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Natural Disasters, Epidemics and Intergovernmental Relations: More or Less Decentralisation?

Luiz de Mello¹ and João Tovar Jalles^{2,3}

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Abstract

The subnational governments, at the regional and local levels, play an important role in the prevention, management and recovery from natural disasters and pandemics/epidemics. These jurisdictions are responsible for issuing and monitoring compliance with several aspects of regulation that are essential for risk prevention, including land use and construction codes; for providing frontline services that are crucial for effective crisis management, including health care, civil protection, and public order and safety; and for 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 and the outbreak of pandemics/epidemics are 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 cyclical expansions.

Keywords: decentralisation; natural disasters; pandemics; epidemics; public finances; regional autonomy; impulse response functions; panel data.

JEL Classification codes: H11, H23, H77, Q58

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I. Introduction

The occurrence of natural disasters and the outbreak of pandemics/epidemics put governments at all layers of administration to the test. This is because the human and material losses associated with these hazards are often large. For example, the economic losses associated with extreme weather- and climate-related events are estimated to have amounted to over USD 740 billion between 2017 and 2021 in the United States, with damages of USD 145 billion in 2021 alone (NCEI, 2022). In the case of Europe, these events accounted for about 80% of total economic losses from natural hazards between 1980 and 2020 (EEA, 2022). The human losses associated with epidemics/pandemics are also large, with the H1N1 (swine flu) pandemic of 2009-10 accounting for estimated deaths in excess of 200 thousand (Bloom et al., 2022). While these hazards are exogenous to policy action, their outcomes 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 risk distributions depend on climate and geographical conditions that vary within a country's territory. Pandemics/epidemics also have a strong local dimension, given the differences that exist in incidence rates within a country's territory. Second, the subnational governments are responsible for several aspects of regulation, from 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, the regional and local governments provide important health care services, including the procurement and management of medical supplies, which are essential in disaster management, especially when

dealing with pandemics/epidemics. Rescue, public order and safety, and civil protection services are also typically under the purview of the local governments. Moreover, the 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. Indeed, for all these reasons the Sendai Framework for Disaster Risk Reduction emphasises the role of local governments at all phases of a disaster, from prevention to recovery (UNISDIR, 2015).

The relationship between natural disasters, pandemics/epidemics 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 disaster hazards, increase exposure to extreme weather conditions, and facilitate the emergence of zoonotic diseases. Indeed, the impacts of climate change are expected to rise with temperature increases (IPCC, 2022): between 2030 and 2050, 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 (de Mello, 2021). These mechanisms will also 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 and 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 change to, intergovernmental relations.

Against this background, this paper contributes to the empirical literature by providing cross-country evidence on how the occurrence of natural hazard-associated disasters and

pandemics/epidemics affect the assignment of policymaking, administrative and political responsibilities among the different layers of government. Most of the literature focuses instead on natural disasters alone, thereby excluding pandemics/epidemics (e.g., Tselios, 2021), and on case studies, rather than cross-country analysis (e.g., Steytler, 2022). The literature also focuses primarily on how decentralisation influences the outcomes of natural disasters and epidemics/pandemics in terms of human and material loss (e.g., Escaleras and Register, 2012; Skidmore and Toya, 2013; Tselios and Tompkins, 2017 and 2020; Rodríguez-Pose and Vidal-Bover, 2022; Lopez-Valcarcel and Lopez-Casasnovas, 2022), rather than on how the occurrence of these disasters shapes the internal organisation of government (e.g., Tselios 2021; Cadaval et al., 2022). Moreover, this paper contributes to the literature by focusing on the dynamic linkages between shocks related to natural disasters and pandemics/epidemics and decentralisation through the computation of impulse response functions (Jordà, 2005; Auerbach and Gorodnichenko, 2012 and 2013; Romer and Romer, 2019), rather than by estimating long-term equilibrium relationships based on cross-country panel regressors, as in Tselios (2021) and Cadaval et al. (2022).

In this paper, emphasis is placed 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), and the chronology of pandemics/epidemics available from Ma et al. (2020). 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 and Jalles, 2020 and 2022), as well as on indicators of subnational policy autonomy, such the Regional Authority Index (RAI) computed by Hooghe et al. (2010 and 2016) and subsequently updated by

Schakel et al. (2018). These indicators are widely used in the literature on decentralisation and natural disasters (e.g., Tselios, 2021; Cadaval et al., 2022; Rodríguez-Pose and Vidal-Bover, 2022; Lopez-Valcarcel and Lopez-Casasnovas, 2022).

The main findings of the empirical analysis are as follows. First, empirical evidence based on impulse responses shows that the occurrence of natural disasters is associated with an increase in the subnational shares of government spending in the years following these shocks, especially for droughts, in both advanced economies and developing countries. In the case of pandemics/epidemics, there tends to be an increase in the subnational spending share in the group of developing countries. The impulse responses are defined less precisely for revenue, especially among the advanced economies. Climate change vulnerabilities and pandemics/pandemics are also associated with greater regional policy autonomy in both advanced economies and developing countries. These findings indeed underscore the role of the 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, these decentralisation effects vary not only according to shocks, but they are also conditional on the business cycle. In particular, shocks 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 by 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 but, interestingly, in the case of pandemics/epidemics the opposite appear to be the case in the developing countries, where shocks of this type tend to be followed by some decentralisation (decentralisation) of revenue

and spending during recessions (cyclical upswings). These conditional effects are likely due to the fact that 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 (excessive subnational revenue autonomy), 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 shock.

The paper is structured as follows. Section 2 reviews the empirical literature with emphasis on cross-countries studies on the association between the internal structure of government, on the one hand, and the occurrence of natural disasters and the outbreak of pandemics/epidemics, 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, comparing and contrasting 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.

II. Insights from the Literature

There is a growing empirical literature on the association between natural hazard-associated 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, but the results are not robust to the different aspects of decentralisation considered in the Regional Authority Index computed by Hooghe et al. (2010 and 2016), which is the main indicator of decentralised used in the 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 the materialisation of natural disaster hazards 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 et al. (2022) 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 to multilayered 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 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 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 these shocks in the future. This is not to say that decentralisation affects the distribution of natural disaster 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 materialisation of natural hazards 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 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 and 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 damage associated with these natural disasters may be greater, not lower, in more decentralised countries, despite lower human loss. 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 and 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 (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, this paper relates to the literature on the economic effects of pandemics and epidemics. Studies of the macroeconomic impact of past pandemics and of other major diseases (such as SARS and HIV/AIDs) have typically quantified the resulting short-term loss in output and growth.^{4 5} However, there is little consensus on the economic consequences of pandemics. Results critically depend on the models used and on the availability of data (Bell and Lewis, 2005). A study by Brainerd and Siegler (2003), one of the few on the economic effects of the

⁴ Even then, direct measures based on data from past episodes are not generally available (e.g. in the United States, see Meltzer et al., 1999). An alternative would be to look at microeconomic outcomes for a given population in response to episodes for which high-quality administrative data are available (e.g. in Sweden, see Karlsson et al., 2014). Absent such data, economic historians have to use more aggregated data at the regional or national level to study the relationship between the outbreak of epidemics and economic outcomes (e.g., the 1918 flu epidemic across the US states, see Brainerd and Siegler, 2003).

⁵ For a historic view of pandemics, see Kenny (2021).

Spanish flu, show that the 1918-19 pandemic actually increased growth in the United States during the 1920s. In contrast, Almond and Mazumber (2005) argued that the Spanish flu had long-term negative effects through its impact on foetal health. Using a theoretical model, Young (2004) argued that the AIDS epidemic in South Africa would increase net future per capita consumption, while Bell and Gersbach (2004) found strong negative effects. Jonung and Roeger (2006) estimated the macroeconomic effects of a pandemic using a quarterly macro-model constructed and calibrated for the EU-25 countries as a single economic entity.

