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Natural disasters and intergovernmental relations: more or less decentralisation?

Luiz de Mello[a] and João Tovar Jalles[b,c,d,e]

ABSTRACT
Subnational governments, at the regional and local levels, play an important role in the prevention, management and recovery from natural disasters. These jurisdictions are responsible for issuing and monitoring compliance with several aspects of regulation that are essential for risk prevention, providing frontline services that are crucial for effective crisis management, and rebuilding lost or damaged physical infrastructure in the recovery phase. This paper provides empirical evidence based on impulse response functions that the occurrence of natural disasters is associated with an increase in the subnational shares of government spending and revenue in the years following these shocks. These decentralisation effects vary according to specific shocks and are conditional on the business cycle: they tend to be stronger when the shocks materialise during economic expansions.

KEYWORDS
Decentralisation; natural disasters; public finances; regional autonomy; impulse response functions; panel data

1. INTRODUCTION

The occurrence of natural disasters puts governments at all layers of administration to the test. This is because the human and material losses associated with these disasters are often large. For example, the economic losses resulting from extreme weather and climate-related events are estimated to have amounted to over US$740 billion between 2017 and 2021 in the United States, with damages of US$145 billion in 2021 alone (NCEI, 2022). In the case of Europe, these events accounted for about 80% of total economic losses from natural disasters between 1980 and 2020 (EEA, 2022). While hazards are exogenous to policy action, the outcomes of natural disasters depend on the preparedness of the public administration in prevention, management and recovery, particularly at the regional and local levels of government, for two main reasons.

First, natural disasters are local in nature, given that their hazard distributions depend on climate and geographical conditions that vary within a country's territory. Second, subnational governments are responsible for several aspects of regulation, including building codes, urban planning and land use, that are essential for risk

prevention. They are also responsible for monitoring compliance with those regulations, so that man-made vulnerabilities, such as the ones associated with informal construction in hazardous areas, for example, do not add to those related to climate change risks. In addition, regional and local governments provide important health care services, including the procurement and management of medical supplies, which are essential in disaster management. Rescue, public order and safety, and civil protection services are also typically under the purview of local governments. Moreover, subnational jurisdictions play an important role in the recovery phase, including by rebuilding lost or damaged physical infrastructure and identifying good practices that can be shared and used to improve resilience to similar shocks in the future.

The relationship between natural disasters and intergovernmental relations is likely to gain increasing attention among analysts and practitioners in the years to come. This is not least because climate change is expected to reshape the distribution of natural hazards and therefore increase exposure to extreme weather conditions. Indeed, the impacts of climate change are set to rise with temperature increases (IPCC, 2022): between 2030 and 2050,

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climate change is expected to cause 250 thousand additional deaths annually, mostly in developing countries (WHO, 2021). Governments will therefore be called upon to devise appropriate, often spatially differentiated prevention, management and recovery mechanisms to cope with these climate change-related disasters (de Mello, 2021). These mechanisms will need to be effective in the sense of minimising adverse outcomes when hazards do materialise, but also by making economies and societies resilient to climate change more broadly (de Mello & Ter-Minassian, 2022). Because policy action in all these areas cuts across the different layers of government, it is expected to influence, and ultimately prompt, institutional reform of intergovernmental relations.

Against this background, this paper contributes to the empirical literature in two main ways. First, the main hypothesis to be tested is that the occurrence of natural disasters affects the assignment of policymaking, administrative and political responsibilities among the different layers of government. Instead, except for Tselios (2021) and Cadaval Sampedro et al. (2023), most of the empirical literature focuses on the opposite direction of causation: how decentralisation influences the outcomes of natural disasters in terms of human and material loss (e.g., Escaleras & Register, 2012; Skidmore & Toya, 2013; Tselios & Tompkins, 2017, 2020). Also, the empirical literature focuses on case studies, instead of cross-country analysis (e.g., Steytler, 2022).

Second, this paper focusses on the dynamic linkages between natural disasters and decentralisation through the computation of impulse response functions (Jordà, 2005; Auerbach and Gorodnichenko, 2012, 2013a; Romer & Romer, 2019). Instead, most of the literature estimates long-term equilibrium relationships based on cross-country panel regressors, as in Tselios (2021) and Cadaval Sampedro et al. (2023). This paper, therefore, fills a gap in the literature by shedding light on the short-to-medium term mechanisms through which natural disasters affect intergovernmental relations and multi-level public finances before institutional changes triggered by natural disasters may lead to longer-lasting changes in the assignment of fiscal-financial functions across the different levels of administration.

The empirical evidence reported in this paper is based on the country-wide chronology of natural disasters and indicators of climate change vulnerability available from the Emergency Events Database (EM-DAT), compiled by the Centre for Research on the Epidemiology of Disasters (CRED). The assignment of responsibilities across the layers of government is measured using national accounts data on the subnational shares of general government spending and tax revenue (e.g., de Mello & Jalles, 2020, 2022), as well as indicators of subnational policy autonomy, such the Regional Authority Index (RAI) computed by Hooghe et al. (2010, 2016) and subsequently updated by Schakel et al. (2018). These indicators are widely used in the literature on decentralisation and natural disasters (e.g., Cadaval Sampedro et al., 2023; Tselios, 2021).

The paper's main findings are as follows. First, empirical evidence based on impulse responses shows that natural disasters are associated with an increase in the subnational shares of government spending in the years following the shock, especially for droughts, in both advanced economies and developing countries. The impulse responses are defined less precisely for revenue, especially among the advanced economies. Climate change vulnerabilities are also associated with greater regional policy autonomy in both advanced economies and developing countries. These findings indeed underscore the role of subnational governments in crisis management and recovery in areas that affect the public finances directly, such as increased spending on frontline services to the population and the mobilisation of resources for post-disaster recovery.

Second, decentralisation effects vary not only according to specific natural disasters, but they are also conditional on the business cycle. In particular, natural disasters tend to be followed by some centralisation of both revenue and spending (i.e., a drop in the subnational shares of revenue and spending) when they occur during recessions and some decentralisation (i.e., an increase in the subnational share of revenue and spending) when they occur during cyclical expansions. This is the case for both advanced economies and developing countries. These conditional effects are likely because in periods of constrained public finances, such as recessions, financial support to cope with the adverse impacts of shocks typically comes from the central government, given that the subnational governments' margin for manoeuvre are constrained by the presence of vertical fiscal imbalances, fiscal rules and other impediments to financing emergency spending by running budget deficits. By the same token, more favourable financial conditions during cyclical upturns allow the subnational governments to finance out of their own budgets at least part of the emergency spending needed to cope with the effects of natural disasters.

The paper is structured as follows. Section 2 reviews the theoretical and empirical literatures, with emphasis in the latter on cross-countries studies on the association between the internal structure of government, on the one hand, and the occurrence of natural disasters, on the other. It reviews studies that deal with causality running from decentralisation to natural disaster outcomes, which dominate the empirical literature, and point to the merit of looking at the converse direction of causality. Section 3 presents the estimating strategy and the data used in the empirical analysis and compares and contrasts our approach to alternatives available in scholarly work. Section 4 reports the baseline findings and associated robustness analysis. Section 5 discusses the main contributions of the paper and concludes by identifying remaining gaps in the literature and areas for future scholarly work in this area.

2. INSIGHTS FROM THE THEORETICAL AND EMPIRICAL LITERATURE

2.1. Theoretical frameworks and hypotheses

Natural disasters may affect the public finances through various channels, depending on the assignment of revenue,

spending and managerial functions across the different levels of government (de Mello & Martinez-Vazquez, 2022; Martinez-Vazquez, 2021). For example, revenue losses and spending pressures will be larger at the subnational level to the extent that the subnational governments have greater policymaking and fiscal-financial autonomy in areas that are relevant for natural disaster prevention, crisis management and post-disaster reconstruction and recovery (de Mello & Ter-Minassian, 2022, 2023). The specific effects on subnational budgets also vary along the different phases of the natural disaster cycle (ex-ante prevention, crisis management, and post-disaster recovery and reconstruction), as well as on the nature and severity of specific shocks. Indeed, for all these reasons the Sendai Framework for Disaster Risk Reduction emphasises the role of subnational governments and the importance of intergovernmental governance arrangements at all phases of the natural disaster cycle (UNISDIR, 2015).[1]

During prevention, the subnational finances are affected primary depending on the investment and regulatory functions assigned to the subnational levels of administration. Typically, the regional and local governments are responsible for investment in critical infrastructure in the transport, energy and water/sanitation sectors, most often through enterprises in which they have ownership or controlling interest, which are at greatest risk of disruption when natural disasters occur, especially severe weather conditions and earthquakes (de Mello & Ter-Minassian, 2022, 2023). Through their regulatory powers, the subnational governments are typically responsible for setting norms and regulations for the use of land, including by banning construction in areas that are vulnerable to landslides and flooding (OECD, 2017). They are also responsible for the issuance of building codes, often in cooperation with builders' associations, by requiring adoption of construction standards and technologies that reflect local conditions and vulnerabilities (OECD, 2021). Moreover, the subnational governments are responsible for monitoring compliance with these regulations and therefore influence the preparedness of local communities to face natural disasters, especially in areas that are exposed to earthquakes and extreme weather conditions.

Even though subnational governments have a prominent role to play in these areas, the national governments are important actors in prevention. They can shape local choices through the provision of transfers and grants that encourage investments and adoption of specific technologies that can best respond to local vulnerabilities to specific hazards (Ishiwatari, 2013). The national governments can also set minimum standards through the national territory to deal with interjurisdictional externalities that may arise from local choices. In the specific case of natural hazards associated with climate change, the central government can do much to influence, through cooperation and/or fiscal-financial means, subnational adaptation policies and strategies (de Mello & Ter-Minassian, 2022, 2023).

