



Financial Crises and Climate Change

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Abstract

Climate change is a big challenge of our time. While there is a burgeoning literature on the economic impact of climate change, research on how financial crises affect climate change is limited. We empirically use the local projection method to empirically study the impact of past financial crises on climate change vulnerability and resilience indices. Using a dataset covering 178 countries over the period 1995–2019, we observe that resilience to climate change shocks has been increasing and that advanced economies are the least vulnerable. Our econometric results suggest that financial crises (particularly systematic banking ones) tend to lead to a short-run deterioration in a country's resilience to climate change. This effect is more pronounced in developing economies. In downturns, if an economy is hit by a financial crisis, vulnerability to climate change increases.

Keywords Climate change · Vulnerability · Resilience · Local projection method · Impulse response functions · Recessions · Financial crises

JEL Classification C23 · C83 · E30 · G10 · O30 · Q40

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Introduction

Climate change can be a big threat to the world economy.¹ The economic consequences of climate change are already being felt across the world, but the extent of potential vulnerability going forward depends on the size and composition of economies, the resilience of institutions and physical infrastructure, and the capacity for mitigation and adaption to climate change. It also depends on the idiosyncratic shocks each country is subjected to. The Global Financial Crisis (GFC), the Covid-19 pandemic, and the recent war in Ukraine (with some countries unilaterally going back to using energy sources based on non-renewable resources), reopened the debate on the compatibility between economic development and environmental protection but has also led to a wider discussion on the usefulness of environmental policies and actions within recovery packages.² The resulting fall in economic activity following these types of events³ typically leads to reductions in energy consumption and, thus, carbon dioxide—the major greenhouse gas—emissions.⁴

While there is a growing literature on the economic impact of climate change (Gallup et al. 1999; Nordhaus 2006; Dell et al. 2012), research on how crises affect climate change indicators is limited. For some authors, crises tend to lead to deferment and postponement of environmental projects and investments, as surviving the crisis becomes the aim, rather than becoming a “green” economy (see, e.g., Del Río and Labandeira 2009). Others advocate the opposite, i.e., that crises provide an opportunity for developing and investing in low-carbon technologies that, in turn, could provide a way out of the downturn (Greenpeace 2008). This paper aims to empirically test these two conflicting propositions and answer whether crises are environmentally friendly or not. A perusal of the literature reveals no such study conducted systematically for a wide sample of heterogeneous countries. We take advantage of a new dataset of climate change vulnerability and resilience developed by the Notre Dame Global Adaptation Institute (ND-GAIN). Others have also recently relied on this source of data to study many other aspects related to climate change (see Zenios 2022 for a sovereign debt and climate risk paper; similarly, Beirne et al. 2020 and Cevik and Jalles 2022 explore the sovereign debt-climate nexus from a bond yield perspective; more specifically, Namdar et al. (2021) pay a particular attention to the MENA region). Even though climate change is a slow-moving issue, its effects (on multiple fronts) can be felt structurally in the long term

¹ Climate change climate change describes environmental shifts in the distribution of weather outcomes toward extremes.

² Given the lockdown observed in many countries as consequence of the Covid-19 pandemic, polluting emissions have been falling, but many feel it will not fundamentally have a long-lasting impact on climate change. <https://www.bbc.com/future/article/20200326-covid-19-the-impact-of-coronavirus-on-the-environment>.

³ See e.g. Frenkel (2013) for a comparative analysis of financial crises in a set of eurozone countries and emerging market economies.

⁴ The assessment of the output-emissions decoupling hypothesis has been done by several authors (e.g. Kriström and Lundgren (2005) for Sweden; Ajmi et al. (2015) for G7 countries; Doda (2014) for 81 countries; Cohen et al. (2018) for the top 20 emitters). Others have focused on the validity testing of the so-called Environmental Kuznets Curve—see, e.g., Stern (2004) and Kaika and Zervas (2013a, b).



(typically evaluated using reduced form models based on classical growth theories) but also in the shorter term. For this reason, we relied on Jordà's (2005) local projection method to obtain impulse responses and track the shorter-to medium-term temporal dynamics which can be often forgotten in detriment of longer-term consequences. A large heterogeneous sample of 178 advanced and developing economies between 1995 and 2019 was used in the empirical analysis. Our contribution to the literature is threefold. First, no previous study has provided in a coherent and comprehensive fashion for such a large number of countries an empirical analysis of the effects of crises on climate change indicators. Second, when they did, they rather focused on a specific country or geographical region and confounded short- and long-run effects, while here we focus on the short- to medium-term dynamic effects. Third, we are the first to inspect if initial characteristics and conditions at the time the crisis hits matter for the climate change effect.

We find that financial crises (particularly systematic banking ones) tend to lead to a short-run deterioration in a country's resilience to climate change. This effect is more pronounced in emerging market economies. In downturns, if an economy is hit by a financial crisis, climate change vulnerability increases. Our results are robust to several sensitivity and robustness checks.

The remainder of this paper is organized as follows. Section "[Literature Review](#)" discusses the relevant literature. Section "[Data Overview](#)" describes the data used in the empirical analysis. Section "[Methodology](#)" introduces the salient features of our econometric strategy. Section "[Empirical Results](#)" presents the empirical results, including a series of robustness checks. Finally, the last section offers concluding remarks with policy implications.

Literature Review

There is a growing literature on the economic and financial effects of climate-related shifts in the physical environment.⁵ Starting with Nordhaus (1991, 1992) and Cline (1992), aggregate damage functions have become a mainstay of analyzing the climate-economy nexus. Although identifying the macroeconomic impact of annual variation in climatic conditions remains a challenging empirical task, Gallup et al. (1999), Nordhaus (2006), and Dell et al. (2012) find that higher temperatures result in a significant reduction in economic growth in developing countries. Burke et al. (2015) confirm this finding and conclude that an increase in temperature would have a greater damage in countries that are concentrated in geographical areas with hotter climates. Using expanded datasets, Acevedo et al. (2018), Burke and Tanutama (2019), and Kahn et al. (2019) show that the long-term macroeconomic impact of weather anomalies is uneven across countries and that economic growth responds nonlinearly to temperature. In a related vein, it is widely documented that climate change by increasing the frequency and severity of natural disasters affects economic development (Loayza et al. 2012; Noy 2009; Raddatz 2009; Skidmore and Toya

⁵ Tol (2018) provides a recent overview of this expanding literature.



2002; Rasmussen 2004), reduces the accumulation of human capital (Cuaresma 2010), and worsens a country's trade balance (Gassebner et al. 2006). More recently, Cevik and Miryugin (2022) looking at subnational non-financial firms for 24 developing countries, find that those firms operating in countries with greater vulnerability to climate change tend to experience difficulty in access to debt financing, while being less productive and profitable relative to firms in countries with lower vulnerability to climate change.

There is, however, close to no research on the relationship going from financial crises into climate change. The closest line of research concerns the impact of recessions on pollutant emissions. The major greenhouse gas—carbon dioxide—has been shown to move in tandem with the economy and to be strongly correlated with both GDP and energy consumption (Giedraitis et al. (2010) and Lane (2011)). The analysis of the 1870s and 1930s depressions by Giedraitis et al. (2010) and, more recently, by Stavtysky et al. (2016) supports the claim that economic crises are associated with lower CO₂ emissions. Inspecting the Asian Financial Crisis, Siddiqi (2000) alluded to some positive consequences stemming from it to the global environment. York (2012) demonstrated that the response of emissions to an increase in income was greater during good times than during bad times. Sobrino and Monzon (2014) assessed the environmental effects of the Global Financial Crisis in Spain and found that it led to a fall of transport activity and to higher road energy efficiency. Declercq et al. (2011), who investigated the impact of recessions on CO₂ emissions in the European power sector from 2008 to 2009, argued that the lower demand for electricity during recessionary times was the most important factor in mitigating CO₂ emissions.

