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Sustainable development and economic disasters☆

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ABSTRACT

This paper argues that economic disasters represent a considerable risk for sustainability objectives. To address this issue, two empirical methods are used. First, the relationship between economic disasters and sustainable development is tested by panel regression. Second, the local projection method is used to explore the dynamics, i.e., the behavior of sustainable development indices for ten years after the onset of a typical economic disaster. The results suggest that the relationship between economic disasters and sustainable development is negative, and that the effects of economic disasters are much larger than the effects of "ordinary" economic crises. Moreover, sustainability indices continue to decline even after a typical economic disaster ends. Understanding the complex relationship between economic disasters and sustainability can help policymakers develop strategies to mitigate these adverse effects and ensure the transition to sustainability.

1. Introduction

Modern countries are typically focused on achieving high output growth. However, economic growth at current rates of environmental depletion cannot continue indefinitely (Cantone et al., 2021). The substantial degradation of the ecological system requires a drastic departure from fixation on output growth (Hardt and O'Neill, 2017) and the creation of an alternative macroeconomic policy goal. In 1987, the Brundtland Report (Brundtland, 1987: 43) coined the term "sustainable development," defined as the "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." This approach to development accounts not only for economic sustainability but also for environmental and social sustainability.

However, despite general commitment to sustainability objectives represented by initiatives like the United Nations' (2015) 2030 Agenda for Sustainable Development and the European Commission's (2019) Green Deal, sustainability concerns can quickly become neglected during economic crises. This paper argues that economic disasters represent a substantial risk for sustainability objectives. While the term "economic crises" typically refers to any (however slight) decline in output (usually over two consecutive quarters), "economic disasters" are characterized by significant cumulative declines in output for a period of one or more years, amounting to at least 10 percent (Barro and Ursúa, 2008). The historical data on economic disasters indicates that the probability of a country entering an episode of a 10% cumulative decline in output from 1820 to 2016 was above 2% per year (Barro and Ursúa, 2008; Ćorić, 2021). Due to these extreme drops in output, economic disasters may force policymakers to prioritize the short-run economic goals over the long-run sustainable development objectives. This paper, hence, investigates the relationship between economic disasters and sustainable development. A better understanding of this relationship may be particularly important today when several large and succeeding crises have affected economies across the globe. The main research questions of this study are: Is there a connection between economic disasters and sustainable development? Are there any differences between the effects of "ordinary" economic crises and economic disasters? Do these effects persist even after the economic disaster has subsided?

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To address these issues, two empirical methods are used. First, the relationship between economic disasters and sustainable development is tested by panel regression. Second, the local projection method is used to explore the dynamics, i.e., the behavior of sustainable development indices for ten years after the onset of a typical economic disaster.

This study contributes to the literature by documenting the empirical effects of economic disasters on sustainable development. Second, this study emphasizes the distinction between the effects of "ordinary" economic crises and economic disasters. The results indicate that the change in sustainable development indicators associated with economic disasters is much larger than the change related to "ordinary" economic crises. Third, sustainable development is measured by three different aggregated indices: the World Bank's genuine (adjusted) net savings, the Human Development Index, and the Sustainable Development Goals (SDG) index (overall) score. Previous papers on similar topics focus only on a specific aspect of sustainability, mainly on the environment or poverty. Sustainability is, in these papers, captured through air pollutants (Pacca et al., 2020), pollutant emissions (Jalles, 2020), deforestation (Antonarakis et al., 2022), air quality, forests, and biodiversity (Antoniades et al., 2022) and Multidimensional Poverty indicators (Antoniades et al., 2020). These specific aspects are too narrow, and focusing on them can results in an oversimplification of this complex concept.

For this reason, this paper uses aggregated indices, which provide a holistic assessment of sustainability by accounting for various dimensions simultaneously. As argued before, sustainability is a multidimensional concept that incorporates economic, environmental, and social aspects, which are interconnected. Aggregated indicators capture these interdependencies and give a more complete picture of the overall sustainability impact. Fourth, to go beyond the empirical assessment of the average effect on sustainable development, this study also employs a local projection method to forecast the behavior of sustainable development indicators over a 10-year horizon. Finally, the study also expands the (still scarce) literature by focusing on an exhaustive cross-country examination (over 180 countries) over a long time (29 years).

The paper is organized as follows. Section 2 overviews the theoretical links between economic disasters and sustainable development. Section 3 reviews the related literature. Data, methodology, and the results of the empirical analysis are given in Section 4. Section 5 provides a discussion of the results, while Section 6 concludes.

2. The link between economic disasters and sustainable development

The impact of economic disasters on sustainable development can, *a priori*, result in both favorable and unfavorable outcomes. Since sustainability encompasses economic, environmental, and social aspects, each can be affected differently. Moreover, some of them, like poverty eradication and environmental protection, are often seen as contradictory goals, as poverty requires growth rates to be high, which can be bad for the environment (Antoniades et al., 2022).

Since sustainable development is closely related to environmental issues, sustainable development, and environmental sustainability are often used as synonyms. The connection between economic growth and the environment has been studied extensively in the literature. Grossman and Krueger (1995) noted that environmental quality does not steadily deteriorate with economic growth; the relationship is non-linear. This is often referred to as "environmental Kuznet's curve," whereby economic growth leads to an increase in environmental deterioration up to a certain level of income when it changes and starts to descend, i.e., environmental quality improves, resulting in an inverted U-shaped curve in graphical terms. Initially, at lower levels of GDP, the negative impact on the environment stems from the fact that economic growth results in increased activity, more industrial production, and, as a result, more emissions and waste. Unsustainable consumption and production exhaust natural resources and negatively impact the environment (Jie et al., 2023). The situation changes, however, and the positive impact on the environment occurs when more developed countries change the composition of their production and adopt cleaner and greener activities (Pacca et al., 2020). Governments start paying more attention to non-economic aspects of the living conditions, resulting in more rigorous environmental standards and enforcement of environmental protection laws. As countries develop, they cease producing pollution-intensive goods and import them from less developed countries with less restrictive laws (Grossman and Krueger, 1995).