During crisis management, subnational governments are typically responsible for the provision of frontline services to the population, such as health care, and law and order, that are at risk of disruption by natural disasters and whose demand increases when disasters hit (OECD, 2020). They are also responsible for the provision of rescue services, which may be particularly complex depending on the nature and severity of the shock. Moreover, the damage or destruction of public and private assets arising from natural disasters disrupts economic activity, with an adverse effect on subnational revenue. This is especially the case of the collection of taxes on immovable property, which are typically under the purview of local governments. Subnational revenue collection may also be affected adversely by disruptions to local tax administration (Lee et al., 2018; Miao et al., 2018; Noy & Nualsri, 2011; Unterberger, 2017). Where the subnational governments collect taxes on income (either directly or through surcharges on national taxes), their revenue may suffer from associated disruptions. Once again, the specific effects on subnational budgets depend on the severity of the disaster and the governance arrangements for the sharing of policymaking and fiscal-financial functions across administration levels.

As in the case of prevention, the central government has a role to play during crisis management in support of subnational efforts. This role is nevertheless shaped by legal and organisational constraints in different settings. In many federations, engagement of higher levels of administration may not be automatic and require a request by the affected subnational jurisdictions that often have primary responsibilities to respond to natural disasters (Cohn, 2005).[2] Central government support may be in kind, as in the case of deployment of rescue teams and the provision of health care, or through financial support in the form of special purpose grants and intergovernmental transfers. The central government can also act to mobilise response to an emergency where reaction is slow due to capacity constraints and/or interjurisdictional conflict in different institutional settings. Where specific intergovernmental coordination fora are in place and the distribution of own and shared responsibilities among the levels of administration, the management of natural disasters may involve the engagement of other same-level jurisdictions and their agencies, including in situations where a natural disaster straddles interjurisdictional borders.[3]

As for post-disaster recovery and reconstruction, subnational governments play a leading role, depending on their autonomy in spending and regulatory matters, the breadth of their tax bases and their reliance on the central government for the financing of investment (de Mello & Ter-Minassian, 2022, 2023). The central government has a role to play at this stage of the cycle as well, even where there is significant subnational fiscal-financial and regulatory autonomy, especially in the case of large natural disasters, whose damages and destruction may overwhelm local capabilities. Intergovernmental cooperation is desirable so that lessons learned can be shared across the national territory and benefit jurisdictions that have not been affected by a given disaster but are vulnerable to

the same type or comparable hazard (Smith & Wenger, 2007). The recovery phase also offers an opportunity for intergovernmental cooperation, and appropriate financing, where relevant, to set higher standards for the construction and maintenance of critical infrastructure in a manner that reduces vulnerabilities to future shocks, as well as for the issuance of stricter building codes and land use regulations, where needed.

For all these reasons, the occurrence of natural disasters, depending on their nature and severity, is likely to lead to an increase in subnational spending and a reduction in revenue, which may be financed in part or in full through increases in grants and transfers from higher levels of administration. These effects are likely stronger in the short-to-medium run than over extended periods of time. This depends on the specific recovery and reconstruction pathways, and on whether or not concrete experience with a particular disaster exposes gaps in the multi-level governance of natural disaster risk management and the policies of different levels of government in a manner that leads to longer-term changes in the assignment of own and shared fiscal-financial functions within governments.

2.2. A review of the empirical literature

Consistent with the theoretical considerations above, there is a growing empirical literature on the association between natural disasters and decentralisation, or more generally the internal structure of government. For example, Tselios (2021) tests the hypothesis that the occurrence of natural disasters influences the sharing of policymaking and administrative authority among the layers of government. He finds that large natural disasters, measured in terms of their death toll, reinforces decentralisation. However, the results are not robust to the different aspects of decentralisation considered in the Regional Authority Index computed by Hooghe et al. (2010, 2016), which is the main indicator of decentralised used in his analysis. The typology of natural disasters is available from the Emergency Events Database (EM-DAT) compiled by the Centre for Research on the Epidemiology of Disasters (CRED). In other words, the author finds that the human and economic losses associated with natural disasters influence the internal structure of government in a manner that encourages the decentralisation of policymaking and political prerogatives to the subnational levels of administration.

Evidence is also available from Cadaval Sampedro et al. (2023) for a variety of extreme events, including economic crises, natural disasters, epidemics/pandemics and military conflicts. The authors test the hypothesis that these extreme events lead to durable changes in multi-layered governance systems that affect the level of decentralisation. They find that, unlike Tselios (2021), natural disasters tend to reduce the level of decentralisation, while military conflicts tend to increase it, in both cases with long-lasting effects. The parameter estimates are less precise for the sample of OECD countries, suggesting that the institutional frameworks of more advanced countries appear to be more resilient to the shocks associated with natural disasters. They also use the RAI indicator along with the conventional expenditure and revenue decentralisation metrics, as well as the natural disaster indicators available from EM-DAT.

Causality can also go from decentralisation to the materialisation of natural disaster risks, which is the focus of most of the empirical literature to date. This is to the extent that decentralisation influences the preparedness of government to deal with natural disasters in a manner that reduces unfavourable outcomes, such as human and material loss, and makes economies and societies more resilient to future shocks. This is not to say that decentralisation affects the distribution of natural hazards per se, which are exogenous to policy, but it can contribute to mitigating the adverse human and economic consequences of these hazards, when they materialise. In other words, decentralisation may be associated with better outcomes from the occurrence of natural disasters in terms of lower human and material losses.

There is indeed cross-country empirical evidence that decentralisation is associated with better outcomes from natural disasters. Escaleras and Register (2012) focus on expenditure decentralisation and on the death toll of the disaster registry available in EM-DAT. They find that greater expenditure decentralisation is associated with a lower death toll from natural disasters. Skidmore and Toya (2013) also report a negative correlation between decentralisation and death tolls using similar definitions of decentralisation and natural disasters, while identifying significant non-linearities in the relationship between these two variables. Tselios and Tompkins (2017) focus instead on political, rather than fiscal, decentralisation and on disasters related to storms and earthquakes, rather than the full spectrum of events included in EM-DAT. They use the Regional Authority Index computed by Hooghe et al. (2010, 2016) as the indicator of decentralisation and find that human losses from storms and earthquakes are lower in countries where the regional governments have greater political and policy authority. They also find that the economic damages associated with these natural disasters may be more, not less, severe in more decentralised countries, despite lower human losses. Tselios and Tompkins (2020) focus instead on the occurrence of a natural disaster based on EM-DAT, rather than its human or economic fallout, and use the Regional Authority Index computed by Hooghe et al. (2010, 2016) as the indicator of decentralisation. Contrary to previous evidence, they find that the structure of government does not affect a country's natural disaster probability in a statistically significant manner, even though the quality of government does, but evidence is weak.

Empirical work on the effects of natural disasters considers a variety of controls, including a country's income level, population and socio-political indicators (e.g., Bloom et al., 2022). Geographical and disaster susceptibility indicators are also often considered. In general, empirical analysis shows that richer countries and those with better socio-political indicators, including educational attainment and democratic governance, tend to

have better disaster outcomes, which in turn tend to be strongly influenced by propensity to natural disasters, including those related to geographical characteristics. Poverty, urbanisation, environmental degradation and income inequality are powerful predictors of adverse natural disaster outcomes. Political systems also affect the ability of countries to minimise the adverse outcomes from these shocks.

Moreover, empirical analysis tends to focus on long-term equilibrium relationships, rather than the short-term dynamics, between the variables of interest (e.g., Cadaval Sampedro et al., 2023; Tselios, 2021). In other words, the estimating strategies consist of running reduced-form equations in levels for panels of country-level or regional data, often including country and time fixed effects to exploit the between dimension of the data. In doing so, the empirical literature overlooks the interconnections associated with intergovernmental arrangements for the management of crises and the attendant post-crisis recovery that tend to have short- to medium-term effects on the variables of interest. It is therefore possible that statistically significant relationships may emerge in the short-to-medium term even if none is discerned over longer periods of time. In other words, support for dealing with crises and recovering from them may entail time-bound increases in intergovernmental grants and transfers to the affected areas, increases in policy autonomy to address local needs and increases in local revenue mobilisation to finance (at least in part) the post-crisis recovery and reconstruction efforts within existing arrangements without a durable change to the governance and institutional underpinnings of intergovernmental relations (de Mello & Ter-Minassian, 2022).

Against this background, this paper contributes to the empirical cross-country literature in two main ways. First, it tests the hypothesis that the occurrence of natural disasters is associated with the decentralisation of policymaking, administrative and political responsibilities to the subnational layers of government, as in Tselios (2021) and Cadaval Sampedro et al. (2023). Second, the paper emphasises the short-to-medium term dynamic linkages between shocks and decentralisation by computing impulse responses, rather than estimating long-term equilibrium relationships based on cross-sectional panel regressions, as in the literature surveyed above.

3. ESTIMATING STRATEGY AND DATA

As noted above, the main hypothesis to be tested is whether the occurrence of natural disasters is associated with the decentralisation of policymaking, administrative and political responsibilities to the subnational layers of government, at least in the short-to-medium term while controlling for other co-variates. To estimate the response of fiscal decentralisation to major natural disasters, we follow the local projection method proposed by Jordà (2005) to estimate impulse-response functions. This approach has been advocated by Auerbach and Gorodnichenko (2013a, 2013b) and Romer and Romer (2019) as a flexible

alternative to estimating long-term relationships between variables. The local projection method looks at dynamic responses such as those based on the interactions between the occurrence of natural disasters, on the one hand, and the rules and procedures governing intergovernmental fiscal relations, on the other.