Notwithstanding, these studies mix the short- and the long-term implications of financial crises for the environment. For some, despite short-term reductions in emissions in crisis years, economic crises are typically not good for the environment. The main argument is that recessions, by making access to capital more difficult, negatively affect emissions reduction efforts through their discouraging effects on investments (including investments in low-carbon technologies) (Del Río and Labandeira 2009). Both governments and the private sector focus on the recovery and on adapting their respective budgets, are shifted away from climate policies. As a result, crises lead to postponement of environmental projects as surviving the crisis becomes the goal, rather than transitional at that time to a “green” company or economy. Also, at a time of economic crisis, carbon lock-in is much more likely.⁶ Additionally, lower energy prices during crises, reduce the economic viability of cleaner technologies. Governments are likely to avoid burdening businesses with extra costs and regulation at a time when the economy is fragile and jobs may be at risk (Wooders and Runnals 2008). Such scenarios also assume a low political will to

⁶ Carbon lock-in refers to the difficulty to shift the economy and technological systems into a low-carbon path (Unruh 2000). Depressed aggregate demand, the fall in the prices of some goods, and lower economic capacity encourage the consumption of goods with a lower environmental quality (typically cheaper) and to an over-exploitation of resources with associated environmental degradation effects (Del Río and Labandeira 2009).



implement climate policy in the short term and a reduced incentive to participate in international agreements to tackle the issue in the longer term.

In contrast, another group of people advocate exactly the opposite that economic crises provide an opportunity for developing and investing in low-carbon technologies that, in turn, could provide a way out of the recession (Greenpeace 2008). According to this view, given the long lifetime of most energy infrastructures and technologies, the opportunities provided by crises to replace carbon-intensive technologies by cleaner alternatives should not be missed. For Papandreou (2015), crises can open up opportunities for new institutional pathways if the forces they unleash or the rebalancing of conflicting political and economic interests give rise to changes in existing norms and institutions.⁷ Crises throw existing institutions, governance structures, and theories that legitimize them into new critical light.⁸ Given the greater competition on scarce resources and short-term priorities for the use of those resources, crises should strengthen the case for a suitable design of climate policies which lead to cost-effective emissions reductions in an intertemporal perspective. Crises can be used to strengthen efforts to achieve low-carbon economic growth. OECD analysis (OECD 2009) shows that ambitious policy action to address climate change makes economic sense, and that delaying action could be costly. Crises offer an opportunity and an incentive to improve efficiency in the use of energy and materials, to move toward more sustainable manufacturing, and to develop new green businesses and industries. Crises can also be a spur to much needed structural reforms, where there is an opportunity for both economic and environmental gains. It provides an opportunity to reform or remove policies that may be expensive, inefficient, and environmentally harmful. Policy reforms will also improve the incentives for innovation, as they remove distortions in the market. Proponents of this view call for clear, long-term, and stable policy frameworks and more collaboration at the international level.

Data Overview

We use several sources to construct a panel dataset of annual observations covering 178 countries over the period 1995–2019. The main dependent variables are climate change vulnerability and resilience as measured by the ND-GAIN indices, which capture a country's overall susceptibility to climate-related disruptions and capacity to deal with the consequences of climate change, respectively.⁹ While climate change could in principle be measured by alternative proxies, we opted for this

⁷ Acemoglu and Robinson (2012) provide a sweeping account of the development of nations over millennia and how different crises, or historical contingencies were often turning points that could substantially alter the trajectory of a country, locking them into a virtuous cycle of prosperity, or sometimes having the opposite effect.

⁸ Geels (2013) frames the relationship between the financial crises and sustainability transitions within a multi-level perspective (see also Geels 2002; Van Bree et al. 2010).

⁹ The ND-GAIN database, covering 184 countries over the period 1995–2019, is available at <https://gain.nd.edu/>.



Table 1 Summary statistics

| Variable | Observations | Mean | SD | Minimum | Maximum |
|---------------------|--------------|-------|-------|---------|---------|
| Vulnerability | 4002 | 45.25 | 9.83 | 25.98 | 70.90 |
| Resilience | 3979 | 39.16 | 15.49 | 0.14 | 80.19 |
| Real GDP growth | 3934 | 3.76 | 5.74 | -45.73 | 90.81 |
| Crisis | 4002 | 0.039 | 0.19 | 0 | 1 |
| Banking crisis | 4002 | 0.016 | 0.13 | 0 | 1 |
| Currency crisis | 4002 | 0.20 | 0.14 | 0 | 1 |
| Debt crisis | 4002 | 0.005 | 0.08 | 0 | 1 |
| Debt restructurings | 4002 | 0.007 | 0.09 | 0 | 1 |

Table 2 Correlation matrix between climate change indices, growth, and crises

| | Vulnerability | Resilience | Real GDP growth | Crisis |
|-----------------|---------------|------------|-----------------|--------|
| Vulnerability | 1.00 | | | |
| Resilience | -0.71 | 1.00 | | |
| Real GDP growth | 0.09 | -0.10 | 1.00 | |
| Crisis | -0.04 | -0.03 | -0.10 | 1.00 |

source since, as mentioned by the data creators, “the ND-GAIN index is a measurement tool that helps governments, businesses and communities examine risks exacerbated by climate change, such as over-crowding, food insecurity, inadequate infrastructure, and civil conflicts. Free and open source, the Country Index uses 20 years of data across 45 indicators to rank over 180 countries annually based on their level of vulnerability, and their readiness to successfully implement adaptation solutions.” For these reasons, we relied on this source to maximize coverage, time span, and relevant climate change dimensions.

The composite indices are based on 45 indicators, of which 36 variables contributing to the vulnerability score and 9 variables constituting the resilience score. Tables 4 and 5 in Appendix come from the NG-GAIN technical document and list all the 45 indicators used to construct their indices. Vulnerability 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. However, since the ND-GAIN climate vulnerability index tends to be correlated with macroeconomic variables, such as real GDP per capita, we use a version of the index adjusted for the level of income. This GDP-adjusted climate vulnerability index is calculated by subtracting a country’s measured climate vulnerability from its expected value based on the regression of climate vulnerability and real GDP. As a result, the correlation between the GDP-adjusted climate vulnerability index and real GDP per capita becomes statistically insignificant. The ND-GAIN climate resilience index, on the other hand, assesses “a country’s capacity to apply economic investments and convert them to adaptation



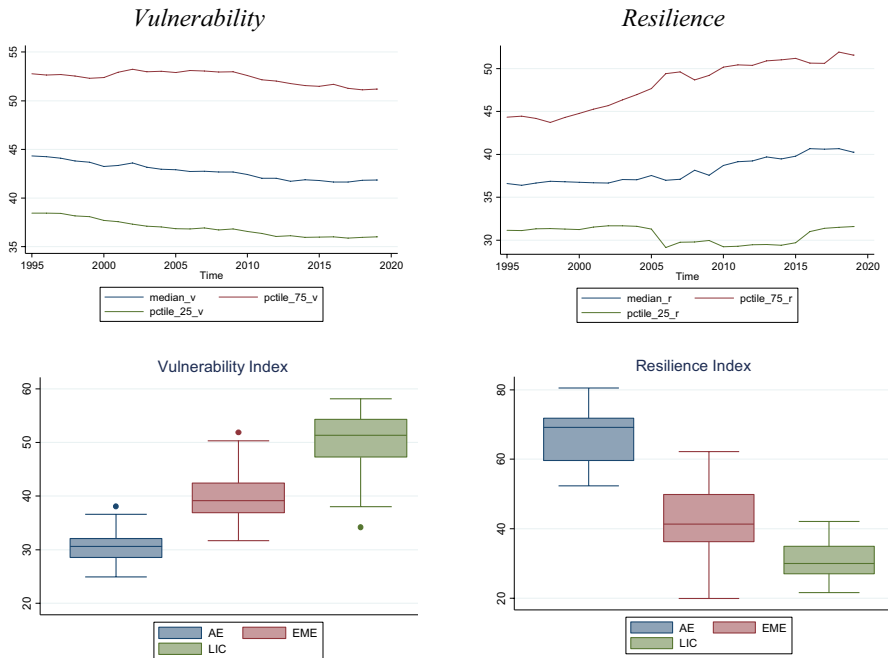


Fig. 1 Climate change vulnerability and resilience. *Note:* top panel: “median_v”= median of the vulnerability index; “pctile_75_v” = top 75th of the vulnerability index distribution; “pctile_25_v” = bottom 25th percentile of the vulnerability index distribution. Mutatis mutandis for the resilience index. bottom panel: *AE* Advanced Economies, *EME* Emerging Market Economies, *LIC* Low-Income Countries. *Source:* ND-GAIN; authors’ calculations

actions” and covers three areas—economic, governance, and social readiness—with nine indicators.¹⁰ Although we also use the GDP-adjusted climate resilience index, it is important to acknowledge that the ND-GAIN climate resilience index incorporates governance and social indicators that are not directly related to climate change. Therefore, we present estimations including the resilience index as a point of reference in the empirical analysis, not for causal inference.