An opposite pattern could be expected regarding the impact of economic disasters on the environment. Namely, economic disasters, by definition, negatively impact GDP growth. Lower growth, in combination with a reduction in industrial production, trade, and consumption, leads to less energy consumption, lower emissions, better air and water quality (Pacca et al., 2020), and a decline in demand for goods that rely on environmentally damaging methods (Elliott, 2011). Therefore, environmental conditions can improve at first. Later on, however, this trend can be reversed as the economies recover. Government policies adopted to combat crises often promote more emissions, and rapid easing of energy prices increases the fossil-fuel intensity of the world economy (Peters and Hertwich, 2008). As governments focus on recovery in these periods, they abandon or postpone climate policies and environmental projects.

However, as noted before, the issue of sustainable development and the consequences of economic disasters go beyond environmental issues. For example, conventional wisdom is that people experiencing poverty suffer disproportionately from the non-poor in times of crisis. Baldacci et al. (2002) find that financial crises lead to an increase in poverty at both the macro and micro level, while Ćorić and Gupta (2023) find that economic disasters increase inequality by 4%, on average, with the overall effect being statistically significant and highly persistent over 20 years following the shock. As mentioned previously, poverty alleviation often necessitates high growth rates, which can harm the environment; hence, these policy goals can conflict, making the relationship between economic disasters and sustainability extremely complex. This paper employs empirical analysis to provide new insights on this multifaceted issue.

3. Related literature

As noted by Leal Filho et al. (2023) and Koasidis et al. (2023), a combination of adverse circumstances and prolonged, sequential crises (recession, pandemics, and international conflict) that the world has witnessed recently have drastically undermined the achievement of sustainable development goals. However, only a few studies investigate this critical link.

The majority of the papers in this field focus on environmental issues. Siddiqi (2000) finds that the world environment benefited from the Asian financial crisis in terms of decreased air and water pollutants from energy use. On the other hand, an adverse effect stems from increased pressure to clear forests for wood or agricultural land. Similarly, Elliott (2011) looks at the impact of the Asian crisis and global financial crisis of 2008/09 and finds that both crises generated similar patterns in East Asia; the positive impact on the environment was short-lived, while the negative impact persevered in the long term. Declercq et al. (2011) focus on the 2008/09 recession and find that European emissions radically decreased because of the crisis. Pacca et al. (2020) find that the impact of crises is different in the short-vis-à-vis the long run, whereby the positive environmental effect of crises on emissions in the short-run is cancelled out in the medium- and long-run.

Similarly, Antoniades et al. (2022) find the global crisis to outlive the short-term positive effects on air quality from 1970 to 2015. Jalles (2020) differentiates between various economic crises and concludes, by examining 55 countries from 1980 to 2012, that banking crises negatively affect CO_2 emissions, while debt and currency crises positively affect methane and fluorinated gas emissions. Antonarakis et al. (2022)

find crises associated with declining deforestation rates and drivers (Roundwood, cattle, and cocoa production). Similarly, Antoniades et al. (2022) find financial crises to have beneficial effects on deforestation rates at a global level. Botetzagias et al. (2018) also examine the effect of economic crises on environmental performance (in EU countries); however, a specificity of their research is that they also account for the so-called "Troika effect," i.e., a rescue package received from the IMF/EU/ECB. Overall, they find this impact to be non-significant to positive. If an interaction between the two is accounted for, the effects of receiving "the package" while in a recession harm the environment. Finally, Cantone et al. (2021) do not take economic crises as the primary variable of interest but focus on periods of stagnation, which they label as periods of "degrowth." The main idea is that a slowdown in growth can be a strategy for transitioning to a sustainable socio-environmental system. The authors find that the great stagnation (after the 2008/09 financial crisis) did not produce a homogeneous positive impact on environmental sustainability measured by 15 environmental indicators in 217 countries.

Poverty, another sustainability dimension, has also been under-investigated this context. Rewilak (2018) looks at the impact of three types of crises, banking, currency, and debt crisis, on the income of people experiencing poverty. He concludes that currency crises reduce the income of people experiencing poverty by approximately 15%, while banking crises lead to a 10.6% reduction. Antoniades et al. (2020) focus on a comprehensive definition of poverty, accounting for its social, economic, and environmental aspects. Their analysis of 150 countries from 1980 to 2015 used 15 Multidimensional Poverty indicators as the dependent variable. They find that financial crises result in a 10% increase in extreme poverty levels in low-income countries.

Several research gaps can be identified from the above literature review. First, the relationship between economic disasters and sustainable development has not been studied so far. This paper is the first one to address this issue. Second, the current literature refers primarily to banking crises, which are only a subset of economic crises. Economic crises (including economic disasters) encompass a more comprehensive range of adverse economic conditions. They can be caused by economic, financial, or debt crises and non-economic events such as natural disasters, war devastations, pandemics, and revolutions. This paper addresses this gap in the existing literature by examining this more comprehensive definition of crises. Third, this study distinguishes between the effects of ordinary recessions and economic disasters and provides empirical evidence of substantially different magnitudes of their effects. Fourth, most research predominantly investigates the impact on the environment or poverty. In doing so, they neglect other dimensions of sustainability. Certain aspects of sustainability (like eradicating poverty and environmental protection) are often perceived as conflicting policy goals; hence, aggregated sustainability indicators, an approach adopted in this paper, provide a more comprehensive assessment of the overall effect of crises and disasters. Fifth, some papers employ a coefficient on the lagged dependent variable in their empirical models to estimate the difference between crises' short- and long-run effects. This paper goes one step further. By applying the local projection method, this paper forecasts sustainability behavior over the 10-year horizon, thus allowing a comprehensive understanding of economic dynamics. Finally, most studies focus on a particular crisis or country, and only a few papers look at a more extended period and multiple countries, as this study does.

