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Previous studies show that natural disasters decelerate economic growth, and more so in countries with lower financial development. We confirm these results with more recent data. We are the first to show that fiscal stability reduces the negative economic impact of natural disasters in poorer countries, and that catastrophe bonds have the same effect in richer countries.

Disasters · Financial development · Fiscal stability · Catastrophe bonds · Disaster risk management · Climate change

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Empirical evidence suggests that emerging economies are more vulnerable to disasters, the frequency and intensity of which have increased due to the growing population, greater wealth accumulation, and climate change. In 2020, the Centre for Research on the Epidemiology of Disasters (CRED) reported 80 disasters, almost double the amount of 42 disasters in 1980 in emerging economies. The higher frequency and severity of catastrophes imply higher costs for these economies, more so when countries do not have integral risk disaster management. Moreover, in the aftermath of the Covid-19 pandemic, fiscal constraints are raised, especially in those poor countries with previous fiscal imbalances, increasing their vulnerability to deal with any catastrophic event.

The present paper hypothesizes that financial development and fiscal stability play key roles in dealing with disasters in the case of emerging economies. Several studies have researched the relationship between natural disasters, financial development, and economic growth; however, few studies have analysed the impact of fiscal stability prior to the disastrous events that occurred. In this aspect, the literature has focused on what happened after the event and the effect of disasters on government debt. Using a panel fixed effects approach during 1980-2020, and a dynamic panel estimator as a robustness check, we find that financial development and fiscal stability are crucial to dealing with natural disasters in emerging economies.

In addition, the effect of the increasingly popular catastrophic bonds (CAT bonds) is analysed. From their creation in 1997 until 2020, we demonstrate that CAT bonds are a powerful vehicle to deal with natural disasters in advanced economies using a panel fixed effects approach, in contrast with emerging economies where other type of analysis have to be used given the small observations in the data. In fact, maare

2.1 Disasters and economic growth

The literature on the disaster's impact on economic growth remains inconclusive. Some economists argue that natural disasters have a positive effect on economic growth (Albala-Bertrand, 1993; Skidmore and Toya, 2002; Onuma et al. , 2021). Albala-Bertrand (1993) argues that disasters rarely have adverse effects on economic growth because of the regenerative capacity of economies and the disproportionate impact on families from different income levels. Skidmore and Toya (2002) find that climatic disasters are positively correlated with economic growth, human capital investment, and total factor productivity growth in the long run. The authors assert that the reduction of the expected return to physical capital when a disaster occurs has a positive externality, boosting the return on human capital. Additionally, disasters bring the opportunity to introduce new technologies, raising total factor productivity. However, this result is exclusive to climate disasters, not geologic disasters. This is not surprising because the latter type of disaster is more destructive. The process of recovery of physical capital can take years, and human capital can be affected. Despite both papers using all data availab

Moreover, a public intervention must be accompanied by a comprehensive disaster risk management strategy[12]. It implies planning to better manage disaster costs; ensure predictable and timely access to funds during te(s)-1.2 2p94 711 .5 (n)-4

are used only in exceptional conditions. For example, insurance and CAT bonds can cover extreme events such as earthquakes, but they are not appropriate to protect against low-intensity disasters that occur frequently. The government could consider setting up a contingent fund for those cases of lower layer risk (Figure 2).

Source: World Bank, 2021.

primary insurer ceding the risk ("the cedent") is a local insurance company, given the limited underwriting data available on insurers and markets. Therefore, adverse selection costs are likely to be relatively high for primary insurers, raising the reinsurance prices. Agency costs arise when managers of insurance companies are out of the common interest of all parties, and consequently, the price of insurance increases. High travel costs are a common example that raises operational costs in the insurance market. Monitoring and disclosure mechanisms to control agency costs are weak in most developing countries. Hence, high expenditure for monitoring and control mechanisms is needed that again raises the cost of insurance.

In contrast with insurance, CAT bonds do not have credit risk and can provide lower spreads because catastrophic events are not correlated with market investment returns (such as equity or comso iiq ei

Data on natural disaster events is obtained from the publicly available Emergency Events Database (EM-DAT) provided by the Centre for Research on the Epidemiology of Disasters at the School of Public Health of the Catholic University of Louvain in Belgium. The data set covers all major disasters across the world from 1900 to the present, compiled from various sources including the United Nations, governmental and non-governmental agencies, insurance companies, research institutions, and press agencies[15].

EM-DAT defines a disaster event as fulfilling at least one of the following criteria: (i) 10 or more people killed; (ii) 100 or more people affected; (iii) a state of emergency declared; or (iv) a request for international assistance. Disaster

The macroeconomic variables are obtained from the World Development Indicators database, published by the World Bank (WB)[16], and the World Economic Outlook database, published by the International Monetary Fund (IMF)[17]. In the former, the data is available from 1960 to 2020, and in the latter, from 1980 to 2021, and projections are given for the next two years. As we will use both databases, the analysis focus on the period 1980 to 2020 for 196 countries around the world. Gross domestic product per capita (GDPpc), credit as a percentage of GDP, and gross public debt as a percentage of GDP are the main variables used in our analysis. Moreover, we follow the same country classification of the IMF: advanced economies and emerging economies[18].