Figure 1 shows the time profile between 1995 and 2019 and box-whisker plots for both the climate change vulnerability and resilience indices for the entire sample and by income group, respectively.¹¹ Although the ND-GAIN indices show improvements in climate change vulnerability and resilience in recent years, there is significant heterogeneity across countries. For example, while the mean value of climate change resilience is 40.7, it varies between a minimum of 11.8 and a maximum of 81.6. It is also clear from the data that advanced economies (AE) are much less vulnerable to climate change than developing countries (emerging

¹⁰ The ND-GAIN database refers to this series as “readiness” for climate change, which we use as a measure of resilience against climate change.

¹¹ Income group classification comes from the International Monetary Fund and World Bank.



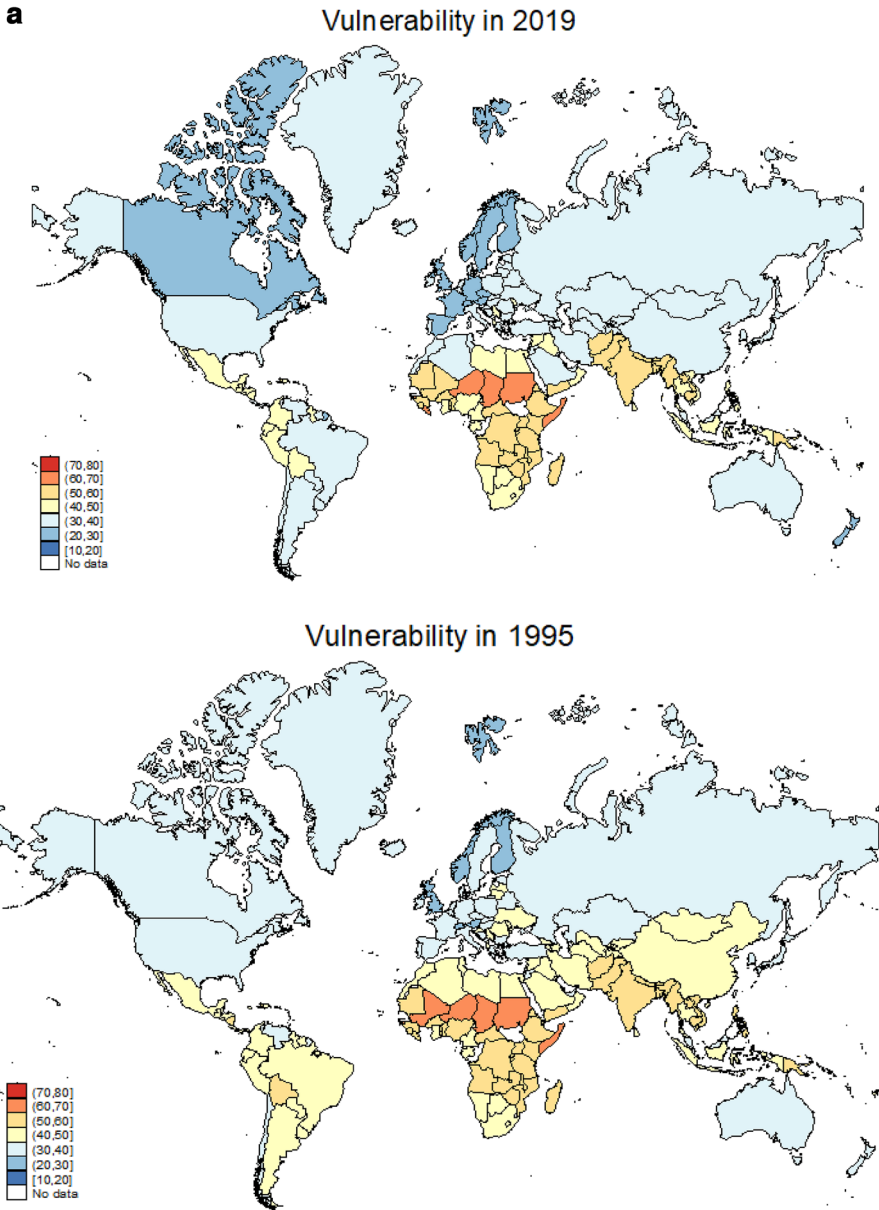


Fig. 2 a Climate change vulnerability across the world in 1995 versus 2019. *Note:* color scheme for less (blue) to more vulnerable to climate change (red). *Source:* ND-GAIN; authors' calculations. **b** Climate change resilience across the world in 1995 versus 2019. *Note:* color scheme for less (red) to more resilient to climate change (blue). *Source:* ND-GAIN; authors' calculations. (Color figure online)