The baseline specification is:

$$y_{i,t+k} - y_{t-1,i} = \alpha_i + \tau_i + \beta_k shocks_{i,t} + \theta X_{i,t} + \varepsilon_{i,t} \quad (1)$$

in which $y_{i,t}$ is the dependent fiscal decentralisation variable of interest in country i at time t; $shocks_{i,t}$ denotes the occurrence of a natural disaster in country i at time t; β_k denotes the (cumulative) response of the variable of interest in each k year after the occurrence of a natural disaster in country i; α_i, τ_i are country and time fixed effects, respectively, included to take account for cross-country heterogeneity and global factors (such as the world business cycle or oil price movements); $X_{i,t}$ is a set a of control variables including two lags of the shocks, two lags of real GDP growth and two lags of the relevant dependent variable; and $\varepsilon_{i,t}$ is an error term.[4]

Equation (1) is estimated by ordinary least squares (OLS).[5] Impulse response functions (IRFs) are obtained by plotting the estimated β_k for k = 0,1, … ,5 with 90 (68) percent confidence bands computed using the standard deviations associated with the estimated coefficients β_k based on robust standard errors clustered at the country level. Shocks are treated as exogenous events as they cannot be anticipated nor correlated with past changes in the internal structure of government.

We equally inspect if initial economic positioning at the time of occurrence of a natural disaster affect the inter-actions with fiscal decentralisation. This is important, because claims on government budgets also vary along the business cycle, not least those related to the operation of the automatic stabilisers, such as increases in unemployment benefits during downturns (Jalles, 2023). These pressures influence the ability of governments to respond to crises and in turn the fiscal relations that underpin the sharing of responsibility among the different layers of administration. We posit that the path of spending and revenue in response to shocks depends on the position of the economy in the business cycle when a given shock occurs.

To test the above-mentioned hypothesis, we now allow impulse responses to vary in accordance to a continuous function $F(z_{it})$:

$$y_{i,t+k} - y_{i,t-1} = \alpha_i + \tau_i + \beta_k^L F(z_{i,t}) shocks_{i,t} + \beta_k^H (1 - F(z_{i,t})) shocks_{i,t} + \theta X_{i,t} + \varepsilon_{i,t}, \quad (2)$$

with $F(z_{it}) = \dfrac{\exp(-\gamma z_{it})}{1 + \exp(-\gamma z_{it})}, \quad \gamma > 0.$

in which z_{it} is an indicator of economic activity (proxied by real GDP growth or the output gap estimated via HP filter) normalised to have zero mean and unit variance.[6] The coefficients β_L^k and β_H^k capture, for instance, the decentralisation impact of natural disasters at each horizon k in cases of recessions ($F(z_{it}) \approx 1$ when z goes
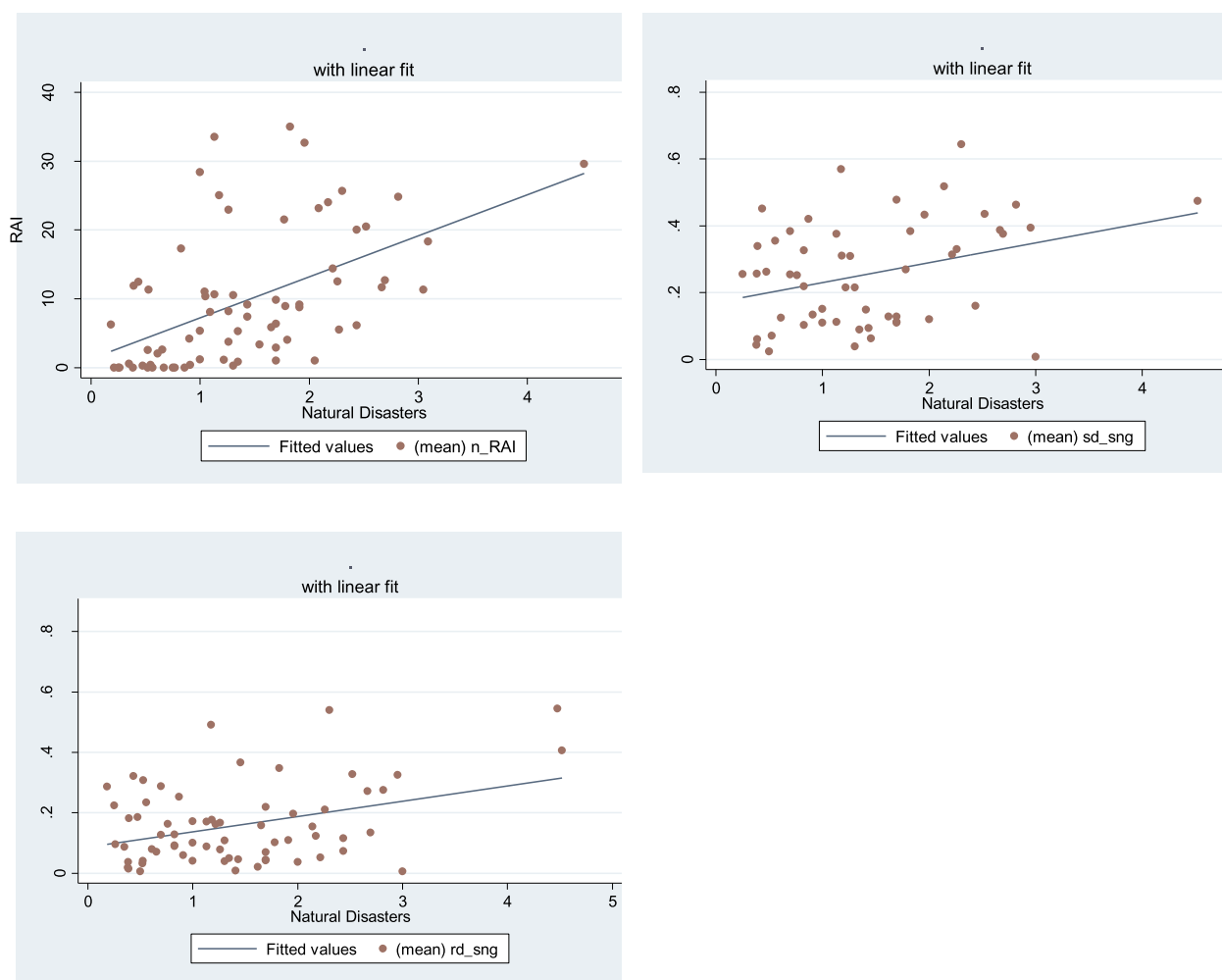
Figure 1. Decentralisation and natural disasters.
Note: The scatter plot shows unconditional correlations between the fiscal decentralisation measures and natural disasters occurrence.
Source: Authors' calculations.

to minus infinity) and expansions ($1 - F(z_{it}) \approx 1$ when z goes to plus infinity), respectively. We chose $\gamma = 1.5$.[7]

Auerbach and Gorodnichenko (2012, 2013) discuss how the application of the local projection method to non-linear estimations is equivalent to Granger and Teräsvirta (1993) smooth transition autoregressive (STAR) model. At least two advantages can be mentioned. First, compared with a model in which a dependent variable would be interacted with an indicator of the economic positioning, the STAR approach in the context of local projections allows a direct test of whether there is a differentiated effect of natural disasters on decentralisation depending on whether the economy is in a recessions or expansions. Secondly, in comparison with the alternative of running structural vector autoregressions for each regime (expansions and recessions), the STAR approach in the context of local projections allows the effect of natural disasters to change smoothly between regimes by considering a continuum of states to compute the impulse response functions and this makes the responses more stable and precise.

The indicator of fiscal decentralisation, y_{it}, measures the functional composition of government spending and revenue, defined as the subnational shares of total general government spending and revenue. Data are available from the IMF's Government Finance Statistics database and include updates (up to 2019) by Dziobek et al. (2011). Our starting sample includes 70 countries with decentralisation data from 1990–2019. An alternative indicator used in the analysis, the RAI, computed by Hooghe et al. (2010, 2016) and subsequently updated by Schakel et al. (2018), goes beyond the fiscal relations across levels of government and include aspects of subnational policy autonomy. The indicator covers several provisions related to own and shared responsibilities of the regional (middle-tier) jurisdictions in the areas of administration, the executive and law-making prerogatives of the subnational governments, as well as inter-jurisdictional coordination mechanisms. Data are available for 81 countries over the period 1950–2010.