4. The relationship between economic disasters and sustainable development

4.1. Model

To formally test for the relationship between economic disasters and sustainable development, a panel linear regression model is used:

$$SD\ index_{i,t} = \beta ED_{i,t} + \theta X_{i,t} + u_{i,t} \tag{1}$$

where superscripts i and t denote country and time, respectively. $SD\ index_{i,t}$ represents the sustainable development index. $ED_{i,t}$ is the variable for economic disasters, while $X_{i,t}$ is a kx1 vector of k control variables. $u_{i,t}$ is the error term.

4.2. Variables and data sources

For the dependent variable (SD index) this paper employs the data on sustainable development for all the countries of the world (for which the data was available) from 1990-2019.[1] Table A1 in the Appendix gives the definitions and the data sources of the used variables, while Table A2 presents their descriptive statistics. As noted previously, sustainable development is a concept that cannot be described as a single, defined idea. It has many dimensions: environment, poverty, hunger, health, education, gender equality, and employment. Therefore, this paper uses several aggregated sustainable development indicators, which account for various aspects.

First, the World Bank's genuine (adjusted) net savings (ANS) are used, which measure the "real" rate of saving in an economy after taking into account investments in human capital, depletion of natural resources, and damages caused by pollution. It is calculated as a sum of net national savings (gross national saving − consumption of fixed capital) and education expenditures minus energy, mineral, and net forest depletion and damage from carbon dioxide and particulate emissions. In short, this measure suggests that an economy can keep its level of consumption if saving each year covers the depreciation of made and natural capital. This indicator is expressed as a percentage of Gross National Income (GNI) and can take on positive or negative values, whereby positive values suggest that a country is on a sustainable development path.

Next, the Human development index (HDI) is used as an additional proxy for sustainable development. HDI is a metric that provides a composite measurement of a country's development by considering indicators related to the quality of life of its citizens, including health, education, and income. Even though the HDI does not directly measure sustainability's environmental dimension, it provides some insights into the social and economic dimensions. The HDI can be used as an indicator of social sustainability by measuring the extent to which people can live long and healthy lives, access education, and have an enhanced living standard. The HDI is multiplied by 100 to make its values comparable to the SDG index below. Hence, the HDI can take on values between 0 and 100, with higher values indicating higher levels of human development.

Finally, the SDG index (overall) score (SDGindex) is used. The SDG Index score measures a country's progress towards achieving the Sustainable Development Goals set by the United Nations. It is calculated based on indicators that measure a country's performance on various aspects of sustainable development, including poverty, health, education, gender equality, clean energy, and climate action. The SDG Index score ranges from 0 to 100, where a higher score indicates better progress towards achieving the Sustainable Development Goals.

To construct the primary variable of interest, this paper employs an updated version of Ćorić's (2021) global database that provides data on economic disasters up to 2019. The variable for economic disasters (ED) is constructed using data on the starting year and duration of economic disasters as a dummy variable that takes a value of 1 for "disaster" years

[1] The 1990–2019 timeframe was chosen to maximize the inclusion of years, but data for some variables is missing in specific periods and countries. Additionally, specific years may be missing within some (otherwise available) series. While the period mentioned in the text (1990–2019) serves as a general description of our approach, the data is not balanced. Disparities in the number of observations and countries across the sample are evident in Table 1 for each estimation. Unlike the other two indicators, SDG data is available from 2000.

and zero otherwise. “Disaster” years comprise the years between the peak and trough for each disaster event.

Regarding control variables, neither theory nor literature gives a clear-cut answer as to what that model should contain. Namely, the issue of the determinants of sustainable development has yet to be widely researched, and those papers tackling this issue vary widely in terms of model specification, so it is hard to draw a unanimous conclusion. Thus, in addition to the lagged dependent variable included for methodological reasons, explained in section 4.3 below, this paper uses variables for economic crises, GDP *per capita*, and total natural resource rent as additional explanatory variables.

Following the literature on the relationship between economic crises and sustainable development described in section 3 above, the variable for economic crises (CRISES) is included in the model. This variable is introduced to take into account the possible effect of “ordinary size” economic crises (i.e., economic crises that are smaller than economic disasters) on sustainable development and to distinguish between the effects of “ordinary” crises and economic disasters. In particular, the Harding and Pagan (2002) BBQ algorithm is used to identify economic crises in GDP in constant national prices. Namely, Jordá et al. (2021) show that at a yearly frequency, this algorithm replicates the NBER’s dating of US business cycle peaks and troughs almost perfectly. In real GDP data that generally trend upwards, this algorithm generates local maximums (peaks) and local minimums (troughs) dates.

Consequently, for each country in the sample, the variable CRISES corresponds to the periods between detected peaks and the following troughs. Finally, economic disasters are excluded from the selected group of economic crises. Hence, “ordinary” economic crises include more minor crises than economic disasters. Analogously to the variable for economic disasters, the variable for economic crises is constructed as a dummy variable that takes a value of one for “crises” years and zero otherwise.

For many reasons, GDP *per capita* (GDPpc) is essential to sustainable development. First, countries with high GDP *per capita* have the financial resources to invest in sustainable development projects and infrastructure. Second, a higher standard of living can lead to more sustainable practices, such as reduced reliance on non-renewable resources and increased investment in renewable energy. Finally, these countries tend to focus more on the non-economic dimensions of their citizens’ living conditions, leading to stricter environmental regulations and improved enforcement of environmental protection laws. Hence, many empirical studies use GDP *per capita* as a control.

Additionally, it should be stressed that GDP is a component of some sustainability indicators used in this paper, like the HDI. The inclusion of GDP as a separate variable isolates the direct impact of GDP on sustainability indicators, while the residual impact can be attributed to economic disasters. In other words, if the coefficient on economic disasters is found to be significant, then this means that disasters have an impact on sustainability beyond GDP.

Furthermore, Total natural resource rent (TOTRESRENT) is used as an additional explanatory variable because it reflects economic value generated from natural resources such as minerals, timber, fisheries, and oil. Natural resource rent can contribute to a country’s economic growth and development if the income generated from these resources is used to invest in infrastructure, education, and other vital sectors. On the other hand, overexploitation of natural resources can lead to their depletion, which can have long-term consequences for future generations. Therefore, sustainable development requires efficient use and management of natural resources to minimize environmental and other damages.

