Burke et al. (2015), Letta and Tol (2019), Kalkuhl and Wenz (2020), Newell et al. (2021) and Kahn et al. (2021), examined how unpredictable temperature and precipitation shocks influence GDP per capita and total factor productivity. In addition, Mumtaz and Theophilopoulou (2024) found that climate change not only weakens economic performance but also exacerbates inequality, especially in low-income and agriculture-dependent countries. According to the IMF (2008), each 3^{o}C increase in global warming could reduce global GDP by up to 3%.

Another strand of the literature (e.g., Stromberg, 2007) highlights that developing countries are more vulnerable to climate change due to their warmer climates, less favorable initial macroeconomic conditions, greater income inequality, and weaker institutions. Beyond average temperature increases, climate change also intensifies the frequency of extreme weather events, increasing the likelihood of natural disasters with large and unpredictable economic consequences (Dey and Lewis, 2021). Moreover, Nguyen (2024) found that higher temperatures negatively affect job growth in the summer but improve labor market conditions in winter.

In this context, several studies examine the macroeconomic impact of natural disasters. Bakkensen and Barrage (2018) and Kotz et al. (2022) investigate natural disasters effects on economic growth, while Desbureaux and Rodella (2019) focus on the labor market. Raddatz (2007) and Noy (2009) found that natural disasters can yield negative short-term effects on the economy by reducing GDP growth up to 3%. Mechler et al. (2016) argue that natural disasters weaken government finances both through short-term revenue declines and higher reconstruction spending, potentially crowding out essential public investment and reducing long-term growth. To mitigate these risks, they emphasize the role of disaster insurance and fiscal buffers.

A related strand of the literature examines strategies to deal with the effects of natural disasters. Townsend (1994) highlights the importance of innovative financial instruments and effective insurance schemes. Jha et al. (2021) found that natural disasters have a heterogenous effects on financial outcomes; access to finance worsens after epidemics and earthquakes but improves following floods and droughts, suggesting that insurance schemes (public or private) can stabilize post-disaster financial conditions. In a similar vein, Jayaraman et al. (2023) show that even private charitable donations in response to natural disasters is highly concentrated on a few severe, media-covered events, leaving the majority of disasters underfunded.

The fiscal consequences of natural disasters have long been a cause for concern. Standard studies on fiscal balances and debt dynamics (e.g., Hallerberg and von Hagen, 1999; Woo, 2003; Gali and Perotti, 2003) have been extended to include natural disasters as important fiscal risk factors. Malluci (2022) shows that natural disasters increase fiscal vulnerabilities and heighten sovereign default risk by reducing governments' borrowing capacity. Johar et al. (2022) found that extreme natural disasters damaging residential assets heighten household financial distress and risk aversion. Canova and Pappa (2021)

employing U.S. state data for the period 1980-2018, find that disasters have substantial negative effects on output but smaller impacts on unemployment, with poorer and coastal states recovering more slowly. States with greater fiscal flexibility, such as rainy-day funds, experience smaller output and debt effects. Fuje et al. (2023) report heterogeneous disaster effects by type and income level: in developing economies, droughts reduce output by 1.4% and revenues by 0.7%, while storms increase public spending due to reconstruction needs; in contrast, effects are negligible in advanced economies. Similarly, Miao et al. (2018) show that U.S. state expenditures rise and tax revenues fall after disasters, while Melecky and Raddatz (2011) and Akyapi et al. (2022) document that natural disasters elevate debt ratios.

Beyond the direct effects of natural disasters, indirect effects arise through reconstruction spending, which may stimulate economic activity. Adam and Bevan (2020) argue that when public infrastructure is destroyed, indirect losses occur through reduced private output during reconstruction, especially in developing countries with limited external financing. Consequently, post-disaster fiscal expansion becomes crucial for economic recovery. Consistent with Barro (1990) and Blanchard and Perotti (2002), government spending can enhance growth when it supports private production and raises aggregate demand. The literature on fiscal multipliers provides valuable insights for understanding reconstruction effects. Studies such as Auerbach and Gorodnichenko (2012, 2013), Bachmann and Sims (2012), Fazzari et al. (2013), Atems (2019), Klein and Linnemann (2019) and Georgantas et al. (2023) show that multipliers are larger during recessions or when monetary policy is constrained. Other studies emphasize the role of monetary conditions (see e.g., Cogan et al., 2010; Christiano et al., 2011; Banerjee and Zampolli 2019; Coenen et al., 2012; Cantelmo et al., 2024). Ilzetzki et al. (2013) found that the spending effects depend on trade openness, exchange rate regime, and debt levels, while Klein (2017) and Banerjee and Zampolli (2019) argue that both private and public debt influence the output response to fiscal policy.

Most studies identify fiscal shocks using institutional or econometric approaches, such as structural VARs (Blanchard and Perotti, 2002), sign restrictions (Uhlig, 1999), narrative identification (Devries et al., 2011; Alesina et al., 2017), or fiscal rules residuals (Corsetti et al., 2012). However, there is limited research on fiscal expansion triggered by natural disasters. In this context, Fidrmuc et al. (2015) highlight that government spending multipliers following U.S. state-level disasters range between 1.5 and 2.5, implying strong

short-term stimulus effects. More recently, Deryugina, (2022), showed that disasters increase public spending and reduce tax revenues but that their overall impact on activity is modest, leaving the optimal post-disaster fiscal policy unresolved.

Overall, while existing research provides valuable evidence on the short-term macroeconomic and fiscal consequences of natural disasters, a significant gap remains. Prior studies focus primarily on country-level, direct effects, overlooking the medium-term, indirect effects that operate through reconstruction spending. This paper fills that gap by offering the first empirical cross-country analysis that examines how post-disaster reconstruction expenditure affects economic activity in the medium-term, thereby uncovering a key mechanism linking natural disasters to economic performance.

3. Data

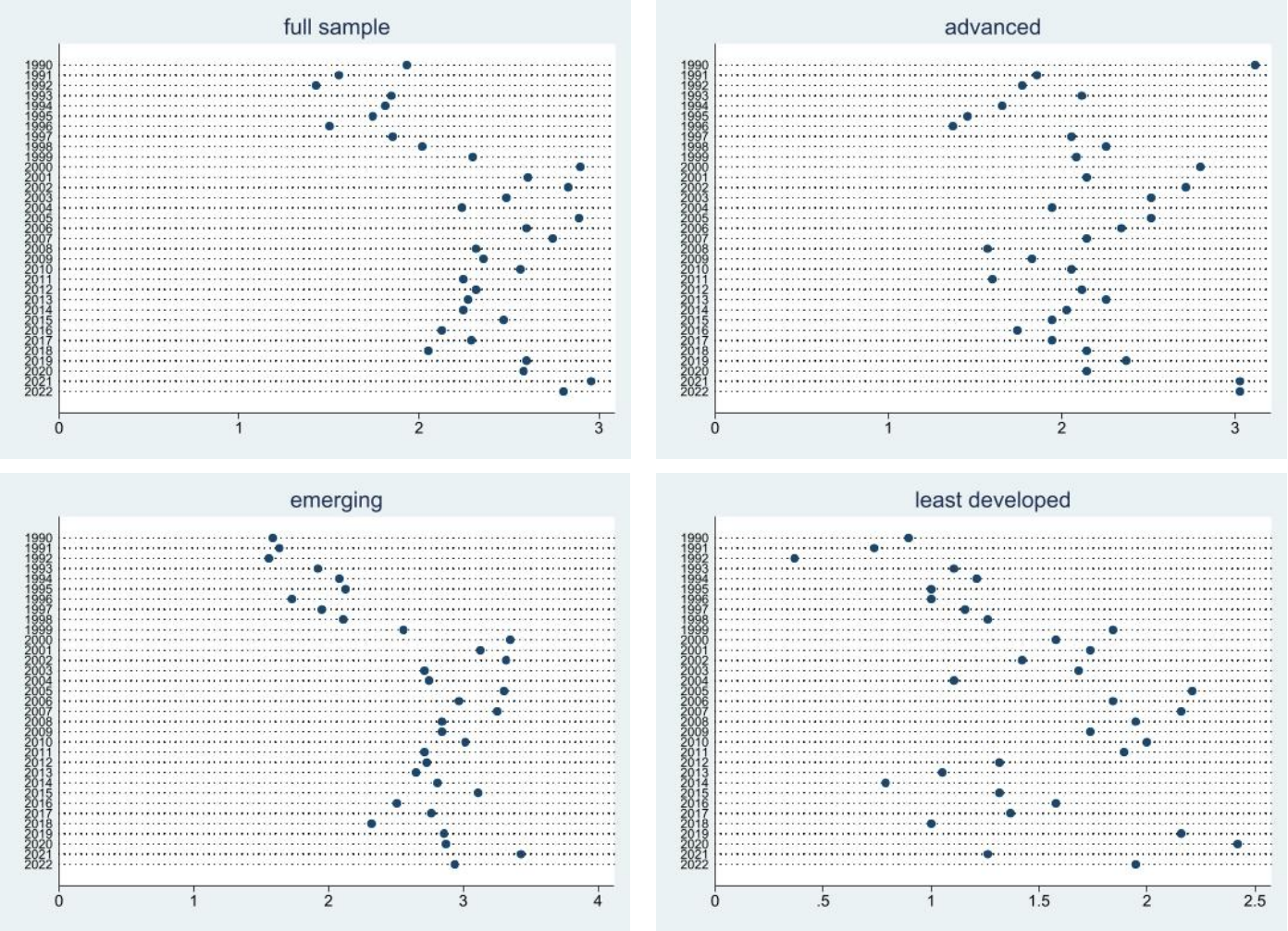
We use a yearly unbalanced panel dataset spanning the period from 1990 to 2022 for 116 advanced and emerging market economies.[1] The macroeconomic variables are taken from the IMF and in particular from the World Economic Outlook and the "Public Finances in Modern History" database (see supplementary material, Appendix A, Table A1 presents the summary statistics for the variables employed in our analysis). The institutional variables, such as the government effectiveness index, as well as trade openness and terms of trade, are taken from the World Bank.

Turning to the variables of interest, data pertaining to extreme weather events utilized in this study have been extracted from the Emergency Events database (EM-DAT), which is systematically maintained by the Centre for Research on the Epidemiology of Disasters (CRED) at the Universite Catholique de Louvain. This database provides information regarding on the type of natural disasters (i.e., climatological, hydrological, biological, geophysical, meteorological, and extra-terrestrial), the number of people affected, or killed, the estimated economic damage costs (in thousands of USD dollars), whether a country received international financial assistance, as well as the frequency of natural disasters per country. The EM-DAT database includes 8832 natural disasters episodes (for the countries and years in our sample), varying in scale from minor to major disaster, for which countries sought international assistance or the former Office of U.S. Foreign Disaster Assistance (OFDA) or the Bureau for Humanitarian Assistance (BHA) involved

[1] The list of countries is presented in the supplementary material, Appendix A.

to the disasters, or a state of emergency was declared to the country after the natural disaster. Figure 1 reports the average number of natural disasters for the full sample and by level of economic development per year. Interestingly, natural disasters have increased significantly over time.