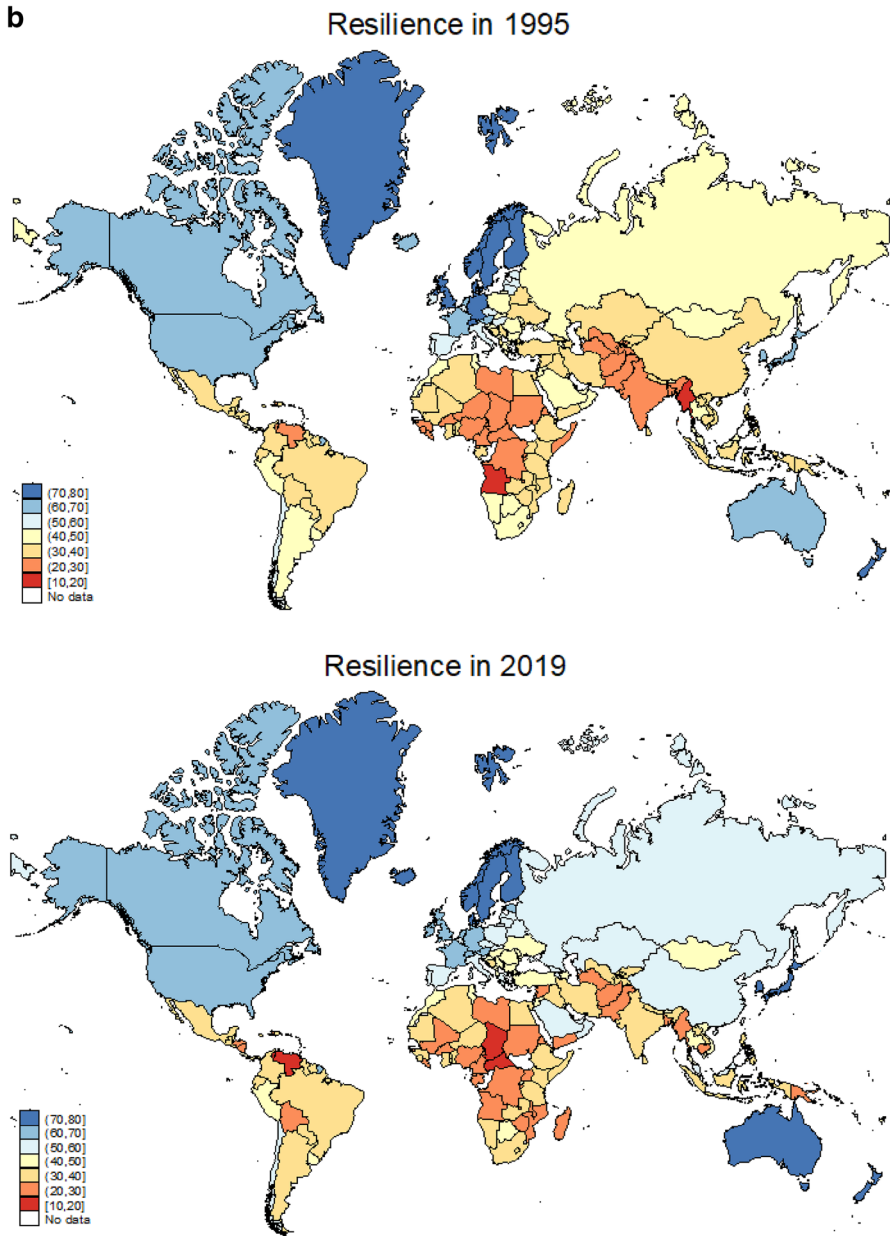


Fig. 2 (continued)

market economies (EME) and low-income countries (LIC)). It is important to highlight that the time-series variation in the ND-GAIN indices reflects the changes in countries' levels of vulnerability and resilience (which are not



necessarily forward-looking), not from the changes in the projected vulnerability and resilience to physical risks associated with climate change.

Aggregate pictures, however, hide marked heterogeneity across countries. Figure 2a compares climate change vulnerability in 1995 with that in 2019. We can see that Canada, Australia, some parts of South America, and Asia improved the situation, while Sub-Saharan Africa remained relatively unchanged over the past two decades. In Fig. 2b, we do the same for climate change resilience. We observe a slight deterioration in the case of the USA and in some countries in Sub-Saharan Africa, but improvements in Europe, Russia, and other parts of Southeast Asia as well as South America.

Financial crises come from Leaven and Valencia's (2018) database which was recently updated, and which is publicly available. These include precise dating for (systemic) banking crises, currency crises, debt crises and sovereign debt restructurings. These differ from economic crises as the latter typically refer to recessions measured in terms of two consecutive quarters of negative real GDP growth. Real GDP is retrieved from the IMF's World Economic Outlook database. Summary statistics and correlation matrix of the variables employed are shown in Tables 1 and 2.

Methodology

In order to estimate the response of climate change indicators variables to major financial crises shocks, we follow the local projection method proposed by Jordà (2005) to estimate impulse response functions. The baseline specification is:

$$y_{t+k,i} - y_{t-1,i} = \alpha_i + \tau_t + \beta_k FC_{i,t} + \theta' X_{i,t} + \varepsilon_{i,t} \quad (1)$$

in which y is the dependent trade variable of interest; β_k denotes the (cumulative) response of the variable of interest k years after the pandemic shock; α_i and τ_t are country and time fixed effects, respectively, included to take account for cross-country heterogeneity and global shocks; $FC_{i,t}$ denotes the financial crisis dummy from Laeven and Valencia (2018) which takes value 1 when a financial crisis took place and zero otherwise. $FC_{i,t}$ takes the value of 1 for the starting year of a given financial crisis and 0 otherwise (to improve the identification and minimize possible reverse causality issues);¹² $X_{i,t}$ is a set of controls including two lags of the dependent variable, two lags of the crisis variable, two lags of real GDP growth.¹³ $\varepsilon_{i,t}$ is an i.i.d. disturbance term satisfying standard assumptions of zero mean and constant variance. Equation (1) is estimated via ordinary least squares (OLS) for each $k=0, \dots, 7$ with Driscoll–Kraay (1998) robust standard errors clustered at the country level. This is a nonparametric technique that assumes the error structure to be heteroskedastic, autocorrelated up to some lag, and possibly correlated between the groups. Impulse response functions (IRFs) are computed using the estimated coefficients β_k , and the

¹² All financial crisis shocks featured in our analysis are assumed to be country-wide shocks.

¹³ The number of lags chosen is 2, but different lag lengths were tested.



confidence bands are obtained using the estimated standard errors of the coefficients β_k . While the presence of a lagged dependent variable and country fixed effects may in principle bias the estimation of β_k in small samples (Nickell 1981), the length of the time dimension mitigates this concern.¹⁴

This approach has been advocated by Auerbach and Gorodnichenko (2013) and Romer and Romer (2017) as a flexible alternative to vector autoregressions and/or distributed lag models.¹⁵ Given the panel data setting we have in the paper, we adopted the local projection method over commonly used VAR models for the following specific reasons. First, the way we are using the financial crises shocks are already orthogonalized to contemporaneous and expected future macroeconomic conditions. For this reason, we do not need to further identify financial crises shocks using restrictions in VAR models—a common approach in many empirical analyses in both domestic and international setups. Second, our estimation entails a large international panel dataset with a constellation of fixed effects, which makes a direct application of standard VAR models more difficult. In addition, the local projection method obviates the need to estimate the equations for dependent variables other than the variable of interest, thereby significantly economizing on the number of estimated parameters. Third, the local projection method is particularly suited to estimating nonlinearities (for example, how the effect of financial crises shocks differs during expansions and recessions in the source economy), as its application is much more straightforward compared to nonlinear structural VAR models, such as Markov-switching or threshold-VAR models.¹⁶ Moreover, it allows for incorporating various time-varying features of source (recipient) economies directly and allows for their endogenous response to financial crises shocks. Lastly, the error term in the following panel estimations is likely to be correlated across countries. This correlation would be difficult to address in the context of VAR models, but it is easy to handle in the local projection method by using the Driscoll–Kraay (1998) standard errors as we do.

York (2012) elaborated on the nonlinear effects of polluting emissions to an increase in income during economic expansions and contractions. For this reason, in a second specification, the dynamic response of climate change indicators to financial crises is allowed to vary with the state of the economy. More specifically, we explore whether initial economic conditions at the time of the financial crisis shock influence its effect on climate change outcomes. We implement this by allowing the response to vary as follows:

$$y_{i,t+k} - y_{i,t-1} = \alpha_i + \mu_t + \beta_k^L F(z_{i,t}) FC_{i,t} + \beta_k^H (1 - F(z_{i,t})) FC_{i,t} + \theta M_{i,t} + \epsilon_{i,t} \quad (2)$$

with

¹⁴ The finite sample bias is in the order of $1/T$, where T in our sample is 25.

¹⁵ Plagborg-Møller and Wolf (2021) further discuss the properties of local projections, as well as the relationship between these and VAR estimation of impulse responses.

¹⁶ See Choi et al. (2018) and Miyamoto et al. (2019) for the recent application of local projections to the estimation of nonlinearities and interaction effects of exogenous shocks using a large international panel dataset, as it is the case with our sample.



