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The Impacts of Disasters on Capital Flows, International Reserves and Exchange Rates: Implications for Public Sector Financial Risk Management and Development Lenders

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Abstract

This study investigates empirically the effect of disasters on capital flows, international reserves and exchange rates, and discusses implications for risk management and potential mitigation strategies. We define major disaster quarters as quarterly impacts exceeding 1% losses as percent of GDP or 1% of total population affected. We find that for developing countries eligible to borrow from the World Bank Group's International Development Association (IDA), a major disaster causes a statistically significant decline in net investment flows (portfolio and other) over three quarters and a depreciation of the real effective exchange rate. When observing nominal exchange rates for the entire sample of emerging and developing economies, an initial currency appreciation effect is offset by depreciation in the periods after in the majority of cases: a year after the disaster almost 3 out of 5 countries see their currency depreciating. Our panel dataset combines disaster losses between 2005 and 2021 with foreign exchange, economic and financial flow data for up to 66 countries. Our results provide new colour to policy makers and aid organisations attempting to deal with the increasing severity and frequency of disasters. The documented vulnerabilities of IDA countries support recent policy reform calls. These include a medium to long-term agenda to strengthen domestic savings and funding markets, more immediate efforts to strengthen the currency and interest rate risk management capacities of IDA recipient debt management offices, and a strong mandate for providers of international development finance to assist IDA borrowers to reduce currency mismatches by offering loans indexed to the local exchange rate and supporting the creation of currency risk markets.

Keywords: Disasters, portfolio investment, exchange rate, international reserves, public debt management.

JEL classification: F31, F34, H63, Q54.

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1. Introduction

The number and intensity of climate-related disasters are increasing, and so are their economic and fiscal costs. Physical risks emanating from climate change have become a major driver of sovereign risk (Volz et al. 2020), increasing the cost of capital of climate-vulnerable countries (Buhr et al. 2018; Kling et al. 2018; Beirne at al. 2021a, 2021b). Besides direct and indirect impacts on fiscal balances, climate disasters can also have significant impacts on exchange rates and international reserves. Awareness has been growing of the significance of foreign exchange (FX) risk in international lending, thanks in part due to the Bridgetown Initiative and the Paris Summit (Persaud 2023, Élysée Palace 2023). Despite efforts to reduce vulnerabilities from borrowing in foreign currencies, developing countries are still exposed to FX risk (Eichengreen et al. 2023). Calls for climate resilient lending have intensified, along with efforts to enhance global currency risk markets.

Against this background, this study investigates empirically the effect of disasters on financial account flows, international reserves, and real effective exchange rates in a global sample. By analysing these together, it is possible to identify relationships between them and potential implications. The included disasters are storm, flood, wildfires and earthquakes. We test the following hypotheses:

(H1) Major disasters affect net portfolio investment flows of an impacted country.

(H2) Major disasters affect net foreign direct investment (FDI) flows of an impacted country.

(H3) Major disasters affect net other investment flows (e.g., bank deposits and loans) of an impacted country.

(H4) Major disasters affect the international reserves of an impacted country.

(H5) Major disasters affect the impacted country's real effective exchange rate (REER).

Net FDI, net portfolio investment and net other investment flows are the three main components of the financial account of the balance of payments. For 2021, the International Monetary Fund (IMF) reported global FDI asset flows of USD 2.3 trillion, portfolio asset flows of USD 3.4 trillion, and other asset flows of USD 2.8 trillion.[1] These figures reflect acquisitions and disposals of assets by non-residents only. International reserves and REERs may be impacted in their own right, as well as acting as mediators between financial flows and wider economic effects.

As will be discussed in Section 2, the literature comprises a handful of empirical studies on FDI flows (Escaleras and Register 2011, Neise et al. 2021, Khan et al. 2020), and one that fails to find significance on portfolio investment flows (Yang 2008) following disasters. Our results on net portfolio and net other investment flows form the first novel contribution of this paper. Secondly, research to date on exchange rates and reserves has been contradictory, finding in favour of both appreciation and depreciation of exchange rates, and rises and falls in reserves. We address this with more recent granular quarterly data, and explanatory context. For example, arguably reserves should rise after a disaster as much multilateral and bilateral support enters recipient countries via the reserve accounts. The third contribution of this paper is to combine and evolve our findings into a discussion that may help policy makers and international lenders deal with the increasing frequency and severity of disasters. The

[1] https://data.imf.org/regular.aspx?key=60961513

hypotheses chosen juxtapose balance of payments financial flows with changes to an impacted country's ability to pay for imports and make interest payments.

We test these hypotheses using disaster data from the Emergency Events Database (EM-DAT).[2] We convert reported losses into quarterly time series. This is used to define a major disaster quarter where either 1% of the population has been affected, or losses exceed 1% of GDP.

This study focuses on three country groupings:

(G1) Full country sample, comprising up to 66 countries of all income levels.

(G2) Emerging market and developing economies (EMDE), which excludes high income countries, and are a subset of the full country sample, comprising up to 43 countries.

(G3) International Development Association (IDA) eligible borrowers, which are a subset of EMDEs, comprising up to 12 countries.[3]

This categorisation reflects several factors. Firstly, our empirical work finds no impacts of major disasters on high income countries.[4] Secondly, IDA eligible borrowers are a group of countries that are either low income or lack the creditworthiness for borrowing from commercial lenders and the International Bank for Reconstruction and Development, the lending arm of the World Bank Group.[5] These poorer countries tend to be disproportionally affected by climate change.

Results vary by country grouping. For the full sample, major disaster quarters cause statistically significant portfolio inflows and reserve increases. For EMDEs, disasters cause statistically significant reserve increases and REER appreciation. A driver for these results may be the international community's assistance after the disaster. For IDA eligible countries, disasters cause statistically significant portfolio and other investment outflows, and REER depreciation.

Drilling deeper into the IDA eligible results, portfolio investment flows see a statistically significant marginal outflow effect from a disaster over three calendar quarters. Other investment flows (including cross-border bank lending) see a statistically significant outflow effect in the second quarter after the disaster quarter. REERs see two statistically significant quarters of depreciation subsequent to a disaster. This presents us with a loss of short-term private capital coincident with real currency depreciation, yet no statistically significant reserves increase for countries that need it most. This arguably highlights the importance and role of other offsetting flows through multilateral support or even debt relief.

Following the econometric analysis, we use nominal exchange rates to visualise our sample graphically. We find that nominal currency appreciation is temporary and rapidly reverses. This extends to increases in FX volatility, which implies increased FX risk and hedging costs. This links to Aghion et al. (2009) who find that increased FX volatility has negative impacts on productivity growth for less financially developed countries.

[2] https://www.emdat.be/

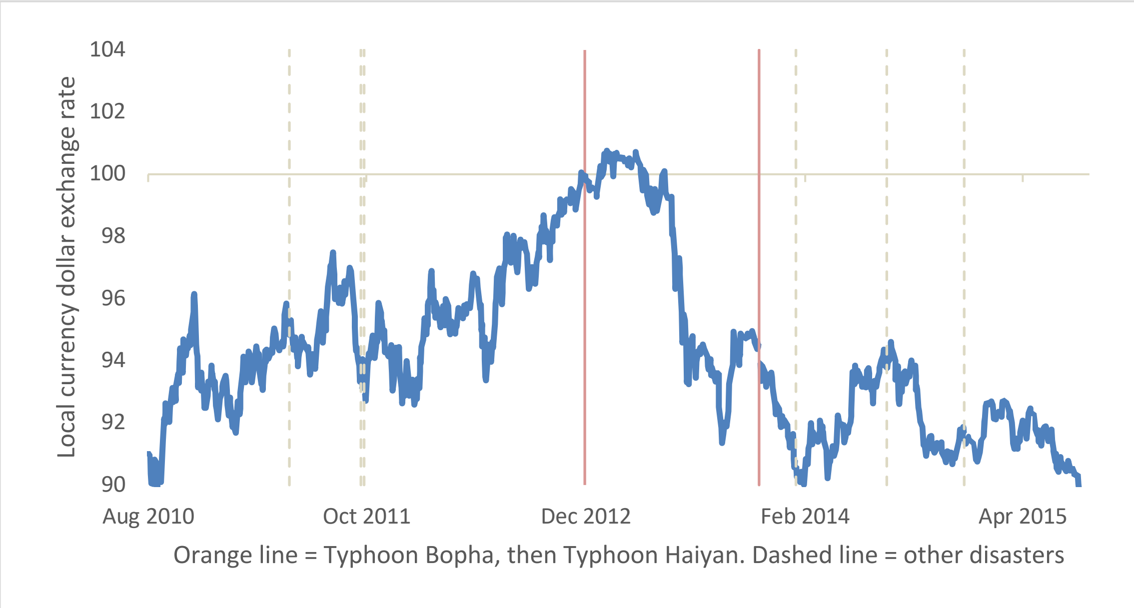
[3] https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups

[4] We do not report the results for high income countries. They are available on request.

[5] https://ida.worldbank.org/en/about

Furthermore, in contrast to its framing in the literature, we highlight how disasters are not rare. There are many countries which suffer major disasters every year. In Figure 1, we mark disaster quarters on the nominal local currency dollar exchange rate for the Philippines and observe a total of eight major disasters between 2011 and 2015, two of which, typhoons Bopha and Haiyan, were particularly severe. Climate change may increase the number of countries within this category.

Figure 1 – Major disaster quarters Philippines, 2010-2015



Source: Compiled by authors with data from Refinitiv & EMDAT

A limitation of our research is that in cases where a disaster occurs, there is first a disaster effect, followed by a disaster response (including, possibly, international support measures). Our framework does not distinguish between the two. Therefore, our results estimate the average financial effects of the combination of disaster effects and response. Clearly disaster response is endogenous and will vary between disasters. A second limitation is the difficulty in analysing the IDA eligible group in the way we can with the full sample group. For the latter it is meaningful to isolate countries with narrow fixed FX regimes, and also to test for disaster quarter threshold sensitivities. Conversely, slicing the IDA sample sometimes creates sub-groups consisting of a single disaster. A third limitation is data availability. The countries studied have been dictated by this, and a number of specifications reflect choices that ensure a base sample size of IDA eligible countries.

The remainder of this paper is structured as follows. The next section is a brief literature review. Section 3 provides an overview of the data and variables used. Section 4 lays out the methodology and methodological tests. Section 5 reports our empirical findings. Section 6 presents additional robustness checks, including a comparison of the impact of alternative disaster thresholds, and use of an alternative methodology. Section 7 contextualises the results, discusses implications for risk management and mitigation strategies and the inclusion of debt suspension or disaster risk clauses. The final section concludes.

2. Research context

Arguably, the theoretical starting point of financial market impacts of disasters originates in explanations of the equity risk premium. Rietz (1988) uses uncommon economic disasters, such as the World Wars, to explain the conundrum of higher-than-expected equity premiums. Barro (2006) puts forward an extension of this model, based on empirical data, that predicts the high equity premium, low risk free rate and equity market volatility seen in the real world. This work observes and utilises a disaster probability of 1.7 percent, with a range of GDP impacts between 15-64 percent.

Farhi and Gabaix (2015) move the discussion to FX rates. They develop a model of exchange rates based on extreme disasters. They fit disasters as a stochastic process and use their model to explain a variety of phenomena such as how the riskiest currencies have a positive correlation with world stock market returns. This strand of research joins an extensive literature of the economic effects of disasters, e.g., Noy (2009) and Cavallo et al. (2013). An important point is the difference between countries with a fixed or floating exchange rate. Countries with the latter may see shocks mediated primarily through the exchange rate, whereas countries with a fixed exchange rate may see shocks primarily mediated via FX reserves. Strobl and Kablan (2017), who focus their analysis of the impacts of tropical cyclones on the exchange rate of small island developing states, find that under flexible exchange rate regimes there is a real exchange appreciation up to two months after the storm. On the other hand, Zhou et al. (2021) examine the impact of COVID-19 on nominal exchange rates, finding significant depreciation effects on exchange rates of emerging markets, but not on those of advanced countries. Hale (2022) models the effect of a disaster on exchange rates as a Poisson distribution. Her model predicts disasters to cause a real depreciation for risky countries, and a real appreciation for safe countries.