More recent scholarly work has been motivated by the Covid-19 pandemic and provides evidence of large and persistent effects of the crisis on economic activity. This includes, for example, Atkeson (2020), Barro et al. (2020) and Eichenbaum et al. (2020). In fact, Ma et al. (2020) analyse the economic effects of past pandemics and find that real GDP is 2.6 percent lower on average across 210 countries in the year the outbreak is officially declared and remains 3 percent below its pre-shock level five years later. Moreover, according to Jordà et al. (2020), significant macroeconomic after-effects of pandemics persist for decades, with real rates of return to investment substantially depressed. Pandemics induce relative labour scarcity in some areas and/or a shift to greater precautionary savings. All in all, whereas the macroeconomic effects of pandemics have been studied, there is a clear lack of empirical analysis on the effects of pandemics on the internal structure of government, a gap that this paper contributes to filling.

As for the relationship between decentralisation and the outcomes of epidemics/pandemics, recent empirical evidence for the Covid-19 pandemic is inconclusive. The analysis carried out by Lopez-Valcarcel and Lopez-Casasnovas (2022) based on regional data takes into account cross-country differences in public health systems and shows that excess mortality has been lower in more decentralised settings. Nevertheless, the evidence reported by

Rodríguez-Pose and Vidal-Bover (2022), also using regional data, suggests that a mismatch between fiscal and political decentralisation, reflecting the ability of decentralised settings to fulfil policy mandates, rather than the extent of fiscal decentralisation itself, is associated with higher mortality from the pandemic. Moreover, the case studies reported in the volume edited by Steytler (2022) caution against excessively top-down approaches to respond to crises, such as that brought about by the Covid-19 pandemic. The case studies highlight the importance for effective crisis management of central government leadership in combination with active contributions by the subnational jurisdictions to reflect the diversity of situations and accountability mechanisms that exist in decentralised settings so that informed and legitimate intergovernmental decisions can be made in a cooperative manner.

In all these cases, empirical analysis focuses on long-term equilibrium relationships, rather than the short-term dynamics, between the variables of interest. 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 may be 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 and Ter-Minassian, 2022).

Against this background, this paper contributes to the empirical cross-country literature in three main ways. First, it focuses on the causality running from natural disasters to decentralisation, as in Tselios (2021) and Cadaval et al. (2022), for which the literature offers limited guidance and evidence. Second, as in Cadaval et al. (2022), it fills a gap in the literature by looking at the occurrence of pandemics/epidemics in addition to natural disasters as the main shocks to which the resilience of economies and societies may be sought through policy action. Third, the paper emphasises the 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.

III. Estimating Strategy and Data

The main hypothesis to be tested is whether the occurrence of natural disasters and the outbreak of epidemics/pandemics are associated with the decentralisation of policymaking, administrative and political responsibilities to the subnational layers of government, while controlling for other co-variates. In order to estimate the response of fiscal decentralisation to major natural disasters and epidemics/pandemics, 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 the estimation of long-term equilibrium relationships between the variables of interest. Instead, the method focuses on dynamic responses such as, in our context, those based on the interactions between the occurrence of natural disasters and pandemic/epidemics,

on the one hand, and the rules and procedures governing intergovernmental fiscal relations, on the other.

The baseline specification is:

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

in which y is the dependent fiscal decentralisation variable of interest; β_k denotes the (cumulative) response of the variable of interest in each k year after the natural disasters and epidemic/pandemic event or shock (we use these concepts interchangeably); α_i, τ_i are country and time fixed effects, included to take account for cross-country heterogeneity and global factors (such as the world business cycle or oil price movements) and trends that can affect the evolution of the pandemic; $shocks_{i,t}$ denotes the natural disaster and epidemic/pandemic shocks; $X_{i,t}$ 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.

Equation (1) is estimated by OLS.⁶ Impulse response functions (IRFs) are then 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 also explore whether initial business cycle conditions at the time of occurrence of a natural disaster or outbreak of a pandemic/epidemic affect the interactions with fiscal

⁶ 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.

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 a fall in cyclical revenue and increases in unemployment benefits during downturns. These pressures influence the ability of government 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 this hypothesis, the impulse responses are allowed to vary according to a continuous function $F(z_{it})$, as follows:

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

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

in which z_{it} is an indicator of economic activity (proxied by real GDP growth or the output gap estimated via HP filter) normalized to have zero mean and unit variance.⁷ The coefficients β_L^k and β_H^k capture, for instance, the decentralisation impact of natural disasters or pandemics/ epidemics at each horizon k in cases of recessions ($F(z_{it}) \approx 1$ when z goes to minus infinity) and expansions ($1 - F(z_{it}) \approx 1$ when z goes to plus infinity), respectively. We chose $\gamma = 1.5$.⁸

As discussed in Auerbach and Gorodnichenko (2012, 2013), the local projection approach to estimating non-linear effects is equivalent to the smooth transition autoregressive (STAR) model developed by Granger and Teräsvirta (1993). The advantage of this approach is

⁷ The weights assigned to each regime vary between 0 and 1 according to the weighting function $F(\cdot)$, so that $F(z_{it})$ can be interpreted as the probability of being in a given economic space state, recession or boom.

⁸ Our results hardly change when using alternative values of the parameter γ , between 1 and 4.

twofold. First, compared with a model in which each dependent variable is interacted with a measure of the business cycle position, it permits a direct test of whether the effect of natural disasters or pandemics/epidemics on decentralisation varies across different regimes, such as recessions and cyclical expansions. Second, compared with estimating structural vector autoregressions for each regime, it allows the effect of natural disasters or pandemics/epidemics to change smoothly between recessions and cyclical expansions by considering a continuum of states to compute the impulse response functions, thus making the response 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 decentralization data from 1990-2019. An alternative indicator used in the analysis, the Regional Authority Index (RAI) computed by Hooghe et al. (2010 and 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.

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

often 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 entered into EM-DAT 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/or 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, as in Tselios and Tompkins (2020).

The EM-DAT dataset also contains information of 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.

The other key regressor in the study, the pandemic/epidemic event or shock, is taken from the dataset of pandemics/epidemics constructed by Ma et al. (2020). This dataset starts in 2000 and covers SARS in 2003, H1N1 in 2009, MERS in 2012, Ebola in 2014 and Zika in 2016. Among the five events, the most widespread one is H1N1 (Swine Flu Influenza). We constructed a dummy variable, the pandemic/epidemic event or shock, which takes the value 1 when the World Health Organisation declares a pandemic for the country and zero otherwise. The list of countries that are affected by each event is given in Table 1 below.