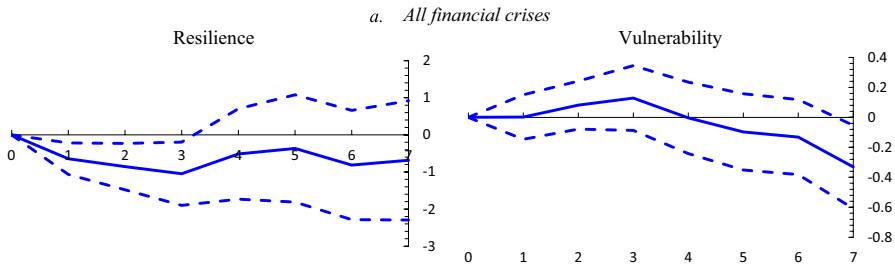


Fig. 3 Climate change responses to financial crises: baseline (in percent). *Note:* The impulse responses reflect cumulative changes (in percent) in response to a financial crisis shock over $h = 0, 1, 2, \dots, 7$ years. Blue continuous line denotes the impulse response from equation 1. Dotted blue lines are the 90% confidence bands using Driscoll–Kraay robust SE. $t=1$ is the first year of impact after a financial crisis. (Color figure online)

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

in which z_{it} is an indicator of the state of the economy normalized to have zero mean and unit variance. Despite substantial progress in methodologies to calculate potential output, there is still not a widely accepted approach (Borio et al. 2013). Mindful of the criticisms surrounding the use of the Hodrick-Prescott (HP) filter (see, e.g., Cogley and Nason 1995), the state of the economy is measured by the output gap computed via the more recent Hamilton (2018) filter.¹⁷ F_{it} is a smooth transition function used to estimate the climate change impact of financial crisis in expansions versus recessions. Auerbach and Gorodnichenko (2012) set $\gamma=1.5$. When $\gamma = 0$, we are in the linear case, while when γ takes very high values, the indicator resembles a usual dummy. Auerbach and Gorodnichenko (2013) calibrate γ so that the economy spends about 20% of time in recession. Results do not qualitatively change for alternative positive values of γ . M is the same set of control variables used in the baseline specification, but now including also two lags of $F(z_{i,t})$. Equation (2) is also estimated using OLS.

As discussed in Auerbach and Gorodnichenko (2012, 2013), the local projection approach to estimating nonlinear effects is equivalent to the smooth transition autoregressive (STAR) model developed by Granger and Teräsvirta (1993). The advantage of this approach is twofold. First, compared with a model in which each dependent variable would be interacted with a measure of the business cycle position, it permits a direct test of whether the effect of financial crises varies across different regimes such as recessions and expansions. Second, compared with estimating structural vector autoregressions for each regime, it allows the effect of financial

¹⁷ Hamilton (2018) points out some serious potential shortcomings with the HP filter in general, in particular that: (1) it produces spurious dynamics that are not based on the underlying data-generating process; (2) the dynamics at the ends of the sample differ from those in the middle; and (3) the standard implementation of the HP filter stands at stark odds from its statistical foundations. He concludes that you should never use the HP filter for any purpose. He proposes the use of linear projections as an alternative to derive deviations from trends.



Table 3 Climate change responses to financial crises: (a) resilience regression output, (b) vulnerability regression output

| Regressors/horizon | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|--------------------|------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|
| Dep.var. (t-1) | 0.102*** (0.0288) | 0.0813* (0.0497) | 0.0482 (0.0654) | 0.0401 (0.0801) | -0.7082 (0.0899) | -0.1982** (0.0793) | -0.2733*** (0.0755) |
| Dep.var. (t-1) | -0.0315 (0.0321) | -0.0471 (0.0478) | -0.0738 (0.0586) | -0.11668** (0.0733) | -0.2815*** (0.0651) | -0.3631*** (0.0615) | -0.4247*** (0.0706) |
| Shock_all | -0.0064** (0.0025) | -0.0085** (0.0038) | -0.1047** (0.0051) | -0.0051 (0.0074) | -0.0036 (0.0087) | -0.0081 (0.0089) | -0.0068 (0.0097) |
| Shock_all (t-1) | -0.0010 (0.0023) | -0.0023 (0.0042) | 0.0023 (0.0067) | 0.0042 (0.0084) | -0.0001 (0.0094) | -0.0002 (0.0105) | -0.0010 (0.0097) |
| Shock_all (t-2) | -0.0018 (0.0024) | 0.0017 (0.0049) | 0.0029 (0.0069) | -0.0006 (0.0082) | 0.0018 (0.0092) | 0.0023 (0.0087) | -0.0031 (0.0081) |
| Growth (t-1) | 0.0001 (0.0001) | 0.0004** (0.0002) | 0.0006*** (0.0002) | 0.0005* (0.0003) | 0.0006** (0.0003) | 0.0010*** (0.0004) | 0.0006* (0.0003) |
| Growth (t-2) | 0.0002** (0.0001) | 0.0004*** (0.0002) | 0.0003 (0.0002) | 0.0005 (0.0003) | 0.0007* (0.0004) | 0.0001 (0.0003) | 0.0002 (0.0003) |
| Obs | 3484 | 3307 | 3130 | 2953 | 2776 | 2600 | 2424 |
| R2 | 0.1221 | 0.1941 | 0.2648 | 0.3355 | 0.4010 | 0.4706 | 0.5411 |
| Dep.var. (t-1) | -0.1669*** (0.0479) | 0.0020** (0.0009) | 0.0011 (0.0013) | -0.0007 (0.0013) | -0.0013 (0.0013) | -0.0032** (0.0014) | -0.0015 (0.0014) |
| Dep.var. (t-1) | -0.0228 (0.0291) | -0.0003 (0.0011) | -0.0018 (0.0013) | -0.0026* (0.0013) | -0.0042*** (0.0014) | -0.0029** (0.0015) | -0.0035** (0.0016) |
| Shock_all | 0.0002 (0.0009) | 0.0008 (0.0009) | 0.0012 (0.0013) | -0.00003 (0.0014) | -0.0009 (0.0015) | -0.0013 (0.0015) | -0.0033* (0.0016) |
| Shock_all (t-1) | 0.0008 (0.0007) | -0.1719*** (0.0456) | -0.2462*** (0.0425) | -0.316*** (0.0441) | -0.3606*** (0.0386) | -0.4219*** (0.0407) | -0.1794*** (0.0404) |
| Shock_all (t-2) | 0.0012* (0.0007) | -0.1047*** (0.0259) | -0.1361*** (0.0325) | -0.2126*** (0.0337) | -0.2436*** (0.0366) | -0.3021*** (0.0389) | -0.3458*** (0.0426) |
| Growth (t-1) | 0.0000 (0.00003) | -0.00003 (0.00005) | -0.0001 (0.0001) | -0.0002** (0.0001) | -0.0002*** (0.0001) | -0.0003*** (0.0001) | -0.0003*** (0.0001) |



Table 3 (continued)

| Regressors/horizon | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|--------------------|-----------------------|-----------------------|-----------------------|------------------------|------------------------|----------------------|---------------------|
| Growth (t-2) | -0.00003 (0.00005) | -0.00012* (0.0001) | -0.0002** (0.0001) | -0.0002*** (0.0001) | -0.0003*** (0.0001) | -0.0002* (0.0001) | -0.0002 (0.0001) |
| Obs | 3425 | 3252 | 3079 | 2906 | 2733 | 2561 | 2389 |
| R2 | 0.1087 | 0.1806 | 0.2606 | 0.3462 | 0.4251 | 0.4969 | 0.5678 |

Driscoll-Kraay robust SE in parenthesis

*, **, ***, ***-statistical significance at the 10, 5, and 1% levels, respectively. Country and time fixed effects included but omitted. Constant term omitted



crisis shocks to change smoothly between recessions and expansions by considering a continuum of states to compute the impulse response functions, thus making the response more stable and precise.

Empirical Results

Figure 3 presents the results obtained by estimating equation (1). Table 3(a) and (b) shows—for completeness purposes—the estimation regression output for resilience and vulnerability indices, respectively, for each horizon plotted in Fig. 3. We observe that financial crises (irrespective of their type) tend to lead to a short-run deterioration in a country's resilience to climate change. The resilience index falls by around 1% three years after the financial crisis (that is, two standard deviations). This suggests that financial crises negatively affect the ability to do climate friendly investments and/or take actions toward productive capacity adaptation/conversion. The main rationale is that crises, by making access to capital more difficult, negatively affect climate change mitigation efforts through their discouraging effects on investments (including those in low-carbon technologies) (Del Río and Labandeira 2009). As both governments and the private sector focus on the recovery and on adapting their respective budgets, they shift priorities away from climate policies.¹⁸ The effect of crises on the vulnerability index is not statistically different from zero throughout the horizon considered.