As in the remainder of the literature, the decentralisation indicators used in the empirical analysis suffer from

Impact of Revenue Decentralization (% revenue): natural disaster shocks
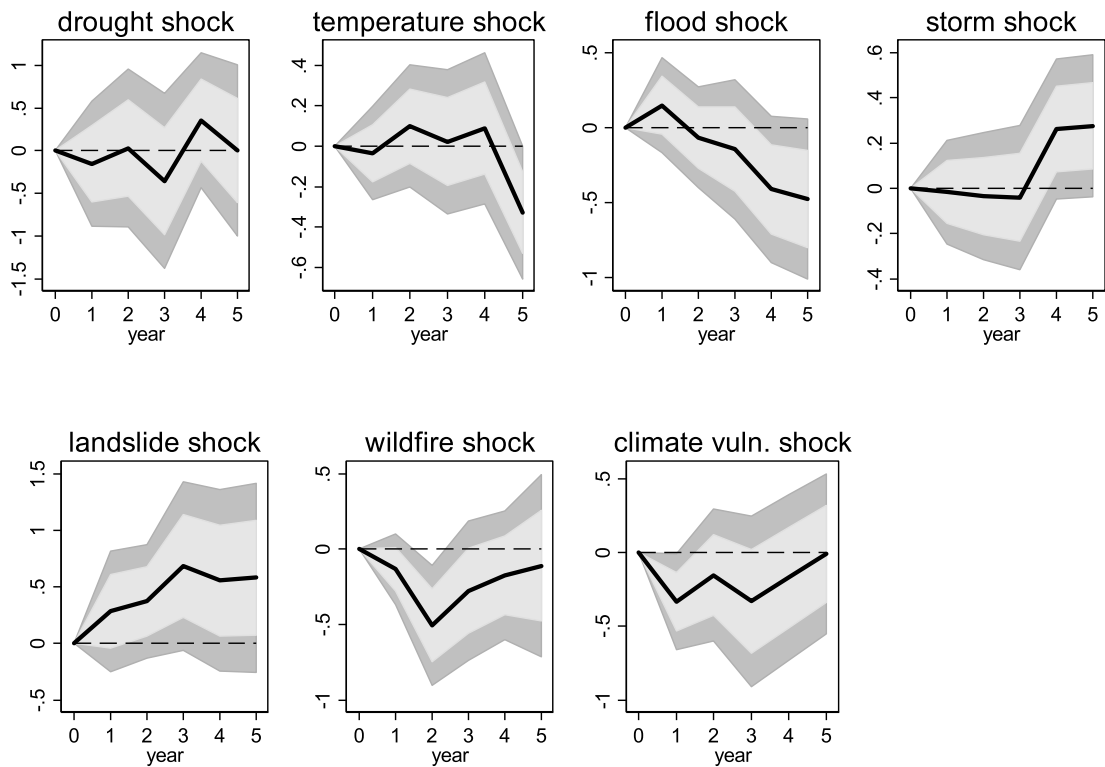
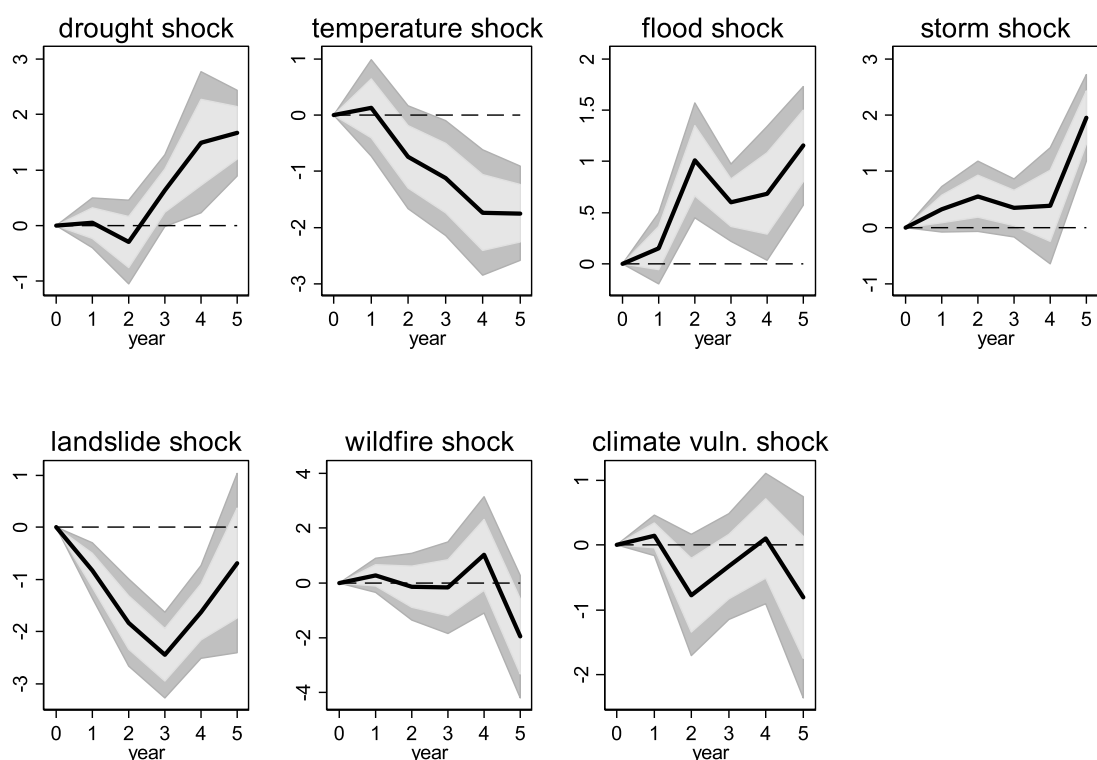## Impact of Spending Decentralization (% expenditure): natural disaster shocks
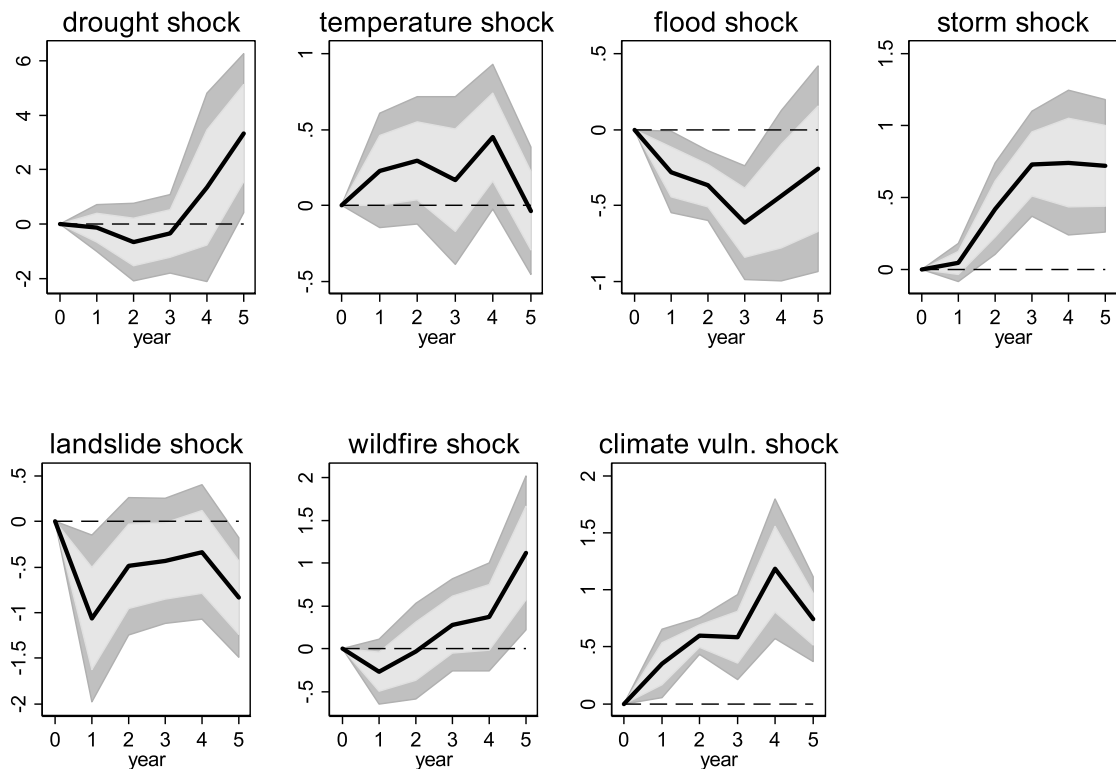
Figure 2. Revenue and spending decentralisation: Impulse responses for the advanced economies.
Note: Impulse responses of local projection estimates of the effect of natural disaster shocks on cumulative fiscal decentralisation proxies in $t = 1, \ldots, 5$. The solid black lines plot the impulse responses based on Equation (1). So, the position of the line at $t = 5$ shows the accumulated impact of a given shock on revenue or spending decentralisation in percentage points, 5 years after the shock. The y axis displays single-digit percentage points. The dark grey shaded areas display the 90% SCC error bands; the light grey shaded areas display the 68% SCC error bands. Year $t = 1$ is the first year after a shock, which occurs at $t = 0$.
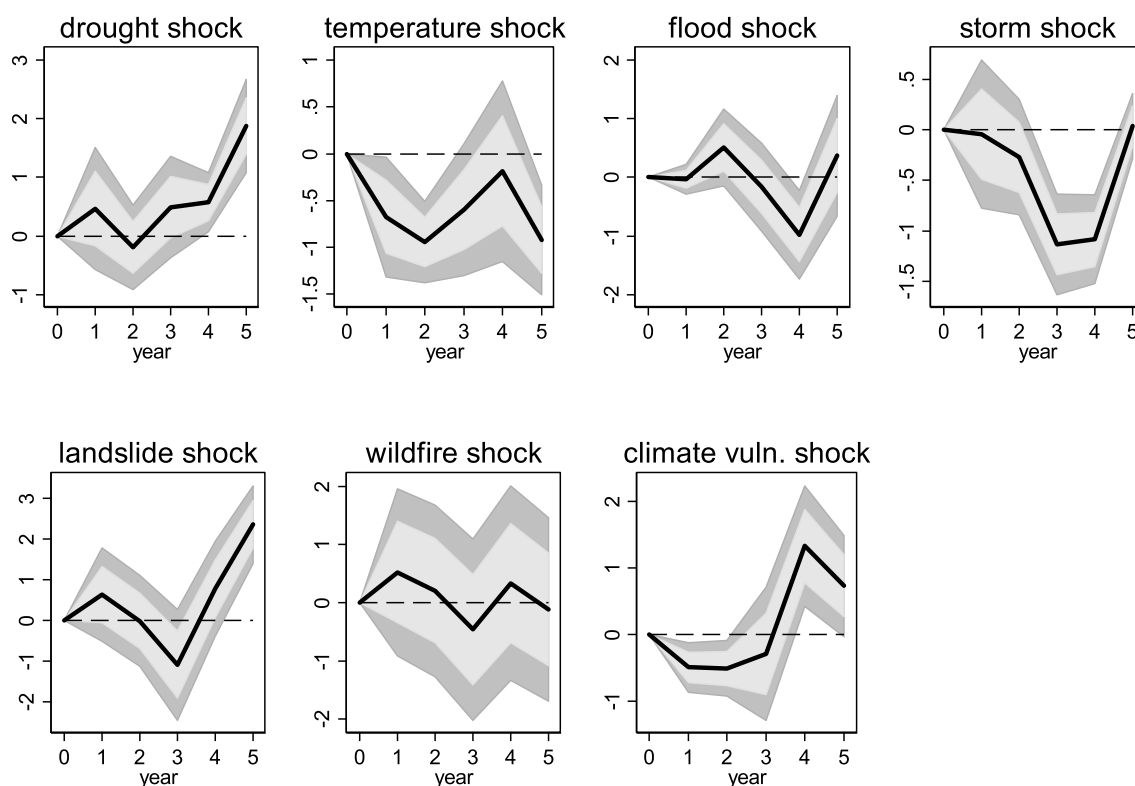Source: Authors' calculations.