Figure 1. The average number of natural disasters over time.



Notes: Figure 1 shows the average number of natural disasters per year. Top row: left column: full sample, right column: advanced economies; Bottom row: left column: emerging market economies, right column: least developed countries.

Natural disasters have negative effects on the economy. Primarily, disasters lead to significant loss of human life, infrastructure, property and productivity, causing a reduction in production and worsening public finances. In addition, natural disasters most affect sectors of economic activity such as agriculture and tourism. In any case, however, the extent of the losses depends on the type of natural disaster and on the intensity of the phenomenon. However, as a consequence of the disasters, significant fiscal support measures are taken for the affected areas and in several cases, there is an increase in

international financial aid to finance the reconstruction. The process of reconstruction leads to a stimulation of demand and has positive effects on the economy by offsetting some of the economic costs of a disaster. [2] However, the total social and economic costs of natural disasters, such as the loss of human life, the migration they can cause and the loss of property among many others, cannot be fully recovered.

3.1 Construction of natural disaster variables

In line with earlier studies, such as Fuje et al. (2023), we focus on major or extreme natural disasters, which are expected to have more significant effects on public finances and economic activity. For this reason, out of the above-mentioned natural disasters, we construct a new variable (X) that takes into account the population either killed or affected by the natural disaster, and we then divide this sum by the total population in each country, obtaining the percentage of population being affect by the natural disaster. Next, we construct a dummy variable (D1) based on the median value[3] of this new variable (X). This dummy variable, representing the occurrence of a major natural disaster which affected a large share of the population, takes the value of 1 when the ratio X is above the median, and 0 when the ratio X is below the median and when there is no natural disaster. This definition generates 1637 country-year episodes of large-scale or major natural disaster episodes. In these cases, on average, 4.46% of the population was either killed or affected by the disaster.

Additionally, we consider a second definition of extreme natural disasters. Thus, we construct a dummy variable (D2) that takes the value of 1 when the former Office of U.S. Foreign Disaster Assistance (OFDA) or the Bureau for Humanitarian Assistance (BHA) involved to the disasters and 0 when this is not the case and when there is no natural disaster. This definition captures only extreme events. Hence, the natural disaster episodes are only 524 and, in these cases, on average, 5.17% of the population was either killed or affected by the extreme natural disaster.

This work closely relates the study by Fuje et al. (2023) who examine the effect of natural disasters on public finances and Fidrmuc et al. (2015) who use the natural disasters

[2] A great example is the case of the European Union, where, during the recent pandemic crisis the European Commission introduced the Next Generation EU. Through this tool, the EU-27 member states received substantial financial resources for various sectors of economic activity and as a result, many of these countries are experiencing significant economic rebound in the post-pandemic period.
[3] The median value is 0.143 %.

that occurred in US states as an exogenous event in order to quantify the growth effects of the associated fiscal expansions. In contrast to Fuje et al. (2023) we examine also the post-natural disaster reconstruction effect of government spending. Whereas, contrary to Fidrmuc et al. (2015) we examine a group of advanced, emerging market and developing economies and not US states, while at the same time we investigate the direct effects of natural disasters on output and public finances.

3.2 Control variables

Following earlier studies (e.g., Georgantas et al., 2023; Fuje et al., 2023), we include a set of control variables to isolate the true effect of natural disasters, ensuring that our estimates are not confounded by other factors influencing the outcome variable. Specifically:

1) Inflation rate (based on GDP deflator): Captures macroeconomic stability; high inflation can reduce real economic activity (Barro, 1995).

2) Debt-to-GDP ratio: Reflects fiscal constraints that may limit the government's capacity to respond to shocks (Reinhart and Rogoff, 2010).

3) Terms of trade: Measures external competitiveness and purchasing power; favorable terms can stimulate output (Edwards, 1993).

4) Trade openness: Captures exposure to global markets; higher openness can affect GDP through trade shocks and disaster recovery (Frankel and Romer, 1999).

5) Primary balance: Indicates fiscal stance excluding interest payments which are not under the direct control of the governments; increased primary balance may support economic resilience following shocks (Ilzetzki et al., 2013) but weighs on growth.

4. Direct effects of natural disasters on public finances and economic activity

4.1 Model description

In this section we examine the direct impact that major and extreme natural disasters have on public finances and economic activity. The closely related work of Fuje et al. (2023) employs panel local projections with an OLS estimator, however, we use the panel-event methodology of Freyaldenhoven et al. (2019). This approach allows us to address

potential issues of endogeneity and to account for any potential pre-trends in the dependent variables. To this end, we estimate:

$$Y_{i,t} = \sum_{m=-G}^{M} \beta_m ND_{i,t-m} + X_{i,t-1}\psi + C_{i,t} + \omega_\tau + \eta_i + \varepsilon_{i,t} \quad (1)$$

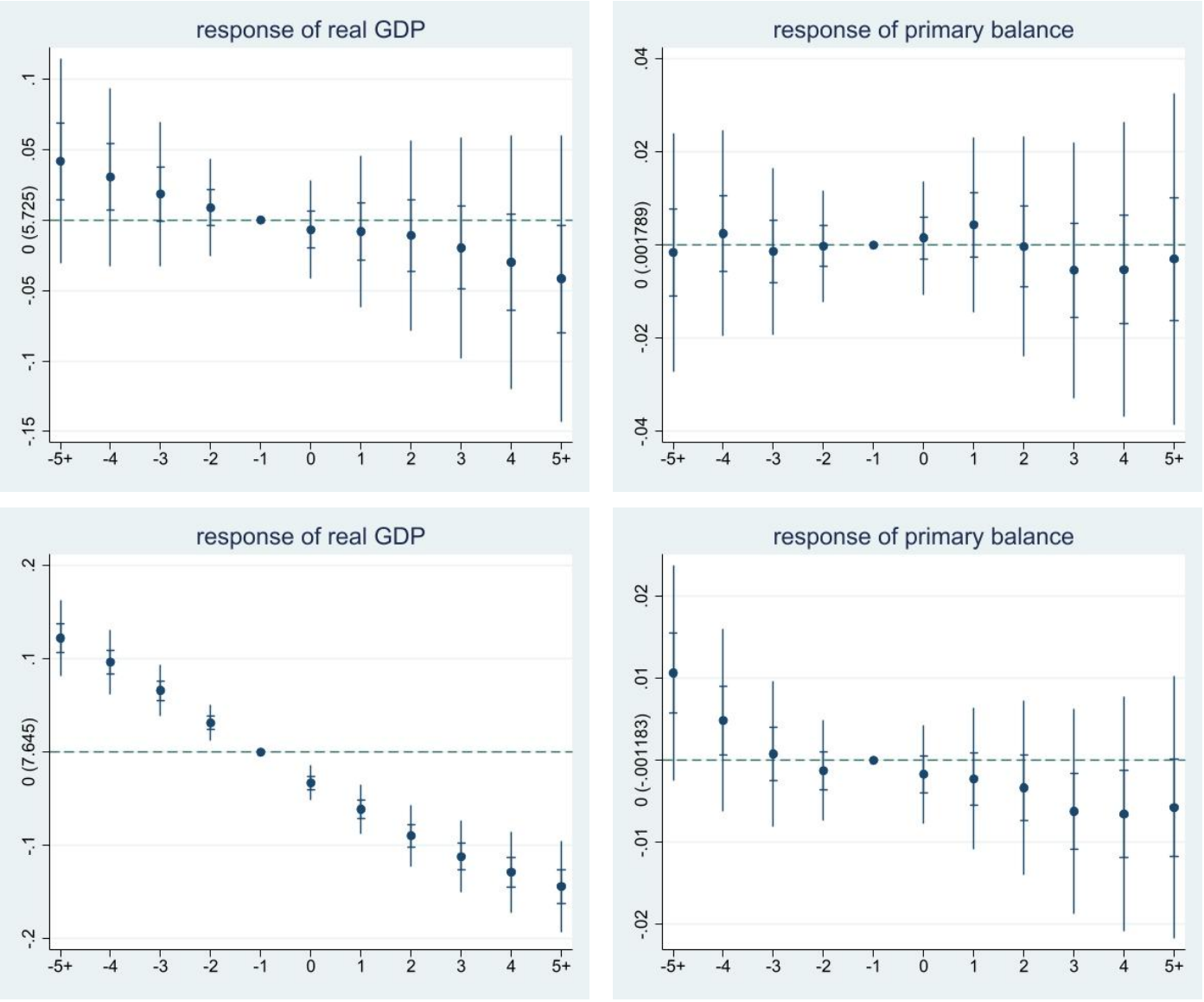
where $Y_{i,t}$ is the dependent variable (i.e., the natural logarithm of real GDP and the primary balance as a % of GDP), $\omega_\tau \; and \; \eta_i$ are fixed time and country effects to control for global shocks and unobserved heterogeneity, $\varepsilon_{i,t}$ is an unobserved and uncorrelated shock with the variable of interest and $C_{i,t}$ signifies a potential unobserved cofound. $X_{i,t-1}$ is a vector of control variables with conformable coefficients ψ which includes, the first lag of trade openness, the first lag of the natural logarithm of the terms of trade, the first lag of the inflation rate (based on GDP deflator), and the first lag of the debt to GDP ratio.[4] The coefficients $\{\beta_m\}_{m=-G}^{M}$ are the dynamic effects of the variables of interest. The outcome of the contemporaneous time can be directly affected by natural disasters at most M≥0 periods before time t=0 and at most G≥0 periods after the natural disaster shock.

4.2 Empirical findings

Figure 2 reports the results based on equation (1). The solid lines depict the true causal average effect of natural disasters on output (left panel) and on primary balances (right panel). In line with Fuje et al. (2023) a natural disaster that occurs at t=0 reduces real GDP and lowers the primary balance with the output effect being more pronounced in the case of an extreme (bottom row) rather than a major natural disaster (top row).

[4] In addition, when real GDP is the dependent variable, we include the first lag of the primary balance as a control, and conversely, when the primary balance is the dependent variable, we control for the first lag of real GDP.

Figure 2. The effects of natural disasters on economic activity and primary balances.