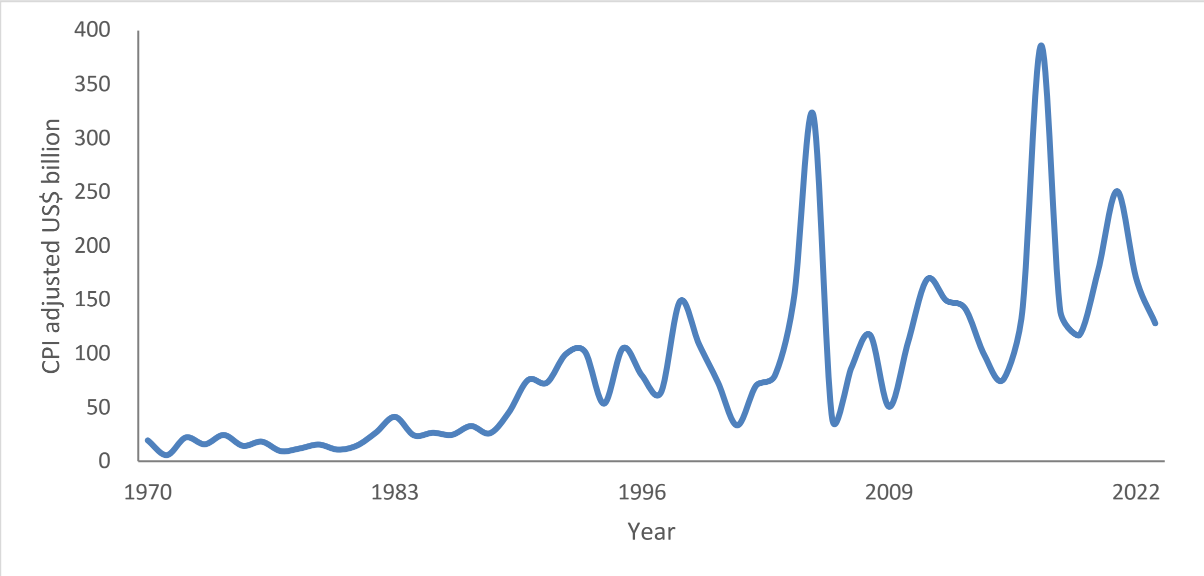
Segueing to international reserves, Moore and Glean (2015) analyse the optimal level of reserves for small island states. Research on this topic has gathered momentum recently with the publication of four papers. Ta, Jinjarak and Noy (2022) use a variety of methodologies, including panel fixed effects, and finds that earthquakes cause a rise in international reserve levels across a 5-year time frame. Khan and Anwar (2022) use a generalised method of moments (GMM) model and finds that reserve levels decline in the year after a disaster for non-high-income countries. Wang, Wang and Xing (2022) use a VAR model with bootstrapped rolling windows and find that at times climate disaster losses Granger causes changes in international reserves. Cantelmo et al. (2022) document how, within their sample, after a disaster countries typically saw an appreciation in exchange rates, declines in GDP, increases in inflation, and monetary policy changes. They then compute a stylised model based on this.

The effect of disasters on financial flows, has received less attention. Many papers analyse their drivers and touch on the connection with disasters, e.g., Belke and Volz (2019). Nevertheless, in a literature review Osberghaus (2019) notes how research on disasters and international financial flows has been dominated by flows most relevant to development finance, notably remittances and aid. Three multi country empirical papers test for the effect of disasters on FDI. Escaleras and Register (2011) find the trailing disaster count to be a statistically significant predictor of FDI. Khan et al. (2020) find a negative impact from a disaster dummy on FDI for Belt and Road Initiative countries. Neise et al. (2021) find that numbers affected can increase FDI into certain economic sectors. A noteworthy paper on capital flows is Yang (2008) that tests the theory that flows should smooth consumption and examines the impact of hurricanes on six types of financial flows. It finds several statistically significant results (official development aid, multilateral and bank lending), but none with respect to portfolio flows.

3. Data overview

Data on global disasters for the period 2005 to 2021 have been obtained from EM-DAT.[6] Disaster damage losses reported have been rising over time as shown in Figure 2. For the purpose of empirical analysis, we convert reported deaths, numbers affected and damages to quarterly totals by country – creating quarterly time series. We calculate the numbers affected relative to population and reported damages relative to GDP.

Figure 2 – Global reported disaster damages (adjusted for OECD CPI), 1970-2023



Source: Compiled by authors with data from EMDAT

Table 1 – Descriptive statistics

	N	Mean	Standard dev.	Min	Median	Max
Major disaster dummy	4,964	.0411	.199	0	0	1
Net Portfolio inv. flow, USD millions	4,215	-1,923	24,100	-335,239	-.1	199,562
Net FDI flow, USD millions	4,502	-778	11,939	-230,136	-266	149,756
Net Other inv. flow, USD millions	4,502	-307	20,281	-352,474	-11	182,570
First diff. log REER	2,972	.00151	.0376	-.458	.00138	.325
First diff. log nominal exchange rate	4,676	-.0149	.39	-17.6	-.000384	13.7
First diff. log international reserves	4,868	.0213	.138	-1.5	.0154	2.25
Rep. disaster deaths in quarter	1,577	202	2,946	0	10	87,776
Rep. disaster deaths / population	4,964	.0000429	.00068	0	0	.0421
Rep. disaster affected in quarter	1,577	1,087,971	6,691,780	0	14,473	140,182,192
Rep. disaster affected / population	4,964	.181	1.17	0	0	26.5
Rep. adj. disaster losses USD '000s	1,577	1,774,863	11,551,515	0	0	273,218,368
Rep. adj. disaster losses / GDP	4,964	.0891	1.8	0	0	81.4
First diff. log country CPI	4,384	.0197	.0853	-.32	.0091	2.22
First diff. log EUR-USD exchange rate	4,964	-.00262	.045	-.119	.00103	.108
Population, '000s	4,756	81,329	222,670	83	20,451	1,412,600
Comparable 12mth GDP, USD mil	4,620	783,810	2,289,358	446	146,611	19,190,000
First diff. log 12mth rolling GDP	4,603	.00864	.0155	-.284	.00875	.285
Narrow FX peg dummy	4,964	.189	.392	0	0	1
Financial openness index	4,940	.545	.375	0	.45	1

[6] Validated EM-DAT data is available for 2022, and unvalidated data for 2023. However, the sample period is constrained by the FX regime and financial openness variables which are up to 2021. EM-DAT caveats disaster data prior to 2000 as subject to reporting biases.

We source real effective exchange rates, nominal exchange rates, financial flows, international reserves and macroeconomic data from the IMF, the World Bank and Eikon Refinitiv. Specifically, on FDI, portfolio and other investment flows we do not distinguish between residents and non-residents, i.e., they are the net of inward and outward flows. We consider this more relevant for our study. IMF data on trade weighted bilateral de-facto FX regimes are used. The IMF infers FX regimes based on exchange rate volatilities and policy actions, adjusting its de-jure classifications, and is sourced from Harms and Knaze (2021). The Chinn-Ito financial openness index is sourced from Chinn and Ito (2006). Given the multiple sources, the focus on quarterly data, and each source with different data availability, our empirical samples are restricted by overlapping data constraints. The largest sample size for the presented results are 66 countries. Sampled countries vary between dependent variables. Appendix A.1 lists the variables.

4. Methodology

4.1 Disaster quarter dummy

As we are interested in the impact of disasters, we construct a dummy variable reflecting large disaster losses occurring within a calendar quarter. The dummy disaster variable is based on meeting one of two thresholds:

(1) Aggregated number of people affected by a disaster is 1% of country population or larger.

(2) Reported losses exceed 1 percent of country GDP.

Where either threshold is exceeded the major disaster dummy takes a value of 1, otherwise 0 is recorded. The list of disasters includes storms, floods, earthquakes and wildfires. We identify 295 major disaster quarters across 177 countries over a 16-year period. We exclude 27 countries that are members of the euro area, and 77 countries due to no reported disasters or missing data. This reduces the sample set to 73 countries and 204 disaster quarters (Appendix A.2). This list includes Venezuela and Zimbabwe, both of which are EMDEs (not full IDA eligible) that have been subject to hyperinflation during the sample period. Regressions are run without these two countries and do not change the findings of statistical significance for the full sample or EMDEs (not shown). This may partly be due to data gaps, i.e., neither was included in the REER regression by default. It is noted that an analysis of disasters is by definition an analysis of outlier events and therefore we are wary of backward-looking exclusions. The widest sub-sample used for the results presented are 66 countries. Alternative disaster thresholds applied to the full sample are used for robustness analysis.

It is necessary to control for the type of exchange rate regime. For the FX regime data, the de-facto regime is reported by the IMF in its Annual Reports on Exchange Arrangements and Exchange restrictions (AREAER), and consolidated by Harms and Knaze (2021) into a range of 1 to 4, where 1 is a hard peg (for example a currency board), and 4 is managed or freely floating. We compress this further to ease interpretation. Therefore, a Boolean "narrow FX peg" dummy is created by setting the dummy equal to 1 for all FX regime values under 3, covering no separate legal tender, hard pegs and narrow soft pegs. The narrow FX peg dummy is equal to 0 for wide soft pegs, managed and free floating.

Most regressions include the narrow FX peg as a control dummy. However, at times this dummy is used to divide samples into with and without a narrow FX peg. As visible in Table 2, the sampled IDA countries are approximately as likely to be subject to a disaster quarter

(3.8%) as the EMDE group it is part of (5.3%) but are much less likely to have a narrow FX peg (11.1% vs 16.8%). The exclusion of droughts from this analysis may contribute to the difference in disaster frequency.

Table 2 – Disaster and fixed exchange rate dummies

	Disaster quarter dummy		Narrow FX peg dummy		Total
	0	1	0	1	observations
Full sample	4,760	204	4,024	940	4,964
EMDE	3,090	174	2,716	548	3,264
IDA eligible	1,177	47	1,088	136	1,224

4.2 Empirical model

The widest empirical sample covers 66 countries organised as panels. We apply the following empirical model to the panel data set.

$$Y_{it} = \alpha + \beta^T X_{it} + \lambda^T Z_i + u_i + \varepsilon_{it} \qquad \text{(E1)}$$

The variable Y_{it} represents separate regressions of the following dependent variables:

$PORT_{it}$ = Net portfolio flows during the quarter for country *i* at time *t*. This is defined as "Cross-border transactions and positions involving debt or equity securities, other than those included in [foreign] direct investment or reserve assets" (IMF 2023, p36). All investment flow data is net of inward and outward flows, i.e., it does not differentiate between residents and non-residents.

FDI_{it} = Net FDI flows during the quarter from the financial accounts of a country's Balance of Payments.

OTH_{it} = Net other investment flows during the quarter. It is defined as a "category that includes positions and transactions other than those included in direct investment, portfolio investment, financial derivatives and employee stock options and reserve assets" (IMF 2023, p37). It is often interpreted as a proxy for bank flows as it includes deposits and loans.

RES_{it} = The first difference of the log of end of quarter international reserves. It can be written as $\Delta(\ln RES_{it})$. These are total official reserve assets valued in US dollars.[7]

$REER_{it}$ = The first difference of the log of the end of quarter REER as calculated by the IMF. It could be written as $\Delta(\ln REER_t)$. The underlying variable reflects how much of the trade weighted FX can be purchased by one unit of local currency, and therefore an increase in this figure represents local currency appreciation, while a decrease implies local currency depreciation. When modelling $REER_t$ we exclude the local CPI_t as a control.

The dependent variables above are regressed on the independent variables and other terms below.

X_{it} = A vector of time varying k x 1 dependent variables. This includes the disaster dummy of interest and its lags, and the narrow FX peg dummy. The full set of control variables include lagged difference in log quarterly local consumer price index (L.DLQCPI), lagged difference in four quarter rolling log of comparable GDP in US dollars (L.DLQGDP), difference in log euro US dollar exchange rate (DLQEUR: increase is euro appreciation, dollar depreciation), net

[7] https://data.imf.org/?sk=e6b49d2e-9eea-457d-8d0f-723ee0147924&hide_uv=1

FDI flows in US dollars, and an index of financial openness (Chinn and Ito 2006). Use of lags for some controls is a parsimonious method of mitigating endogeneity.

Z_i = A p x 1 vector of time invariant dependent variables, e.g., narrow FX peg dummy and index of financial openness for specific countries.

ε_{it} = Error term with mean zero and unit variance.

u_i = Cluster (country) specific error term.

α = Constant.

β = k x 1 coefficient vector.

λ = p x 1 coefficient vector.

$u_i + \varepsilon_{it}$ constitutes the composite error of a panel model. For the pooled OLS regressions in Section 6.2, there is no u_i term as the existence of clusters is ignored.

4.3 Variable and methodological testing

We carry out unit root tests for non-stationarity. Stationarity refers to time series where the mean, variance and autocorrelations can usually be approximated by a single set of realisations over long time averages (Enders 1995). Conversely, non-stationary time series contain unit roots, do not mean revert and are prone to producing misleading evidence of linear relationships, and therefore a transformation may be appropriate.