The credit measure is the value of credits by financial intermediaries to the private sector divided by GDP, as proposed by Levine, Loayza and Thorsten (2009). This measure is well recognized in the literature as a proxy of the level of financial development because it isolates credit issued to the private sector from the credit issued by governments, central banks, and public enterprises. Thus, higher levels of private credit indicate higher levels of financial services and therefore deeper financial intermediary development.

To choose the appropriate fiscal stability variable, we avoid using specific debt thresholds. After the critiques of Reinhard and Rogoff's estimations (2010)[19], many studies highlight the lack of evidence of any particular debt threshold above which medium-term economic growth prospects are compromised by Herndon, Ash and Pollin, (2014). In contrast, public debt trajectory and debt volatility are associated with economic growth. Pescatori, Sandri and Simon (2014) find that countries with high but declining debt appear to grow equally as fast as countries with lower debt, and they find evidence that higher debt is associated with a higher degree of output volatility. For that reason, we employ the change of gross public debt as a percentage of GDP[20] with respect to the previous period as our fiscal stability variable. A higher difference indicates higher volatility and a negative impact on the economic growth rate in the medium term.

Finally, a specific financial instrument, “catastrophe bonds”, is included in the analysis. Usually called CAT bonds, these are securities that are not re

The data on CAT bonds are obtained from Artemis[22], a leading alternative risk transfer and weather trading market enterprise. They published a comprehensive database containing almost every deal since the first emission in 1997, featuring over 570 catastrophe bond transactions.

As it was estimated by McDermott et al. (2014), the interaction between the credit measure and the disaster index ($_{,\ -1}$) test directly the effects of financial development on economic growth when severe events occur. We would expect to find a positive sign in the coefficient of the interaction term, suggesting that greater financial development mitigates the growth effects of disasters. Furthermore, the difference in the gross public debt between and -1 and its interaction with the disaster index (Δ _) is added. We would expect to find a negative sign in the coefficient result of the inverse relationship between public debt volatility and economic growth when a disaster happens.

We include country-fixed effects ( ) and cluster errors by country to control for any omitted country-specific and time-invariant factors. For example, variables such as culture, country size, and race are time-invariant factors. We also incorporate time-fixed effects ( ) to control for any shocks that affect all regions simultaneously such as the business cycle. [illegible]

Dis*Credit	0.0192***	0.0100*	0.0121**
	(0.00682)	(0.00541)	(0.00582)
Public debt		-0.0743***	-0.0677***
		(0.0181)	(0.0202)
Dis*Public debt			-0.0446
			(0.0294)
Observations	4,966	3,656	3,656
R-squared	0.159	0.265	0.267
Number of countries	193	193	193

Note: Annual data 1980-2020, except where lost due to lags. All models include a constant term and annual fixed effects. Errors clustered at the country level[25]. *t*-statistics in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Moreover, model 3 tests our hypothesis that fiscal stability may be a significant factor in determining the economic effects of natural disasters for the full sample (Table 4). However, as it is noticed in model 3, the coefficient of the interaction between disaster and public debt is not significant for the full sample. In contrast, our hypothesis holds for the case of emerging countries (Table 5, model 6), suggesting the relevance of fiscal stability to avoid a negative economic impact in those countries. When we disaggregate by the level of income, the interaction term is particularly significant in lower-middle-income countries and low-income countries (Table 6).

The relevance of financial development as well as fiscal stability highlight the importance to boost policies oriented to deepening the financial channel and developing a responsible and transparent public finance, especially in emerging economies where the dependency on the commodities cycle is much higher, and the occurrence of disaster is more frequent and costliest (Table 5, model 6). It begins by shifting the policy perspective from the old, outmoded approach of relying solely on donor community assistance to a comprehensive risk financing approach that must include an ex-ante and ex-post perspective of catastrophic management and where the use of the financial instrument is technically dependent on the probability of occurrence and frequency of the events (Figure 1). According to Cummins and Mahul (2008), Disaster Risk Management (DRM) framework should focus on five-pillar: risk assessment; emergency preparedness; risk mitigation; institutional capacity building; and catastrophe risk financing. Those pillars have to base on the principle that loss of life and economic losses can be reduced by advanced planning and cost-effective investment.

Variables	Model 4 (Emerging countries)	Model 5 (Emerging countries)	Model 6 (Emerging countries)

[25] As it will noticed in the results, the clustered standards errors only convergence on their true parameter values when the number of clusters (not the number of observations) is large.