Notes: Top row refers to a shock of a major natural disaster (with D1 definition). Bottom row to a shock of an extreme natural disaster (with D2 definition). Standard errors are clustered at the country level. 68% confidence bands have been used. The full set of estimations are presented in the supplementary material, Appendix A, Table A2.

Given that we use a large heterogeneous sample, incorporating both advanced and developing economies, we re-estimate equation (1) by splitting our sample based on the level of economic development. We find that real GDP declines significantly following a major and an extreme natural disaster in developing economies. On the contrary, in advanced countries, a major natural disaster does not lead to a reduction in economic activity but to an increase. This could be attributed to expansionary fiscal policy to contain the social and economic effects of the natural disaster. However, in cases of extreme natural disasters, economic activity contracts significantly in advanced economies (see Figure 4).

Interestingly, in contrast to Fuje et al. (2023) who report that the primary balances are unaffected in advance economies, we find that primary balance deteriorates following a major natural disaster, while in cases of extreme natural disasters there is only a marginally reduction in primary balances in the year of the shock and the following2 years. Furthermore, primary balance deteriorates following an extreme natural disaster in developing countries (but not in major disasters) (see supplementary material, appendix A. Figures A1 and A2).

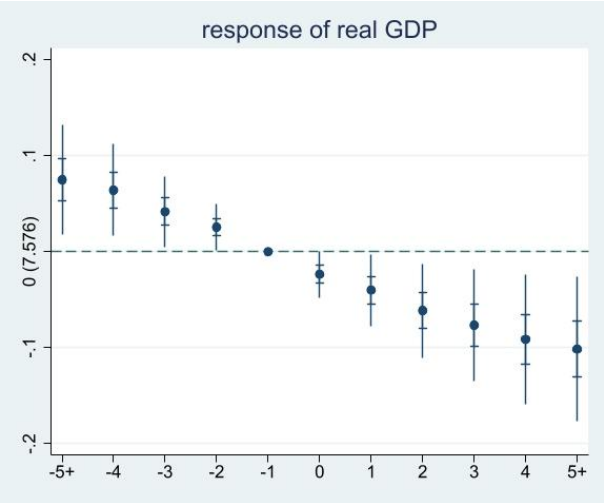
Overall, the negative effects of natural disasters depend on both the scale of the disaster and the level of economic development of the affected country. As anticipated, the effects of natural disasters are more pronounced in developing countries. This group of countries largely depends on the agricultural sector, which makes them particularly vulnerable to natural disasters. Beyond the social and humanitarian impacts (such as loss of life, property damage, and potential increases in migration), these disasters may also result in job losses due to destruction in the productive capacity of the agricultural sector. Consequently, economic activity in these countries may contract significantly for up to five years following a natural disaster.

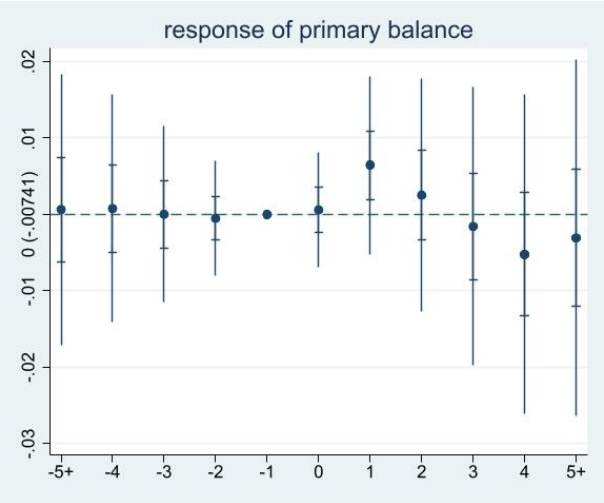
4.2 The case of weather-related natural disasters

Given the negative effects of major and extreme natural disasters on economic activity and primary balances, it would be beneficial to examine weather-related disasters (such as storms, floods, wildfires, droughts, and extreme temperatures), as these are likely to have a greater negative impact on countries dependent on agriculture or tourism, compared to natural disasters associated with earthquakes or mass movements. As shown in Figures 3 and 4, the findings regarding the type of disaster are mixed (as in Fuje et al., 2023). However, we observe that among major disasters, droughts and floods have negative effects on economic activity, while droughts, wildfires and to a lesser extent other non-weather-related disasters (such as mass movement, earthquakes, volcanic activity) adversely affect primary balances (see Figure 3). In cases of extreme natural disasters, droughts, floods, storms, wildfires, and other disasters have severe consequences for economic activity, while it is mainly floods, wildfires and high temperatures that have negative effects on public finances (see Figure 4).

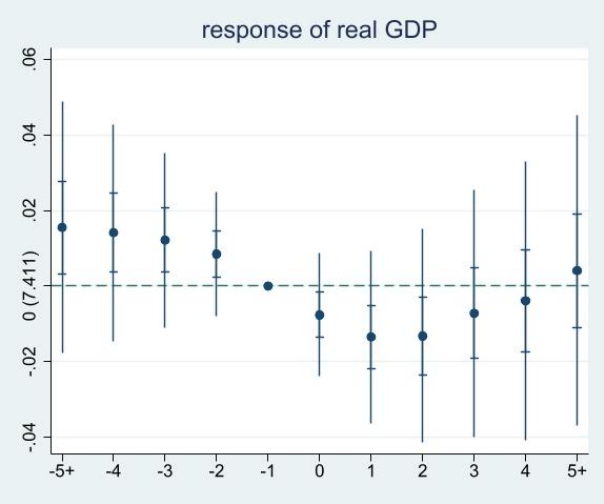
Figure 3. The effects of a major natural disaster on economic activity and primary balances by disaster type.