The only independent variable that takes identical values across all our panels is the euro – US dollar exchange rate. The cross rate used is the number of dollars per one euro, implying a rise is euro appreciation, dollar depreciation. We apply the augmented Dickey-Fuller (ADF) test with and without a trend component, and the Phillips-Peron (PP) test. These tests do not reject the null of a unit roots for the original time series and do reject the null for the first difference of log euro – US dollar exchange rate. This implies that this variable is stationary of order I(1) and justifies first differencing. The choice of logs is to improve the interpretability of the results, and equivalent to making the relevant variables percentage changes.

All the other variables chosen are in the form of country panels and require alternative testing. Although data has been collected in a uniform fashion, null values mean that the panels are unbalanced. This limits the types of tests appropriate. We use ADF based Fisher-type tests for panel unit roots. As laid out by Choi (2001), these are a set of four statistical methods that combine the p-values from ADF tests applied to each panel. The null hypothesis is that all panels contain a unit root. The alternative hypothesis is that at least one panel has a unit root.

These results are shown in Table 3. It is unsurprising that economic time series require first differencing. We take first difference of logs to ensure these variables are symmetric. Regarding the normalised disaster measures we note that the modal and median observation value is zero, ensuring a degree of mean reversion. Arguably more controversial is FDI, portfolio and other investment flows. We observe that as these are net flows, they take positive and negative values, and are by definition the first difference of FDI and portfolio investment balances. Finally, the financial openness index causes some difficulties, with a two reject, two do not reject for the four Fisher-type tests for panel unit roots. Given the index we use is 0 to 1, and is often time invariant within a panel, we argue it is stationary by design. Based on these unit root tests we suggest that our model is balanced with I(0) variables and transformations on both sides, which is useful in enabling a stationary error term. All future references to these variables refer to the first difference in logs, or investment flows, as used in our primary empirical model.

Table 3 – Panel unit root test results

	Levels			First difference of logs		
	1 lag	2 lags	3 lags	1 lag	2 lags	3 lags
Real effective exchange rate	NS	NS	NS	R	R	R
International reserves	NS	NS	NS	R	R	R
Consumer price index	NS	NS	NS	R	R	R
Affected persons / population	R	R	R			
Deaths / population	R	R	R			
Damage / GDP	R	R	R			
Net Direct investment (FDI) flows	R	R	R			
Net Portfolio investment flows	R	R	R			
Net Other investment flows	R	R	R			
Financial openness index	Mixed	Mixed	Mixed			
GDP, 4 quarter rolling	NS	NS	NS	R	R	R

Fisher-type ADF tests (Choi 2001) for panel unit roots are applied to the variables listed. NS = do not reject the null that all panels are non-stationary. R = reject the null in favour of the alternative hypothesis that at least one panel has a unit root. Mixed = two of the four Fisher-type ADF tests reject the null and two do not reject.

We move on to examine the key assumptions underpinning our analysis, starting with exogenous variables. Despite the theoretical exogeneity of disasters, clearly variables such as real effective exchange rate, international reserves, inflation, GDP and financial flows influence each other. We perform a Durbin-Wu-Hausman test by regressing inflation and GDP, the two we use as explanatory controls, on the other dependent variables and record the residuals. These are then inserted into our primary regressions and t-tests are applied to the residual coefficients. With a null hypothesis that the coefficient on these residuals is equal to zero, the t-statistics do not reject the null at the 95% statistical significance level with one exception. The residuals for GDP, when used to predict changes in the real effective exchange rate would reject the null at the 95% significance level when CPI is included. Therefore, we remove CPI from these regressions. We mitigate further when including changes in CPI and GDP by using lags.

It is not possible to use fixed effects OLS in the presence of time invariant dummies, or other values, as they would be collinear and are absorbed by the fixed effects. However, the Hausman test can be used to compare the appropriateness of fixed versus random effects by excluding these dummies. The Hausman test examines whether panel characteristics are correlated with the dependent variables. The null hypothesis is that they are not correlated, and random effects are appropriate. For REER, international reserves and portfolio flows, the Hausman test does not reject the null at the 95% significance level, suggesting random effects is appropriate. Portfolio flows would reject at the 90% significance level. The other investment flows test does not complete as it does not meet the required assumptions. The applicableness of the Hausman test is unfortunately debateable: the variables used in this test are not the same as in our final models, not only excluding the FX regime dummy but also financial flows, and excludes elements such as cluster robust standard errors, which we show are required.

We test for serial correlation by following Wooldridge (2010) and regress the residuals of the pooled OLS regressions for REER, reserves portfolio flows and other flows on the lagged residuals. Under a null hypothesis of a negative 0.5 coefficient on the lagged residuals (no serial correlation), the F-test rejects the null for all the dependent variables at the 95%

significance level. As stated by Wooldridge, tests for heteroscedasticity are not valid in the presence of serial correlation. Therefore, we address the presence of serial correlation and the potential for heteroscedasticity with cluster robust standard errors. A third benefit of cluster robust standard errors (and random effects) is that it is appropriate when seeking to generalise the result to other panels or countries outside of our sample (Cameron and Miller 2015).

As a final test we use the Breusch and Pagan Lagrange Multiplier (LM) test to test the appropriateness of Random Effects versus standard OLS. The null hypothesis is that variances between panels are equal to zero, i.e., no difference between panels. At the 95% statistical significance level, we do not reject the null for reserves, but we do reject the null for REER, FDI flows and Portfolio flows. This is an interesting result in its own right that for reserves there is a weak case that there are model differences between countries. In order to retain consistency, and based on the test results above, our primary analysis uses a random effects generalised least squares (GLS) model with cluster robust standard errors. We briefly compare our study choice with using GMM, another popular way to address endogeneity. Ullah et al. (2018) discuss the three typical steps or levels to GMM: (1) first difference transformation, (2) second order transformation using the average of all future observations and (3) the use of instrumental variables. We observe that our model manually incorporates the first step. The second step is particularly appropriate for high N (many panels), low T (few time period) analyses. This is less applicable for our dataset which utilises quarterly data – at its widest for the reserves regression N=66 and average T=54. We accept that instrumental variables could further mitigate the remaining endogeneity of our economic controls, however given the acceptable test statistics, we choose efficiency over further reducing bias. Furthermore, as our goal is to estimate the impact of disasters, rather than predict our dependent time series, a static, as opposed to dynamic model incorporating lags of the dependent variable, is parsimonious and appropriate.

5. Results and discussion

As discussed, the key explanatory variable is the disaster dummy, which takes the value of 1 in a quarter where reported persons affected exceeds 1% of population or reported losses exceed 1% of GDP. This does not adjust for the number of reported disasters in a quarter and the timing of disasters. Therefore, the current quarter dummy value could relate to a disaster that occurred at the beginning of a quarter, or at the end, or relate to multiple disasters. Four quarterly lags constitute one year. Presentation of one year of quarterly disaster lags provides the results with some comparability with prior literature using annual data. A problem with using this methodology for annual data is identified: some countries reach disaster thresholds every year, making an annual disaster dummy time invariant for those panels.

We run multiple regressions and segment our results by three country groupings: full sample, EMDEs and IDA eligible.[8] Due to data availability, the number of country panels in each regression may vary. Control variables are not reported in the regression tables and are available on request. These are lagged difference in log quarterly local consumer price index (L.DLQCPI), lagged difference in four quarter rolling log of comparable GDP in US dollars (L.DLQGDP), difference in log euro US dollar exchange rate (DLQEUR: increase is euro

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[8] https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups

appreciation, dollar depreciation), net FDI flows in US dollars, and an index of financial openness (Chinn and Ito 2006).

Regressions including euro area countries have been run (sample of up to 86 countries) and do not change the statistical significance on the disaster dummy for the relevant sample groups (not shown). The regressions find no statistical significance on the disaster dummy for high income-countries (not shown). Venezuela and Zimbabwe are EMDEs (not IDA) in the sample that have been subject to periods of hyperinflation during the sample range. Regressions are run excluding these countries and do not change the findings of significance for the full sample or EMDEs. This may partly be due to data gaps, i.e., neither was included in the REER regression.

5.1 (H1) Major disasters affect net portfolio investment flows of an impacted country

Changes in net portfolio investment flows are regressed on the disaster dummy and four of its lags (equating to one year). The results are presented by country grouping (Tables 4-6) and the full sample split by FX regime (Tables 7-8). Any country group with significant results are checked for robustness with alternative lag specifications, and as floating or wide peg FX regime observations only.

In a regression of net portfolio investment flows for the full sample, the positive coefficient on the third lag of the disaster dummy rejects the null hypothesis of zero (Table 4). This is at the 95% statistical significance level. There appears to be no statistically significant coefficients for the EMDE group. However, for the IDA eligible subset the positive coefficient on the current quarter disaster dummy, and the negative coefficients on the first and second lags are statistically significant at the 95% level. As the dependent variable is the net flow in millions of US dollars, the three coefficients imply a USD 65 million outflow over three quarters.

Table 4 – Net portfolio investment flows, country groups

Net portfolio investment	(P1) Full sample	(P2) EMDE	(P3) IDA eligible
Major disaster dummy	-2,218.284	-338.815	60.574*
	(-1.19)	(-0.85)	(2.06)
L1(Major disaster dummy)	1,112.244	-244.460	-69.012*
	(0.67)	(-0.38)	(-2.13)
L2(Major disaster dummy)	-4,906.154	4.840	-56.125*
	(-1.51)	(0.01)	(-2.34)
L3(Major disaster dummy)	1,232.490*	1,427.298	37.870
	(2.49)	(1.54)	(1.85)
L4(Major disaster dummy)	2,554.114	589.679	-198.519
	(1.32)	(0.99)	(-1.42)
Observations	3,395	1,943	414
Countries	63	40	9

t statistics in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

As a test of robustness, alternative lag specification results for net portfolio investment flows for the full sample are presented in Table 5. The statistically significant third lag is present across specifications.

Table 5 – Net portfolio investment flows, full sample alternative lag specification

Net portfolio investment, Full	(P4) No lags	(P5) One lag	(P6) Two lags	(P7) Three lags	(P1) Four lags
Major disaster dummy	-1,845.551	-1,837.122	-2,460.200	-1,816.436	-2,218.284
	(-0.97)	(-0.96)	(-1.09)	(-1.15)	(-1.19)
L1(Major disaster dummy)		281.040	147.769	271.844	1,112.244
		(0.29)	(0.15)	(0.28)	(0.67)
L2(Major disaster dummy)			-4,881.694	-4,806.155	-4,906.154
			(-1.52)	(-1.50)	(-1.51)
L3(Major disaster dummy)				1,180.269*	1,232.490*
				(2.51)	(2.49)
L4(Major disaster dummy)					2,554.114
					(1.32)
Observations	3,527	3,527	3,484	3,440	3,395
Countries	63	63	63	63	63

t statistics in parentheses. * p < 0.05, ** p < 0.01, *** p < 0.001

In Table 6, the alternative lag specifications for IDA eligible countries are shown. For the model with no lags and four lags, there is a positive coefficient on the current period disaster dummy that rejects the null of zero at the 95% statistical significance level or higher. This does not recur in other specifications. For the second lag, it appears to only attain statistical significance in the presence of four lags. However, the coefficient on the first lag rejects the null of zero at the 95% significance level for all specifications. We consider the negative coefficient on the first lag of the disaster dummy, representing a net outflow of portfolio investment, to be robust.

Table 6 – Net portfolio investment flows, IDA eligible alternative lag specification

Net Portfolio investment, IDA	(P8) No lags	(P9) One lag	(P10) Two lags	(P11) Three lags	(P3) Four lags
Major disaster dummy	65.037***	24.483	24.592	24.526	60.574*
	(3.41)	(0.53)	(0.60)	(0.61)	(2.06)
L1(Major disaster dummy)		-71.598*	-73.049*	-73.148*	-69.012*
		(-2.48)	(-2.31)	(-2.11)	(-2.13)
L2(Major disaster dummy)			-58.777	-57.200	-56.125*
			(-1.49)	(-1.51)	(-2.34)
L3(Major disaster dummy)				42.329	37.870
				(1.95)	(1.85)
L4(Major disaster dummy)					-198.519
					(-1.42)
Observations	434	434	428	421	414
Countries	9	9	9	9	9

t statistics in parentheses. * p < 0.05, ** p < 0.01, *** p < 0.001

When the full sample is divided into exchange rate regimes (Table 7), the positive coefficient on the third lag moves higher for floating or wide pegs, and the statistical significance rises to 99%. For the narrow FX peg sample, the negative coefficient on the first lag is statistically significant at the 95% level and implies portfolio investment outflows. Note that some countries change exchange rate regimes during the sample period and therefore appear in both groups.