4.3. Methodology

To estimate the model, a simple pooled OLS estimator is used. The Breusch–Pagan test for heteroskedasticity and Wooldridge test for autocorrelation in panel data indicate a problem of heteroscedasticity and first-order autocorrelation of residuals, while the results of Pesaran’s (2015) test reveal the problem of cross-sectional dependence.[2] To account for the first order autocorrelation, the lagged dependent variable is introduced into the model, while the time dummies are used to address the issue of cross-sectional dependence. Country dummies are also included to consider the possible country-specific effects related to sustainable development. It is known that introducing country-fixed effects in the model with a lagged dependent variable creates a bias in the estimated coefficient on the lagged dependent variable and other explanatory variables. Therefore, Everaet and Pozzi’s (2007) estimator is employed, which corrects for the bias in the regression coefficients caused by introductions of country-fixed effects in the model with a lagged dependent variable. Everaet and Pozzi’s (2007) estimator has the advantage over the standardly used Kiviet (1995) and Bruno (2005) bias-corrected fixed effects estimators because it reports bootstrapped standard errors that are robust to the heteroskedasticity of residuals that are detected.

4.4. Results

Table 1 reports the results of the dynamic panel regression model. As explained above, to address the autocorrelation and heteroscedasticity issues, the lagged dependent variable is included in all models, and wild bootstrapped standard errors are employed. The results of Juodis and Reese’s (2022) test for cross-sectional dependence indicate that the introduced time dummies address the issue of cross-sectional dependence.[3]

As neither theory nor literature gives a clear answer as to what the model should contain, a starting point is the simplest model – using only economic disasters as an independent variable (columns (1), (4), and (7)). After that, the variable for economic crises is added to the model (columns (2), (5), and (8)) to distinguish between the effects of economic disasters on sustainable development and the effects of “ordinary” economic crises. Finally, GDP *per capita* and Total natural resources rent are added (columns (3), (6), and (9)). The comparison among these regressions provides an internal robustness check and shows that the model specification does not substantially influence estimates on the primary variable of interest.

In columns 1–3 of Table 1, results indicate a statistically significant and negative relationship between economic disasters and sustainable development proxied by ANS. These negative coefficients suggest that the sustainable development index ANS is, on average, lower in periods of economic disasters than in periods without disasters. During economic disasters, adjusted net savings drop, meaning countries are depleting their natural resources at an unsustainable rate. The coefficient on economic disasters appears robust concerning the sign, size, and statistical significance when variables for economic crises, GDP *per capita*, and Total natural resource rent are added to the model (columns 2 and 3). The estimates in columns 2 and 3 also indicate a significantly negative relationship between economic crises and sustainable development proxied by ANS. However, the coefficient on economic disasters, in the fully specified model (column 3), is more than three times larger in absolute size than the coefficient on economic crises. Thus, the results indicate that, on average, the reduction of sustainable development indicator ANS is much larger during economic disasters than during the “ordinary” economic recessions.

[2] The results of the diagnostics tests are available upon request.

[3] Please note that in Table 1, we report the results of Juodis and Reese’s (2022) weighted CD test instead of the results of Pesaran’s (2015) CD test that was used for inference in pooled OLS estimates (section 4.3). Namely, Joudis and Reese (2022) show that applying Pesaran’s (2015) CD test to residuals obtained from a model with time-fixed effects renders the test statistics biased for any fixed T and divergent as $T \to \infty$. Hence, we report the results of the weighted CD test proposed by Joudis and Reese (2022), which re-establishes standard regular inference.

Table 1
Results of the panel data analysis of the relationship between economic disasters and sustainable development.

Dependent variable:	ANS	ANS	ANS	HDI	HDI	HDI	SDGindex	SDGindex	SDGindex
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
L.ANS	0.745***	0.744***	0.716***						
	(0.091)	(0.089)	(0.097)						
L.HDI				1.015***	1.014***	1.014***			
				(0.006)	(0.006)	(0.007)			
L.SDGindex							1.058***	1.058***	1.031***
							(0.010)	(0.010)	(0.009)
ED	−5.457**	−5.680**	−5.778***	−0.999***	−1.047***	−0.904***	−0.198*	−0.206*	−0.120
	(2.513)	(2.659)	(2.164)	(0.113)	(0.111)	(0.093)	(0.118)	(0.124)	(0.093)
CRISES		−1.699***	−1.542***		−0.360***	−0.363***		−0.074**	−0.037
		(0.292)	(0.266)		(0.038)	(0.046)		(0.034)	(0.038)
lnGDPpc			2.876			0.058			0.304***
			(2.178)			(0.105)			(0.098)
lnTOTRESRENT			−0.145			−0.025			0.001
			(0.291)			(0.028)			(0.023)
Time period dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	3560	3560	3450	4988	4988	4437	3078	3078	2949
Number of countries	158	158	151	189	189	167	162	162	157
Cross-sectional dependence	0.602	0.693	0.447	0.429	0.774	0.116	0.312	0.914	0.198

Bootstrapped standard errors in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
The reported values for the Joudis and Reese (2022) test for cross-sectional dependence are p-values.

Significantly negative coefficients on economic disasters in columns 4–6 of Table 1 reveal that the HDI index is also lower in periods of economic disasters compared to periods without economic disasters, suggesting that in periods of severe economic downturns, countries are facing challenges in improving the health, education, and income levels of its population. Estimates of economic disasters are robust concerning sign, size, and statistical significance. The results also reveal the significantly negative coefficients on economic crises, but again, the coefficients on economic disasters are much larger in absolute size. The results on the primary variable of interest, in columns 7–9, in which sustainable development is proxied by SDGindex are in line with the results in columns 1–6. The coefficients on economic disasters are negative and about three times larger in absolute size compared to the coefficients on economic recessions. However, the estimates are less precise. The coefficients on economic disasters remain statistically significant at a 10 percent level in columns 7 and 8, but the variable loses statistical significance in column 9.