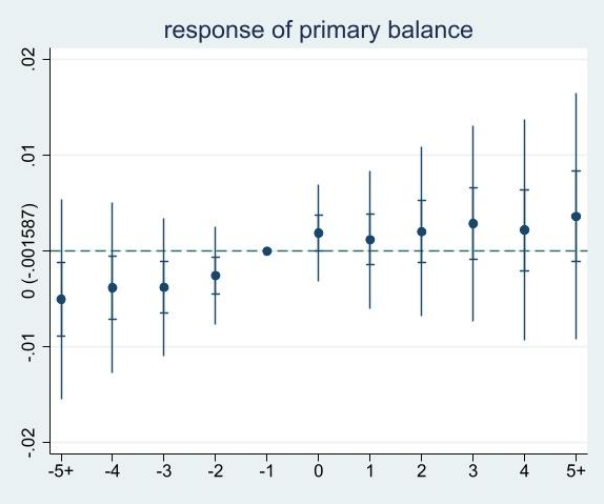
droughts



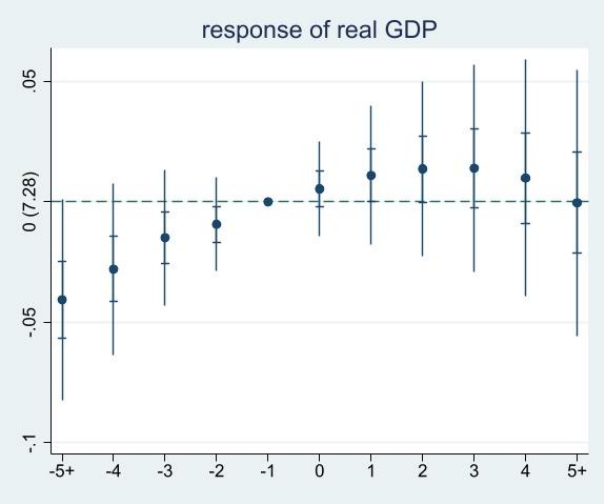


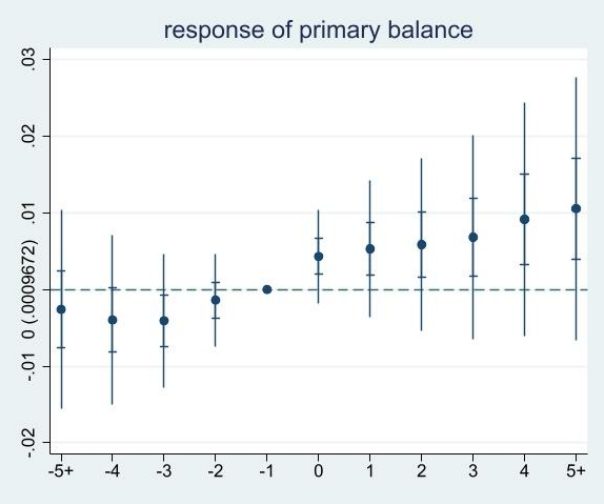
floods



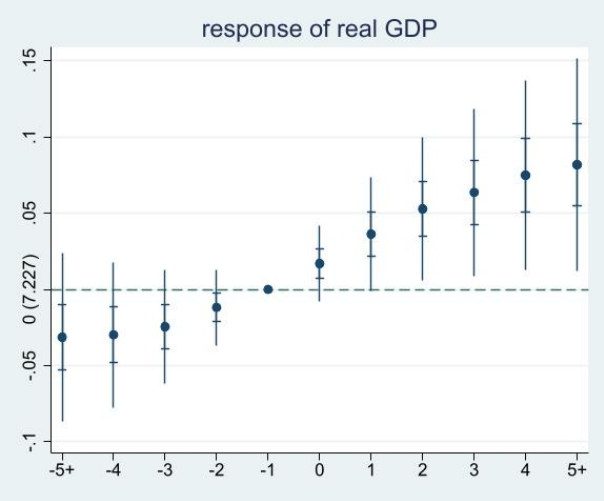


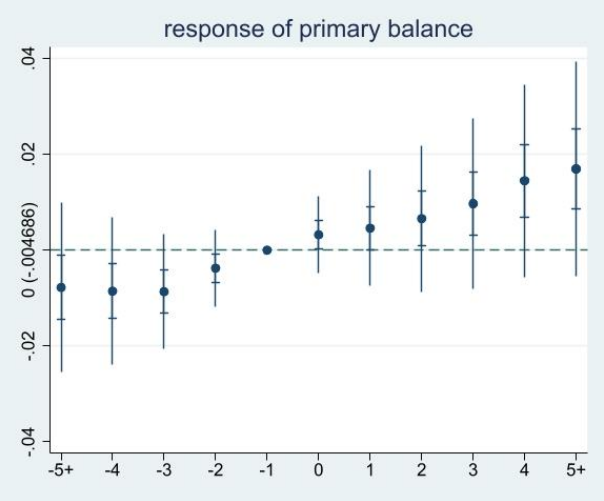
storms



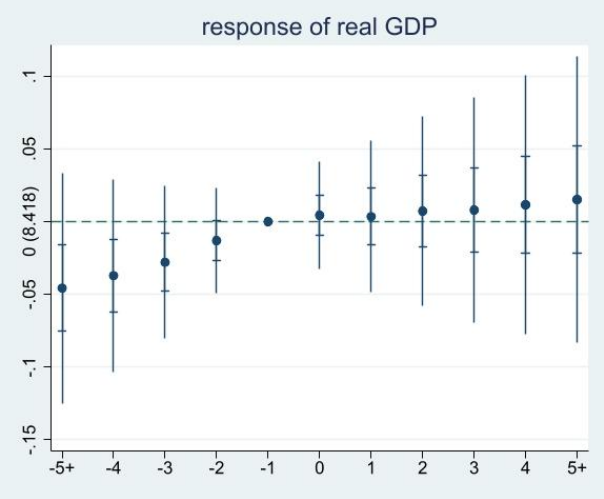


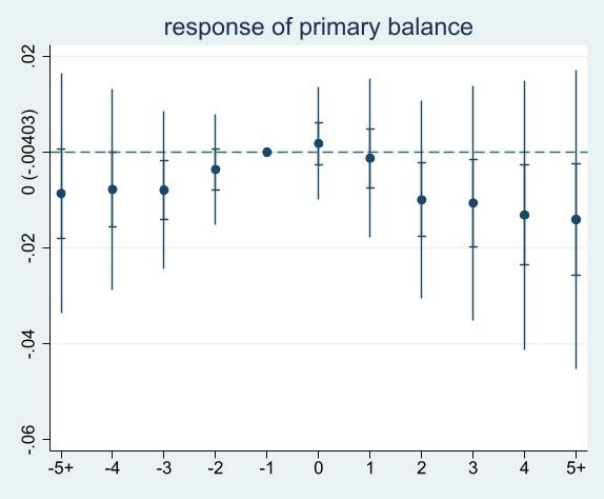
high temperatures



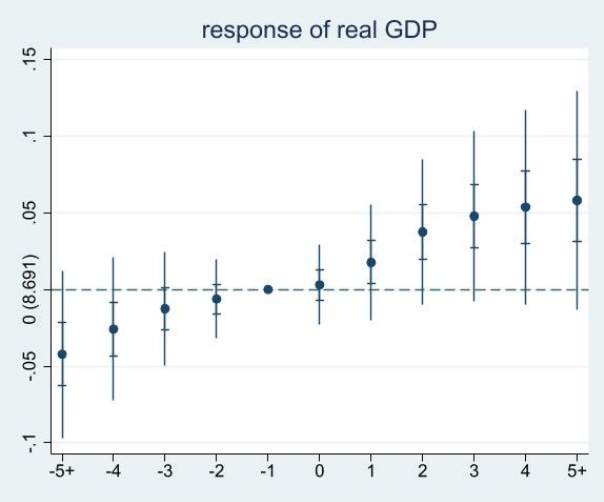


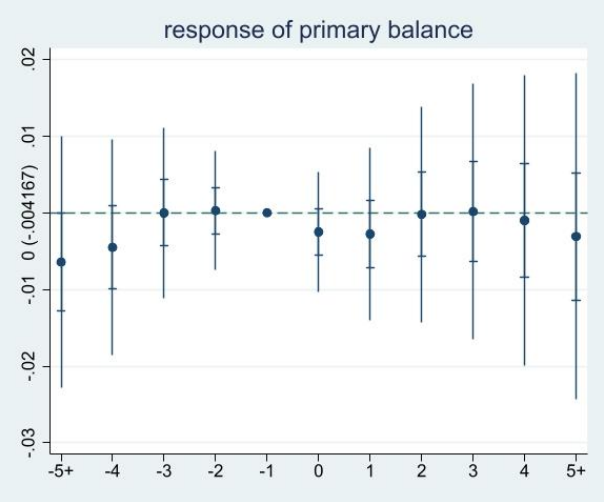
wildfires





other

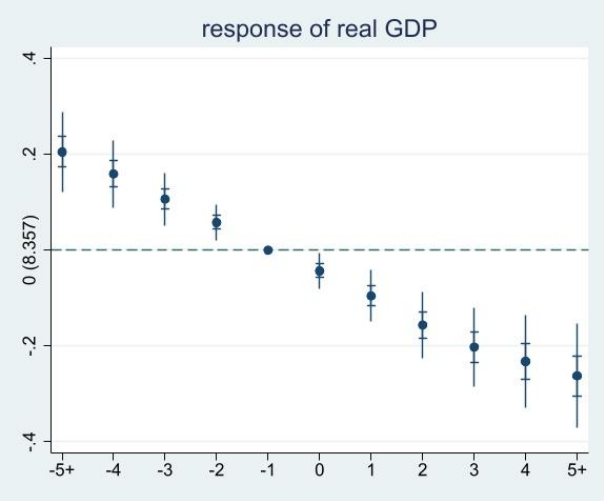


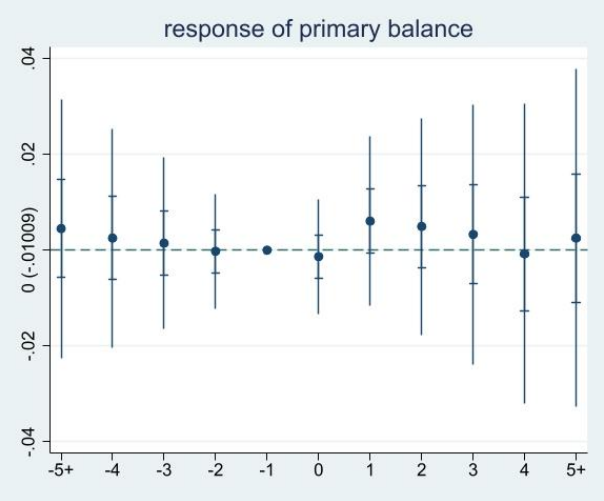


Notes: Standard errors are clustered at country level. 68% confidence bands have used. As other events, we classify the non-weather natural disasters, such as mass movement, earthquakes, volcanic activity, etc.

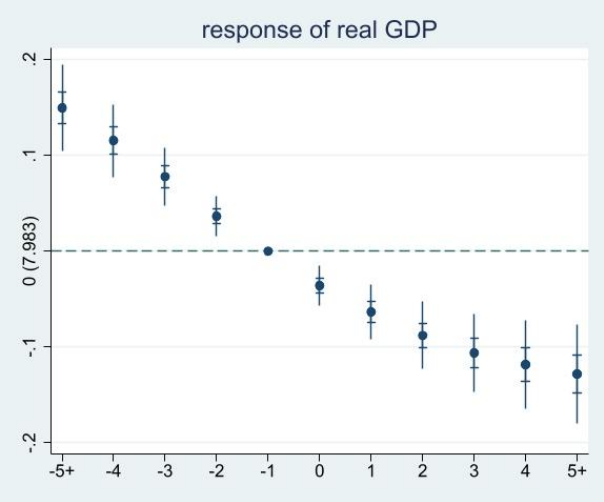
Figure 4. The effects of an extreme natural disaster on economic activity and primary balances by disaster type.