Table 7 – Net portfolio investment flows, fixed versus floating FX regimes

Net Portfolio investment, Full	(P1) Full sample	(P12) Narrow FX peg	(P13) Float / wide peg
Major disaster dummy	-2,218.284	-439.379	-2,405.242
	(-1.19)	(-1.08)	(-1.18)
L1(Major disaster dummy)	1,112.244	-1,289.005*	1,267.045
	(0.67)	(-2.39)	(0.71)
L2(Major disaster dummy)	-4,906.154	-141.402	-5,248.772
	(-1.51)	(-0.47)	(-1.51)
L3(Major disaster dummy)	1,232.490*	-696.046	1,354.346**
	(2.49)	(-1.65)	(2.58)
L4(Major disaster dummy)	2,554.114	154.056	2,740.094
	(1.32)	(0.26)	(1.30)
Observations	3395	608	2787
Countries	63	20	57

t statistics in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The set of narrow FX peg observations appear to be so small as to create odd results at the country grouping level. Therefore, we compare the IDA eligible results with floating and wide peg FX regimes only. This effectively removes the 13% of quarterly observations where the IMF has defined the FX regime as narrow peg or firmer. This change results in statistical significance on the positive third lag. For the sample of nine IDA eligible countries without narrow FX pegs, disasters appear to drive inflows during the quarter of the disaster, then two quarters of outflows and then inflows. The sum of the statistically significant pegs becomes -23.88, which implies an outflow of USD 24 million (Table 8).

Table 8 – Net portfolio investment flows, floating FX regime, IDA eligible

Net portfolio investment, IDA	(P3) IDA eligible	(P14) IDA eligible with float / wide peg
Major disaster dummy	60.574*	64.118*
	(2.06)	(2.36)
L1(Major disaster dummy)	-69.012*	-70.842*
	(-2.13)	(-2.16)
L2(Major disaster dummy)	-56.125*	-57.109*
	(-2.34)	(-2.38)
L3(Major disaster dummy)	37.870	39.951*
	(1.85)	(2.20)
L4(Major disaster dummy)	-198.519	-206.714
	(-1.42)	(-1.43)
Observations	414	362
Countries	9	9

t statistics in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Based on the results above we conclude in favour of (H2) and that disasters affect net portfolio investment flows. Within this dependent variable, an outflow may reflect non-residents selling domestic assets, or residents buying overseas assets. However, they are transactions recorded in the balance of payments, not merely price fluctuations.

5.2 (H2) Major disasters affect net FDI flows of an impacted country

Although regressions were run to test for the impact of major disaster quarters on FDI flows, we discovered problematic issues with the quarterly data used. For example, in the case of Uganda, the IMF reports net FDI flows of USD 262.9 million for each of the four quarters of

2013,[9] and a total for the year of USD 1,051.6 million. It seems likely that the quarterly data is the annual figure divided by four. This affects multiple countries for multiple years. Given this we do not consider the hypothesis on FDI to be tractable on a quarterly time frame with this data set. This applies in particular for the IDA countries we are interested in. Therefore, we do not find evidence for or against (H3) that disasters affect FDI. This hypothesis is left open as an avenue for future research based on alternative sources of FDI data, e.g., from UNCTAD.

5.3 (H3) Major disasters affect net other investment flows (e.g., bank deposits and loans) of an impacted country

The other investment flows from the financial accounts of the balance of payments are defined as “positions and transactions other than those included in direct investment, portfolio investment, financial derivatives and employee stock options and reserve assets” (IMF 2023, p37). As it includes deposits and loans it is sometimes used as a proxy for bank flows. The results by country group are shown in Table 9.

There are no statistically significant coefficients for the full sample or EMDEs. For IDA eligible countries, we find a statistically significant negative coefficient on the second lag of the disaster dummy at the 99% level. As the dependent variable is the net flow in millions of US dollars, this coefficient implies a USD 210 million outflow in the second quarter following the quarter of the disaster.

Table 9 – Net other investment (e.g., bank deposits and loans), country groups

Net other investment	(O1) Full sample	(O2) EMDE	(O3) IDA eligible
Major disaster dummy	1070.140	-1469.750	-164.107
	(0.57)	(-1.82)	(-1.75)
L1(Major disaster dummy)	964.344	1925.243	-53.928
	(0.64)	(0.99)	(-1.15)
L2(Major disaster dummy)	3836.127	2427.228	-209.894**
	(1.57)	(1.03)	(-2.67)
L3(Major disaster dummy)	-1416.098	-1725.795	-386.117
	(-0.69)	(-1.13)	(-1.70)
L4(Major disaster dummy)	-1383.175	-217.604	-287.946
	(-1.74)	(-0.67)	(-1.43)
Observations	3632	2180	643
Countries	66	43	12

t statistics in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

As a test of robustness, alternative lag specifications for IDA eligible countries are shown in Table 10. The statistical significance on the second lag of the disaster dummy holds across specifications. Further, the negative coefficient on the current quarter disaster dummy is also statistically significant for two of the alternative lag specifications, reaching the 99.9% level for the three lag model. As the latter does not hold across all specifications, we do not consider it robust.

[9] IMF, https://data.imf.org/regular.aspx?key=62805742

Table 10 – Net other investment (e.g., bank deposits and loans), IDA eligible alternative lag specification

Net Other investment, IDA	(O4) No lags	(O5) One lag	(O6) Two lags	(O7) Three lags	(O3) Four lags
Major disaster dummy	-147.326	-148.541	-189.366**	-223.120***	-164.107
	(-1.77)	(-1.81)	(-2.93)	(-3.59)	(-1.75)
L1(Major disaster dummy)		17.570	-27.557	-62.684	-53.928
		(0.51)	(-0.72)	(-1.19)	(-1.15)
L2(Major disaster dummy)			-174.888*	-214.948**	-209.894**
			(-2.49)	(-3.10)	(-2.67)
L3(Major disaster dummy)				-383.071	-386.117
				(-1.65)	(-1.70)
L4(Major disaster dummy)					-287.946
					(-1.43)
Observations	667	667	659	651	643
Countries	12	12	12	12	12

t statistics in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

When the full sample is divided into exchange rate regimes, for observations with a narrow FX peg, the positive coefficient for the current quarter disaster dummy is statistically significant at the 95% level (Table 11).

Table 11 – Net other investment (e.g., bank deposits and loans), fixed versus floating FX regimes

Net Other investment, Full	(O1) Full sample	(O8) Narrow FX peg	(O9) Float / wide peg
Major disaster dummy	1070.140	1280.103*	1166.014
	(0.57)	(2.14)	(0.59)
L1(Major disaster dummy)	964.344	646.347	990.868
	(0.64)	(0.92)	(0.60)
L2(Major disaster dummy)	3836.127	332.363	4173.790
	(1.57)	(0.65)	(1.61)
L3(Major disaster dummy)	-1416.098	985.637	-1671.791
	(-0.69)	(1.19)	(-0.78)
L4(Major disaster dummy)	-1383.175	-392.272	-1455.035
	(-1.74)	(-0.57)	(-1.65)
Observations	3632	628	3004
Countries	66	21	60

t statistics in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

In Table 12, the IDA results for floating or wide peg FX regimes are shown. Although the coefficient becomes less negative, and the statistical significance declines, it remains significant at the 95% level. This coefficient implies a USD 158 million outflow in the second quarter after a disaster quarter for IDA countries with floating or wide peg FX regimes.

Table 12 – Net other investment flows, floating FX regimes, IDA eligible

Net Other investment, IDA	(O3) IDA eligible	(O10) Float / wide peg
Major disaster dummy	-164.107	-164.206
	(-1.75)	(-1.52)
L1(Major disaster dummy)	-53.928	-53.521
	(-1.15)	(-1.03)
L2(Major disaster dummy)	-209.894**	-158.181*
	(-2.67)	(-2.43)
L3(Major disaster dummy)	-386.117	-417.927
	(-1.70)	(-1.92)
L4(Major disaster dummy)	-287.946	-293.676
	(-1.43)	(-1.49)
Observations	643	571
Countries	12	12

t statistics in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Based on the results above, we conclude in favour of (H3) and that disasters affect net other investment flows. Note that an outflow may reflect non-residents repatriating capital from a country, or residents exporting capital.

5.4 (H4) Major disasters affect the international reserves of an impacted country

Beginning with the country group analysis for international reserves (Table 13), for the full sample the coefficient on the current quarter and second lag of the disaster dummy rejects the null of zero at the 99% statistical significance level. Both coefficients are positive, indicating an increase in international reserves following a major disaster quarter. This result appears to be driven by EMDEs, with similar statistical significance on slightly higher coefficients. This is plausibly related to the international community's disaster response mechanisms.

Table 13 – International reserves, country groups

International reserves	(R1) Full sample	(R2) EMDE	(R3) IDA eligible
Major disaster dummy	0.018**	0.021**	0.010
	(2.83)	(2.66)	(0.84)
L1(Major disaster dummy)	0.013	0.010	-0.010
	(1.54)	(1.04)	(-0.55)
L2(Major disaster dummy)	0.018**	0.018**	0.006
	(2.95)	(2.75)	(0.40)
L3(Major disaster dummy)	-0.005	-0.011	-0.007
	(-0.71)	(-1.30)	(-0.28)
L4(Major disaster dummy)	-0.003	-0.009	0.020
	(-0.40)	(-0.83)	(0.82)
Observations dummy	3563	2111	604
Countries	66	43	12

t statistics in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

If international aid after a disaster is provided in international currency, and not all of this is spent, this could lead to an increase in gross international reserves (GIR). The International Reserves Management Report of the Central Bank of Seychelles (2023, P.4) provides an example where a country's GIR have been boosted by international donor support: "The higher GIR position was mainly led by external financing from international organisations such as the AfDB [African Development Bank] and IBRD in the form of budget support loans and grants." Clearly, bilateral and multilateral support can be provided via the reserves account. Given this and ignoring the edge case of support being spent as soon as it is received, international reserves should rise after a major disaster. We identify the lack of statistically significant increases in reserves for IDA eligible countries as an area for future research. Is this because aid to these countries is delivered in non-pecuniary terms (e.g., food and medical support) or circumventing their governments? Or is this because not enough support is extended?

Alternative lag specifications for the full sample are reported in Table 14. The 99% statistical significance of the current quarter and second lag of the disaster dummy sustains across specifications. Alternative lag specifications for the EMDEs are shown in Table 15. The current quarter and second lag of the disaster dummy is statistically significant at the 99% level except for the current quarter under the one lag model, and the second quarter of the two lag model, which are significant at the 95% level.

Table 14 – International reserves, full sample alternative lag specification

International reserves, Full	(R4)	(R5)	(R6)	(R7)	(R1)
	No lags	One lag	Two lags	Three lags	Four lags
Major disaster dummy	0.017**	0.017**	0.017**	0.018**	0.018**
	(2.82)	(2.94)	(2.97)	(2.89)	(2.83)
L1(Major disaster dummy)		0.012	0.011	0.011	0.013
		(1.58)	(1.47)	(1.45)	(1.54)
L2(Major disaster dummy)			0.018**	0.019**	0.018**
			(2.81)	(3.00)	(2.95)
L3(Major disaster dummy)				-0.006	-0.005
				(-0.77)	(-0.71)
L4(Major disaster dummy)					-0.003
					(-0.40)
Observations	3701	3701	3655	3609	3563
Countries	66	66	66	66	66

t statistics in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 15 – International reserves, EMDE alternative lag specifications

International Reserves, EMDE	(R8)	(R9)	(R10)	(R11)	(R2)
	No lags	One lag	Two lags	Three lags	Four lags
Major disaster dummy	0.018**	0.017*	0.018**	0.019**	0.021**
	(2.60)	(2.57)	(2.65)	(2.64)	(2.66)
L1(Major disaster dummy)		0.010	0.009	0.008	0.010
		(1.12)	(1.01)	(0.98)	(1.04)
L2(Major disaster dummy)			0.017*	0.019**	0.018**
			(2.43)	(2.78)	(2.75)
L3(Major disaster dummy)				-0.012	-0.011
				(-1.39)	(-1.30)
L4(Major disaster dummy)					-0.009
					(-0.83)
Observations	2183	2183	2159	2135	2111
Countries	43	43	43	43	43

t statistics in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 16 reports regression results organised by FX regimes. The floating and wide peg observations reveal similar results to the full sample, with 99% statistically significant coefficients on the current quarter and second lag of the disaster dummy. For narrow FX pegged observations, the first lag on the disaster dummy is statistically significant at the 95% level. The latter coefficient is an order of magnitude higher than those for without a narrow peg. As the dependent variable is the first difference of logs, 0.133 this model implies a 13.3% increase in reserves in the quarter after a major disaster quarter is identified. This compares to the significant coefficients of a 1.6% and 1.8% rise in reserves for observations outside a narrow FX peg regime. This causes a conundrum within the narrow FX peg group as previously we identified an outflow of portfolio investment flows against the same lag of the disaster dummy – although this is in addition to a prior quarter other investment inflow. As discussed, the countries in each specification are not identical, typically due to gaps in the data.