Looking more closely at the aggregate indices' components yields the results in Figs. 9 and 10 in appendix for resilience and vulnerability, respectively. Following the list of areas presented in Tables 4 and 5 we focus on the economic, social, and government dimensions of resilience on the one hand and on the sectoral vulnerabilities on the other (namely, ecosystems, food, habitat, health, infrastructure, water). From Fig. 9 we see that the generally negative impact of financial crises on climate change resilience comes from strongly from the governance component (the other two yield statistically insignificant results). Turning the sectoral decomposition on the vulnerability index, Fig. 10 shows that while the general vulnerability result is insignificant two sectors seem to be positively affected by financial crises, namely ecosystems and food. In these cases, the short-term effect of crises is positive and significant reaching 0.4% and 1% for ecosystem and food, respectively, after 5 and 2 years, respectively (so the effect in the food sector is more short-lived). All other sectors mimic the most aggregate insignificant response.

In Fig. 4, we see that the negative impact on climate change resilience is driven particularly by the negative effect coming from systemic banking crises (and to a lesser extent, debt crises—panel b). This result is not entirely surprising as the dataset contains more banking crises than other types, which are typically less common. Financial crises affect the environment through reductions in effective demand, by

¹⁸ Our results do not support the findings of Sobrino and Monzon (2014) who looked at the environmental effects of the Global Financial Crisis in Spain and found that it has led to higher energy efficiency on the road sector.



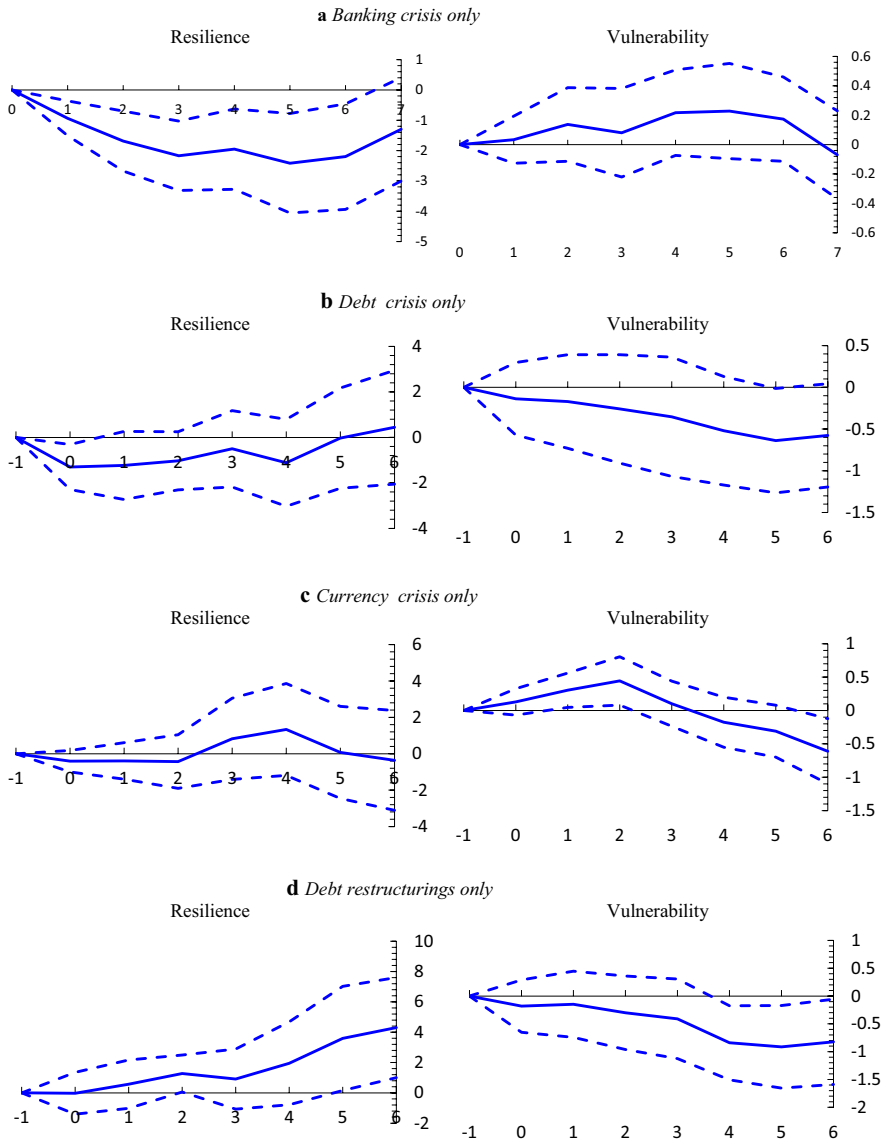


Fig. 4 Climate change responses to financial crises: baseline by type of crisis (in percent). *Note:* The impulse responses reflect cumulative changes (in percent) in response to a financial crisis shock over $h = 0, 1, 2, \dots, 7$ years. Blue continuous line denotes the impulse response from equation 1. Dotted blue lines are the 90% confidence bands using Driscoll–Kraay robust SE. $t = 1$ is the first year of impact after a financial crisis. (Color figure online)

forcing a switch to earlier technologies, and by encouraging the use of lower cost, more polluting fuels (Anger and Barker 2015). Banking crises make it harder to finance investment projects in general and green projects in particular. The causative links between the nature of the crisis—in this case banking crises—and the



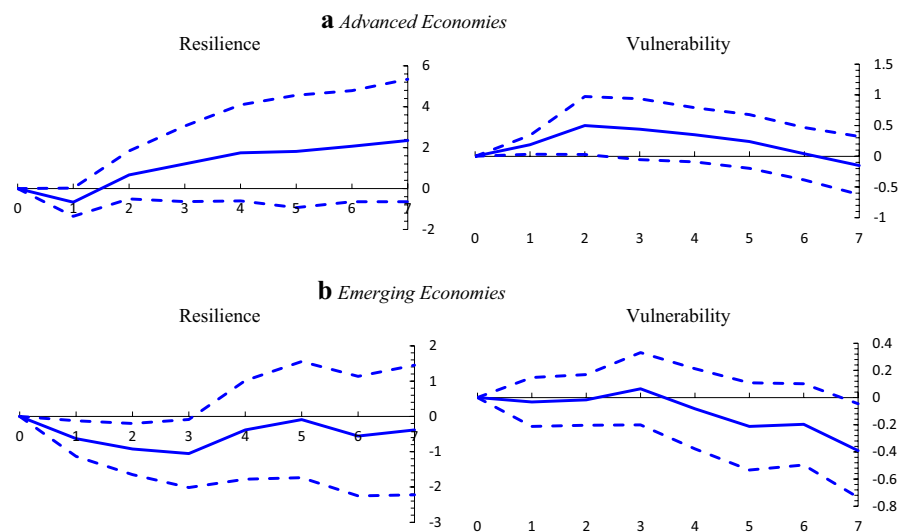


Fig. 5 Climate change responses to financial crises: advanced versus emerging economies (in percent). *Note:* The impulse responses reflect cumulative changes (in percent) in response to a financial crisis shock over $h = 0, 1, 2, \dots, 7$ years. Blue continuous line denotes the impulse response from equation 1. Dotted blue lines are the 90% confidence bands using Driscoll–Kraay robust SE. $t = 1$ is the first year of impact after a financial crisis. (Color figure online)

reduction in long-term GDP growth are done via reductions in the share of investment in GDP which calls for a greater need of green investment and green banking in encouraging environmentally friendly development pathways.