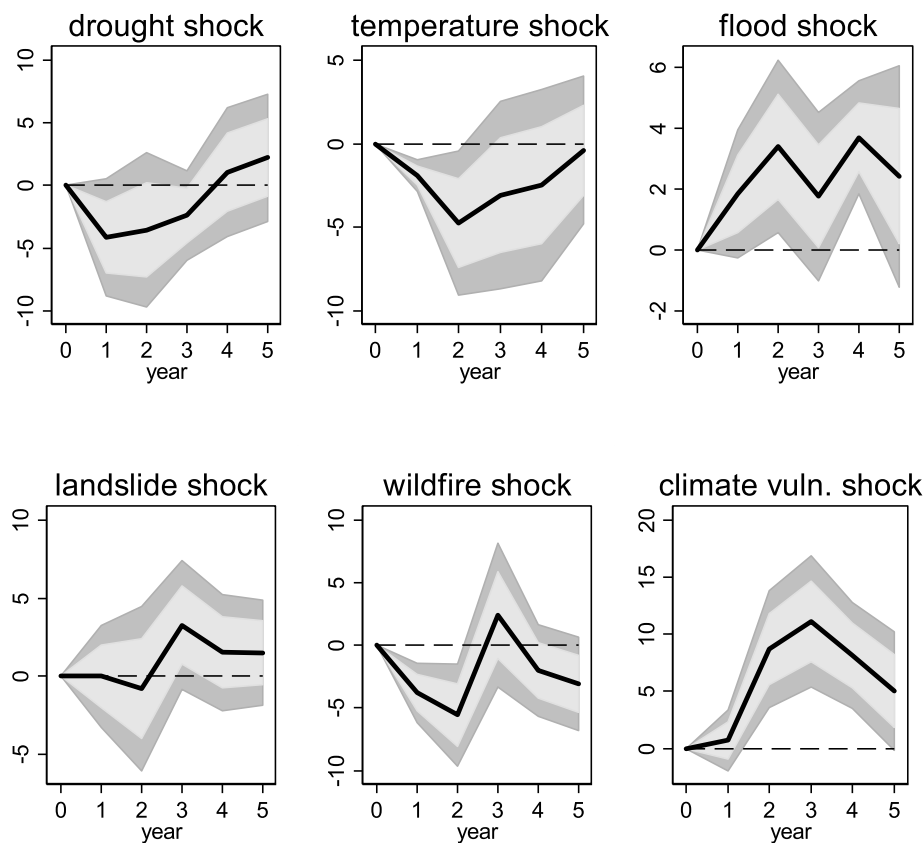## Impact of Revenue Decentralization (% revenue): natural disaster shocks

Impact of Spending Decentralization (% expenditure): natural disaster shocks

Figure 3. Revenue and spending decentralisation: Impulse responses for the developing countries.
Note: Impulse responses of local projection estimates of the effect of natural disaster shocks on cumulative fiscal decentralisation proxies in $t = 1, \dots, 5$. The solid black lines plot the impulse responses based on Equation (1). So, the position of the line at $t = 5$ shows the accumulated impact of a given shock on revenue or spending decentralisation in percentage points, 5 years after the shock. The y axis displays single-digit percentage points. The dark grey shaded areas display the 90% SCC error bands; the light grey shaded areas display the 68% SCC error bands. Year $t = 1$ is the first year after a shock, which occurs at $t = 0$.
Source: Authors' calculations.

Figure 4. RAI (%): Impulse responses for the advanced economies.
Note: Impulse responses of local projection estimates of the effect of natural disaster shocks on cumulative fiscal decentralisation proxies in $t = 1, \ldots, 5$. The solid black lines plot the impulse responses based on Equation (1). So, the position of the line at $t = 5$ shows the accumulated impact of a given shock on revenue or spending decentralisation in percentage points, 5 years after the shock. The y axis displays single-digit percentage points. The dark grey shaded areas display the 90% SCC error bands; the light grey shaded areas display the 68% SCC error bands. Year $t = 1$ is the first year after a shock, which occurs at $t = 0$.
Source: Authors' calculations.

several well-known limitations. For example, the indicators of spending decentralisation do not distinguish between own-account functions and those related to shared responsibilities or reflecting mandates from higher levels of administration. Likewise, the revenue decentralisation indicators do not allow for distinguishing between own sources and shared ones. Moreover, the subnational authority indicators refer to the regional level of government and therefore omit the authority of the local governments, which are often at the forefront of natural disaster management.

The chronology of natural disasters is constructed using data obtained from EM-DAT, as in the literature surveyed above, which documents disaster occurrence and outcomes by country and disaster type from 1900 to the present day.

A natural disaster is defined as an unforeseen and sudden natural hazard-associated event that overwhelms local capacity, necessitating a request to the national or international level for external assistance, and causes great damage, destruction and human suffering. For a disaster to be included in EM-DAT, according to Tselios (2021), at least one of the following Centre for Research on the Epidemiology of Disasters (CRED) criteria has

to be fulfilled: '(a) ten or more people reported killed, (b) a hundred or more people reported affected, (c) declaration of a state emergency, and (d) a call for international assistance'. The events focus on extreme temperatures, floods, droughts, landslides, wildfires and windstorms. 'Natural disaster occurrence (disaster propensity) is measured as a dummy variable, which is equal to 1 if a country in a year has experienced a natural disaster following the EM-DAT criteria, and 0 otherwise. Hence, this dummy variable shows whether a hazard becomes a disaster' (Tselios, 2021; Tselios & Tompkins, 2020).

The EM-DAT dataset also contains information on climate change vulnerabilities. The relevant indicator refers to 'a country's exposure, sensitivity and capacity to adapt to the impacts of climate change' and comprise indicators of six life-supporting sectors: food, water, health, ecosystem services, human habitat and infrastructure. Vulnerability is measured as a continuous variable.