Table 16 – International reserves, fixed versus floating FX regimes

International reserves, Full	(R1) Full sample	(R12) Narrow FX peg	(R13) Float / wide peg
Major disaster dummy	0.018**	0.055	0.016**
	(2.83)	(1.01)	(2.63)
L1(Major disaster dummy)	0.013	0.133*	0.005
	(1.54)	(2.30)	(0.75)
L2(Major disaster dummy)	0.018**	0.026	0.018**
	(2.95)	(1.49)	(2.73)
L3(Major disaster dummy)	-0.005	-0.020	-0.005
	(-0.71)	(-0.31)	(-0.83)
L4(Major disaster dummy)	-0.003	-0.022	-0.002
	(-0.40)	(-0.80)	(-0.25)
Observations	3563	577	2986
Countries	66	21	60

t statistics in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

In Table 17, the floating and wide peg FX regime results for EMDEs are shown. The positive coefficients on the current quarter disaster dummy and the second lag decline slightly, and the statistical significance falls to the 95% level.

Table 17 – International reserves, floating FX regimes, EMDEs

International reserves, EMDE	(R2) EMDE	(R14) Float / wide peg
Major disaster dummy	0.021**	0.016*
	(2.66)	(2.35)
L1(Major disaster dummy)	0.010	0.003
	(1.04)	(0.46)
L2(Major disaster dummy)	0.018**	0.017*
	(2.75)	(2.54)
L3(Major disaster dummy)	-0.011	-0.008
	(-1.30)	(-1.05)
L4(Major disaster dummy)	-0.009	-0.006
	(-0.83)	(-0.60)
Observations	2111	1802
Countries	43	38

t statistics in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Based on the results shown we conclude in favour of (H4) and that disasters lead to an increase in international reserves for the full sample and EMDEs. For IDA eligible countries the results are not statistically significant.

5.5 (H5) Major disasters affect the impacted country's real effective exchange rate (REER)

The REER regressions differ from the other regressions in that they exclude the CPI as a control. This is because REER, by construction, has been CPI adjusted. We observe that the full sample size is somewhat smaller than for the other dependent variables.

Table 18 – Real effective exchange rate, country groups

REER	(FX1) Full sample	(FX2) EMDE	(FX3) IDA eligible
Major disaster dummy	-0.006	-0.008	-0.030
	(-1.54)	(-1.29)	(-1.20)
L1(Major disaster dummy)	0.001	-0.001	-0.018*
	(0.59)	(-0.19)	(-2.12)
L2(Major disaster dummy)	0.003	0.005**	0.003
	(1.84)	(2.70)	(0.46)
L3(Major disaster dummy)	0.003	0.000	-0.011*
	(1.31)	(0.03)	(-2.33)
L4(Major disaster dummy)	0.001	0.004	0.006
	(0.35)	(0.67)	(0.58)
Observations dummy	2,437	1,169	409
Countries	44	23	9

t statistics in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

In a regression of REER on the disaster dummy, we find no significant coefficients for the full sample. Noteworthy results are present for EMDE and IDA eligible groups. For EMDEs, the results reject the null of a zero coefficient on the positive coefficient on the second lag at the 99% statistical significance level. This indicates REER appreciation. For IDA countries, we find the coefficients on the first lag and third lag of the disaster dummy to be statistically significant at the 95% level. Both of these coefficients are negative, indicating REER depreciation. As the dependent variable is the first difference in logs, the -0.018 and -0.011 values implies real deprecation of 1.8% and 1.1%, one and three quarters after the disaster dummy takes the value of one.

Alternative lag specifications for EMDEs are reported in Table 19. The coefficient on the second lag of the disaster dummy is statistically significant across lag specifications. This is at the 95% level for two and three lag models, and 99% for the four lag model.

Table 19 – Real effective exchange rate, EMDEs alternative lag specification

REER, EMDE	(FX4) No lags	(FX5) One lag	(FX6) Two lags	(FX7) Three lags	(FX2) Four lags
Major disaster dummy	-0.007	-0.007	-0.007	-0.007	-0.008
	(-1.42)	(-1.42)	(-1.23)	(-1.33)	(-1.29)
L1(Major disaster dummy)		-0.000	0.000	-0.001	-0.001
		(-0.01)	(0.01)	(-0.17)	(-0.19)
L2(Major disaster dummy)			0.004*	0.004*	0.005**
			(2.15)	(2.15)	(2.70)
L3(Major disaster dummy)				-0.000	0.000
				(-0.17)	(0.03)
L4(Major disaster dummy)					0.004
					(0.67)
Observations	1206	1206	1195	1182	1169
Countries	23	23	23	23	23

t statistics in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Alternative lag specifications for IDA eligible countries are reported in Table 20. The statistically significant negative coefficients on the first and third lag of the disaster dummy occur across specifications.

Table 20 – Real effective exchange rate, IDA eligible alternative lag specification

REER, IDA	(FX8) No lags	(FX9) One lag	(FX10) Two lags	(FX11) Three lags	(FX3) Four lags
Major disaster dummy	-0.030	-0.031	-0.030	-0.031	-0.030
	(-1.18)	(-1.18)	(-1.18)	(-1.19)	(-1.20)
L1(Major disaster dummy)		-0.019*	-0.019*	-0.019*	-0.018*
		(-2.01)	(-2.06)	(-2.10)	(-2.12)
L2(Major disaster dummy)			0.003	0.002	0.003
			(0.40)	(0.39)	(0.46)
L3(Major disaster dummy)				-0.011*	-0.011*
				(-2.34)	(-2.33)
L4(Major disaster dummy)					0.006
					(0.58)
Observations	419	419	417	413	409
Countries	9	9	9	9	9

t statistics in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

When the full sample is divided into with and without narrow FX pegs, the narrow FX peg group gains a statistically significant negative coefficient on the first lag at the 99.9% level (Table 21). Even though it is a small effect, it is perhaps rather surprising to see a significant effect on exchange rates for those countries in the sample that manage their exchange rate, while there is no effect on countries with a free float. A possible explanation is that countries with a narrow FX peg will usually see little exchange rate movement so that even smaller movements caused by a disaster makes this effect statistically significant, in contrast to the relatively free floating currencies where FX volatility is higher anyway even in normal times.

Table 21 – Real effective exchange rate, fixed versus floating FX regimes

REER, Full	(FX1) Full sample	(FX12) Narrow FX peg	(FX13) Float / wide peg
Major disaster dummy	-0.006	-0.009	-0.006
	(-1.54)	(-1.82)	(-1.46)
L1(Major disaster dummy)	0.001	-0.008***	0.002
	(0.59)	(-4.28)	(0.70)
L2(Major disaster dummy)	0.003	0.000	0.003
	(1.84)	(0.06)	(1.51)
L3(Major disaster dummy)	0.003	0.000	0.003
	(1.31)	(0.03)	(1.26)
L4(Major disaster dummy)	0.001	0.001	0.001
	(0.35)	(0.56)	(0.27)
Observations	2,437	423	2,014
Countries	44	15	41

t statistics in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 22 shows the floating and wide peg results for EMDEs. The coefficient on the second lag of the disaster dummy declines slightly and is statistically significant at the 95% level.

Table 22 – Real effective exchange rates, floating FX regimes, EMDE

REER, EMDE	(R2) EMDE	(R14) Float / wide peg
Major disaster dummy	-0.008	-0.008
	(-1.29)	(-1.32)
L1(Major disaster dummy)	-0.001	-0.001
	(-0.19)	(-0.30)
L2(Major disaster dummy)	0.005**	0.004*
	(2.70)	(2.41)
L3(Major disaster dummy)	0.000	-0.000
	(0.03)	(-0.07)
L4(Major disaster dummy)	0.004	0.003
	(0.67)	(0.56)
Observations	1,169	1,010
Countries	23	21

t statistics in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

In Table 23, the results for floating and wide peg results for IDA countries are reported. The statistical significance and coefficients are nearly identical. The reason is straightforward, there are no major disaster quarters, within the narrow FX peg sample, carved out from the regression.

Table 23 – Real effective exchange rates, floating FX regimes, IDA eligible

REER, IDA	(R3) IDA eligible	(R15) Float / wide peg
Major disaster dummy	-0.030	-0.029
	(-1.20)	(-1.17)
L1(Major disaster dummy)	-0.018*	-0.018*
	(-2.12)	(-2.11)
L2(Major disaster dummy)	0.003	0.004
	(0.46)	(0.52)
L3(Major disaster dummy)	-0.011*	-0.011*
	(-2.33)	(-2.22)
L4(Major disaster dummy)	0.006	0.007
	(0.58)	(0.61)
Observations	409	357
Countries	9	9

t statistics in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Based on these results we conclude in favour of (H5) that major disasters affect real effective exchange rates. Disasters appear to have driven REER appreciation in EMDEs and depreciation among IDA eligible countries.

6. Additional robustness checks

6.1 Sensitivity to disaster thresholds

We use alternative disaster dummy thresholds to explore the sensitivity of our dependent variables to changes in disaster impact sizes. The primary specification used above is for affected persons equal or greater than 1% of population, and damages equal or greater than 1% of GDP. We define alternative thresholds of 3%, 5% and 10%. As the threshold increases, the number of disaster observations declines. Lower thresholds include all disasters categorised by higher thresholds. These frequencies are shown in Table 24.

Table 24 – Disaster frequency by threshold and sample group

	1% disasters	3% disasters	5% disasters	10% disasters
Full sample	204	83	42	22
EMDE	174	66	31	14
IDA eligible	47	19	9	4

When alternative disaster thresholds are applied to the full sample for the portfolio investment regression, the statistical significance on the positive coefficient on the third lag disappears (Table 25).

Table 25 – Net portfolio investment, alternative disaster thresholds

Portfolio Investment, Full Disaster thresholds, POP / GDP	(P1) 1%	(PA2) 3%	(PA3) 5%	(PA4) 10%
Major Disaster dummy	-2,218.284	-3015.019	-169.035	2,500.765
	(-1.19)	(-1.03)	(-0.19)	(1.11)
L1(Major Disaster dummy)	1,112.244	-192.744	5,635.446	13,335.813
	(0.67)	(-0.08)	(0.86)	(0.96)
L2(Major Disaster dummy)	-4,906.154	-5,728.118	-8,940.972	-17,906.614
	(-1.51)	(-0.88)	(-1.17)	(-1.11)
L3(Major Disaster dummy)	1,232.490*	966.364	-1,075.271	-3,322.286
	(2.49)	(0.60)	(-0.78)	(-1.02)
L4(Major Disaster dummy)	2,554.114	5,323.922	479.412	472.260
	(1.32)	(1.27)	(0.25)	(0.14)
Observations	3,395	3,395	3,395	3,395
Countries	63	63	63	63

t statistics in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

In Table 26 when alternative disaster thresholds are applied to the full sample other investment (e.g., bank loans and deposits) regression, there are no statistically significant results.

Table 26 – Net other investment (e.g., bank deposits and loans), alternative disaster thresholds

Other Investment, Full Disaster thresholds, POP / GDP	(O1) 1%	(OA2) 3%	(OA3) 5%	(OA4) 10%
Major Disaster dummy	1,070.140	606.033	-3469.598	-381.770
	(0.57)	(0.17)	(-0.67)	(-0.12)
L1(Major Disaster dummy)	964.344	1,440.818	-2,864.432	-2,381.061
	(0.64)	(0.77)	(-1.28)	(-0.60)
L2(Major Disaster dummy)	3,836.127	2,996.098	5,401.070	812.959
	(1.57)	(0.92)	(1.16)	(0.06)
L3(Major Disaster dummy)	-1,416.098	-4,981.672	-3,522.933	-2,443.787
	(-0.69)	(-1.00)	(-0.66)	(-0.30)
L4(Major Disaster dummy)	-1,383.175	-5,238.978	-1,187.096	-6,280.141
	(-1.74)	(-1.61)	(-1.01)	(-0.94)
Observations	3,632	3,632	3,632	3,632
Countries	66	66	66	66

t statistics in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

When alternative disaster thresholds are applied to the full sample for international reserves, the results for a 3% disaster threshold are similar to the 1% threshold (Table 27). The main difference is that the statistical significance on the positive coefficients on the current quarter disaster dummy and second lag declines from 99% to the 95% level. For the 5% threshold, the current quarter coefficient loses statistical significance. At the 10% threshold the second lag loses statistical significance, however a positive coefficient attains statistical significance on the fourth lag.