Table 1. List of Pandemic and Epidemic Episodes

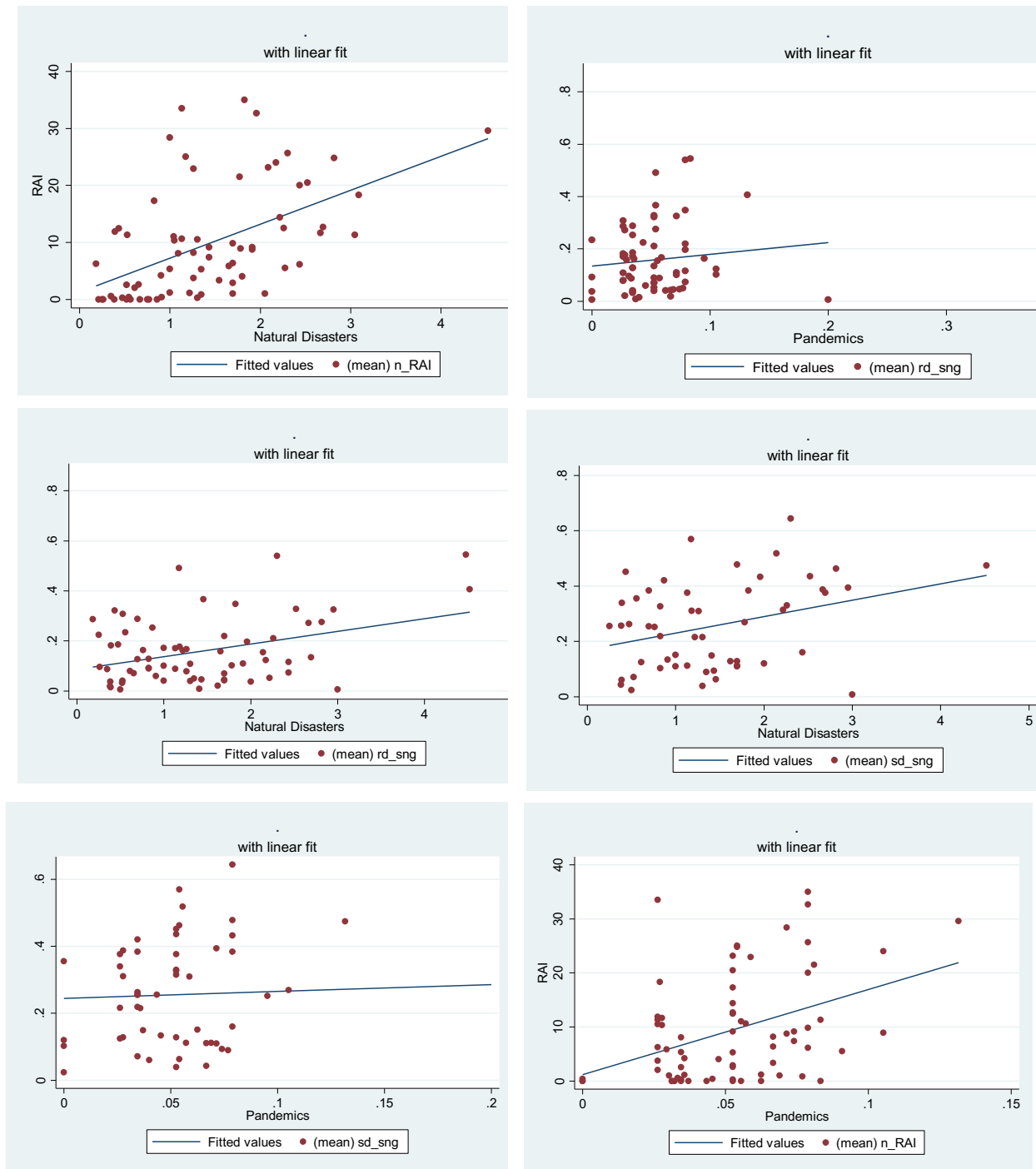
Starting year	Event Name	Affected Countries	Number of countries
2003	SARS	AUS, CAN, CHE, CHN, DEU, ESP, FRA, GBR, HKG, IDN, IND, IRL, ITA, KOR, MNG, MYS, NZL, PHL, ROU, RUS, SGP, SWE, THA, TWN, USA, VNM, ZAF	27
2009	N1H1	AFG, AGO, ALB, ARG, ARM, AUS, AUT, BDI, BEL, BGD, BGR, BHS, BIH, BLR, BLZ, BOL, BRA, BRB, BTN, BWA, CAN, CHE, CHL, CHN, CIV, CMR, COD, COG, COL, CPV, CRI, CYP, CZE, DEU, DJI, DMA, DNK, DOM, DZA, ECU, EGY, ESP, EST, ETH, FIN, FJI, FRA, FSM, GAB, GBR, GEO, GHA, GRC, GTM, HND, HRV, HTI, HUN, IDN, IND, IRL, IRN, IRQ, ISL, ISR, ITA, JAM, JOR, JPN, KAZ, KEN, KHM, KNA, KOR, LAO, LBN, LCA, LKA, LSO, LTU, LUX, LVA, MAR, MDA, MDG, MDV, MEX, MKD, MLI, MLT, MNE, MNG, MOZ, MUS, MWI, MYS, NAM, NGA, NIC, NLD, NOR, NPL, NZL, PAK, PAN, PER, PHL, PLW, PNG, POL, PRI, PRT, PRY, QAT, ROU, RUS, RWA, SAU, SDN, SGP, SLB, SLV, STP, SVK, SVN, SWE, SWZ, SYC, TCD, THA, TJK, TON, TUN, TUR, TUV, TZA, UGA, UKR, URY, USA, VEN, VNM, VUT, WSM, YEM, ZAF, ZMB, ZWE	148
2012	MERS	AUT, CHN, DEU, EGY, FRA, GBR, GRC, IRN, ITA, JOR, KOR, LBN, MYS, NLD, PHL, QAT, SAU, THA, TUN, TUR, USA, YEM	22
2014	Ebola	ESP, GBR, ITA, LBR, USA	5
2016	Zika	ARG, BOL, BRA, CAN, CHL, COL, CRI, DOM, ECU, HND, LCA, PAN, PER, PRI, PRY, SLV, URY, USA	18
Total Pandemic and Epidemic Events			220

Source: Based on Ma et al. (2020)

Preliminary inspection of the data indeed shows a correlation between decentralisation and occurrence of natural disasters. The countries that tend to concentrate the majority of disasters identified in EM-DAT, such as Brazil, Colombia, India, Indonesia, Peru and the United States, are 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, as well as between the outbreak of pandemics/epidemics and the three indicators of decentralisation.

Figure 1. Decentralisation and Natural Disasters



Note: The scatter plot shows unconditional correlations between the fiscal decentralisation measures and natural disasters occurrence (sum of all 8 shocks, collapsed); Source: Authors' calculations.

IV. Baseline Results and Robustness Analysis

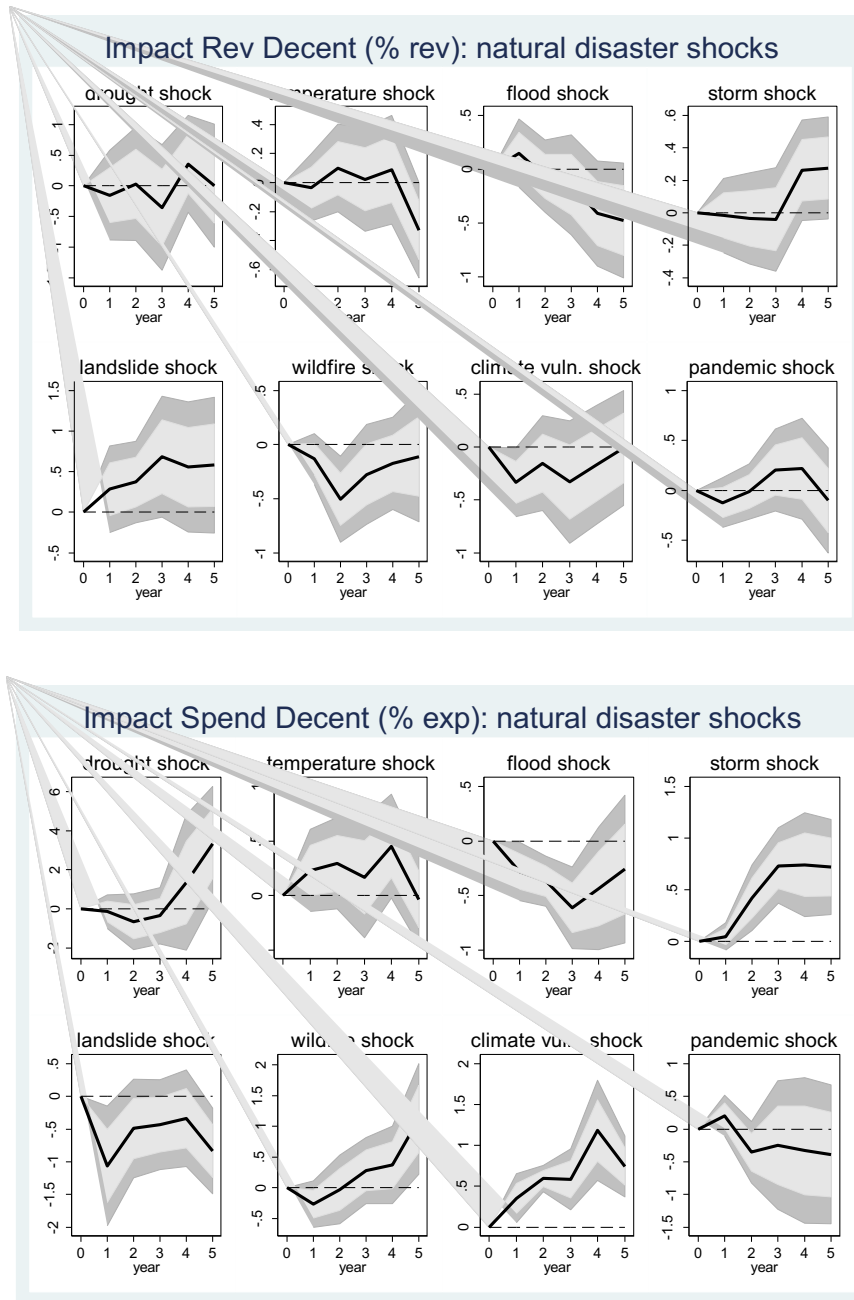
The starting point of the analysis is the estimation of baseline equations for the subnational shares of government spending and revenue, as well as the RAI indicator, which will underpin the computation of the impulse response functions. These baseline regressions are reported in Appendix Table 1 and include a set of standard co-variates based on the decentralisation literature (e.g., de Mello and 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. Overall climate vulnerability is also considered along with the outbreak of a pandemic/epidemic. 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 and the outbreak of a pandemic/epidemic are 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.