GDP *per capita* and Total natural resource rent are statistically insignificant in most models (except column (9), where the coefficient on GDP *per capita* is positive). Including these variables indicates a negative association between disasters and sustainability, encompassing not only a reduction in a country's GDP and economic value derived from natural resources but also extending beyond and above.

The results align with Table 1 when the one-way fixed effects dynamic panel model and Blundell and Bond (1998) system GMM estimator are employed, as robustness checks. To preserve space, these results are not reported here; however, they are available in an Online appendix accompanying the paper (Tables B1 and B2, respectively). To check the robustness of the main results regarding the usage of alternative output data, Ćorić's (2021) data on economic disasters based on real *GDP per capita* data is used. The results reported in the online appendix (Tables B3 and B4) show that the findings on the main variable of interest do not change substantially.

The empirical analysis indicates a statistically significant negative relationship between economic disasters and sustainable development. However, concerning the economic significance, the results are more mixed. A comparison of the size of the estimated coefficients (Table 1) and the corresponding descriptive statistics (Table A2, Appendix) suggests a relatively strong relationship between economic disasters and ANS. In particular, the coefficient on economic disasters in the fully specified model (column 3, Table 1) suggests that the sustainable development index ANS is, on average, 5.78 percentage points lower in periods of economic disasters than in periods without economic disasters. As the mean value of ANS is 7.23 percent and the standard deviation is 12.80, this is a relatively strong economic relationship.

On the other hand, the estimated relationship between economic disasters and HDI is much smaller. The coefficient on economic disasters in the fully specified model (column 6, Table 1) suggests that the sustainable development index HDI is, on average, 0.9 points lower in periods of economic disasters, which is a relatively small difference given that the mean size and standard deviation of HDI are 67.06 and 16.43, respectively. The economic significance of the relationship between economic disasters and sustainable development proxied by SDGindex is even smaller, with the regression coefficient (column 9) being just 0.12 while the mean size and standard deviation of SGDindex are 64.07 and 10.33, respectively.

5. Dynamics of sustainable development indicators after economic disasters

The results of this study indicate that, on average, sustainable development indexes are significantly lower in periods of economic disasters compared to periods without economic disasters. The equally important issue concerning the "threat" that economic disasters impose on sustainable development is the issue of the dynamics of sustainable development after economic disasters. In particular, all crises, even as extreme as economic disasters, eventually end. The average length of economic disasters in the data sample is 3.5 years. The impact of economic disasters should be taken much more seriously if its impact perseveres for a long time, i.e., if the indicators of sustainable development remain low even after the end of economic disasters.

5.1. Model and methodology

An empirical panel autoregressive model of sustainable development and Jordà's (2005) local projection estimator are employed to gain better insight into these dynamics. This method directly estimates the impulse response function (IRF) from the forecast equation for sustainable development indicator h periods ahead. The standard method to calculate IRF is by recursively applying the estimated models to generate forecast values of the dependent variable. As the length of the forecast period increases, IRF becomes an increasingly complex function sensitive to specification errors in the underlying model. The local projection method is more robust to misspecifications than the original dynamic model, as it does not employ the same set of estimated coefficients for all periods ahead. However, a separate set of coefficients is estimated for each forecast horizon (Auerbach and Gorodnichenko, 2014). Several studies employ this empirical approach to estimate the dynamics of output after financial and economic crises (see, for example, Romer and Romer, 2019; Bernardini and Forni, 2020; Ćorić and Škrabić Perić, 2023). This approach is employed here to estimate the average dynamics of sustainable development indicators after the onset of an economic disaster. In particular, sequential estimates of the following local projection panel regression are run:

$$SDindex_{i,t+h} = \alpha_i^h + \beta^h t + \sum_{j=1}^{4} \gamma_j^h SDindex_{i,t-j} + \sum_{j=0}^{4} \delta_j^h EDoutbrake_{i,t-j} + \sum_{j=0}^{4} \rho_j^h CRISESoutbrake_{i,t-j} + \theta^h X_{i,t} + u_{i,t}^h \tag{2}$$

where i and t superscripts index country and time, respectively. j denotes the number of time lags, while h denotes the time horizon (years after time t) being considered. α_i are country fixed effects, while the variable t represents the linear time trend. *SDindex*, and $X_{i,t}$ again represent the sustainable development index and control variables, respectively. *EDoutbrake* is the variable for economic disasters. The variable for economic disasters is again constructed as a dummy variable, but in this model, it takes a value of 1 only in the first year of an economic disaster, i.e., if an economic disaster in country i starts at year t, and 0 otherwise. Analogously, *CRISESoutbrake* is the variable for "ordinary" economic crises that takes a value of 1 in the first year of an economic crisis and 0 otherwise. Finally, $u_{i,t}$ denotes the error term.

The method estimates separate regressions for the increasing horizons between time t and $t + h$. Accordingly, this analysis estimates equation (2) for each $h = 0, \ldots, 10$. The sequence of estimates on *the EDoutbrake* coefficient at time $j = 0$ (δ_0^h) provides the average difference between the value of the *SDindex* before the onset of economic disaster and h successive periods ahead, While the sequence of estimates on *CRISESoutbrake* coefficient at time $j = 0$ (ρ_0^h) denotes the average difference between the value of the *SDindex* before the onset of economic crises and h successive periods ahead.

5.2. Results

Table 2 reports the sequences of estimates on δ_0^h and ρ_0^h for $h = 0, \ldots, 10$, for each sustainable development index. To preserve space, the results are provided only for the fully specified models.[4] The coefficients are estimated using a fixed-effects estimator with serially correlation-robust standard errors. The sequence of regressions for ANS, HDI, and SDGindex is estimated separately. As the main interest is in the dynamics of sustainable development indicators over a 10-year horizon, each set of regressions is run on the sample, including only countries with 15 or more observations for the particular sustainable development indicator. This reduces the number of countries in the sample for the regressions in which the sustainable development index is proxied by ANS from 151 (column 3, Table 1) to 118. The number of countries in the regressions in which sustainable development is proxied by HDI reduces much less, from 167 (column 6, Table 1) to 163, while the number of countries for the regressions in which SDGindex is used remains the same, 157 (column 9, Table 1). In all sets of regressions, the effective sample size reduces gradually as the forecast horizon increases,[5] however, the number of countries in the samples remains unchanged throughout the projection period.