Splitting the sample between 34 advanced and 144 developing countries yields the IRFs in Fig. 5. We see that developing economies are those more negatively affected in their climate change resilience capacity by financial crises. In this group of countries, the stock of capital is typically smaller and, hence, their larger difficulties in adapting existing production structures to mitigate the adverse impacts of climate change. In advanced economies, climate change vulnerability increases in the very short run (up to two years after the crisis), but this effect quickly fades away. These countries are better prepared structurally and also enact more pro-green legislation as confirmed by the OECD’s Environmental Stringency Index with several climate change policies.¹⁹

In Fig. 6 we present the state-contingent results from estimating equation (2). In bad times, if an economy is hit by a financial crisis, climate change vulnerability increases, while resilience seems to be (statistically) unaffected. Depressed aggregate demand, the fall in the prices of some goods, and lower economic capacity may encourage the consumption of goods with an inferior environmental quality (and lower prices) and to an over-exploitation of resources with associated environmental

¹⁹ For a recent discussion on the political economy aspects of climate change policies in advanced economies see Furceri et al. (2021).



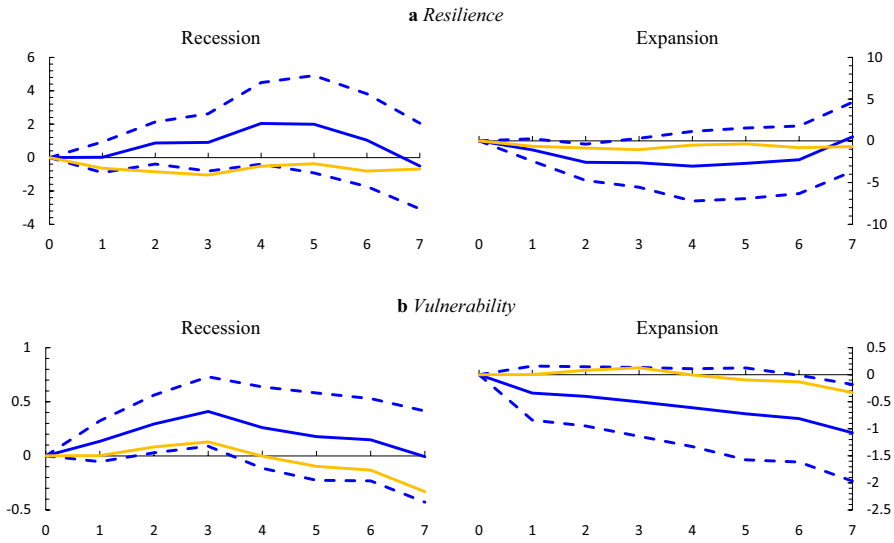


Fig. 6 Climate change responses to financial crises: the role of economic conditions (in percent). *Note:* The impulse responses reflect cumulative changes (in percent) in response to a financial crisis shock over $h = 0, 1, 2, \dots, 7$ years. Blue continuous line denotes the impulse response from equation 2. Dotted blue lines are the 90% confidence bands using Driscoll–Kraay robust SE. The yellow continuous line represents the unconditional baseline IRF from equation 1 (for comparison purposes). $t = 1$ is the first year of impact after a financial crisis. (Color figure online)

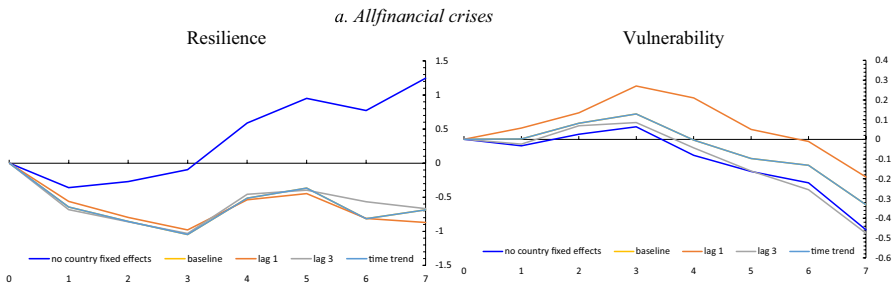


Fig. 7 Climate change responses to financial crises: robustness (in percent). *Note:* The impulse responses reflect cumulative changes (in percent) in response to a financial crisis shock over $h = 0, 1, 2, \dots, 7$ years. Blue continuous line denotes the impulse response from equation 1. Dotted blue lines are the 90% confidence bands using Driscoll–Kraay robust SE. $t = 1$ is the first year of impact after a financial crisis. (Color figure online)

degradation (Del Río and Labandeira 2009). Governments are also likely to avoid burdening business and industry with extra costs and regulation at a time when the economy is fragile and jobs may be at risk (Wooders and Runnals 2008).²⁰ In

²⁰ In fact, economic troubles ahead often prompt governments to loosen regulations. For instance, in the current Covid-19 pandemic, the US’ Environmental Protection Agency has cited the pandemic as justification for a decision to suspend enforcement of pollution rules. <https://www.nationalgeographic.com/science/2020/04/pollution-made-the-pandemic-worse-but-lockdowns-clean-the-sky/>.



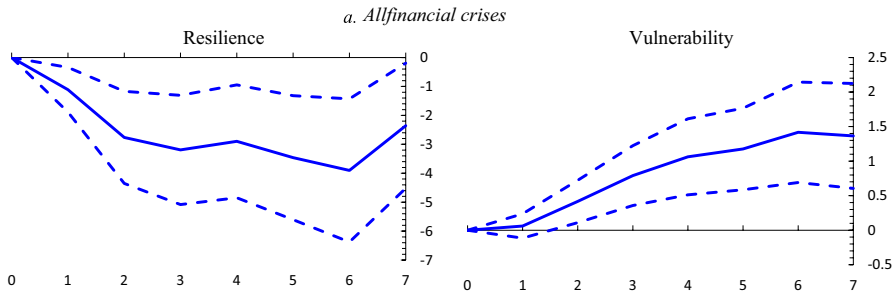


Fig. 8 Climate change responses to financial crises: instrumental variables (in percent). *Note:* The impulse responses reflect cumulative changes (in percent) in response to a financial crisis shock over $h = 0, 1, 2, \dots, 7$ years. Blue continuous line denotes the impulse response from equation 1. Dotted blue lines are the 90% confidence bands. $t = 1$ is the first year of impact after a financial crisis. (Color figure online)

recessionary times, carbon lock-in is also more likely as lower energy prices, reduce the economic viability for the development and operation of cleaner technologies. In good times, economies hit by a financial crisis see their vulnerability to climate change dropping continuously and persistently (becoming statistically significant in medium-run, that is, six years after the crisis).

We performed several sensitivity exercises.

A possible bias from estimating equation (1) using country fixed effects is that the error term may have a nonzero expected value, due to the interaction of fixed effects and country-specific developments (Teulings and Zubanov 2010). This would lead to a bias of the estimates that is a function of k . To address this issue, equation (1) was re-estimated by excluding country fixed effects from the analysis. Results shown in Fig. 7 suggest that this bias is negligible at least in the short term.

Second, equation (1) was re-estimated for different lags (1) of the control variables. Results for one and three lags (see Fig. 7) confirm that previous findings are not sensitive to the choice of the number of lags.

In addition, to try and estimate the causal impact of financial crises on climate change proxies, it is important to control for previous trends in dynamics of these climate indicators that could lead to crises. The baseline specification attempts to do this by controlling for up to two lags in the dependent variable. To further mitigate this concern, we re-estimate equation (1) by including country-specific time trends as additional control variables. Results shown in Fig. 7 keep the main thrust of our findings.

Finally, since the ND-GAIN climate vulnerability index contains many measures that are closely related to economic development, it could be empirically hard to separate economic conditions and this climate measure. This interrelationship can potentially lead to endogeneity in our model despite the fact that we are using a GDP-adjusted series. That said, we try to test this by re-running equation (1) using instrumental variables with instruments being the first two lags of the assumed



endogenous right-hand side variable (that is, the ND-GAIN indices).²¹ Results presented in Fig. 8 show that, if anything, the baseline coefficients show a lower-bound effect of crises on climate indicators as the IRFs are now more precisely estimated.

Conclusion and Policy Implications

Climate change has become an existential threat to the world, with complex, evolving, and nonlinear dynamics that remain a source of great uncertainty. There is a growing body of literature on the economic consequences of climate change, but research on the link between going from crises to climate change remains limited. This paper aims to fill this gap in the literature by focusing on the impact of financial crises on climate change composite indicators by focusing on a large sample of 178 countries between 1995 and 2019.