In particular, starting with the impulse responses for the subnational spending shares, for the group of advanced economies, the impulse responses show that the occurrence of wildfires, droughts and storms is associated with an increase in the subnational spending share within 5 years following the shock (**Figure 2**). The same applies to overall climate vulnerability, but no discernible effect is detected for the outbreak of a pandemic/epidemic. 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, overall climate vulnerability (albeit of short duration) and for the occurrence of a pandemic/epidemic. 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 on decentralisation of shocks related to natural disasters and pandemics/epidemics 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, climate vulnerabilities and pandemics/epidemics 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, extreme temperature events and pandemics/epidemics also have a sustained decentralising effects, whereas droughts and wildfires tend to have the opposite effect (Figure 5).

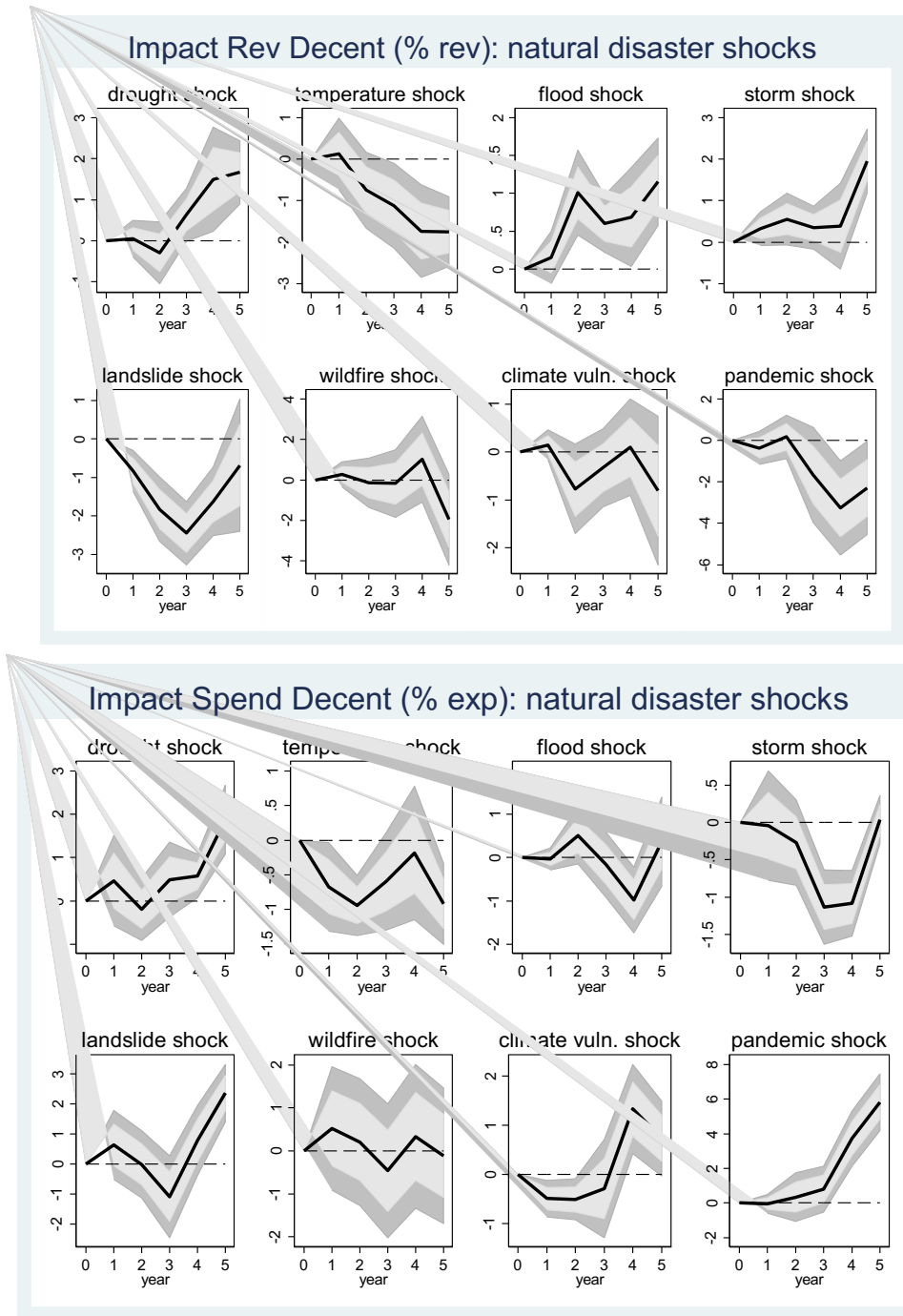
Figure 2. Revenue and Spending Decentralisation: Impulse Responses for the Advanced Economies



Note: Impulse responses of local projection estimates of the effect of natural disaster shocks on cumulative fiscal decentralisation proxies in $t = 1, \dots, 5$. 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 $t = 0$.

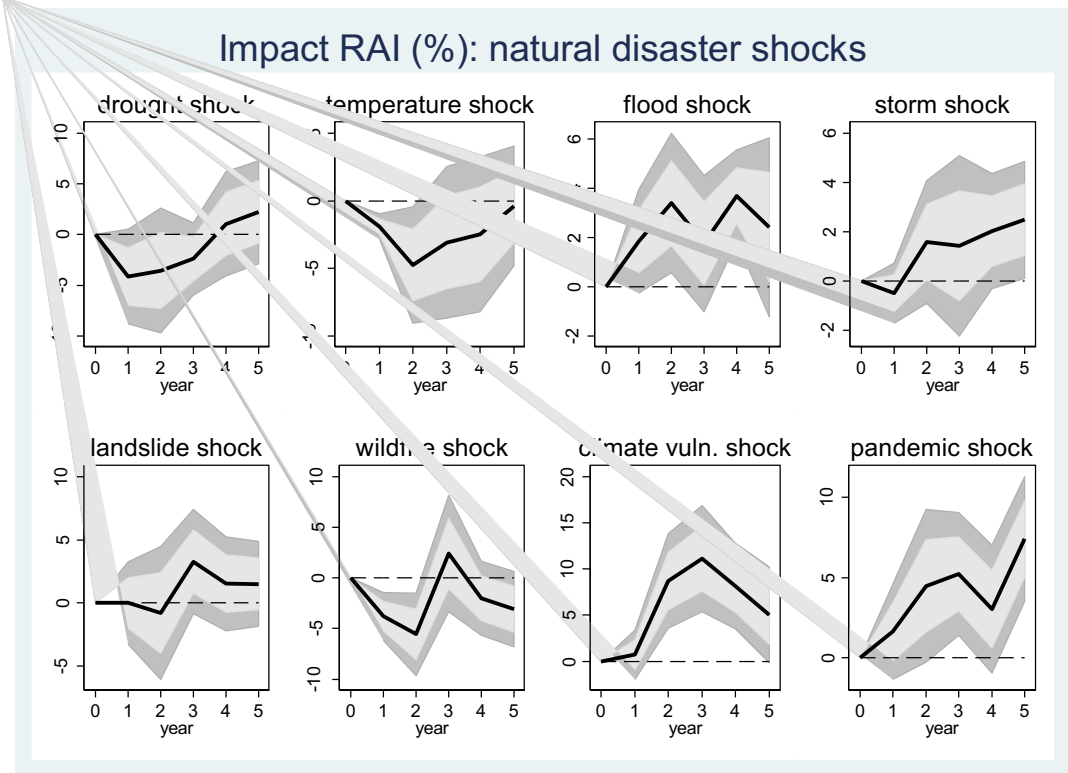
Source: Authors' calculations.