Figs. 1–3 plot the coefficients on δ_0^h and ρ_0^h together with their 95% confidence intervals, for the fully specified models, for each index of sustainable development separately.[6] The plotted results show the average dynamics of sustainable development indexes after the onset of an economic disaster. Taken together, Fig. 1(a)-3(a) show that all sustainable development indexes lose their value after the start of a typical economic disaster and then gradually recover toward their pre-disaster sizes.

ANS index declines at the start of a typical economic disaster by 4.948 percentage points. Over the next three years, it remains more than four percentage points lower than before the economic disaster. Six years after the onset of the economic disaster, the loss is recouped, and the index slightly exceeds its pre-disaster value ($\delta_0^6 = 0.185$). The loss becomes statistically insignificant four years after the economic disaster. As the average duration of economic disasters in the sample is about 3.5 years, the estimates on the dynamics of ANS suggest that ANS does not remain lower after the end of an economic disaster. Hence, regarding the economic importance of the relationship between economic disasters and sustainable development proxied by ANS, the results presented in Fig. 1(a) correspond closely to the estimates in section 4.4. Namely, results for ANS in Table 1 (columns 1–3) suggest that the sustainable development index ANS is about 5.5 percentage points lower in periods of economic disasters than in periods without economic disasters.

The results for HDI and SDGindex, on the other hand, suggest that the values of these indexes remain lower even after the end of economic disasters. In particular, both indexes declined over the first seven years. The estimates of δ_0^7 indicate that seven years after the start of a typical economic disaster, values of HDI and SDG indexes are significantly lower by 1.556 and 0.745 points, respectively. The recovery in both cases begins eight years after the onset of an economic disaster. The HDI index remains below its pre-disaster level over the entire projection period. The estimates of the differences in SDGindex remain negative up to the last year, but they are much less precisely estimated. For comparison, the results for HDI and SDGindex in Table 1 (columns 4–9) suggest that these sustainable development indexes are about 1 and 0.17 points lower, but only during periods of economic disasters (3.5 years on average). Consequently, the results presented in Figs. 2 and 3 indicate that the relationship between economic disasters and sustainable development proxied by these two indexes is economically more important than the earlier estimates in Table 1 suggest.

Fig. 1(b)-3(b) reveal similar dynamics of ANS and HDI indexes, as was the case with economic disasters; however, the size of the estimated changes appears to be substantially smaller in absolute terms; moreover, the negative changes in SDGindex after the "ordinary" economic recessions are not detected.[7]

[4] The results for all model specifications are provided in the online appendix, Tables B5-B7. In particular, following the approach from section 4 (Table 1), for each indicator, we provide results for the model using only economic disasters as an independent variable; after that, we add the variable for economic crises into the model, and finally, we introduce GDP *per capita* and Total natural resource rent.

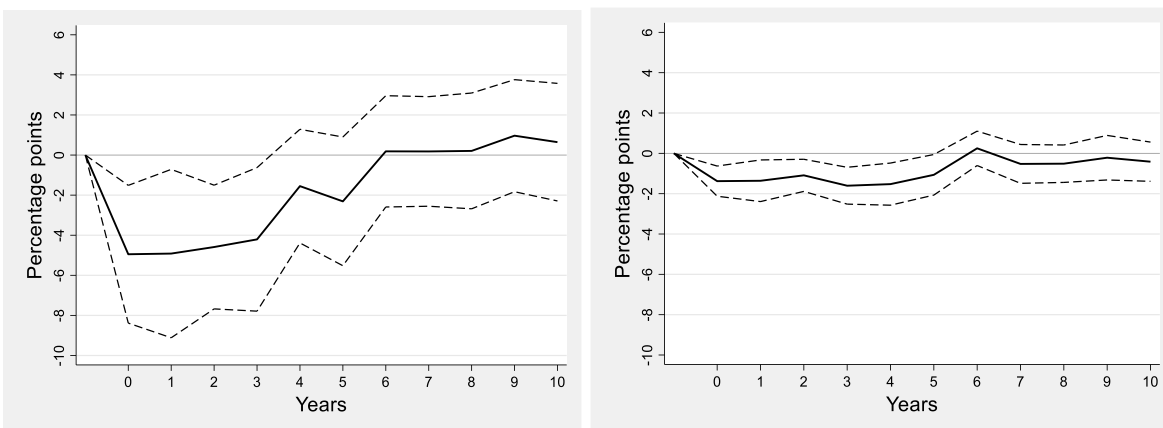
[5] The effective sample size gradually reduces from 2789 to 1716 for the sets of regressions in which sustainable development is proxied by ANS, from 3928 to 2638 when sustainable development is proxied by HDI, and from 2486 to 1245 when it is proxied by SDGindex.

[6] Figures B1-B9 in the online appendix plot the results for all model specifications for each sustainable development indicator.

[7] The results for economic disasters and "ordinary" crises remain in line with the estimates presented in Figs. 1–3 when we employ the economic disasters and economic crises data based on the real GDP *per capita* data (Online Appendix, Figures B10-B18).