By means of local projections, we find that crises (particularly banking ones) tend to lead to a short-run fall in countries' resilience to climate change (driven greatly by developing economies). In recessionary periods, an economy hit by a financial crisis, should expect its vulnerability to climate change to rise. Results are reinforced if concerns about possible endogeneity of the crises shocks are taken into account.

The econometric evidence presented here has clear policy implications, especially for developing countries that are relatively more vulnerable to risks associated with climate change. Policy makers could see financial crises as opportunities to make big reductions in pollutant emissions that one can then lock-in, and ensure that energy pricing, investments, and other policies are conducive toward innovations that create low-carbon societies (through appropriate investments, either public, private, or mixed through PPPs). Although climate change is inevitable, the negative effect of crises on climate resilience shows that enhancing structural resilience through mitigation and adaptation (with appropriate structural reforms—see IMF (2019) for a discussion of these in the context of developing countries), strengthening financial resilience through macroprudential preventive regulation and insurance schemes and improving economic diversification and policy management can help cope with the consequences of climate change for economic development.

Appendix

Tables 4, 5 and Figs. 9, 10.

²¹ We acknowledge the possible limitation of using the first two lags of the NG-GAIN indices (as common practice in empirical macroeconomic exercises). In fact, thinking about the exclusion restriction, the chosen instrument should be correlated with the endogenous variable but with no direct influence on the dependent variable. Given the indices' somewhat temporal persistence, past values of the ND-GAIN indices will likely influence the current value of the dependent variables. We thank an anonymous referee for this point.



Table 4 ND-GAIN vulnerability indicators

| Sector | Exposure component | Sensitivity component | Adaptive capacity component |
|--------------------|--|---|---|
| Food | Projected change of cereal yields | Food import dependency | Agriculture capacity (fertilizer, irrigation, pesticide, tractor use) |
| Water | Projected population change | Rural population | Child malnutrition |
| | Projected change of annual runoff | Fresh water withdrawal rate | Access to reliable drinking water |
| | Projected change of annual groundwater recharge | Water dependency ratio | Dam capacity |
| Health | Projected change of deaths from climate change induced diseases | Slum population | Medical staffs (physicians, nurses and midwives) |
| Ecosystem services | Projected change of length of transmission season of vector-borne diseases | Dependency on external resource for health services | Access to improved sanitation facilities |
| | Projected change of biome distribution | Dependency on natural capital | Protected biomes |
| | Projected change of marine biodiversity | Ecological footprint | Engagement in international environmental conventions |
| Human habitat | Projected change of warm period | Urban concentration | Quality of trade and transport-related infrastructure |
| Infrastructure | Projected change of flood hazard | Age dependency ratio | Paved roads |
| | Projected change of hydropower generation capacity | Dependency on imported energy | Electricity access |
| | Projection of sea level rise impacts | Population living under 5 m above sea level | Disaster preparedness |

Source: ND-GAIN <https://gain.nd.edu/our-work/country-index/>



Table 5 ND-GAIN resilience indicators

| Component | Indicators | | | |
|----------------------|--------------------------------------|-----------------------|-------------|--------------------|
| Economic readiness | Doing business ² | | | |
| Governance readiness | Political stability and non-violence | Control of corruption | Rule of law | Regulatory quality |
| Social readiness | Social inequality | ICT infrastructure | Education | Innovation |

Source: ND-GAIN <https://gain.nd.edu/our-work/country-index/>

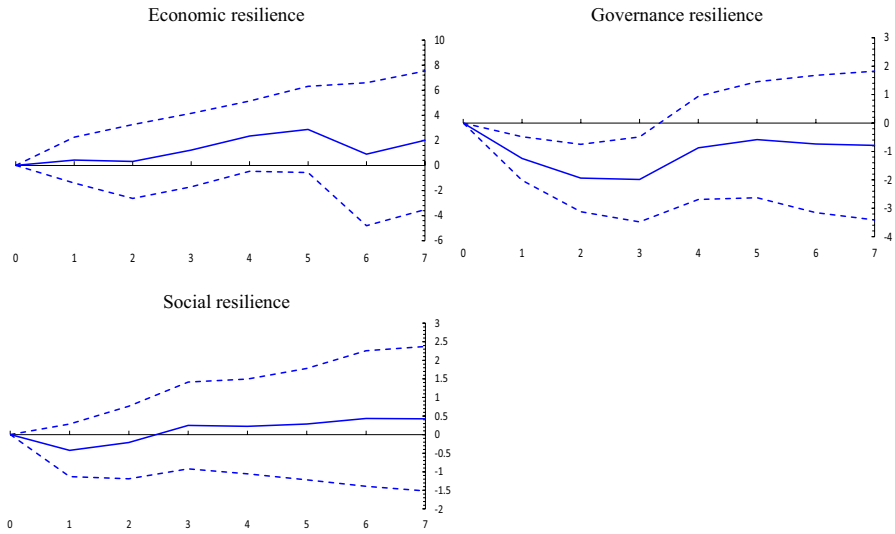


Fig. 9 Climate change responses to financial crises: resilience components (in percent). *Note:* The impulse responses reflect cumulative changes (in percent) in response to a financial crisis shock over $h = 0, 1, 2, \dots, 7$ years. Blue continuous line denotes the impulse response from equation 1. Dotted blue lines are the 90% confidence bands using Driscoll–Kraay robust SE. $t=1$ is the first year of impact after a financial crisis. (Color figure online)



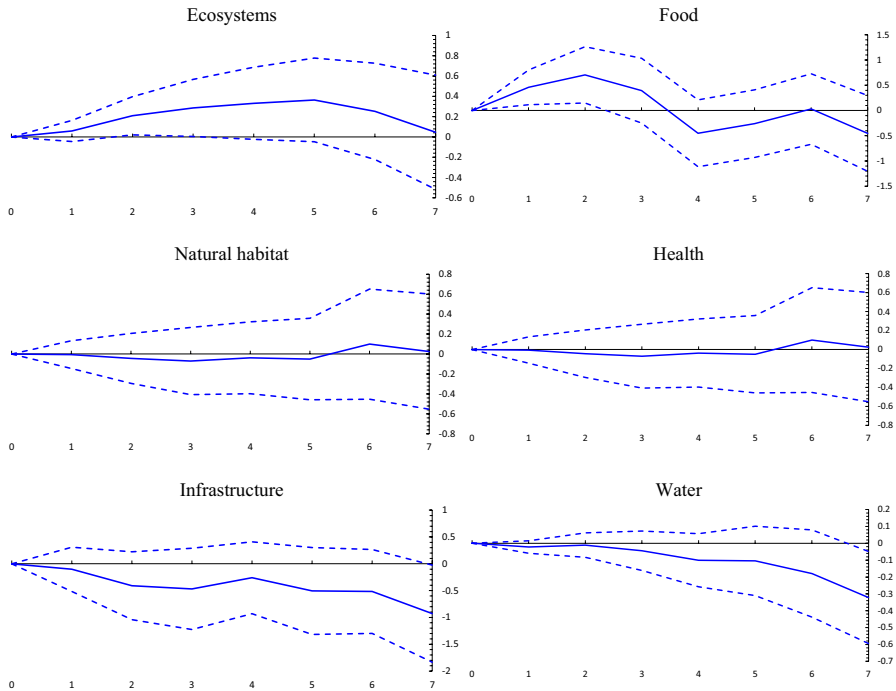


Fig. 10 Climate change responses to financial crises: vulnerability components (in percent). *Note:* The impulse responses reflect cumulative changes (in percent) in response to a financial crisis shock over $h = 0, 1, 2, \dots, 7$ years. Blue continuous line denotes the impulse response from equation 1. Dotted blue lines are the 90% confidence bands using Driscoll–Kraay robust SE. $t=1$ is the first year of impact after a financial crisis. (Color figure online)

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