Figure 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.

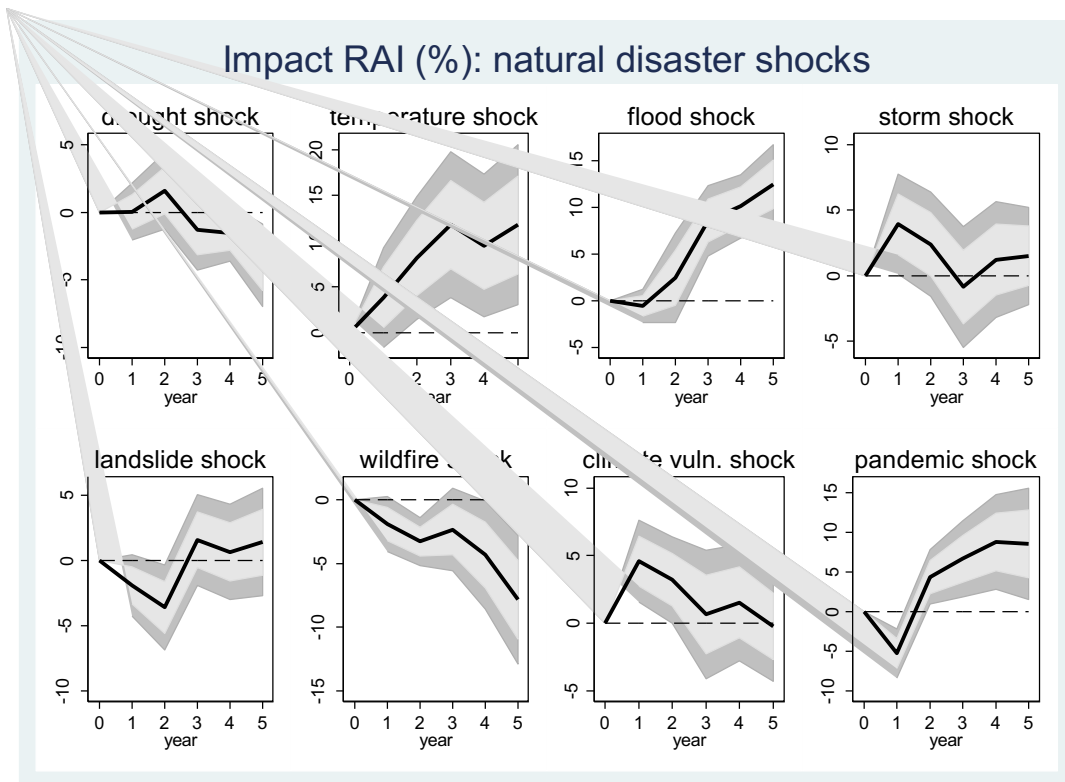
Figure 4. RAI: Impulse Responses for the Advanced Economies



Note: Impulse responses of local projection estimates of the effect of natural disaster shocks on cumulative fiscal decentralisation proxies in $t = 1, \dots, 5$. 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 5. RAI: Impulse Responses for the Developing Countries



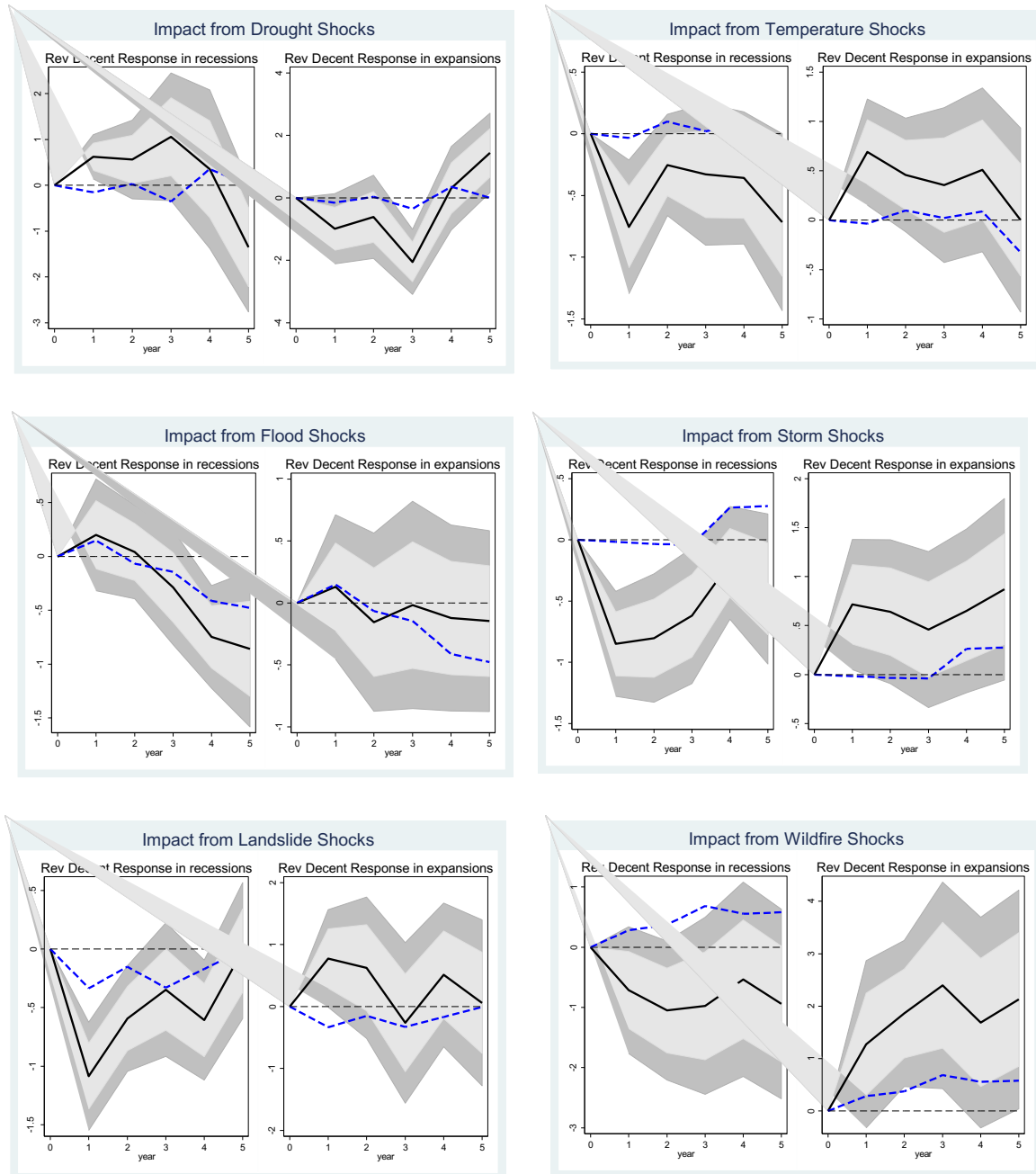
Note: Impulse responses of local projection estimates of the effect of natural disaster shocks on cumulative fiscal decentralisation proxies in $t = 1, \dots, 5$. The solid black lines plot the impulse responses based on Equation (1). So, the position of the line at $t = 5$ shows the accumulated impact 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.