Preliminary inspection of the data indeed shows a correlation between decentralisation and occurrence of natural disasters. The countries that tend to concentrate most disasters identified in EM-DAT, such as Brazil, Colombia, India, Indonesia, Peru and the United States, are
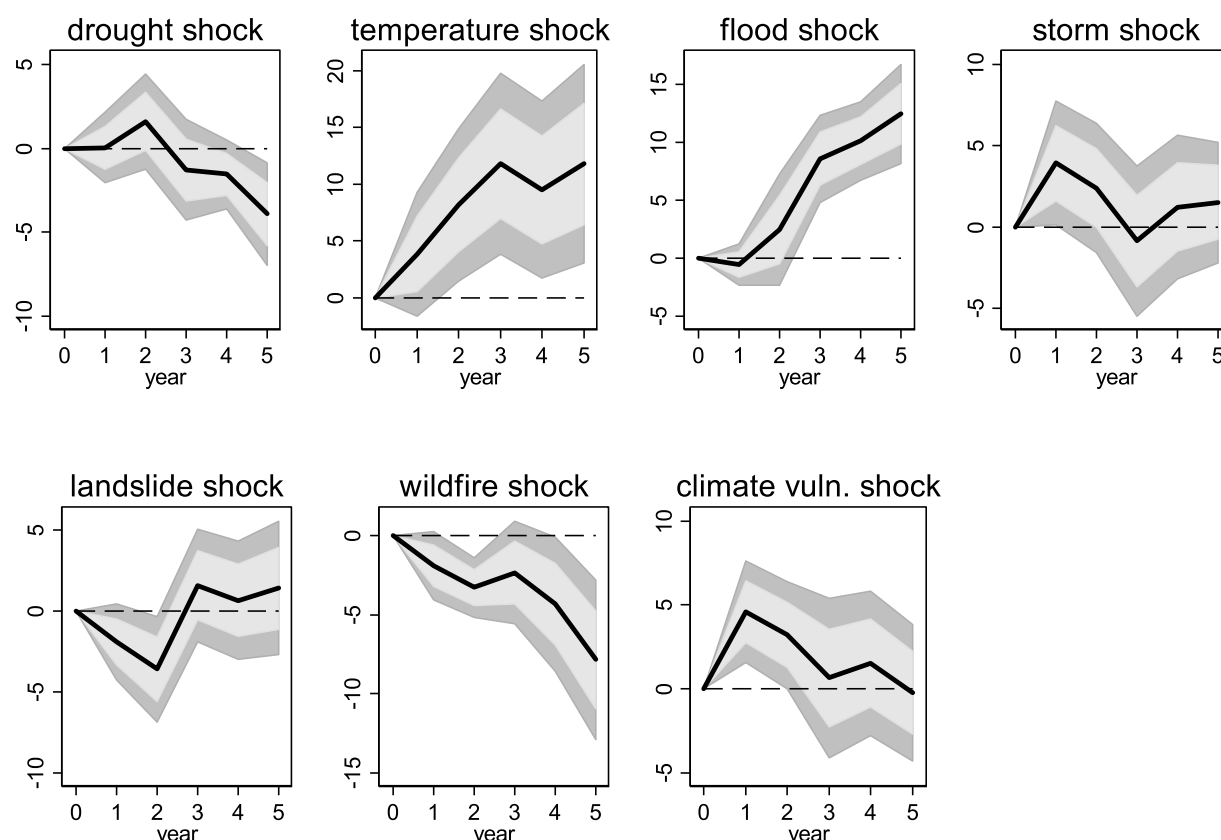
Figure 5. RAI (%): Impulse responses for the developing countries.
Note: Impulse responses of local projection estimates of the effect of natural disaster shocks on cumulative fiscal decentralisation proxies in $t = 1, \ldots, 5$. The solid black lines plot the impulse responses based on Equation (1). So, the position of the line at $t = 5$ shows the accumulated impact of a given shock on revenue or spending decentralisation in percentage points, 5 years after the shock. The y axis displays single-digit percentage points. The dark grey shaded areas display the 90% SCC error bands; the light grey shaded areas display the 68% SCC error bands. Year $t = 1$ is the first year after a shock, which occurs at $t = 0$.
Source: Authors' calculations.

large in terms of landmass and population, and they also tend to be among the most decentralised in the world on the basis of the expenditure and revenue decentralisation metrics used in the analysis (Figure 1). There also seems to be a positive correlation between occurrence of natural disasters and decentralisation as measured by the RAI indicator, which goes beyond fiscal metrics.[8]

4. EMPIRICAL EVIDENCE

4.1. Baseline results and robustness analysis
The starting point of the analysis is the estimation of baseline equations for the subnational shares of government spending and revenue, as well as the RAI indicator, which will underpin the computation of the impulse response functions. These baseline regressions are reported in Appendix Table A2, from the online supplemental data, and include a set of standard co-variates based on the decentralisation literature (e.g., de Mello & Jalles, 2020). The results suggest that the subnational share of revenue is lower in more developed countries (higher GDP per capita) and where output growth is stronger. As for government spending, the subnational share appears to be higher where inflation is higher and in economies that

are more closed to trade. In addition, the subnational shares of both revenue and spending tend to be higher where government indebtedness is lower, reflecting the overall state of the public finances. Moreover, improvements in the terms of trade and a higher share of agriculture in GDP are associated with higher subnational revenue and spending shares. Finally, income distribution tends to be associated with a higher subnational revenue share but a lower spending share.

Turning to the impulse response functions, attention is focused on different natural disasters, including wildfires, droughts, floods, storms, landslides and extreme temperature events, and climate vulnerability. The impulse responses are computed for the sub-samples of advanced and developing countries separately. The main finding of the analysis is that the occurrence of a natural disaster is associated with higher subnational shares of revenue and spending in the years following the shock, even though there is considerable variation across shocks and groups of countries.[9]