Table 27 – International reserves, alternative disaster thresholds

International reserves, Full Disaster thresholds, POP / GDP	(R1) 1%	(RA2) 3%	(RA3) 5%	(RA4) 10%
Major Disaster dummy	0.018**	0.017*	-0.008	-0.001
	(2.83)	(2.54)	(-1.06)	(-0.10)
L1(Major Disaster dummy)	0.013	0.010	-0.003	0.013
	(1.54)	(1.48)	(-0.40)	(0.98)
L2(Major Disaster dummy)	0.018**	0.021*	0.024*	0.020
	(2.95)	(2.35)	(2.15)	(1.23)
L3(Major Disaster dummy)	-0.005	0.007	-0.001	0.004
	(-0.71)	(0.85)	(-0.08)	(0.17)
L4(Major Disaster dummy)	-0.003	0.005	0.000	0.019*
	(-0.40)	(0.80)	(0.06)	(2.07)
Observations	3563	3563	3563	3563
Countries	66	66	66	66

t statistics in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Alternative disaster thresholds against REERs are shown in Table 28. In contrast to the other dependent variables, for REER higher disaster thresholds appear to strengthen the significance of results. The original 1% disaster threshold has no significant results. For the 3% disaster threshold, the positive coefficient on the second lag rejects the null of zero at the 95% statistical significance level. For the 5% disaster threshold, the positive coefficient on the first lag rejects the null of zero at the 95% statistical significance level. Both significant coefficients imply real appreciation.

Table 28 – Real effective exchange rate, alternative disaster thresholds

REER, Full Disaster thresholds, POP / GDP	(FX1) 1%	(FXA2) 3%	(FXA3) 5%	(FXA4) 10%
Major Disaster dummy	-0.006	-0.008	-0.003	-0.009
	(-1.54)	(-1.30)	(-0.84)	(-1.84)
L1(Major Disaster dummy)	0.001	0.001	0.008*	0.003
	(0.59)	(0.31)	(2.11)	(0.62)
L2(Major Disaster dummy)	0.003	0.008*	0.003	0.005
	(1.84)	(2.49)	(0.89)	(0.91)
L3(Major Disaster dummy)	0.003	0.002	0.002	0.001
	(1.31)	(0.72)	(0.55)	(0.19)
L4(Major Disaster dummy)	0.001	0.006	-0.001	-0.001
	(0.35)	(1.13)	(-0.11)	(-0.18)
Observations	2437	2437	2437	2437
Countries	44	44	44	44

t statistics in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

In terms of selecting which disaster threshold to focus on, the key concern is generating enough disaster quarter observations within meaningful sub samples. As shown, higher thresholds produce relatively few disaster observations for IDA eligible countries. Results for disaster thresholds under 1% were not meaningful (not shown). Overall, alternative higher thresholds have mixed effects on full sample statistical significance, reducing the significance of the portfolio investment results and improving the REER results.

6.2 Pooled OLS regressions for country groupings

The results of the Hausman test and the Breusch and Pagan Lagrange Multiplier (LM) test in sub-section 4.3 Variable and methodological testing found that panel random effects was an appropriate methodology for the regression on REERs and portfolio investment flows. The other investment flows testing was inconclusive, while for reserves, testing suggested pooled (or panel) OLS is appropriate. In other words, for reserves, we were not able to reject the null hypothesis that the variances between panels are equal to zero, i.e., no difference between panels. Based on this, pooled OLS is used as a robustness test for all the country grouping results. As discussed, cluster robust standard errors are used for both methods. The difference between panel random effects and pooled OLS is that for the former each cluster has its own adjusted error term, whereas for the latter a single error term is adjusted for correlations within clusters. As there is a single error term, the traditional R^2 and adjusted R^2 are provided.

Table 29 reports the pooled OLS results for net portfolio flows. There are no statistically significant results for the full sample and EMDEs. The negative coefficient on the second lag of the disaster dummy is statistically significant at the 95% level. Compared to the panel random effects model a statistical significance has been lost on the third lag of the full sample and on the current quarter and first lag of the IDA eligible group. The results confirm the robustness of the second lag for IDA eligible countries, with a coefficient that implies a USD 56 million outflow.

Table 29 – Net portfolio investment flows, pooled OLS, country groups

Net portfolio investment	(P1) Full sample	(P2) EMDE	(P3) IDA eligible
Major disaster dummy	-2398.758	-338.815	60.574
	(-1.12)	(-0.85)	(2.06)
L1(Major disaster dummy)	895.252	-244.460	-69.012
	(0.47)	(-0.38)	(-2.13)
L2(Major disaster dummy)	-5452.519	4.840	-56.125*
	(-1.35)	(0.01)	(-2.34)
L3(Major disaster dummy)	267.010	1427.298	37.870
	(0.35)	(1.54)	(1.85)
L4(Major disaster dummy)	1485.644	589.679	-198.519
	(1.14)	(0.99)	(-1.42)
Observations	3395	1943	414
Countries	63	40	9
R^2	0.042	0.076	0.042
Adjusted R^2	0.039	0.071	0.016

t statistics in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

For net other investment flows, the pooled OLS results find no statistically significant results for the full sample (Table 30). For EMDEs, the negative current quarter disaster dummy coefficient becomes statistically significant relative to the panel random effects model. This implies an outflow of USD 1.06 billion in the quarter of the disaster. For IDA eligible countries, the pooled OLS results confirm the 95% statistical significance on the second lag of the disaster dummy. This implies an outflow of USD 210 million in the second quarter after the disaster.

Table 30 – Net other investment (e.g., bank deposits and loans), pooled OLS, country groups

Net other investment	(O1) Full sample	(O2) EMDE	(O3) IDA eligible
Major disaster dummy	1134.616	-1057.907*	-164.107
	(0.78)	(-2.07)	(-1.75)
L1(Major disaster dummy)	945.953	2159.179	-53.928
	(0.44)	(1.02)	(-1.15)
L2(Major disaster dummy)	3506.925	2250.879	-209.894*
	(1.43)	(1.04)	(-2.67)
L3(Major disaster dummy)	-1621.225	-1483.574	-386.117
	(-1.32)	(-1.07)	(-1.70)
L4(Major disaster dummy)	-1608.855	77.986	-287.946
	(-1.26)	(0.30)	(-1.43)
Observations	3632	2180	643
Countries	66	43	12
R^2	0.035	0.077	0.150
Adjusted R^2	0.032	0.072	0.135

t statistics in parentheses. * p < 0.05, ** p < 0.01, *** p < 0.001

As discussed, the methodological testing suggested that pooled OLS was most appropriate for the regression on international reserves. This can be seen in the results in Table 31. The coefficients on the current quarter disaster dummy and the second lag, for the full sample and EMDEs, are statistically significant for both pooled OLS and panel random effects. The coefficient values are the same, with the only change being that the statistical significance on the current quarter coefficient for EMDEs declines from 99% to 95%. There are no statistically significant results for IDA eligible countries.

Table 31 – International reserves, pooled OLS, country groups

International reserves	(R1) Full sample	(R2) EMDE	(R3) IDA eligible
Major disaster dummy	0.018**	0.021*	0.010
	(2.83)	(2.66)	(0.84)
L1(Major disaster dummy)	0.013	0.010	-0.010
	(1.54)	(1.04)	(-0.55)
L2(Major disaster dummy)	0.018**	0.018**	0.006
	(2.95)	(2.75)	(0.40)
L3(Major disaster dummy)	-0.005	-0.011	-0.007
	(-0.71)	(-1.30)	(-0.28)
L4(Major disaster dummy)	-0.003	-0.009	0.020
	(-0.40)	(-0.83)	(0.82)
Observations dummy	3563	2111	604
Countries	66	43	12
R^2	0.039	0.041	0.041
Adjusted R^2	0.036	0.036	0.023

t statistics in parentheses. * p < 0.05, ** p < 0.01, *** p < 0.001

The pooled OLS results for REERs are shown in Table 32. The positive coefficient on the second lag for the full sample and EMDEs are statistically significant at the 95% and 99% level respectively. The result for the full sample is new versus panel random effects. For IDA eligible countries, the negative coefficient on the third lag is statistically significant at the 95% level and appears to be robust. However, the statistical significance on the first lag from the panel random effects model no longer appears.

Table 32 – Real effective exchange rate, pooled OLS, country groups

REER	(FX1) Full sample	(FX2) EMDE	(FX3) IDA eligible
Major disaster dummy	-0.005	-0.006	-0.030
	(-1.40)	(-0.96)	(-1.20)
L1(Major disaster dummy)	0.002	0.002	-0.018
	(1.00)	(0.68)	(-2.12)
L2(Major disaster dummy)	0.004*	0.008**	0.003
	(2.18)	(3.71)	(0.46)
L3(Major disaster dummy)	0.003	0.002	-0.011*
	(1.69)	(1.06)	(-2.33)
L4(Major disaster dummy)	0.002	0.006	0.006
	(0.48)	(0.96)	(0.58)
Observations dummy	2437	1169	409
Countries	44	23	9
R^2	0.010	0.022	0.036
Adjusted R^2	0.005	0.013	0.011

t statistics in parentheses. * p < 0.05, ** p < 0.01, *** p < 0.001

The panel random effects findings presented in Section 5 found that for the full sample, major disaster quarters cause statistically significant portfolio inflows and reserve increases. The pooled OLS results endorse the reserve increase, do not confirm the portfolio inflow result, but adds a statistically significant REER appreciation.

For EMDEs, the panel random effects model found that disasters cause statistically significant reserve increases and REER appreciation. The pooled OLS model endorses the reserve increase and REER appreciation and adds a statistically significant result on other investment outflows.

For IDA eligible countries, the panel random effects model found that disasters cause statistically significant portfolio and other investment outflows, and REER depreciation. The pooled OLS model endorsed all these results, though with fewer statistically significant coefficients.

7. Discussion and policy implications

7.1 Contextualising the results

A dummy representing major disaster quarters was regressed on international reserves, portfolio and other investment flows and real effective exchange rates. For the full sample, there are statistically significant positive coefficients on portfolio inflows and reserves. We find no effects of disasters on high income countries. However, for EMDEs and IDA eligible countries, we see statistically significant but divergent results. For EMDEs, we see modest appreciation in REER and a somewhat larger increase in international reserves. This result is consistent with an international disaster response that might involve the bilateral and multilateral extension of budget support loans and grants passing through recipient country monetary authorities.

In contrast, for IDA eligible countries we find portfolio investment outflows, other investment outflows, REER depreciation and yet no statistically significant changes in international reserves. This is consistent with a group of countries that have insufficient resources to address the second order financial challenges wrought by major disasters.

Zambia is a country within the IDA sample for real effective exchange rates. It was subject to three major disaster quarters due to flooding in Q1 2007,[10] Q1 2009,[11] and Q1 2020.[12] To help connect the specific countries to the wider sample, we perform an ordinary least squares regression with the same variables as used earlier to Zambia. The results for REERs are shown in Table 33 with and without controls and lags of the disaster dummy. Both the narrow FX peg and financial openness index are omitted due to being time invariant.

Table 33 reveals a number of country specific findings and observations. The negative (depreciation) coefficient on the current quarter disaster dummy is statistically significant at the 95% level for both the model with and without controls or additional lags. The non-significant constant to the model with controls is -0.022, which implies a trend quarterly REER depreciation of 2.2%, and therefore the depreciation during disaster quarters occurs in addition to the intercept. The countervailing element to the model is the non-significant coefficient on changes in GDP. As the latter is an elasticity, it implies a 1.97% appreciation in the REER for a 1% quarterly rise in GDP. As expected, the number of variables negatively impacts the adjusted R^2. Nevertheless, a model of REER (column ZR2) generates an interesting R^2 for a model parsimoniously consisting of a (positive) intercept and a current quarter disaster observation. A critique of the Zambia example arises from other disasters: one major disaster quarter based on flooding was in the middle of a longer period of severe drought (IFRC 2021). Droughts have not been included in this study as drought tends to be spread out over time, and effects cannot be easily located within a calendar quarter.