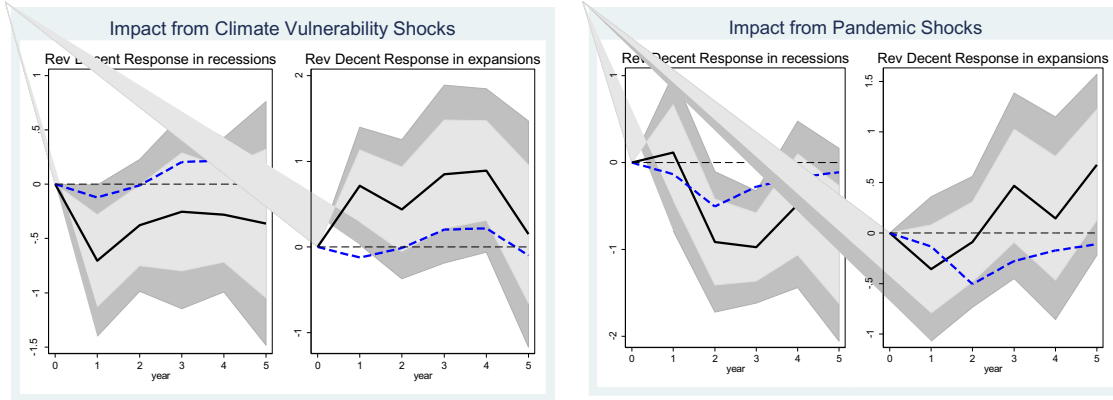
As for the conditional impulse responses, the analysis suggests that when a shock occurs during recessions (cyclical expansions), they tend to have a stronger revenue centralising (decentralising) effect in the advanced economies. This is the case for both revenue and spending decentralisation in the 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, even though interestingly the opposite is true for pandemics/epidemics,

where shocks appear to be followed by greater decentralisation of both revenue and spending during recessions and centralisation during cyclical expansions (Figures 8 and 9).⁹

Figure 6. Conditional Revenue Decentralisation Impulse Responses: The Role of the Business Cycle in the Advanced Economies

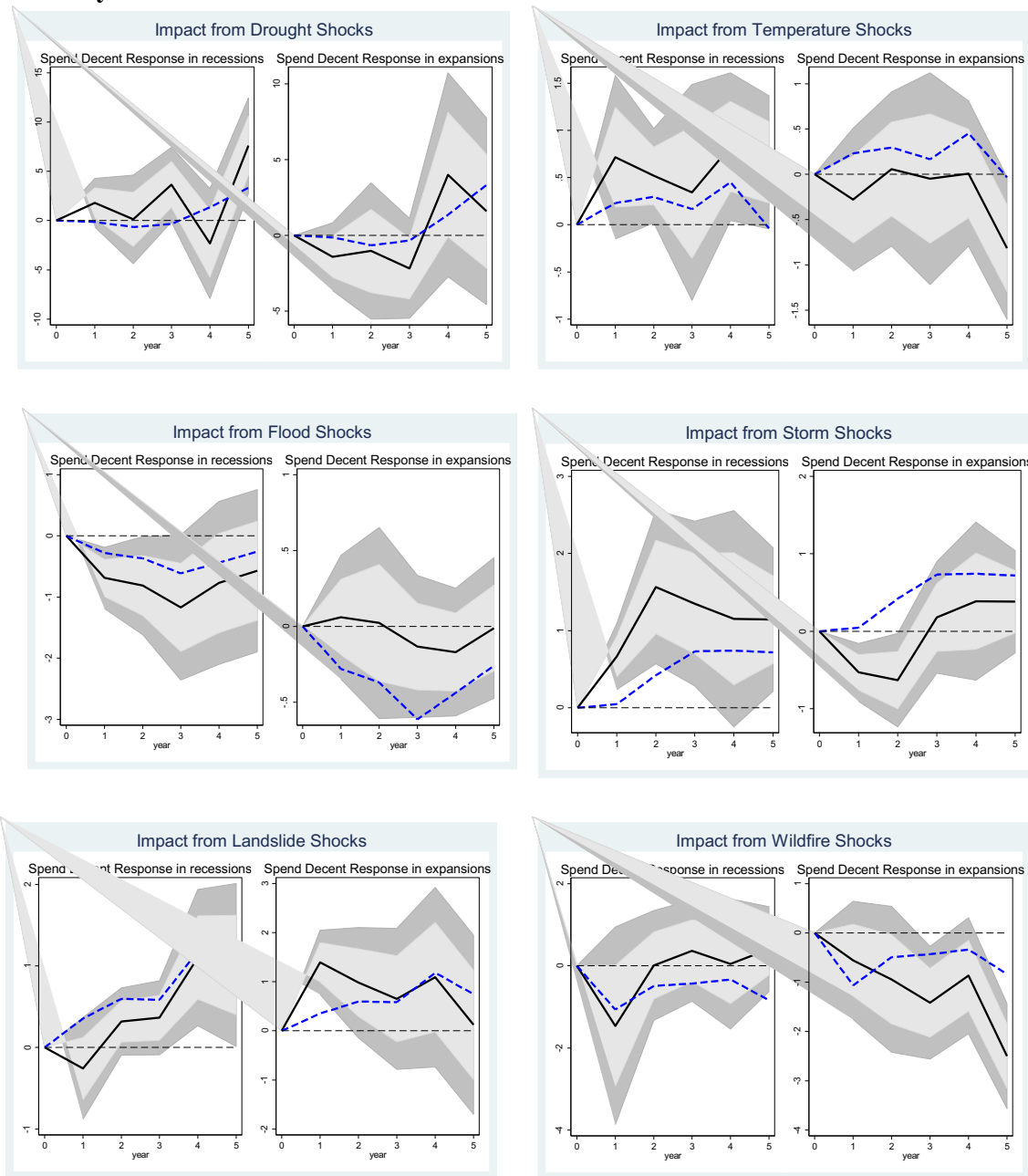


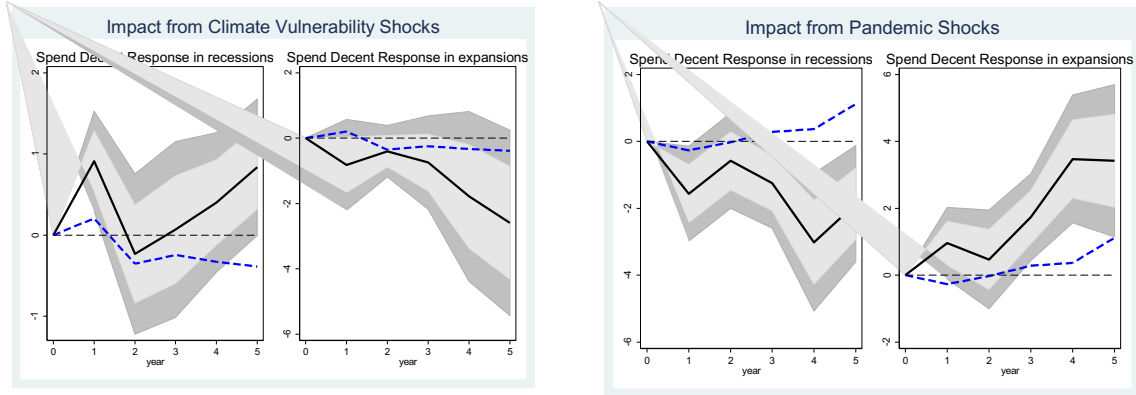
⁹ This exercise cannot be performed for the RAI indicator as the dependent variable due to a lack of degrees of freedom. The common set after merging the required dependent and independent variables is too small to allow for valid inferences.



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 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.