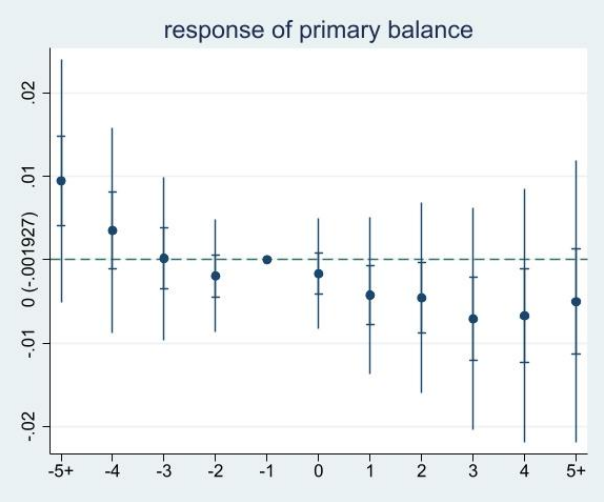
droughts



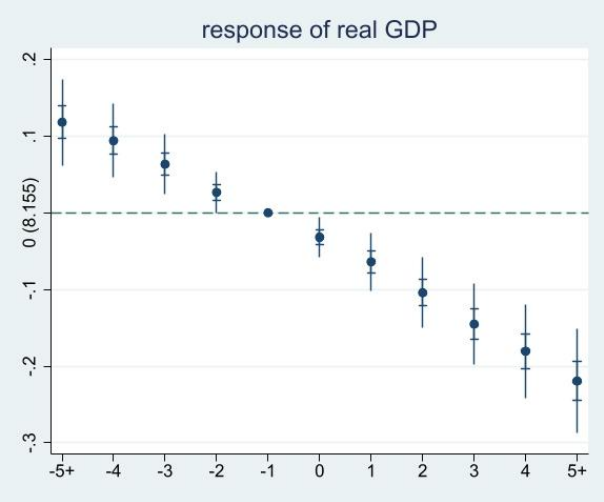


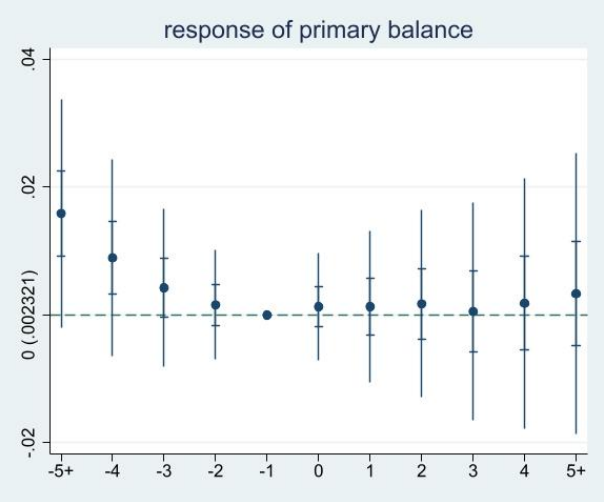
floods



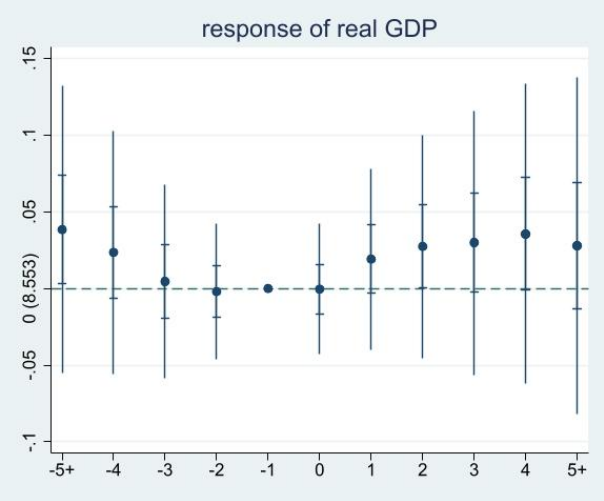


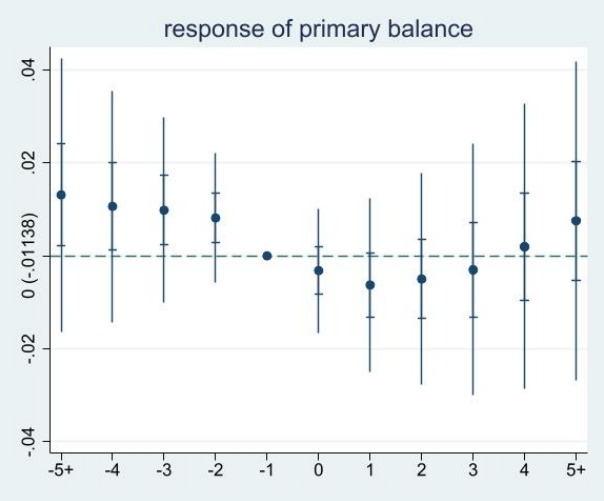
storms



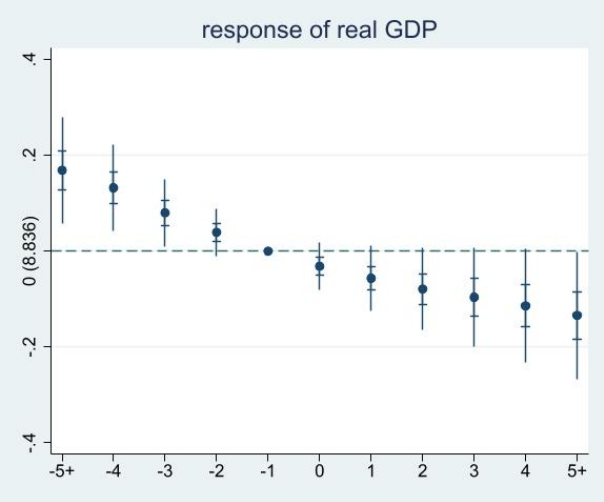


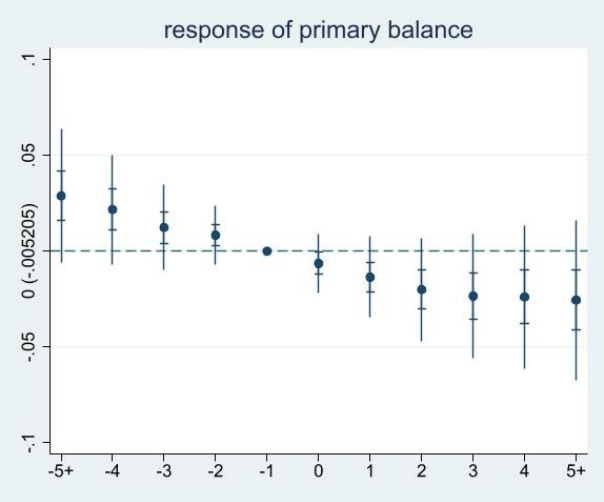
high temperatures



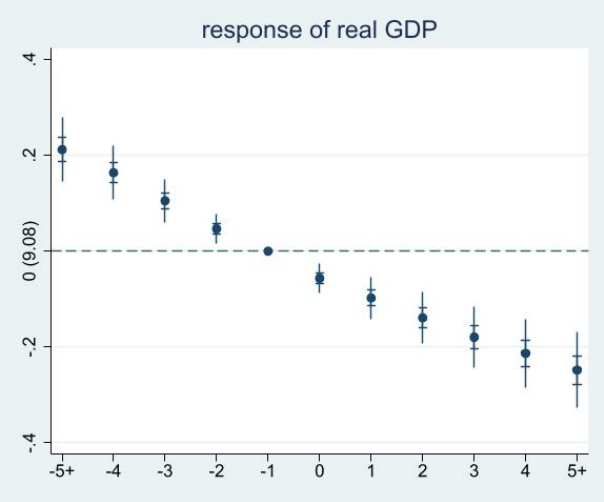


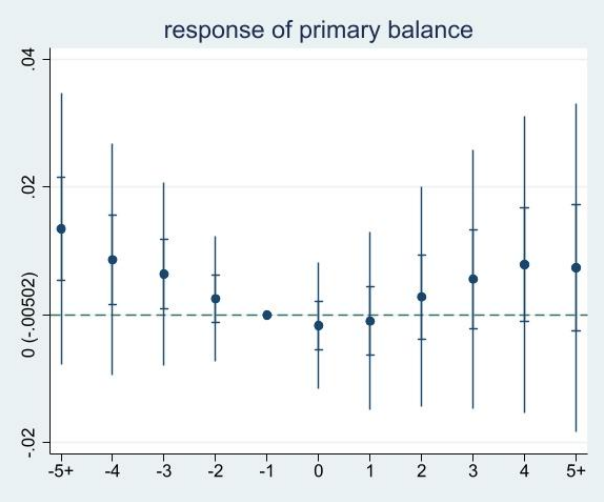
wildfires





other





Notes: Standard errors are clustered at country level. 68% confidence bands have used. As other events, we classify the non-weather natural disasters, such as mass movement, earthquakes, volcanic activity, etc.

5. The medium-term effects of reconstruction expenditure on output

What we have observed so far is that natural disasters lead to a reduction in the primary balance as well as economic activity. However, during the period of the natural disaster and in the following years there is an effort to rebuild and deal with the effects of the natural disaster through a significant increase in government spending. For example, fiscal stimulus packages after the unexpected exogenous shock of the COVID-19 pandemic led to fiscal expansion, which boosted demand and led countries to achieve faster economic recovery after the 2020 pandemic shock.

We will next attempt to estimate the impact of this post-disaster increase in reconstruction spending on economic activity. To this end, we will use total government spending expressed in real terms (by means of the GDP deflator). However, the response of real government expenditure to a natural disaster incorporates both an automatic and a discretionary response. The automatic response could include both increased unemployment benefits, but also compensation for damage to household goods, dwellings and losses to physical capital and business premises as well as other income supports and transfers. In several cases, countries include in their budget reserves for use in case of natural disasters. In principle, this automatic increase in government spending should be excluded from the analysis. Building on earlier studies (such as in Fatás and Mihov, 2003, 2006) we calculate a measure of the cyclically adjusted real government spending expenditures (baseline definition) which excludes the automatic increase in government spending in response to economic conditions and extreme natural disasters. In more detail, we estimate by means of OLS:

$$\Delta ln(real\ government\ spending)_{i,t}$$

$$= a_0 + a_1 * \Delta ln(real\ GDP)_{i,t} + a_2 ND_{i,t} + \eta_\iota + \lambda_\tau + \varepsilon_{i,t} \quad (2)$$

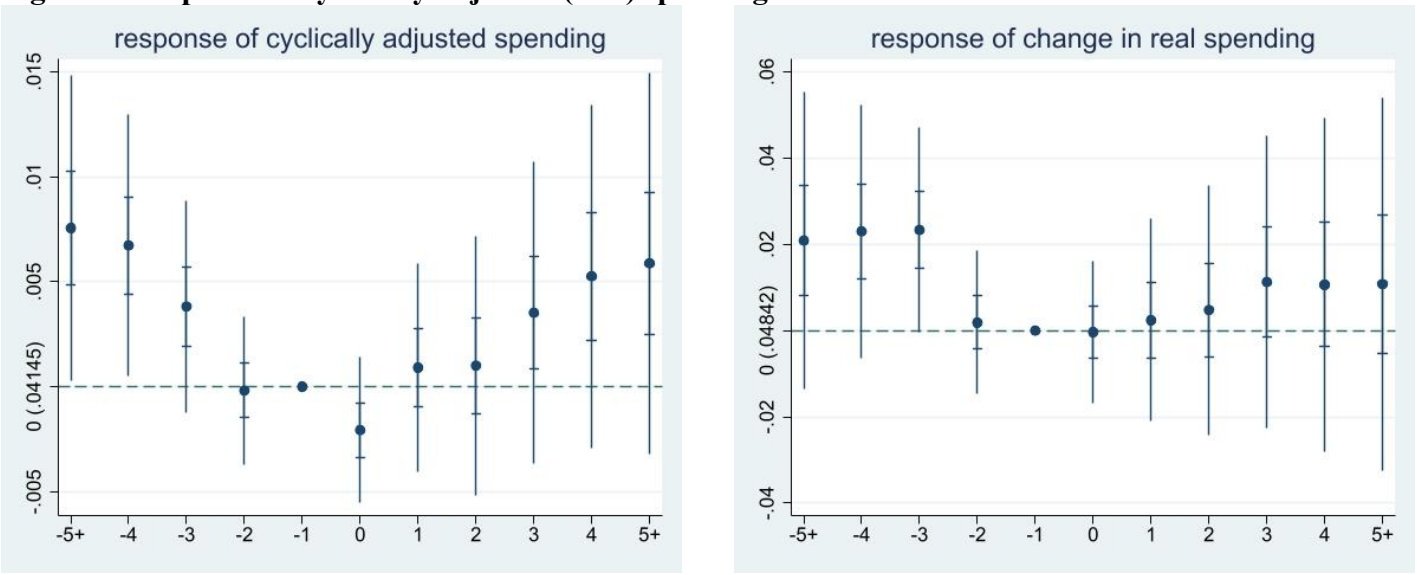
Where the dependent variable is the change in real government spending, and the independent variables include the change in real GDP and extreme natural disasters (D2) at time t.[5] In addition, we include country and time fixed effects to capture global shocks and the unobserved heterogeneity across countries that could affect economic activity. The

[5] From this point onward, we focus exclusively on extreme natural disasters, as these are expected to exert more substantial negative effects (Noy, 2009; Cavallo et al., 2013) and, consequently, are more likely to affect reconstruction spending over the medium-term.

residuals obtained from equation (2) are the cyclically adjusted real government expenditures.