Table 33 – Ordinary least squares model for one country: Zambia

OLS model, Zambia Dependent variable	(ZR1) DLQREER	(ZR2) DLQREER
Major Disaster dummy	-0.089*	-0.092*
	(-2.28)	(-2.32)
L1(Major Disaster dummy)	-0.035	
	(-0.88)	
L2(Major Disaster dummy)	0.010	
	(0.26)	
L3(Major Disaster dummy)	-0.014	
	(-0.35)	
L4(Major Disaster dummy)	0.027	
	(0.69)	
L1(DLQGDP)	1.971	
	(1.97)	
DLQEUR	-0.001	
	(-0.00)	
FDI flow	0.000	
	(0.19)	
Constant	-0.022	0.008
	(-1.33)	(0.91)
N	64	68
R^2	0.158	0.076
Adjusted R^2	0.036	0.062

t statistics in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Nevertheless, the Zambia example illustrates how major disasters can have detectable financial effects for individual countries. The more important question is how strong the

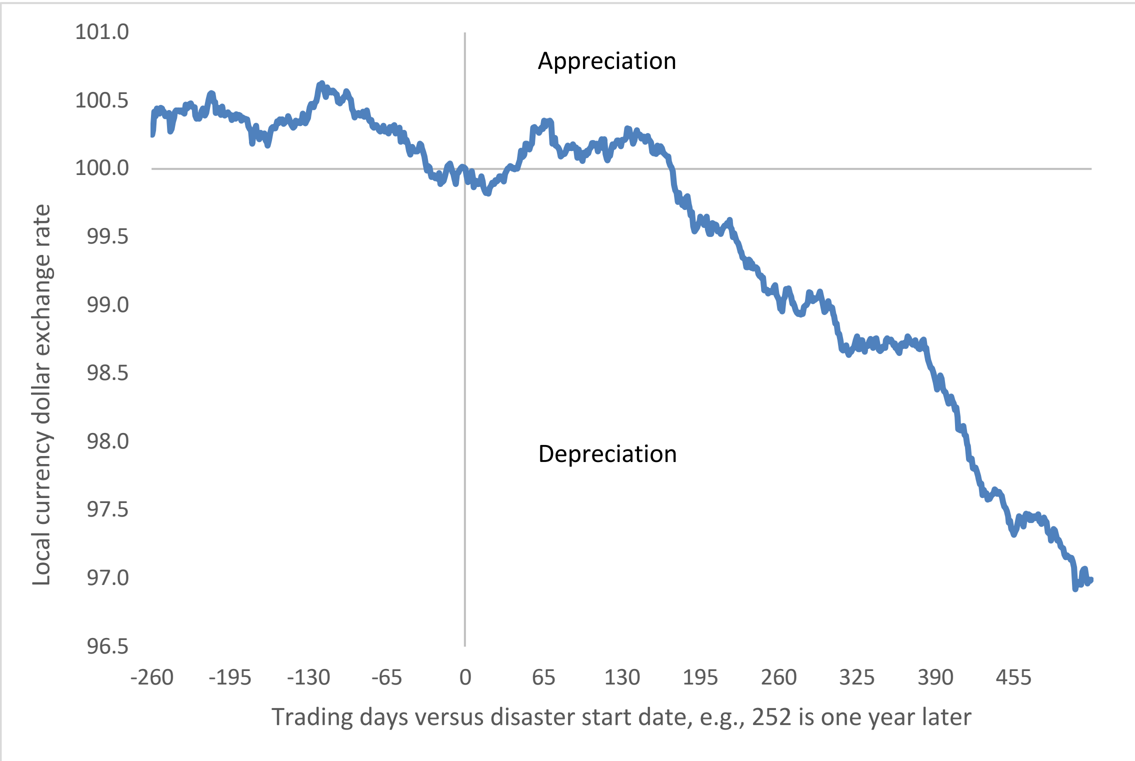
[10] https://reliefweb.int/disaster/fl-2007-000011-zmb
[11] https://reliefweb.int/report/zambia/zambia-and-namibia-face-worst-floods-40-years
[12] https://reliefweb.int/report/zambia/zambia-floods-flash-update-no-1-16-january-2020

evidence of effects is across countries – which has been presented in the prior sections. Further, when comparing these OLS results with the wider IDA eligible REER panel regression, we observe that the statistical significance on the current quarter disaster dummy for Zambia does not extend to the wider group, showing how effects in one country are balanced within larger samples.

7.2 Nominal exchange rates and exchange rate volatility

To help illustrate the FX impact of major disasters, we chart the start dates of disasters, consistent with our disaster quarter dummy, on daily nominal local currency dollar exchange rates (Figure 3). The full sample of countries puts forward 195 disasters with data extending one year before and two years after the related disaster start date. These are collated and the average graphed. After a 1-2 quarter period of stability (or slight appreciation), a clear downward trend becomes apparent in the sample. We find that one year after the disaster, 3 out of 5 countries see nominal currency depreciation.

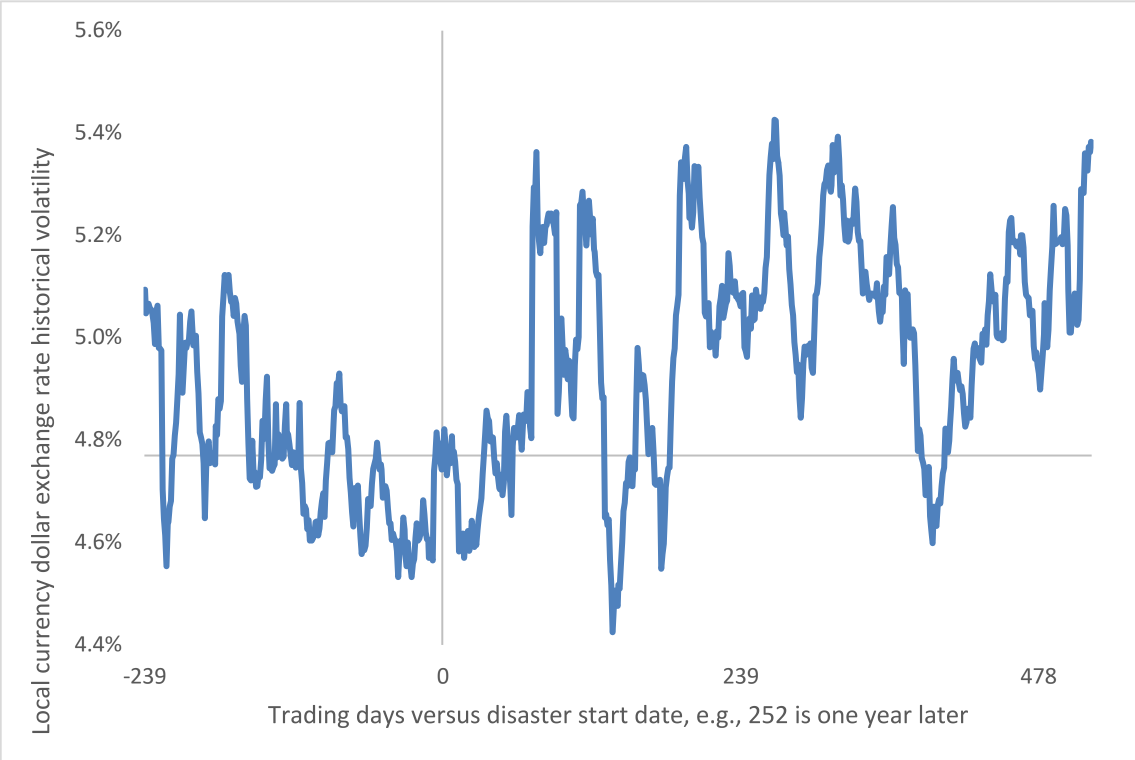
Figure 3 – Local currency dollar exchange rate and major disasters



Note: Sample of 195 disasters for all countries. Start value normalized to 100 and day 0.
Source: Compiled by authors with data from Refinitiv

A calculation of nominal FX volatility is shown in Figure 4. It is observed that volatility picks up prior to the nominal exchange rate declining. The potential implications of this connects to Aghion et al. (2009) who find that increased FX volatility has negative impacts on productivity growth for less financially developed countries.

Figure 4 – Local currency dollar exchange rate historical volatility and major disasters



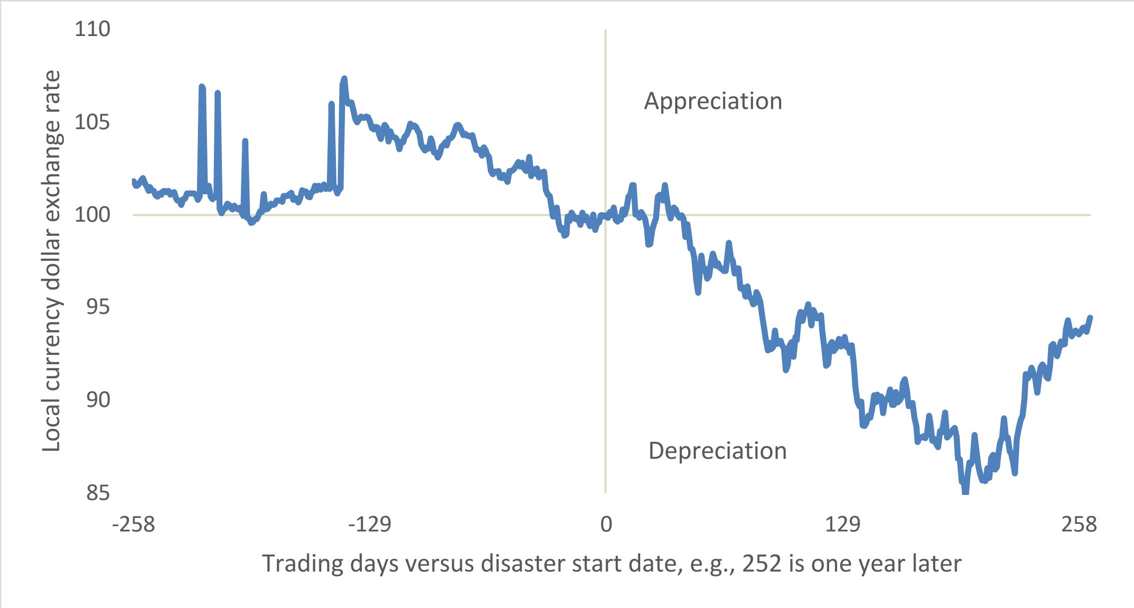
Note: Sample of 195 disasters for all countries. Exchange rate volatility calculated as 20-day sample standard deviation, annualized. Average at disaster date of 4.77%.
Source: Compiled by authors with data from Refinitiv

São Tomé is an IDA eligible country that is categorised as a lower middle income. The World Bank has produced an excellent story map of the flood risks it faces. Its complex challenges include climate change, the increasing cost of necessities, and limited land that is often rugged. The disaster highlighted came after Covid-19. The World Bank's flood hazard and risk assessments execute combined modelling of simultaneous coastal and rainfall flooding. They estimate average annual losses for the country of 3.06% of GDP in 2020 rising to 4.16% in 2050 and 6.17% in 2080. São Tomé requires large investments in climate adaptation and climate resilience.

Figure 5 highlights a disaster at the end of our sample in São Tomé and Príncipe. Heavy rainfall peaked on 29 December 2021 and led to floods across the country. This date is marked as zero in Figure 5. While the country was still responding to this, two further rounds of flooding occurred in March and May 2022 (IFRC 2022). The figure shows the almost 15% nominal depreciation in the currency in 2022.

São Tomé is an IDA eligible country that is categorised as a lower middle income. The World Bank has produced an excellent story map of the flood risks it *faces* (World Bank 2023). Its complex challenges include climate change, the increasing cost of necessities, and limited land that is often rugged. The disaster highlighted came after Covid-19. The World Bank's flood hazard and risk assessments execute combined modelling of simultaneous coastal and rainfall flooding. They estimate average annual losses for the country of 3.06% of GDP in 2020 rising to 4.16% in 2050 and 6.17% in 2080. São Tomé requires large investments in climate adaptation and climate resilience.

Figure 5 – Floods in São Tomé and Príncipe, December 2021



Note: Normalised to 100 and day 0.
Source: Compiled by authors with data from Refinitiv & EMDAT

7.2 Policy recommendations

While the impact of disasters on capital flows, reserves and exchange rates is not uniform across countries, depending on an economy's specific context and the international support it receives in response to the disaster, our analysis has provided clear indication that countries facing disaster risk confront heightened exchange risk resulting from disasters. In particular, IDA-eligible countries tend to suffer from capital outflows, exchange rate depreciation, and greater exchange rate volatility. Moreover, a majority of EMDEs also suffers from depreciation effects and an increase in exchange rate volatility after a disaster. This poses serious challenges for the public sector with respect to public debt and financial risk management. It also raises important questions for development lenders.