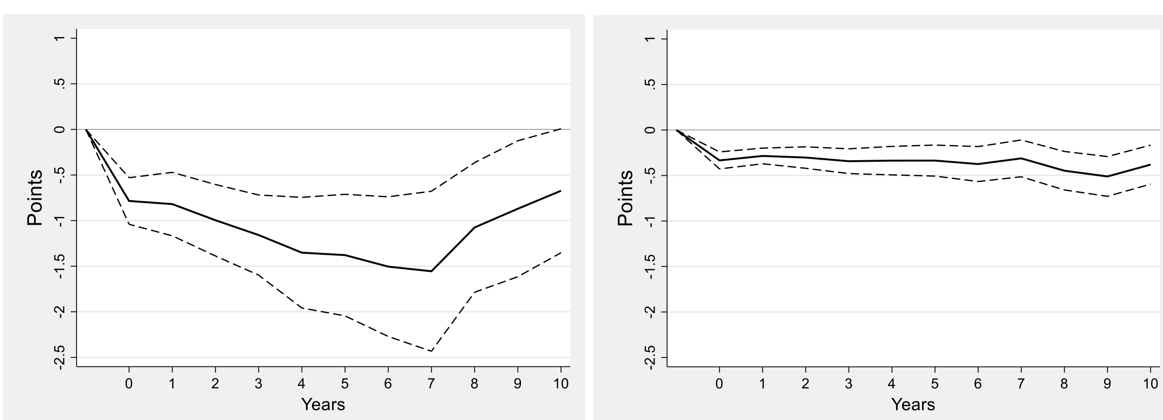
Table 2
Cumulative change in the sustainable development indicator after economic disasters and economic crises: the model with all control variables.

h	ANS				HDI				SDGindex			
	Economic disasters		Economic crises		Economic disasters		Economic crises		Economic disasters		Economic crises	
	δ_0^h	p-value	ρ_0^h	p-value	δ_0^h	p-value	ρ_0^h	p-value	δ_0^h	p-value	ρ_0^h	p-value
0	−4.948	0.005	−1.378	0.000	−0.785	0.000	−0.334	0.000	−0.099	0.413	−0.027	0.511
1	−4.915	0.022	−1.360	0.010	−0.819	0.000	−0.285	0.000	−0.265	0.161	0.012	0.821
2	−4.589	0.004	−1.090	0.008	−0.996	0.000	−0.303	0.000	−0.147	0.428	−0.011	0.855
3	−4.207	0.022	−1.604	0.001	−1.159	0.000	−0.343	0.000	−0.327	0.106	0.001	0.988
4	−1.550	0.281	−1.526	0.005	−1.352	0.000	−0.337	0.000	−0.373	0.183	0.010	0.896
5	−2.310	0.157	−1.064	0.038	−1.378	0.000	−0.336	0.000	−0.518	0.082	−0.005	0.945
6	0.185	0.895	0.249	0.564	−1.505	0.000	−0.374	0.000	−0.647	0.038	0.001	0.986
7	0.181	0.896	−0.524	0.283	−1.556	0.001	−0.312	0.003	−0.745	0.024	−0.061	0.403
8	0.207	0.888	−0.513	0.276	−1.075	0.003	−0.447	0.000	−0.246	0.197	−0.096	0.158
9	0.967	0.495	−0.215	0.700	−0.870	0.022	−0.510	0.000	−0.104	0.639	−0.162	0.050
10	0.643	0.665	−0.414	0.400	−0.673	0.052	−0.381	0.001	0.215	0.423	−0.103	0.239



(a) Economic disasters (b) Economic crises

Fig. 1. Cumulative change in ANS index after economic disasters and economic crises.



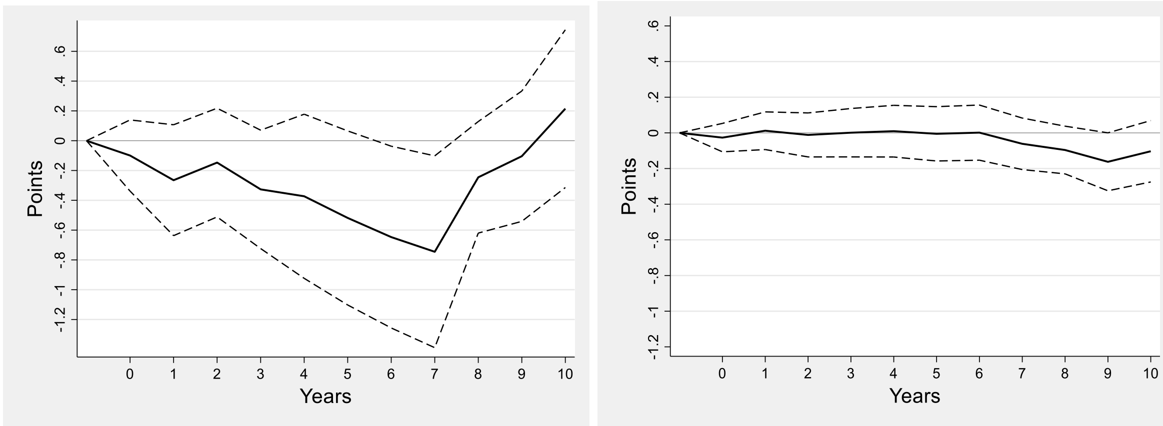
(a) Economic disasters (b) Economic crises

Fig. 2. Cumulative change in HDI index after economic disasters and economic crises.

6. Discussion

As advocated by Antoniades et al. (2022), the transition to sustainability cannot be achieved on autopilot; instead, it should result from a direct and determinate action undertaken to achieve a more sustainable society. If this transition to sustainability requires direct action, it is crucial to understand the factors that might undermine this objective. This paper investigates one of them – economic disasters.

The results of this study indicate that the threat of economic disasters to sustainability is much larger than the threat from “ordinary” economic crises. The empirical estimates also underscore that the adverse effects can be felt even seven years after the onset of a typical economic



(a) Economic disasters (b) Economic crises

Fig. 3. Cumulative change in SDGindex after economic disasters and economic crises.

disaster. Accordingly, these results suggest that the first-class issue for policymakers in achieving sustainability is addressing economic disasters rather than "ordinary" recessions. This might be particularly important today when multiple large crises have hit countries worldwide over the last few years.

In that respect, two lines of policy measures can be crucial. The first line is related directly to sustainable development policy measures. These measures should comprise investment in direct resilience-building measures to minimize the negative impact on sustainability. As economic disasters are relatively rare, these measures should also include measures that increase public support for sustainability in "good" years (i.e., in years without disasters). During these "good" years, the government should encourage the adoption of cleaner production technologies as part of broader sustainability strategies to mitigate environmental damages and increase long-term resilience. Building strong public support for sustainable development objectives over "good" years would ease the pressure on governments to prioritize short-term economic gains over (long-term) sustainable development objectives when economic disasters occur. The second line of policy measures comprises general economic measures to avoid or at least reduce the frequency of economic disasters.