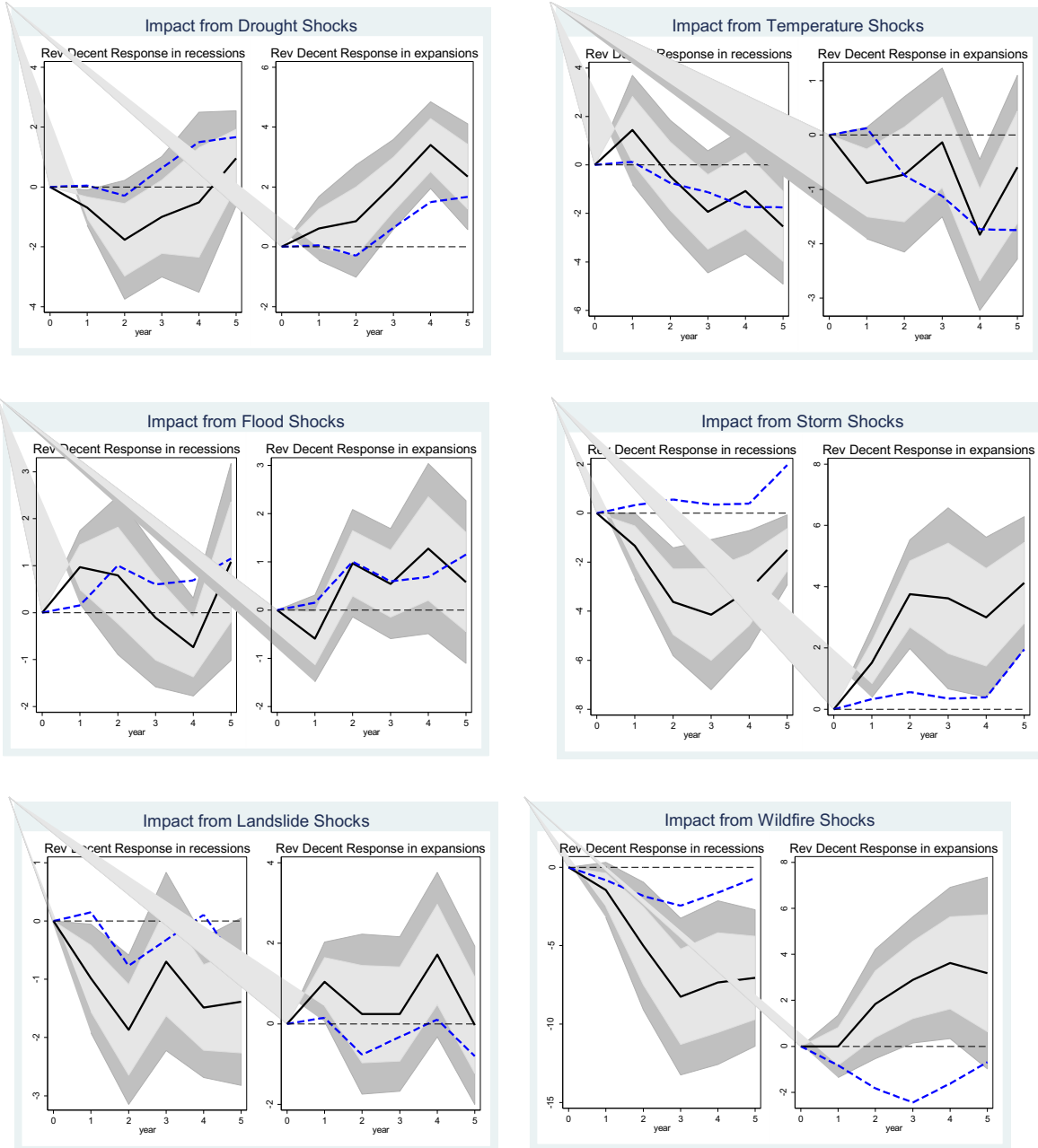
Figure 7. Conditional Spending Decentralisation Impulse Responses: The Role of the Business Cycle in the Advanced Economies

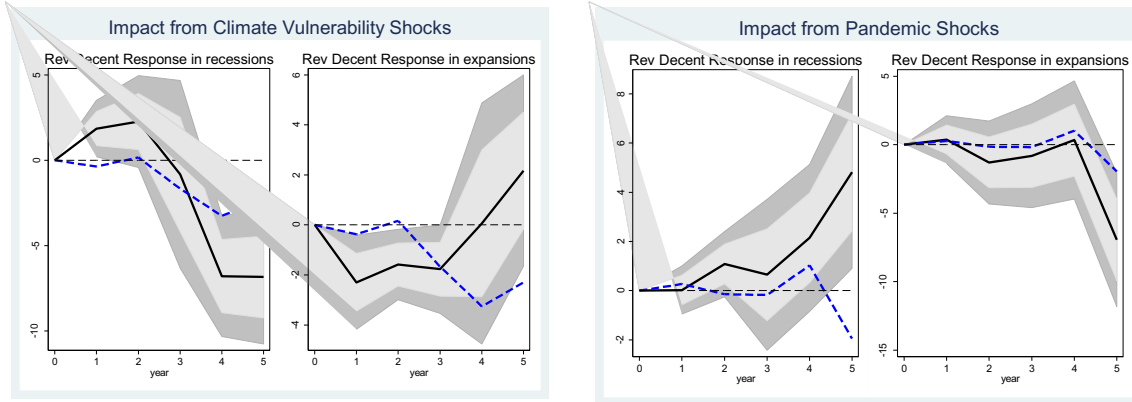




Note: Impulse responses of conditional local projection estimates of the effect of natural disaster shocks on cumulative fiscal decentralisation proxies in $t = 1, \dots, 5$. The solid black lines plot the impulse responses based on Equation (2). So, the position of the line at $t = 5$ shows the accumulated 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.

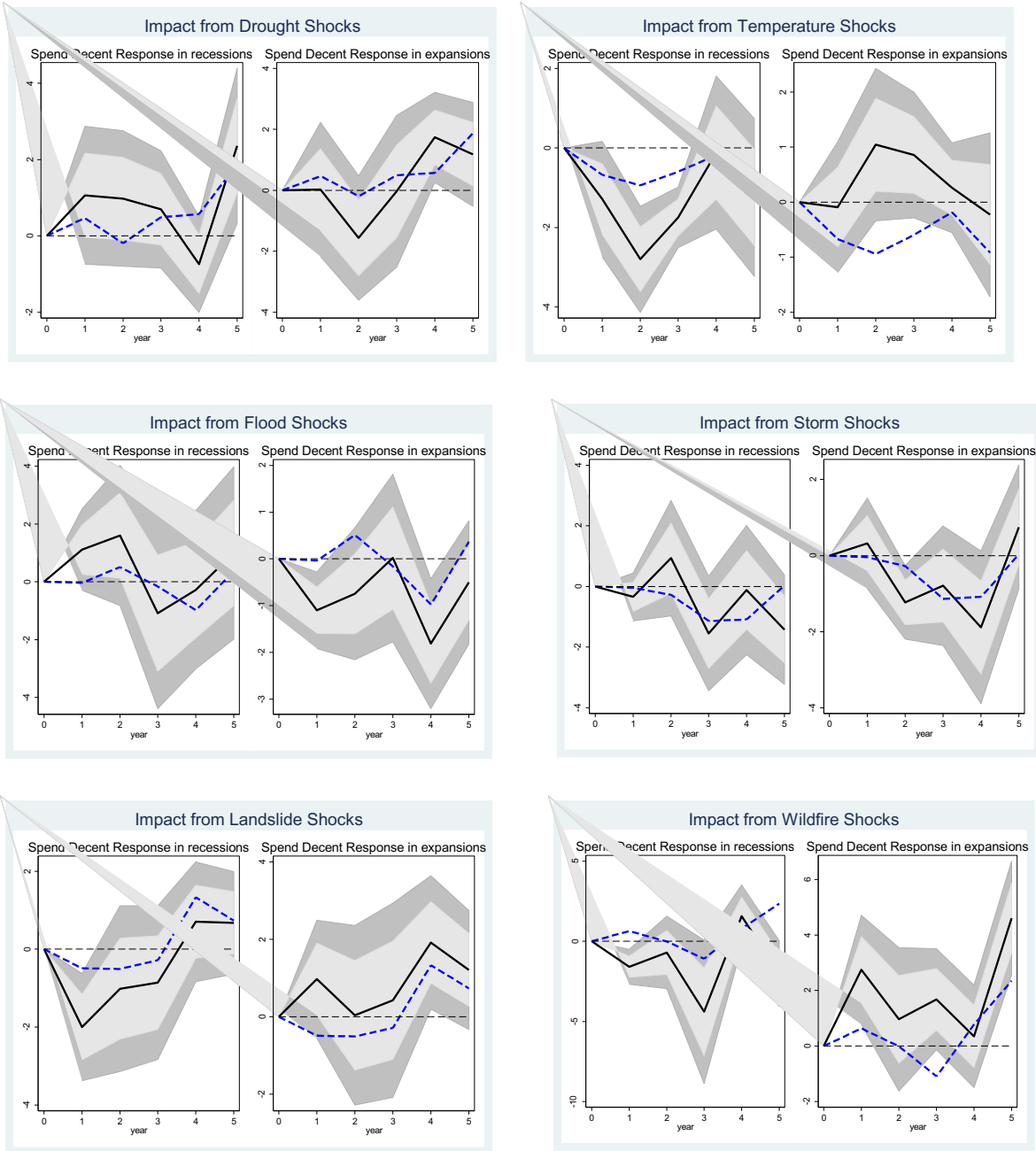
Figure 8. Conditional Revenue Decentralization Impulse Responses: The Role of the Business Cycle in Developing Countries