Before proceeding, it is worth examining the correlation between the cyclically adjusted real government spending and the (unadjusted) real government spending. To this end, we use the panel-event study methodology of Freyaldenhoven et al. (2019). As shown in Figure 5, during the period when a natural disaster occurs public spending is practically (right column) unchanged while cyclically adjusted public spending falls (left column). In contrast, over the next five years both variables increase, but the increase is much more pronounced for total public spending, which includes the effect of the business cycle, than for cyclically adjusted public spending. These findings are important as they suggest that cyclically adjusted public spending does not increase immediately during a natural disaster but only over the next years and not to the extent that total spending increases.

Figure 5. Response of cyclically adjusted (real) spending to an extreme natural disaster.



Notes: left column: response of cyclically adjusted real government spending. right row: response of the change in total real government spending.

Next, following Auerbach and Gorodnichenko (2012; 2013), Ramey and Zubairy (2018), Klein (2017), Georgantas et al. (2023), and Fuje et al. (2023), we examine the medium-term effect of cyclically adjusted government spending on economic activity, using the dynamic differences-in-differences estimator of Local Projections (LPs) method as proposed by Jordà (2005) and (Jordà and Taylor, 2025). As pointed by Jordà (2005) and (Jordà and Taylor, 2025) the LP method has many advantages compared to Vector autoregressions (VARs) to compute Impulse Responses, as (1) their estimation can be

accomplished with simple regression techniques (2) they exhibit increased robustness against misspecification (3) the execution of joint or point-wise analytic inference is straight-forward and (4) they provide a simple technique to account for state dependence (see Klein, 2017; Ramey and Zubairy, 2018). As a result, these methods present a natural alternative for deriving impulse responses as opposed to utilizing VARs (Jordà and Taylor, 2025).

In more detail, building on Klein (2017), Ramey and Zubairy (2018), and Georgantas et al. (2023), we let $Y_{t+h} - Y_{t-1}$ denote the cumulative response of the natural logarithm of real GDP to a change in the cyclically adjusted government spending ($shock_{it}$) at time t. In more detail, we estimate a specification of the form:

$$Y_{it+h} - Y_{it-1} = \psi_{Ah}(L)[a^h + a_1^h X_{it-1}] + a_2^h shock_{it} + \eta_i^h + \lambda_t^h + \varepsilon_{it}^h \quad (3)$$

η_i^h are country fixed effects to capture the unobserved heterogeneity across countries, λ_t^h are time effects to control for global shocks, ε_{it}^h is the error term, which is assumed to have a zero mean and strictly positive variance and $\psi_{Ah}(L)$ is a polynomial in the lag operator. $Y_{t+h} - Y_{t-1}$ signify the cumulative change in the natural logarithm of the real GDP for forecast horizons h taking values 0 up to 5 years ahead (h = 0 is the year of the exogenous shock of a natural disaster). The model also includes the first lag of the dependent variable and a vector of control variables, i.e., X_{it-1} which includes the first lag of the inflation rate (based on the GDP deflator), the first lag of the debt to GDP ratio, the first lag of the natural logarithm of the terms of trade, the first lag of the trade openness and the first lag of primary balance, a^h is a vector of constants.

Equation (3) is estimated by means of an IV technique where the shock variable (i.e., the cyclically adjusted government spending) is instrumented by the first, second and third lags of the international aid flows received by countries.[6] The use of lagged international aid flows as instruments is motivated by the assumption that such aid inflows are strongly correlated with cyclically adjusted public spending responses following disaster events (relevance condition), while being exogenous to contemporaneous domestic output fluctuations (exogeneity condition). In particular, the use of multiple lags helps to mitigate concerns about potential simultaneity between international aid and GDP.

[6] We would like to thank one referee for this useful suggestion.

6. Results

6.1 Baseline findings

Before proceeding to the discussion of the main estimation results, it is important to assess the statistical validity of the instrumental variables employed. Table 1 reports the diagnostics from the first stage regressions concerning the validity and the strength of the instrumental variables used in equation (3). The high and statistically significant values of first-stage F-statistics confirm the strength and validity of the instruments employed. The full set of estimations are presented in the supplementary material, Appendix B, Table B1.

Table 1. Diagnostics of first stage regressions.

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
First stage F-statistic	287122.09***	4161.36***	2778.40***	1722.13***	1913.54***	953.08***
R-squared	0.99	0.63	0.52	0.39	0.27	0.19
Observations	2,138	2,049	1,960	1,869	1,776	1,683

Notes: Estimator: 2SLS. Instrument variables: cyclically adjusted spending. Instruments: the first, second and third lags of international aid flows. *** p<0.01, ** p<0.05, * p<0.1

Figure 6 reports the results based on equation (3). The solid line depicts the cumulative response of real GDP from year t=0 to year t+5, in response to a shock on cyclically adjusted government spending increase at t=0. The pink-shaded area corresponds to the 90% confidence bands and the fuchsia-shaded area corresponds to the 68% confidence bands.

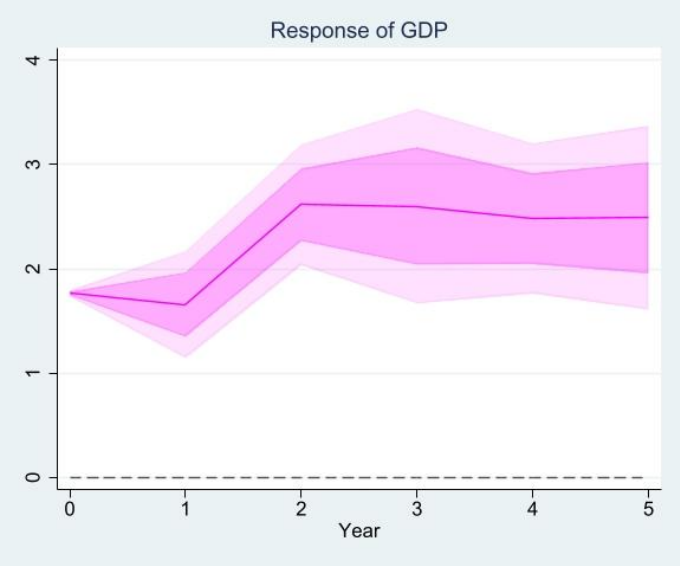
We find that a 1% increase in cyclically adjusted real government spending to finance reconstruction activities following international aid flows in the weak of natural disasters leads to a rise in real GDP by 2.49% 5 years after the natural disaster. This sizable and statistically significant effect suggests that post-disaster fiscal expansion has a strong and persistent impact on economic recovery. The magnitude of the response shows that spending geared towards reconstruction mitigates the output losses caused by the disaster.

Several mechanisms may account for this relatively large response. First, reconstruction spending typically entails substantial public investment in infrastructure, which can foster capital deepening and improve long-run productive capacity (see, e.g., IMF, 2020). Second, fiscal multipliers tend to be non-linear and can be considerably higher during periods of economic slack or in the aftermath of crises when monetary policy is

constrained (Auerbach and Gorodnichenko, 2012; Blanchard and Leigh, 2013). These effects may amplify the output gains observed in our estimates.

Compared with benchmark results from international institutions, our medium-term estimates lie above the average short-run multipliers of around 0.4–1.5 typically reported by the IMF, but remains within the upper range found in studies focusing on disaster-related or investment-driven fiscal expansions (e.g., Ilzetzki et al., 2013; IMF, 2014). This suggests that the magnitude of our results is economically plausible and consistent with the idea that post-disaster reconstruction spending can yield stronger-than-usual growth effects.

Figure 6. Response of real GDP to a cyclically adjusted spending increase in order to finance the reconstruction following a natural disaster shock.



Notes: Figure 6 reports the cumulative response of real GDP after an increase in cyclically adjusted government spending. Shaded areas indicate the 68% (darker – fuchsia colour) and 90% (lighter – pink colour) confidence bands. The full set of estimations are presented in the supplementary material, Appendix B, Table B1.

6.2 Robustness checks

6.2.1 New measures of cyclically adjusted spending

A potential concern with the baseline specification relates to the possible endogeneity of the fiscal shock variable, which may arise if the instruments or the construction of the cyclically adjusted fiscal measure are not fully exogenous to domestic economic conditions. In particular, while international aid flows are employed as instruments for cyclically adjusted government spending shocks, one might question

whether such flows could themselves respond, even indirectly, to domestic economic activity. To address this concern, it is important to emphasize that international aid flows related to extreme natural disasters are largely determined by exogenous humanitarian and geopolitical factors and therefore are unlikely to be directly affected by contemporaneous movements in output. Nevertheless, to ensure the robustness of our baseline findings, we conduct a series of robustness exercises. Specifically, we use alternative procedures to measure the cyclically adjusted primary balance and employ different sets of instruments to test the stability of the estimated fiscal multipliers. In addition, we perform additional robustness checks to verify that the selected instruments do not exert a direct influence on economic activity.[7]

More specifically, we first re-estimate equation (2) by adding the first lag of natural disasters. In more detail, we estimate by means of OLS:

$$\Delta ln(real\ government\ spending)_{i,t} = a_0 + a_1 \Delta ln(real\ GDP)_{i,t} + a_2 ND_{i,t} + a_3 ND_{i,t-1} + \eta_\iota + \lambda_\tau + \varepsilon_{i,t} \quad (4)$$

Where the dependent variable is the change in real government spending, and the independent variables include the change in real GDP and extreme natural disasters (D2) at time t and at time t-1. In addition, we include country and time fixed effects to capture global shocks and the unobserved heterogeneity across countries that could affect economic activity. The residuals obtained from equation (4) are the cyclically adjusted real government expenditures (alternative definition 1).[8]

Second, to adopt a more rigorous definition of the cyclically adjusted primary balance, equation (2) is reformulated as follows:

$$\Delta log(real\ GDP)_{i,t} = a_0 + a_1 ND_{i,t} + \eta_\iota + \lambda_\tau + \varepsilon_{i,t} \quad (5)$$

$$\Delta log(real\ government\ spending)_{i,t} = a_0 + a_1 ND_{i,t} + \eta_\iota + \lambda_\tau + \varepsilon_{i,t} \quad (6)$$

$$Residuals2_{i,t} = a_0 + a_1 Residuals1_{i,t} + \eta_\iota + \lambda_\tau + \varepsilon_{i,t} \quad (7)$$

[7] We would like to thank one referee for raising this issue.
[8] We also consider a specification in which equation (4) includes up to five lags of extreme natural disasters, after which we retain the residuals as a measure of cyclically adjusted expenditures. The findings are qualitatively similar to those presented in Figure B1 in the supplementary material appendix, left column (see supplementary material, Appendix B, Figure B2).