A potential limitation of this research is that aggregated indices simplify complex concepts and undermine conclusions regarding various sustainability components, which might be affected in opposite directions. Additionally, there are likely to be specific differences between countries, which are not reflected in the overall results. Finally, despite a relatively long period under investigation, an even more extended period would be advisable from the perspective of economic disasters. In this case, five- or ten-year averages could smooth out the variability in yearly data, making it easier to identify long-term trends and underlying patterns.

The results of this study also suggest a few new lines of inquiry. First, in line with the above discussion, the results suggest that it would be necessary to investigate why economic disasters and sustainable development are negatively associated. More precisely, while this study argues that economic disasters have a residual impact on sustainability after GDP-related factors are accounted for, future research should go into depth as to what these residual factors might be. It might also be beneficial to investigate the related question of what the policymakers can do to reduce this adverse effect. Additionally, to improve the understanding of the effects of economic disasters on sustainable development, it might be helpful to investigate the effects of economic disasters on particular components of sustainable development indices. Finally, future research could enhance the list of dependent variables to contain the resilience index developed by Khan et al. (2022). This index investigates various resilience dimensions, such as economic stability, emergency workforce, agricultural development, human capital, digitalization, infrastructure, governance, social capital, and women empowerment, thus enabling the assessment of the impact of economic disasters on the resilience of a country, which could offer additional insights for policymakers seeking targeted strategies to enhance overall sustainability.

7. Conclusions

Long-term sustainability is increasingly recognized as an essential policy target by many countries and organizations worldwide. However, sustainability concerns can become neglected during economic crises, especially during economic disasters. In addition to being large and extreme, these economic disasters tend to be clustered across countries, making them more challenging. Indeed, the UN has recognized that "the multiple crises of the last three years have dealt "a major blow" to the Sustainable Development Goals" (United Nations, 2023). This paper addressed three key research questions to investigate closely the impact of these disasters on sustainability.

Is there a connection between economic disasters and sustainable development? This research suggests that the answer is yes. The results suggest that the relationship between economic disasters and sustainable development is negative and that this effect goes beyond the pure effect of GDP and natural resource rent. The results of panel data analysis reveal that all employed sustainable development indicators are, on average, significantly lower in the disaster years than those without disasters.

Are there any differences between the effects of "ordinary" economic crises and economic disasters? This study suggests substantial differences in these effects. The effects of disasters are much larger than those of "ordinary" economic crises, whereby the coefficients on economic disasters are about three times larger in absolute size compared to the coefficients on economic recessions.

Finally, do these effects persist even after the economic disaster has subsided? The answer again is yes. The local projection analysis reveals that some sustainable development indices continue to decline even after the end of an economic disaster. More precisely, after the start of a typical economic disaster, these indices begin declining, reach the minimum after seven years, and then gradually start to recover toward their pre-disaster values.

Overall, these findings underline the importance of the relationship between economic disasters and sustainable development and suggest that this relationship should receive more attention from policymakers.

CRediT authorship contribution statement

Lena Malešević-Perović: Conceptualization, Data curation, Supervision, Visualization, Writing – original draft, Writing – review & editing. **Bruno Ćorić:** Data curation, Funding acquisition, Methodology, Project administration, Software, Writing – review & editing.

Declaration of competing interest

None.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jclepro.2023.140043.

Appendix

Table A1
Definitions and sources of the variables

Variable	Full name	*Definition*	Source
ANS	Adjusted net savings	Adjusted net savings, including particulate emission damage (% of GNI)	WDI
HDI	Human development index	The Human Development Index (HDI) is a summary measure of achievements in three key dimensions of human development: A long and healthy life, access to knowledge and a decent standard of living, measured by Life expectancy at birth, Mean years of schooling and/or Expected years of schooling and GNI *per capita* (in PPP adjusted international-$), respectively. The HDI is the geometric mean of normalized indices for each of the three dimensions.	UNDP
SDGindex	SDG Index Score	The SDG Index is an assessment of each country's overall performance on the 17 SDGs, giving equal weight to each Goal. The score signifies a country's position between the worst possible outcome (score of 0) and the target (score of 100).	Sachs et al. (2022)
ED	Economic disasters	Dummy for economic disasters (based on real GDP data) which takes the value of 1 for years between peak and trough of each economic disaster, 0 otherwise	Ćorić (2021)
EDoutbreak	Economic disasters start	Dummy for economic disasters (based on real GDP data) which takes the value of 1 for the first year of an economic disaster (peak), 0 otherwise	Ćorić (2021)
CRISES	Economic crises	Dummy for economic crises (based on real GDP data) which takes the value of 1 for years between peak and trough of each economic crises, 0 otherwise	PWT 10.0
CRISESoutbreak	Economic crises start	Dummy for economic crises (based on real GDP data) which takes the value of 1 for the first year of an economic crises (peak), 0 otherwise	Ćorić (2021)
GDPpc	Gross domestic product *per capita*	Expenditure-side real GDP *per capita* at chained PPPs (in mil. 2017US$)	PWT 10.0
TOTRESRENT	Total natural resources rents (% of GDP)	Total natural resources rents are the sum of oil rents, natural gas rents, coal rents (hard and soft), mineral rents, and forest rents.	WDI

Table A2
Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
ANS	3921	7.24	12.80	−165.21	52.11
HDI	5559	67.06	16.43	21.6	96.2
SDGindex	3564	64.07	10.34	38.88	86.48
ED	6180	0.07	0.25	0	1
EDoutbreak	6149	0.07	0.13	0	1
CRISES	6150	0.09	0.29	0	1
CRISESoutbrake	6135	0.07	0.25	0	1
lnGDPpc	5370	9.07	1.24	5.50	12.02
lnTOTRESRENT	5321	0.27	2.57	−9.05	4.47

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