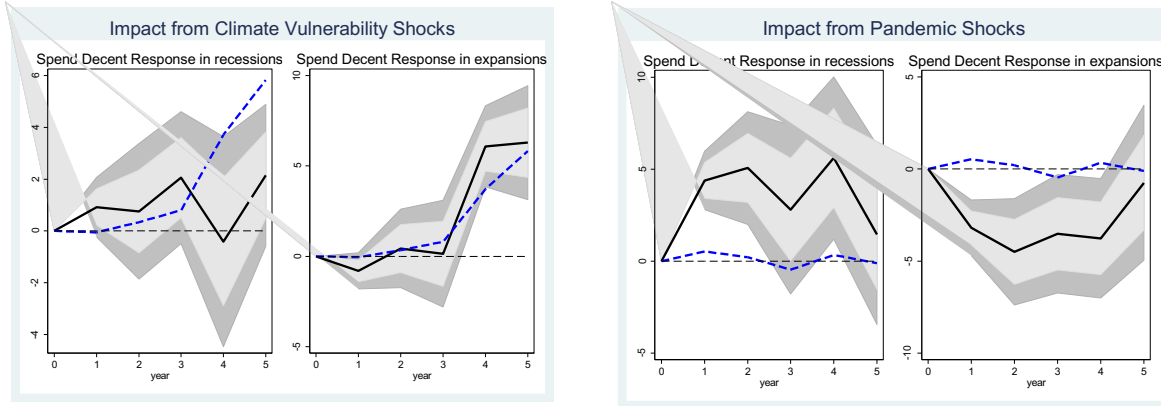




Note: Impulse responses of conditional local projection estimates of the effect of natural disaster shocks on cumulative fiscal decentralisation proxies in $t = 1, \dots, 5$. The solid black lines plot the impulse responses based on Equation (2). So, the position of the line at $t = 5$ shows the accumulated 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.

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 decentralization 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.

V. 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 and the outbreak of pandemics or epidemics, at least in the short-to-medium run. The 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.

Notwithstanding these considerations, the empirical analysis reported above 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 and pandemics/epidemics. Of course, in the short-to-medium run most of the 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 and good practices can be identified and shared.

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 and Ter-Minassian, 2022). In the case of pandemics and epidemics, national government support is often required for effective management of frontline health care services, as well as the procurement and deployment of drugs and medical equipment within a country's territory. 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 and Martinez-Vazquez, 2022). This is to the extent that climate change affects the distribution of natural disaster hazards and facilitates the outbreak of zoonotic diseases that can lead to pandemics/epidemics. Therefore, efforts to enhance the preparedness of the subnational governments to cope of natural disasters and pandemics/epidemics 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 and Jalles, 2022).

APPENDIX

Country list: United States, United Kingdom, Austria, Belgium, Germany, Italy, Netherlands, Norway, Switzerland, Canada, Japan, Finland, Iceland, Spain, Turkey, Australia, New Zealand, South Africa, Brazil, Chile, Colombia, Costa Rica, El Salvador, Honduras, Paraguay, Peru, Israel, Afghanistan, Korea, Republic of, Thailand, Mauritius, Tunisia, Armenia, Azerbaijan, Belarus, Georgia, Moldova, ,Russian Federation, China , Ukraine, Estonia, Latvia, Serbia , Hungary, Lithuania, Mongolia, Bosnia and Herzegovina

Appendix Table 1. Summary Statistics

Variable	Obs.	mean	St.Dev.	Min.	Max.
Resilience	4675	0.406	0.132	0.117	0.816
Vulnerability	4500	0.440	0.096	0.241	0.704
Pandemic shock	4514	0.048	0.215	0	1
Spending decentralization	909	0.293	0.168	0.001	0.816
Revenue decentralization	1317	0.184	0.150	0.002	0.892
RAI	1540	9.23	9.694	0	36.98
Shared rule	1540	1.81	3.306	0	15.007
Self Rule	1540	7.41	7.173	0	26.33
real GDP per capita	6490	4.01	2.620	-11.25	11.35
real GDP growth	6960	3.06	6.195	-102.29	91.61
inflation rate	6023	0.32	3.325	-0.493	108.962
public debt (% GDP)	2455	53.83	35.15	2.106	284.069
trade openness (% GDP)	6112	0.829	0.512	0.0002	4.426
terms of trade	5706	1.098	0.530	0.107	10.927
exchange rate stability (Chinn-Ito)	6829	0.638	0.329	0.001	1
labor force	3280	1.373	1.812	-3.590	6.692
Gini disposable income	4819	0.385	0.088	0.172	0.669
share of agriculture in GDP	5739	14.902	13.15	0.029	79.042

Appendix Table 2. Determinants of fiscal decentralisation

	Revenue Decentralisation	Spending Decentralisation	RAI
L.real GDP per capita	-7.8990*** (2.171)	-0.7364 (1.527)	0.7207*** (0.180)
L.real GDP growth	-0.1019** (0.042)	0.0637 (0.044)	0.0075* (0.004)
L.inflation rate	2.0482 (1.782)	7.8062*** (2.041)	-0.0435 (0.030)
L.public debt (% GDP)	-0.0244*** (0.008)	-0.0760*** (0.009)	0.0027*** (0.001)
L.trade openness (% GDP)	0.8412 (1.106)	-2.9350** (1.235)	0.4134*** (0.130)
L.terms of trade	2.4925** (1.100)	3.0925*** (1.138)	-0.0522* (0.030)
L.exchange rate stability (Chinn-Ito)	1.2161 (0.972)	0.0044 (1.102)	0.0229 (0.070)
L.labor force	1.6155 (2.196)	-4.2999 (2.909)	0.1047 (0.177)
L._Gini disposable income	17.6926** (8.349)	-15.5987* (9.497)	3.3722*** (1.019)
L.share of agriculture in GDP	0.8888*** (0.124)	0.9667*** (0.131)	0.0192** (0.008)
Observations	835	648	682
R-squared	0.9610	0.9739	0.9656

Notes: Fixed effects with Driscoll-Kraay (1998) errors estimation. Robust standard errors in parenthesis clustered at the country level. Constant term omitted for reasons of parsimony. Country and time fixed effects are included but omitted. "L" stands for one year lag. *, **, *** denote statistical significance at the 10, 5 and 1 percent significance levels, respectively.

Source: Authors' estimations

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