Starting with the impulse responses for the subnational spending shares, for the group of advanced economies, the impulse responses show that wildfires, droughts and storms are associated with an increase in the subnational
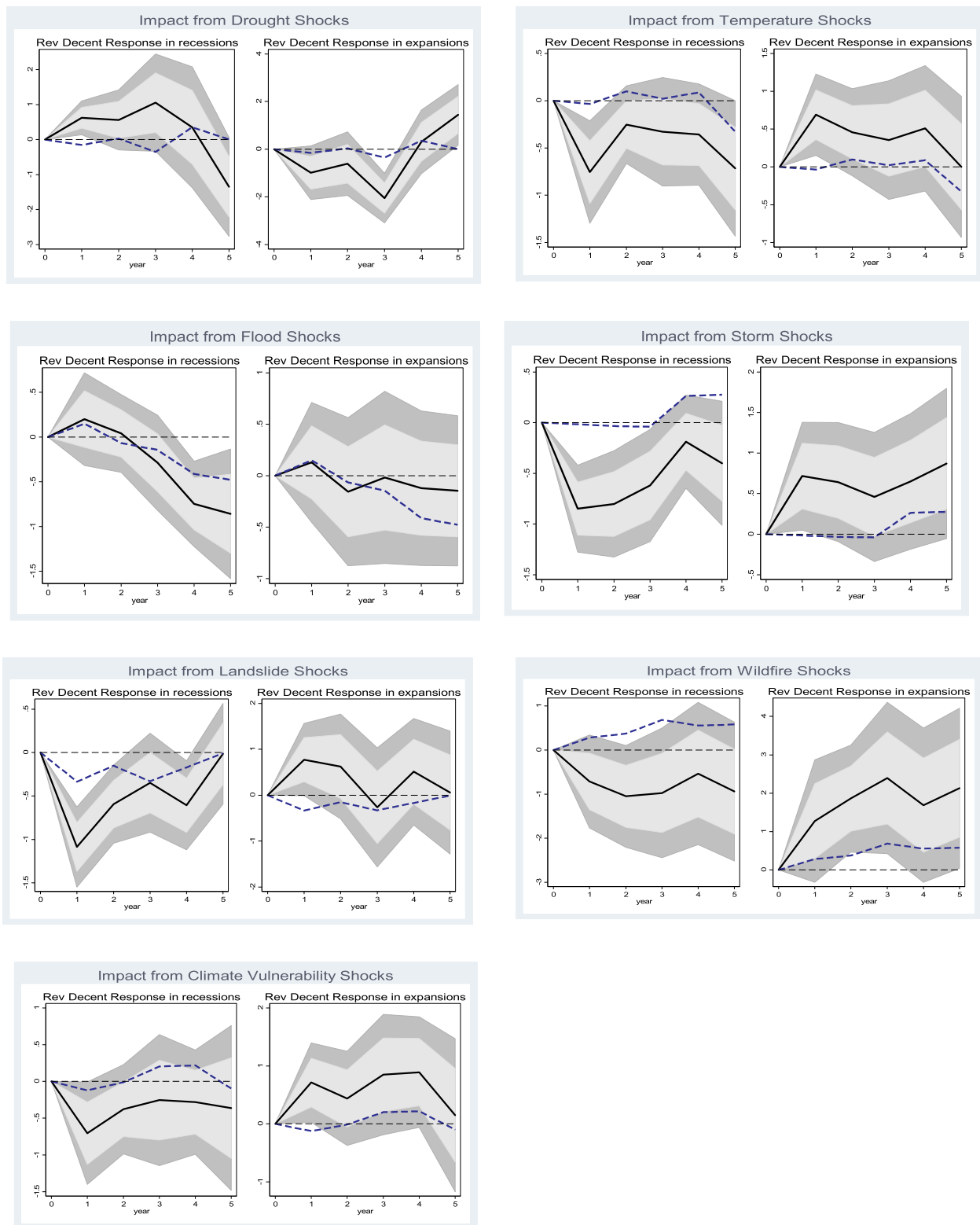
Figure 6. Conditional revenue decentralisation impulse responses: The role of the business cycle in the advanced economies. Note: Impulse responses of conditional local projection estimates of the effect of natural disaster shocks on cumulative fiscal decentralisation proxies in $t = 1, \ldots, 5$. The solid black lines plot the impulse responses based on Equation (2). So, the position of the line at $t = 5$ shows the accumulated impact of a given shock on revenue or spending decentralisation in percentage points, 5 years after the shock conditional on being in a recession or expansion. The solid blue line corresponds to the unconditional response from Equation (1) plotted above. The y axis displays single-digit percentage points. The dark grey shaded areas display the 90% SCC error bands; the light grey shaded areas display the 68% SCC error bands. Year $t = 1$ is the first year after a shock that occurs at $t = 0$.
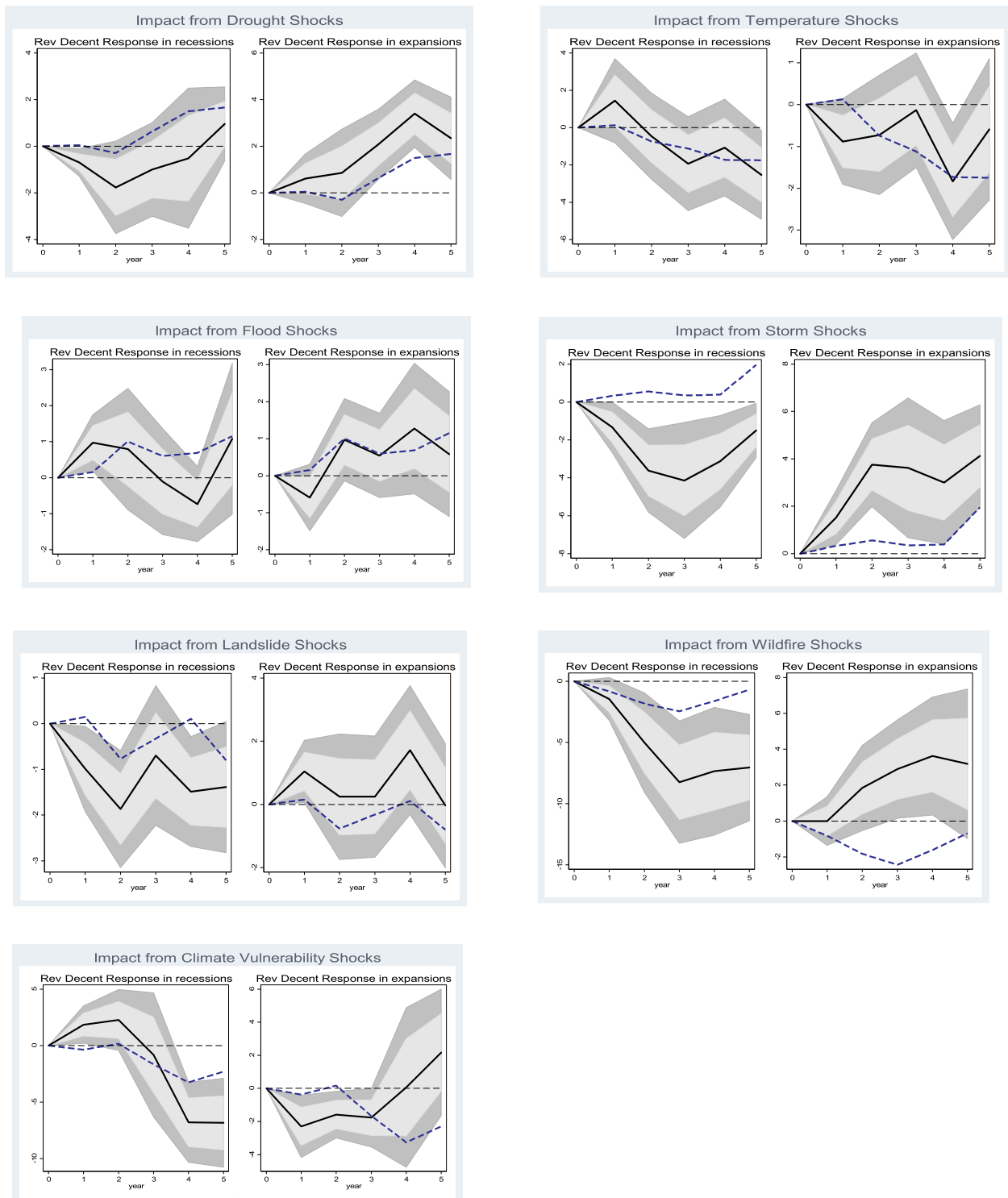Source: Authors' calculations.
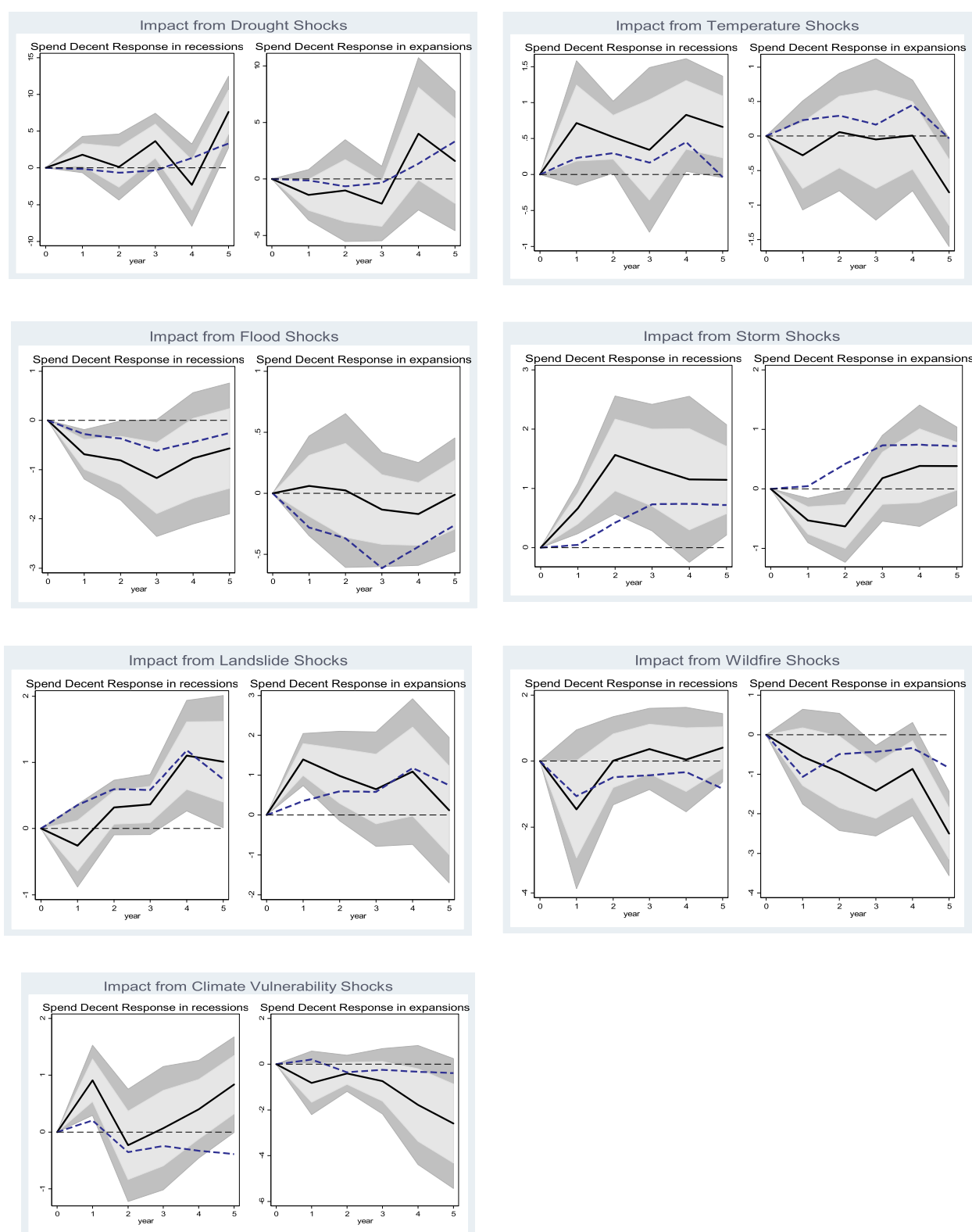
Figure 7. Conditional spending decentralisation impulse responses: The role of the business cycle in the advanced economies. Note: Impulse responses of conditional local projection estimates of the effect of natural disaster shocks on cumulative fiscal decentralisation proxies in $t = 1, \ldots, 5$. The solid black lines plot the impulse responses based on Equation (2). So, the position of the line at $t = 5$ shows the accumulated impact of a given shock on revenue or spending decentralisation in percentage points, 5 years after the shock conditional on being in a recession or expansion. The solid blue line corresponds to the unconditional response from Equation (1) plotted earlier. The y axis displays single-digit percentage points. The dark grey shaded areas display the 90% SCC error bands; the light grey shaded areas display the 68% SCC error bands. Year $t = 1$ is the first year after a shock occurs at $t = 0$.
Source: Authors' calculations.

Figure 8. Conditional revenue decentralisation impulse responses: The role of the business cycle in developing countries.
Note: Impulse responses of conditional local projection estimates of the effect of natural disaster shocks on cumulative fiscal decentralisation proxies in $t = 1, \ldots, 5$. The solid black lines plot the impulse responses based on Equation (2). So, the position of the line at $t = 5$ shows the accumulated impact of a given shock on revenue or spending decentralisation in percentage points, 5 years after the shock conditional on being in a recession or expansion. The solid blue line corresponds to the unconditional response from Equation (1) plotted earlier. The y axis displays single-digit percentage points. The dark grey shaded areas display the 90% SCC error bands; the light grey shaded areas display the 68% SCC error bands. Year $t = 1$ is the first year after a shock occurs at $t = 0$.
Source: Authors' calculations.

Figure 9. Conditional spending decentralisation impulse responses: The role of the business cycle in developing countries. Note: Impulse responses of conditional local projection estimates of the effect of natural disaster shocks on cumulative fiscal decentralisation proxies in $t = 1, \dots, 5$. The solid black lines plot the impulse responses based on Equation (2). So, the position of the line at $t = 5$ shows the accumulated impact of a given shock on revenue or spending decentralisation in percentage points, 5 years after the shock conditional on being in a recession or expansion. The solid blue line corresponds to the unconditional response from Equation (1) plotted earlier. The y axis displays single-digit percentage points. The dark grey shaded areas display the 90% SCC error bands; the light grey shaded areas display the 68% SCC error bands. Year $t = 1$ is the first year after a shock occurs at $t = 0$.
Source: Authors' calculations.

spending share within 5 years following the shock (Figure 2). The same applies to overall climate vulnerability. In the case of floods there seems to be a negative, albeit short-lived effect on spending decentralisation. For the group of developing countries, an increase in the subnational spending share is also detected following a drought (Figure 3). The same applies for landslides and overall climate vulnerability (albeit of short duration). A temperature shock and storms are associated with a lower subnational spending share, but these effects are short-lived. As regards the subnational shares of revenue, the impulse responses are defined more precisely for the group of developing countries. Droughts, floods and storms are associated with an increase in subnational revenue shares within a six-year horizon following the shock, whereas the converse is observed for a temperature shock and landslides (even if it is short-lived in this case).