From equations (5) and (6), we retain the residuals (residuals1 and residuals2, respectively). We then estimate equation (7), in which the residuals from equation (6) (residuals2) serve as the independent variable and the residuals from equation (5) (residuals1) serve as the dependent variable. Equation (7) includes both time and country fixed effects and is estimated by means of OLS. The residuals obtained from equation (7) are subsequently interpreted as a measure of cyclically adjusted spending (alternative definition 2), which, by construction, excludes any contemporaneous effects from either government spending or economic activity. This procedure ensures that the resulting measure of the cyclically adjusted primary balance is purged of any direct influence of natural disasters on economic activity or public spending, thereby isolating the exogenous component of fiscal policy.

Then, we re-estimate equation (3) but as shock variable we use the two new variables (alternative definition 1 and 2) for the cyclically adjusted government spending, one at a time, and we use the first, second and third lag of international aid flows as instruments (as in equation (3)). As in the baseline evidence reported in sub-section 6.1, the strength and validity of the instruments used is fully confirmed by the high and statistically significant values of first-stage F-statistics (see supplementary material, Appendix B, Table B2).

In the supplementary material, appendix B, Figure B1 reports the results of these robustness checks. While the magnitude of the estimated effects changes slightly, the results fully confirm our baseline evidence. Specifically, we find that a 1% increase in cyclically adjusted real government spending to finance reconstruction activities following international aid flows in the event of natural disasters leads to a rise in real GDP by 2.65% (alternative definition 1) and by 1.79% (alternative definition 2) five years after the disaster. Importantly, this exercise reinforces the conclusion that post-disaster fiscal expansions have a persistent and positive impact on medium-term economic activity.

6.2.2 Alternative instruments tests

Next, we conduct an additional robustness check to address potential endogeneity. Instead of using international aid flows as instruments, we employ an index which measures a country's vulnerability to the impacts of climate change, which is taken from the University of Notre Dame. This index can be valid as an instrument because it captures an exogenous source of variation that plausibly affects a country’s exposure to climate-related risks but is unlikely to be directly correlated with the error term. In addition, the

climate vulnerability index is largely determined by geographic, environmental, and structural characteristics (e.g., exposure to droughts, sea level rise, and infrastructure resilience) that evolve slowly over time. Then we re-estimate equation (3) where the shock variable (is the cyclically adjusted government spending with the baseline definition) is instrumented by the first, second and third lags of the climate vulnerability index by each country. In the supplementary material, appendix B, Table B3 confirms the strength and validity of this alternative instrument. Although the size effect varies slightly, the results confirm our baseline findings (see supplementary material, appendix B, Figure B3). Specifically, we find that a 1% increase in cyclically adjusted real government spending to finance reconstruction activities in the weak of natural disasters leads to a rise in real GDP by 1.17% five years after the disaster.

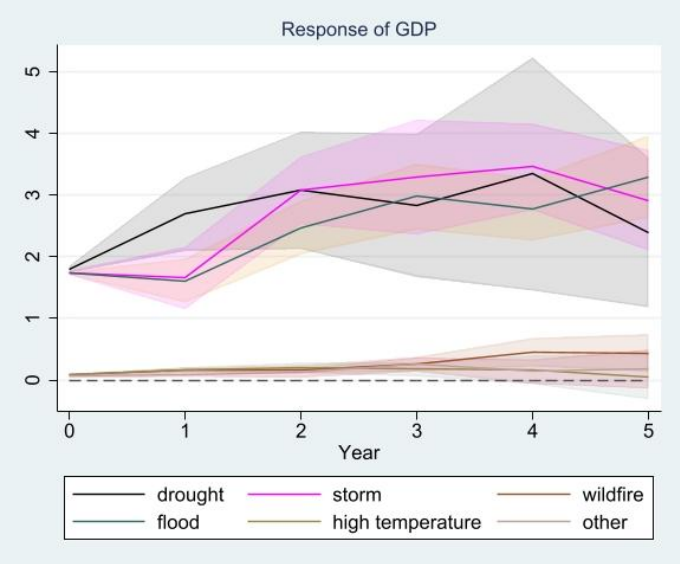
6.3 Effects by type of natural disasters

Having addressed potential endogeneity concerns and established that reconstruction spending in the post-disaster period generates significant multiplier effects for the economy, we now examine how each type of extreme natural disaster impacts economic activity. This analysis, which is based on the baseline specification, allows us to disentangle the heterogeneous effects of different disaster types on output. In particular, we consider the following types: floods, storms, droughts, wildfires, increased temperature, and other events.[9]

As shown in Figure 7, reconstruction spending in the post-disaster period following droughts, storms, and floods has more pronounced effects on economic activity, consistent with our baseline evidence, whereas other types of disasters, i.e. wildfires, extreme temperatures, and other events, exhibit much weaker effects.

[9] As other events, we classify the non-weather natural disasters, such as mass movement, earthquakes, volcanic activity, etc.

Figure 7. Response of real GDP to a cyclically adjusted spending increase in order to finance the reconstruction following an extreme natural disaster shock by type of disaster.



Notes: Figure 7 reports the cumulative response of real GDP after an increase in cyclically adjusted government spending by type of extreme natural disasters. The model estimated is equation (3). Instrumented variable: cyclically adjusted spending (with baseline definition); instruments: the first, second and third lags of international aid flows. Shaded areas indicate the 90% confidence bands.

7. State dependent evidence

Building on previous studies such as Auerbach and Gorodnichenko (2012), Klein (2017), and Ramey and Zubairy, (2018), we examine whether the effects of the baseline model depend on various states of nature. Therefore, we examine:

(a) High versus low public debt countries. According to Ilzetzki et al. (2013) fiscal multipliers are negative in countries with high public debt to GDP ratios. To this end, we classify country-year observations as being in a high public debt state when they are above the sample median of the public debt ratio (47%), and as being in a low public debt state when they are below the sample median.

(b) High versus low trade openness. According to a standard macroeconomic textbook (see e.g., Gartner, 2016), the effects of fiscal policy are more pronounced in closed relative to open economies. To this end, we classify country-year observations as being in high trade openness state (the trade openness ratio is the sum of exports and imports over GDP) when they are above the sample median of 69.8%, and as being in a low trade openness state when they are below the sample median.

(c) High and low financial development as proxied by the IMF financial development index. Countries characterized as financially developed usually have easier access to credit and can more easily borrow and pursue countercyclical fiscal policies (see e.g., Aghion et al., 2007; Afonso and Carvalho, 2022; Ma and Lv, 2023). However, fiscal policy is more potent in boosting economic activity in less financially developed economies, where credit constraints are prevalent (see e.g., Tagkalakis, 2008; McManus et al.,2021). Hence, we classify country-year observations as being in high financial developed state when they are above the sample median of the IMF index (0.27), and as being in low financial developed state when they are below the sample median.

(d) Fixed versus flexible exchange rate. According to a standard macroeconomic textbook (see e.g., Gartner, 2016), the effects of fiscal policy are more pronounced in fixed relative to flexible exchange rate regimes. Data for the exchange rate regime are taken from Reinhart et al. (2004) and Ilzetzki et al. (2019; 2022).

(e) Distinction by income groups. It is important to examine whether the baseline results differ across income groups. Following standard classifications (see e.g., Chrysanthakopoulos et al., 2025), countries are divided into advanced, emerging, and least-developed economies. Distinguishing by income level allows us to capture structural differences in fiscal capacity and the effectiveness of reconstruction spending. Prior evidence suggests that fiscal multipliers tend to be larger in advanced economies (Ilzetzki et al., 2013).

(f) Old-age dependency ratio. Population aging heightens governments' fiscal vulnerability to climate shocks by imposing substantial pre-existing strain on public finances through rising pension and healthcare expenditures. As a result, fiscal space to accommodate disaster-related spending becomes constrained, forcing governments to either reduce essential services, increase taxation, or rely more heavily on borrowing, thereby making fiscal management more difficult and potentially destabilizing (Koutsogeorgopoulou and Morgavi, 2025). To this end, we classify country-year observations as being in high old-age dependency ratio when they are above the sample median of 9.85%, and as being in a low old-age dependency state when they are below the sample median.

(g) It is essential to explore how natural disasters affect economies differently depending on the exposure of key sectors of economic activity such as agriculture and

tourism. These industries are highly sensitive to environmental shocks; agricultural production relies directly on weather and climate conditions, and tourism flows can be disrupted by disaster-related damage to infrastructure and destinations. Examining sectoral heterogeneity helps to identify which economies are most vulnerable and how fiscal reconstruction efforts should be targeted (Loayza et al., 2012). Hence, we classify country-year observations as being in a high agriculture state when they are above the sample median of the agricultural gross value added (GVA) (7.75), and in high tourism countries when they are above the sample median of the tourism arrivals (2687000) and tourism receipts as a % of total exports (8.39%) respectively.

To this end, we estimate:

$$Y_{it+h} - Y_{it-1} = I_{it-1}\left[\psi_{Ah}(L)\left[a^h + a_{1A}^h X_{it-1}\right] + a_{2A}^h shock_{it}\right] + (1 - I_{it-1})\left[\psi_{Bh}(L)\left[a^h + a_{1B}^h X_{it-1}\right] + a_{2B}^h shock_{it}\right] + \eta_i^h + \lambda_t^h + \varepsilon_{it}^h \quad (9)$$