Lagged GDPpc	-4.673***	-6.162***	-6.183***
	(0.762)		

Public debt	-0.0287***	-0.0244	-0.0230***
	(0.00753)	(0.0156)	(0.00818)
Dis*Public debt	-0.0892***	-0.102***	-0.0792***
	(0.0199)		

Dis*Public debt	-0.0446	-0.0504*	-0.0742***	-0.0929***
	(0.0294)	(0.0293)	(0.0278)	(0.0250)
Observations	3,656	2,918	2,769	2,918
Countries	196	145		
R-squared	0.267	0.253		

Government expenditure	-0.0864	-0.455***
	(0.0583)	(0.157)
Observations	2,782	693
Number of countries	146	36
R-squared	0.210	0.585

Note: Annual data 1997-2020. All models include constant term and annual fixed effects. Errors clustered at the country level. *t*-statistics in parentheses. *** p<0.01, ** p<0.05, * p<0.1

No significant result is found for emerging economies, probably because of the little use of this instrument during the period of the study. Notwithstanding the increasing use of this financial tool in emerging markets, more than 90% of the CAT bond market is used by advanced economies (United States, Japan, the European Union, and Australia) and only 8.0% of the CAT bonds are issued in the Caribbean countries and other countries in Latin America and Asia. These findings indicate that emerging economies would follow the use of this financial instrument as it was proof of its positive results in advanced economies.

Removing the interaction with the disaster variable, the sign of the tenancy of a CAT bond is positive and statistically significant, for the full sample and for emerging and advanced economies separately (Table 9). Moreover, when we disaggregate the information by the most common types of disaster covered, earthquakes and storms (Table 10), we find a positive effect of the issuance of CAT bonds on economic growth in the full sample. On average and *ceteris paribus*, the issuance of the CAT bond oriented to deal with earthquakes increases economic growth by 0.52 percentage points and 0.68 percentage points in the case of storms, compared to the status quo of not having a CAT bond. These results suggest the relevance of this financial instrument to deal with earthquakes and storms, events that are generally are less frequent and more severe, and it proves the technical accuracy of disaster risk management and the risk layering approach. However, this finding can also indicate a reverse causality, countries that grow faster can afford CAT bonds. As argued in the literature review above, financial development is a key driver of economic growth.

	(0.00557)	(0.00627)	(0.0129)
Observations	4,318	3,429	887
R-squared	0.155	0.137	0.434

Note: Annual data 1997-2020. All models include constant term and annual fixed effects. *t*-statistics in parentheses. *** p<0.01, ** p<0.05, * p<0.1

	Full sample	Earthquakes	Storms[26]
Lagged GDPpc (in logs)	-0.482***	-0.419***	-0.439***
	(0.0652)	(0.0616)	(0.0627)
Disaster	-0.450**	-0.464**	-0.459**
	(0.215)	(0.215)	(0.215)
Cat bond	0.783***	0.527*	0.675**
	(0.233)	(0.305)	(0.279)
Inflation	-0.0253***	-0.0254***	-0.0254***
	(0.00433)	(0.00434)	(0.00433)
Government expenditure	-0.0199***	-0.0177***	-0.0188***
	(0.00557)	(0.00553)	(0.00556)
Observations	4,318	4,318	4,318
R-squared	0.155	0.154	0.154

Note: Annual data 1997-2020. All models include constant term and annual fixed effects. Using OLS estimation. *t*-statistics in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Natural disasters have a significant negative impact on economic growth. On average and *ceteris paribus*, a disaster reduces the growth rate of gross domestic economic per capita by 1.17 percentage points. Financial development and fiscal stability are key factors in reducing the negative impact of natural disasters in emerging economies. CAT bonds mitigate the impact on economic growth when a disaster occurs in advanced economies. In emerging economies, there is no significant result, probably due to the small number of observations.

The results confirm that natural disasters are bad for economic growth, and more so in countries that are financially less developed. We show, for the first time, that financial stability ameliorates the economic impact of natural disasters, in poorer countries, and so do CAT bonds, in richer countries. The following caveats apply. Any analysis with the CRED data suffers

lightly affects the whole country. The indicators for financial development and fiscal stability used here are both common and appropriate, but certainly not the only choice. Finally, there is a room for improvement in disaster financial instruments data. A database of CAT bonds is created by Artemis, unfortunately lacking data on maturity. Data for other instruments are limited. Efforts can be oriented to enhance and compile data on different financial instruments. It would permit us to compare and analyze historically the effectiveness cost of different instruments between countries across time. Future research should address these issues.

The policy implications are as follows. The results underline that natural disasters have a lasting effect on economic development. Financial development is important for a number of reasons, but also to mitigate the impact of natural disasters. The same is true for fiscal stability. Governments in disaster-prone areas should work to improve both financial development and fiscal stability. CAT bonds are an effective instrument to reduce the negative economic impact of natural disasters and should be deployed more widely.

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