Since the effects of natural disasters can go beyond the public finances, we also used the RAI indicator as a metric of decentralisation. The results reported in Figure 4 for the advanced economies show that floods and climate vulnerabilities tend to lead to a sustained increase in decentralisation within a 5-year period following the shock. Extreme temperature episodes and wildfires tend to have the opposite effects, at least over a short period in the aftermath of the shock. For the developing countries, floods and extreme temperature events also have sustained decentralising effects, whereas droughts and wildfires tend to have the opposite effect (Figure 5).

As for the conditional impulse responses, the analysis suggests that when a shock occurs during recessions (cyclical expansions), they tend to have a stronger revenue centralising (decentralising) effect in the advanced economies. This is the case for both revenue and spending decentralisation in the advanced economies (Figures 6 and 7). These outcomes depend on the specific shock, as for the unconditional impulse responses. This is also the case for the developing countries (Figures 8 and 9).[10]

4.2. Implications of the analysis for regional policy

Intergovernmental relations and the distribution of fiscal, financial and policymaking powers across a country's levels of administration are shaped by history, culture, legal traditions and politics, which evolve slowly. Exogenous shocks, such as those associated with natural disasters, may well trigger longer-term institutional change but they typically lead to dynamic responses within established systems of intergovernmental relations (Cadaval Sampedro et al., 2023; Pierson, 2000). These short- and longer-term effects shed light on the links that exist between decentralisation and the design of intergovernmental relations, on the one hand, and regional policy more generally, on the other. These effects inform policy reform choices to enhance resilience of governance systems and fiscal decentralisation to cope with the presence of extreme events, including natural disasters.

For example, in the case of regional development and policy, which emphasise the importance of local conditions in policy design, the occurrence of natural disasters is likely to lead to place-based responses rather than uniform ones across a national territory. Centralised policies are therefore likely to be less suitable for dealing with local disaster risks and shocks. Disaster risk prevention and management therefore focus on the subnational jurisdictions even though national and supranational governments have a role to play, as discussed above. Lessons also apply to spatial planning and governance, given that the optional scale of policy responses vary across natural hazards, with local governments playing a more prominent role in prevention and risk management in the case of natural disasters whose effects tend to be more localised. Decentralised governance structures affect the coordination and effectiveness of regional disaster management efforts.

Moreover, implications can be identified for economic geography, given the concentration of economic activity within a country's territory and the need to identify those risks posed by natural hazards for the local economy, as well as spillovers within broader geographical areas through supply chains and global production networks (Fold, 2014). The COVID-19 pandemic highlighted important regional effects in this regard (Bailey et al., 2020, 2023). This is of particular interest to policymakers and practitioners working on regional planning, disaster management and local governance.

Empirical evidence of a link between natural disasters and decentralisation also draws attention to the need for a better understanding of how decentralisation may contribute to variations in disaster preparedness and response capabilities across different regions. This is relevant for understanding how subnational governance arrangements influence regional disparities in resilience and vulnerability, as discussed, for example, by de Mello and Ter-Minassian (2022, 2023). Empirical evidence in this area can contribute to a better understanding of the practical implications of governance structures on disaster outcomes.

5. DISCUSSION AND CONCLUSIONS

The main finding of the empirical analysis is that intergovernmental fiscal relations – at least as far as gauged by the subnational shares of government spending and revenue, as well as the assignment of administrative, policymaking and political functions to the regional layers of government – are affected by the occurrence of natural disasters, at least in the short-to-medium run. These effects are defined more precisely for spending than revenue and vary among a wide range of hazards, and between advanced and developing economies. This is not surprising given the cross-country diversity of intergovernmental fiscal arrangements around the world and the specific rules and practices in each country to deal with adverse shocks.

Overall, the empirical findings suggest that implications for decentralisation are likely to be more robust for those natural disasters whose effects are more likely to be felt locally – such as wildfires, droughts, storms

and floods – and for which the subnational governments have a more prominent role to play in prevention and provision of frontline services to the population when disasters occur, as well as in the mobilisation of resources for post-disaster recovery and reconstruction. In addition, the findings for climate vulnerabilities suggest that climate change is expected to influence reforms in intergovernmental relations in the years to come. This is all the more important as climate change reshapes the distribution of natural hazards and adaptation needs, with attendant implications for the public finances at all levels of administration.

Moreover, the empirical analysis provides insights for future scholarly work on the design of intergovernmental relations in a manner that can improve the preparedness of governments at large (all levels of administration) to cope with adverse shocks arising from natural disasters. Of course, in the short-to-medium run options for dealing with these adverse shocks need to reflect existing intergovernmental arrangements, which are typically rooted in broader institutional and legal traditions.

Over time and bearing in mind the diversity of estimated responses documented above, a case could be made for increasing subnational fiscal and policymaking autonomy. This is because of the prominent role played by the subnational governments in prevention, such as by issuing land use regulations to minimise risks of flooding and landslides, investing in infrastructure that is less vulnerable to natural disasters and climate change more broadly, and preparing contingency plans to respond to such disasters when they do materialise. These activities are local in nature, because they need to reflect local conditions and deal with localised impacts, but they too can have some (positive or negative) externalities, especially on adjacent jurisdictions. Intergovernmental cooperation is therefore important, so that these spillover effects can be taken into consideration, good practices can be identified, and risk can be pooled and shared among the different levels of administration through appropriate assignments of policymaking, managerial and fiscal-financial responsibilities.

Against this background, future work could shed light on the effectiveness of the different options available to national governments to support the subnational jurisdictions. In the area of prevention, minimum standards can be set nationally, and the national governments can provide technical support and financial resources to the subnational governments in need through grants and transfers. This is particularly important in the area of adaptation to climate change, since most of the investments in adaptation and disaster recovery are likely to require additional resources (de Mello & Ter-Minassian, 2022, 2023). Grants and transfers can be designed in a manner that ensures that financial support is spent where it is intended, for example through conditionality on the use of funds, and where appropriate used to encourage local revenue mobilisation, as in the case of matching grants and other co-financing arrangements for climate change adaptation initiatives (Martinez-Vazquez, 2021).

Another area for future research on decentralised risk management is related to the design of insurance mechanisms. Few countries invest in the resilience of critical infrastructure, such as those that produce and deliver electricity, gas, water and telecommunications, in the form of system redundancies, diversification of suppliers and availability of back-up productive capacity. Indeed, according to a recent survey by the OECD (Survey on Governance of Critical Infrastructure Resilience, 2019–2020), only a minority of countries offer incentives for critical infrastructure operators to invest in resilience in the form of grants or financial rewards, or through regulatory provisions and financial penalties for service disruption. Also, several OECD countries lack national inventories of critical infrastructure assets, systems, functions or operators (OECD, 2021). Governments therefore need to estimate the value of physical assets at risk to prepare for effective crisis management by purchasing insurance, as is the case of utility companies, including those owned or controlled by government, which are required to maintain up-to-date inventories of assets at risk and can therefore insure those assets. Governments at all levels should also maintain appropriate contingency reserves to face upfront costs when shocks materialise and, where applicable, to support affected lower-level jurisdictions through ad-hoc grants for the management of crisis and during post-shock recovery.

Further work in all these areas would contribute to the literature on the implications of climate change for the public finances and fiscal policy more generally (de Mello & Martinez-Vazquez, 2022). This is to the extent that climate change affects the distribution of natural hazards. Therefore, efforts to enhance the preparedness of the subnational governments to cope with natural disasters would likely have the added benefit of improving the ability of governments to address the challenges associated with climate change. This is also the case to the extent that decentralisation helps to raise awareness among the population about these challenges and creates opportunities for bottom-up policy experimentation in the area of environmental policies (de Mello & Jalles, 2022).

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NOTES

1. Tiernan et al. (2019) provide a literature review on disaster risk management.

2. This is the case for most federations. See FEMA (2016) for more information and governance arrangements for the United States, for example. See also Productivity Commission (2014) for more information and discussion on funding arrangements in Australia. For the case of unitary countries, see for example Kalogiannidis et al. (2023) for intergovernmental governance arrangements in Greece.

3. Hurricane Katrina led to a spur of scholarly work on the multi-level governance of natural and man-made disaster management and implications for fiscal federalism. See, for example, Scavo et al. (2008) for an analysis of the response to the 2005 Gulf Coast hurricanes and implications for reform of intergovernmental relations in the United States. See also Downey and Myers (2020) for a comparison of response arrangements in the United States and Australia.

4. Similar methodology has been used by Jalles and Karras (2023) and Jalles (2023).

5. 'Another advantage of the local projection method compared to vector autoregression (autoregressive distributed lag) specifications is that the computation of confidence bands does not require Monte Carlo simulations or asymptotic approximations. One limitation, however, is that confidence bands at longer horizons tend to be wider than those estimated in vector autoregression specifications' (Gupta & Jalles, 2021).

6. We assign weights to each regime varying between 0 and 1 according to the weighting function $F(.)$. This way $F(z_{it})$ can be interpreted as the probability of being in a given regime, recession or expansion.

7. Results do not change if we use different values of the parameter γ, between 1 and 4.

8. Summary statistics are shown in Appendix Table A1.

9. Adding a proxy of government size given by total expenditure over GDP does not alter the main results qualitatively. These are available from the authors upon request.

10. This exercise cannot be performed for the RAI indicator as the dependent variable due to a lack of degrees of freedom. The common set after merging the required dependent and independent variables is too small to allow for valid inferences.

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