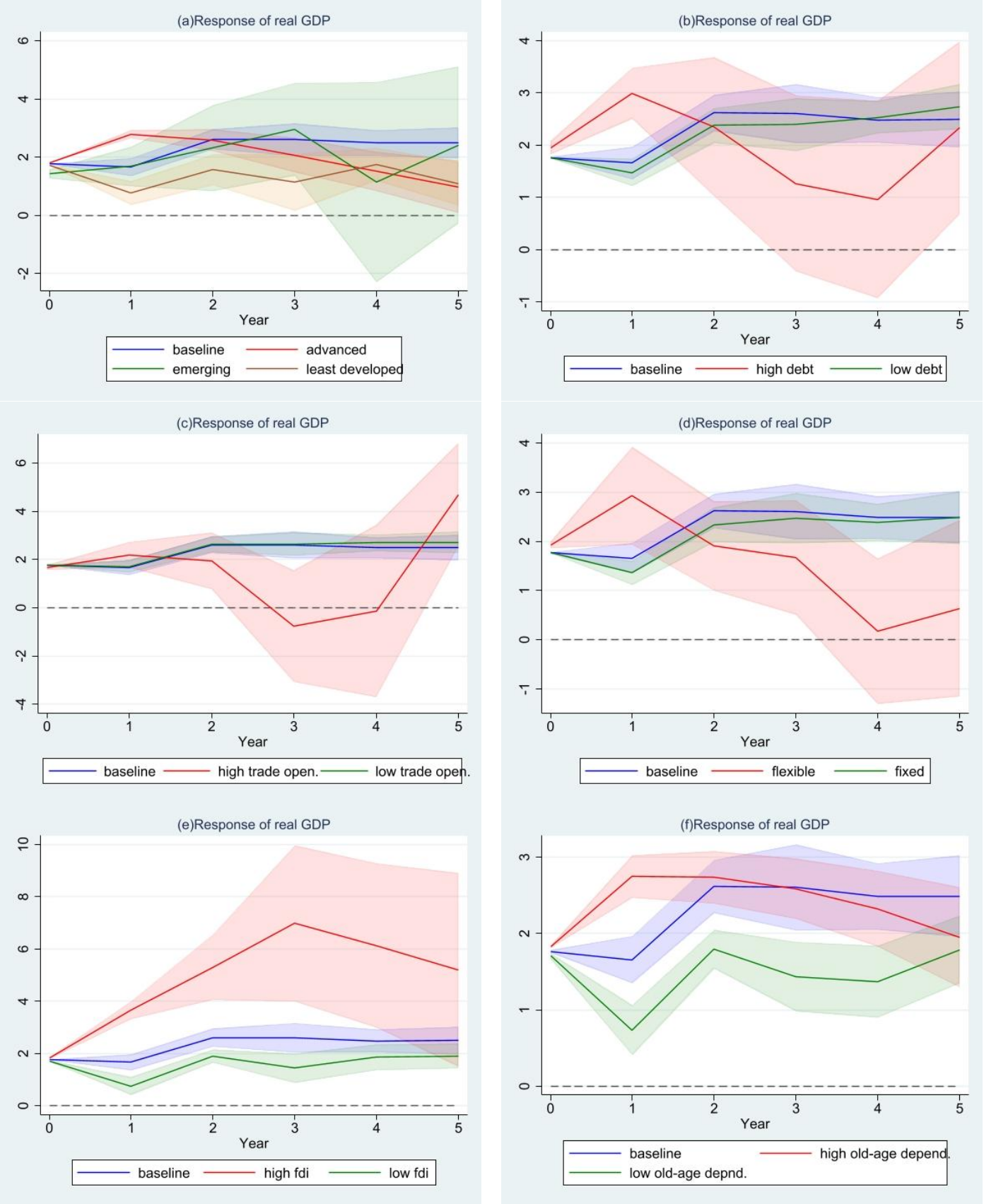
Following Auerbach and Gorodnichenko (2012), Ramey and Zubairy (2014) and Klein (2017) we include the first lag of the transition variable I_{it-1}, in order to minimize the correlation between the series of shocks on spending and changes in the indicator variable, thus, producing robust IRFs. The coefficients a_{2A}^h and a_{2B}^h provide the state-dependent responses of the variable $Y_{it+h} - Y_{it-1}$.

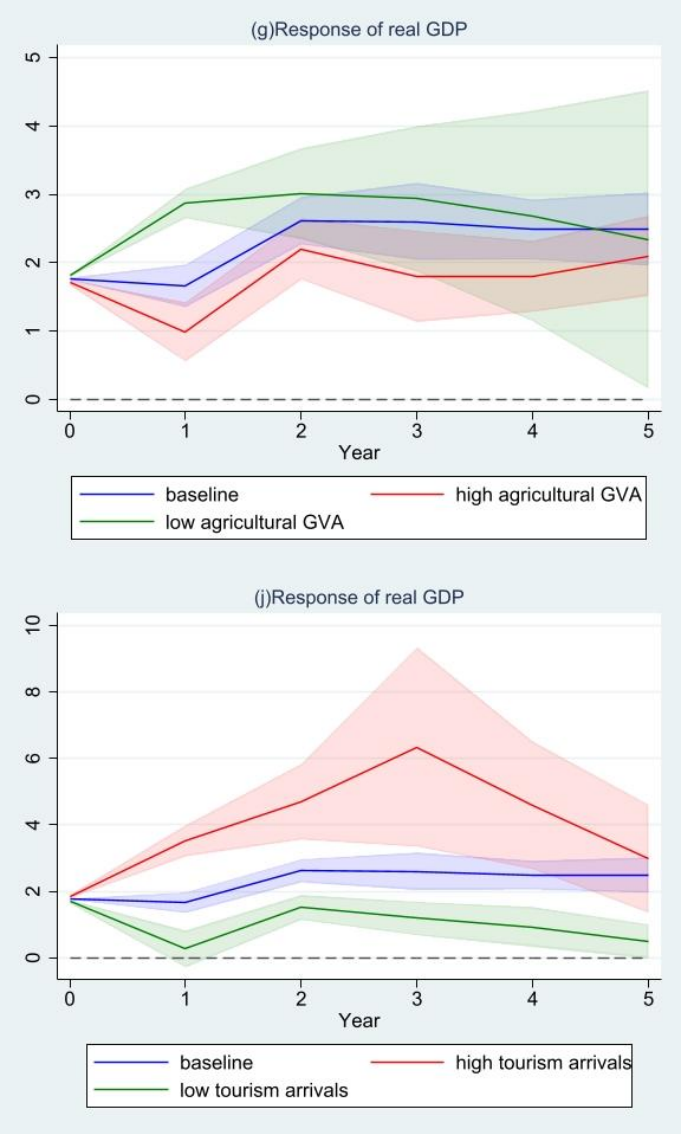
Equation (9) is estimated by means of an IV technique where the shock variable (i.e., the change in cyclically adjusted real government spending) is instrumented by the first, second and third lags of the international aid flows.

Figure 8 presents the results based on equation (9). We find that an increase in cyclically adjusted spending raises real GDP to a greater extent in emerging market versus advanced and least developed economies. In emerging market economies, post-disaster reconstruction expenditure boosts economic activity more due to larger infrastructure gaps, and greater vulnerability to natural disasters, especially in sectors like agriculture. Next, as anticipated, an increase in cyclically adjusted spending raises economic activity to a greater extent in low versus high debt countries. Countries with high debt levels typically face higher borrowing costs, making it difficult to finance their expenditures. An increase in cyclically adjusted expenditures has a more pronounced positive effect on real GDP in low relative to high trade openness countries for the first 4 year after the shock. As anticipated, the response of output to a cyclically adjusted government spending increase is more

pronounced in fixed versus flexible exchange regimes (see e.g., Gartner, 2016).In addition, the effects of fiscal policy are more pronounced in high financially developed economies. Next, we find that fiscal expansion has stronger positive effects on output in countries with a high old-age dependency ratio. Finally, an increase in cyclically adjusted spending raises economic activity to a greater extent in countries with a lower share of agricultural GVA and lower tourism intensity (as measured by arrivals and tourism receipts as a % of total exports). This pattern suggests that economies less dependent on climate-sensitive sectors may experience faster and more efficient transmission of reconstruction spending to overall economic activity, as resources are less exposed to direct disaster-related disruptions.

Figure 8. Response of real GDP under different states of nature.





Notes: Figure 8 reports the cumulative response of real GDP after a shock on cyclically adjusted spending. Shaded areas indicate the 90% confidence bands. Blue solid line referes to baseline specification.

8. Conclusion

The economic effects of climate change and in particular the more frequent and more intense effects of natural disasters have been the subject of several articles in recent years. Several international organizations note that climate change is the greatest threat for long-term growth and welfare around the globe. Consequently, it is a high priority on the political agenda for implementing measures to mitigate the effects of climate change (IMF, 2021; Moshammer, 2024). Using a large panel of 116 advanced, emerging market and developing economies over the period 1990-2022, this paper has two main contributions that are important for both academic literature and policymaking.

First, in contrast to previous studies (Fuje et al., 2023), we use a panel-event study method as pioneered by Freyaldenhoven et al. (2019) to isolate the true direct effects of natural disasters on economic activity and primary balances. We find that a natural disaster reduces real GDP and lowers the primary balance with the output effect being more pronounced in the case of an extreme rather than a major natural disaster. The negative effects of a natural disaster are primarily attributed to developing rather than advanced economies. In line with Fuje et al. (2023), the results are mixed when we examine each type of natural disaster. However, we find that major disasters due to droughts and floods hinder economic activity, while droughts, wildfires, and non-weather-related events have an adverse effect on primary balances. Extreme natural disasters, such as floods, storms, and wildfires, exert a quite negative affect economic activity. Whereas public finances are particularly affected by floods, wildfires, and high temperatures.

The second key contribution of this paper is that we examine the impact of reconstruction expenditure on output after a natural disaster. Building on Fatás and Mihov (2003, 2006), we exclude the automatic response of real government expenditures which among others includes unemployment benefits, transfers and compensation for damage to household goods, dwellings and losses to physical capital and business premises. Next, we use a dynamic panel local projection method as pioneered by Jordà (2005), in order to examine the medium-term effects of reconstruction cyclically adjusted expenditure on output following a natural disaster (see Canova and Pappa, 2021; Fidrmuc et al., 2015). After conducting several robustness checks including different specifications for computing cyclically adjusted expenditures, and various sets of instrumental variables to mitigate potential endogeneity concerns, we find that a 1% increase in real cyclically adjusted government spending to finance reconstruction activities following a natural disaster leads a rise in real GDP by 2.49% 5 years after the natural disaster. Moreover, the output response is found to be stronger in countries with lower public debt, lower trade openness, higher financial development, fixed rather than flexible exchange rate regimes, and in emerging relative to advanced and least developed economies. Additional heterogeneity analysis indicates that the effect is amplified in countries with higher old-age dependency ratios and lower shares of agricultural GVA and tourism intensity.

Overall, our research contributes to the existing literature that assesses the negative effects of natural disasters, while highlighting the important role of the state in post-disaster reconstruction. Our findings suggest that fiscal expansion can stimulate economic activity

after a disaster. However, there are additional issues that should be addressed in future research. For example, although the impact of increased public spending to address the consequences of natural disasters may boost real GDP in the medium-term, it may not necessarily compensate for the loss of productive capacity, for example, in the agricultural sector, or for the effect it may have on increased immigration. In this case, if there are long-lasting negative supply-side effects, we cannot identify them within the scope of this framework. Therefore, further future research is warranted on the subject.

Furthermore, an important aspect for future research is to identify the appropriate type of spending that boosts economic activity in the aftermath of a natural disaster, for example, public investment rather than transfers and public consumption. Finally, a critical aspect for future research is the allocation of risk between the public and the private sector. In this context, it should be considered whether private disaster insurance could limit fiscal costs. This would help make increased public spending more useful, decisive and effective in extreme natural disasters where government intervention cannot be replaced. However, private disaster insurance may mainly concern developed economies and may not be a reliable tool in developing and less developed economies. In these cases, the role of the state and external aid is extremely important.

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