Authorities of countries facing elevated exchange risk resulting from disasters have several options to mitigate this risk. A first and obvious one is to strengthen adaptation and resilience to reduce the impacts of disasters on the economy, the financial system, and public finances (Volz et al. 2020). But this is of course easier said than done, not least because investment in adaptation will require large amounts of funding. Indeed, those countries that need to invest the most in adaptation to boost resilience against climate shocks are the ones that have the least fiscal space, and they also have to pay a higher cost of capital because of their vulnerability (Buhr et al. 2018; Kling et al. 2018; Beirne et al. 2021a, 2021b). Underinvestment in climate resilience is threatening both the economy and public debt sustainability.

Second, governments of disaster-prone countries must strengthen their disaster risk finance, i.e., develop financial protection strategies and instruments to address the fiscal impacts and economic losses caused by disasters and pre-arrange the release of rapid, predictable funding in the aftermath of a disaster so they can respond swiftly and support recovery and reconstruction. This includes the buildup of domestic disaster reserve funds, participation in sovereign catastrophe risk pools (Ciullo et al. 2023) and arranging access to contingent credit facilities and parametric disaster insurance.

Third, they need to enhance their public debt management to mitigate disaster related risks. One solution that has received a lot of attention recently are debt suspension or disaster risk clauses, which basically allow governments to postpone payments (e.g., Landers and Aboneaaj 2023). While this can enhance fiscal space in the aftermath of a disaster, it does not address currency risk as such. The public debt service could be even larger at the time of repayment if the local currency devalues. Foreign currency risk emanates from foreign currency-denominated debt and unhedged debt servicing costs (Jonasson et al. 2024). To mitigate FX risk, governments essentially have two options. They can either reduce FX borrowing by strengthening domestic financial resource mobilisation, or they can hedge exchange risk. The former includes efforts to develop local currency bond markets and broaden the domestic investor base (Volz, Lo and Mishra 2024). For the time being, most developing countries are still suffering from original sin (Eichengreen et al. 2023) – the problem that they are unable to borrow in domestic currency, be it from abroad or long term, even domestically (Eichengreen and Hausmann 1999). Concerted efforts are needed to foster the development of local currency bond markets and overcome original sin. This, however, is nothing that can be achieved in the short run. It is hence important that governments consider options for FX hedging. The challenge here is that for many countries hedging opportunities are either not existing or very expensive.

Especially low and lower middle income countries – the countries that our analysis suggests may face the highest risk of a currency devaluation after a disaster – usually lack sufficiently developed currency risk markets which would allow them or their lenders to hedge currency risks associated with cross border lending. These countries are also most dependent on international development and climate finance, in large part from multilateral development banks (MDBs). MDBs have already endorsed the demand from the Bridgetown Initiative to include “climate resilient debt clauses” in lending contracts (e.g., World Bank 2024). Yet, given the currency and associated sovereign debt sustainability risks, MDBs and other international public lenders still need to pay more attention to the currency risk that they pass on to governments. There are three issues that MDBs and other international public lenders could and should do.

First, they should support governments in raising the domestic savings rate and strengthening domestic financial resource mobilisation to reduce dependency on borrowing from abroad. To this end, Volz et al. (2024) highlight the potential of MDBs and international development finance institutions (DFIs) to work more closely with national development banks and bolster their capacity to issue local currency debt. They also highlight the opportunities of leveraging digital technologies for broadening the local investor base and developing sustainable investment opportunities for investors.

Second, MDBs and international DFIs should themselves lend more in local currency. They could either do this by raising local currency by issuing local currency bonds – eliminating FX risk altogether and the same time contributing to the development of local currency bond markets – or they could manage the exchange risk themselves.

Thirdly, if MDBs cannot raise local currency funding and lend in local currencies, they should make use of existing hedging markets or a cooperative hedging platform like TCX to reduce the overall currency risk exposure of IDA borrowers. This has already been proposed in the Summers/Singh Triple Agenda Report Vol 2 (IEG 2023), and the scaling up of TCX could be an effective short-term measure to facilitate a significant reduction in the currency risk vulnerabilities of IDA lenders and borrowers alike. IDA countries in particular should be made aware of currency risks when borrowing and be offered a choice between traditional (hard currency) borrowing instruments and loans indexed in local currencies. This would effectively work as a form of disaster insurance, working anti-cyclically instead of the existing pro-cyclicality of FX debt. A further elaboration of this would be a systematic voluntary conversion of existing IDA and other concessional debt into local currency-indexed loans. This could go together with capacity building efforts to increase the resilience to shocks. Making climate donor funds available to cover (part) of the higher interest costs should become part of the policy discussions.

8. Conclusion

In this paper, reported disaster impacts have been used to construct a quarterly major disaster dummy. Major disaster quarters are defined as quarterly impacts exceeding 1% losses as percent of GDP or 1% of total population affected. The included disasters are storm, flood, wildfires and earthquakes. This dummy is then used to model disaster impacts on portfolio investment flows, other investment flows, international reserves and real effective exchange rates. By analysing these together, we argue it is possible to identify relationships between them and put forward potential implications and policy interventions.

Regressions are run on samples of up to 66 countries, as well as subsets of EMDEs and IDA eligible countries. For the full sample, major disaster quarters cause statistically significant portfolio investment inflows and reserve increases. For EMDEs, disasters cause statistically significant reserve increases and REER appreciation. This result is consistent with an international disaster response involving the bilateral and multilateral extension of budget support loans and grants. For IDA eligible countries, however, disasters cause statistically significant portfolio and other investment outflows, and REER depreciation.

Drilling deeper into the IDA eligible results, portfolio investment flows see a statistically significant marginal outflow effect from a disaster over three calendar quarters. Other investment flows see a statistically significant outflow effect in the second quarter after the disaster quarter. REERs see two statistically significant quarters of depreciation subsequent to a disaster. This presents us with a loss of short-term private capital coincident with real currency depreciation, yet no statistically significant reserve increase for countries that need it most. This is consistent with a group of countries that have insufficient resources to address the challenges wrought by major disasters. It arguably highlights the importance and role of other offsetting flows such as debt relief and multilateral support.

A graphical analysis of the effect of disasters on nominal exchange rates and FX volatility reveals how the majority of sampled disasters drive nominal depreciation and rising FX volatility. Both of these make the financing and hedging of debt and imports more difficult. It is hence important that MDBs and international DFIs support EMDEs, and low income and lower middle income countries in particular, in reducing their FX exposures.

The documented vulnerabilities of IDA countries support recent policy reform calls. These include a medium to long-term agenda to strengthen domestic savings and funding markets, more immediate efforts to strengthen the currency and interest rate risk management capacities of IDA recipient debt management offices, and a mandate for MDBs to assist IDA borrowers by lending in local currency or reducing currency mismatches by offering loans indexed to the local exchange rate and supporting the creation of currency risk markets.

Vectors for future research include estimating our dependent variables simultaneously and differentiating between types of investment flows, e.g., transactions by residents vs non-residents.

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Appendix

A.1 Data sources

Variable	Description	Source
Reported disaster losses	Total damages are converted to USD thousands and adjusted for OECD consumer price inflation.	EM-DAT
Reported disaster number affected	Total affected is the sum of the number injured, number affected and number homeless.	EM-DAT
Reported disaster deaths	Includes number reported dead or missing.	EM-DAT
International reserves	Calculated as reserve assets less IMF loans and exceptional financing. Reserve assets include monetary gold, special drawing rights, reserve positions at the IMF, currency and deposits, securities, and other claims.	IMF, International Financial Statistics
Real effective exchange rates	For each country a weighted average exchange rate is calculated and then adjusted by an index of consumer price inflation. An increase implies an appreciation in the REER.	IMF, International Financial Statistics
Nominal exchange rates	Some charts use nominal exchange rates of how many dollars can be exchanged for a unit of local currency. An increase implies an appreciation in the local currency.	Eikon Refinitiv
Net FDI flow	Direct investment includes equity and debt instruments associated with transactions between affiliated enterprises. This is the net of changes of non-resident liabilities (inward) in a country and resident assets overseas (outward).	IMF, International Financial Statistics
Net Portfolio Investment flow	Transactions in securities other than those included in direct investment, reserve assets, and exceptional financing. This is the net of changes of non-resident liabilities (inward) in a country and resident assets overseas (outward).	IMF, International Financial Statistics
Comparable 12mth GDP, USD mil	The sum of 4 periods of quarterly constant dollar, seasonally adjusted gross domestic product (GDP) in USD millions	Eikon Refinitiv
Consumer price indices	Headline CPI indices as reported by national statistical organisations	Eikon Refinitiv
Population	Estimated total population.	Eikon Refinitiv
Effective de-facto exchange rate regime	Weighted de-facto IMF exchange rate regimes (1-4). Trade weights based on moving average of prior 3 periods.	Harms and Knaze (2021)
High Income and IDA country lists	As of December 2024.	World Bank

A.2 Major disaster quarters by country

Country	Date	Nominal FX %	Reserves %	Disaster losses, quarter			Disaster losses, % GDP / Pop			EMDE	IDA
	Quarter	4 quarters later	4 quarters later	Death	Affected	USD loss k's	Deaths	Affected	Damage		
Albania	Q1-05	-4	8	2	400,000	0	0.0	13.3	0.0	1	0
Albania	Q1-15	7	24	0	42,000	0	0.0	1.5	0.0	1	0
Albania	Q4-19	7	28	51	202,913	801,300	0.0	7.1	5.4	1	0
Bangladesh	Q3-07	0	14	1,110	13,771,380	141,146	0.0	9.8	0.1	1	1
Bangladesh	Q4-07	1	10	4,234	8,978,541	3,246,350	0.0	6.4	3.3	1	1
Bangladesh	Q2-09	-1	44	197	3,954,550	368,313	0.0	2.7	0.3	1	1
Bangladesh	Q3-11	-8	15	10	1,570,559	0	0.0	1.0	0.0	1	1
Bangladesh	Q2-12	5	48	164	5,203,596	0	0.0	3.4	0.0	1	1
Bangladesh	Q3-14	-1	21	59	3,200,447	197,793	0.0	2.1	0.1	1	1
Bangladesh	Q3-15	-1	20	56	2,610,000	49,390	0.0	1.7	0.0	1	1
Bangladesh	Q3-16	-4	5	106	1,900,000	182,904	0.0	1.2	0.1	1	1
Bangladesh	Q2-17	-4	-2	19	3,300,012	0	0.0	2.0	0.0	1	1
Bangladesh	Q3-17	-2	-3	144	8,000,000	596,963	0.0	4.9	0.3	1	1
Bangladesh	Q2-19	0	10	153	7,610,045	85,854	0.0	4.6	0.0	1	1
Bangladesh	Q2-20	0	29	283	8,048,271	2,261,532	0.0	4.8	1.1	1	1
Bolivia	Q1-06	0	75	25	126,600	50,810	0.0	1.3	0.3	1	0
Bolivia	Q1-07	7	76	40	339,495	127,031	0.0	3.5	0.8	1	0
Bolivia	Q4-07	9	45	75	485,024	705,728	0.0	5.0	4.1	1	0
Bolivia	Q1-10	1	24	26	227,860	0	0.0	2.2	0.0	1	0
Bolivia	Q1-13	0	2	25	145,000	3,141	0.0	1.3	0.0	1	0
Bolivia	Q4-13	0	5	74	338,995	0	0.0	3.2	0.0	1	0
Bolivia	Q4-14	0	-14	38	185,120	0	0.0	1.7	0.0	1	0
Bolivia	Q1-19	0	-23	60	349,540	0	0.0	3.0	0.0	1	0
Bolivia	Q1-20	0	-26	31	163,611	11,308	0.0	1.4	0.0	1	0
Bolivia	Q1-21	0		28	235,972	0	0.0	2.0	0.0	1	0
Brazil	Q1-19	-25	-11	16	10,013,501	0	0.0	4.7	0.0	1	0
Bulgaria	Q3-05	5	22	33	12,200	669,853	0.0	0.2	1.4	0	0

Country	Date	Nominal FX %	Reserves %	Disaster losses, quarter			Disaster losses, % GDP / Pop			EMDE	IDA
	Quarter	4 quarters later	4 quarters later	Death	Affected	USD loss k's	Deaths	Affected	Damage		
Bulgaria	Q3-14	-12	15	6	7,287	686,095	0.0	0.1	1.2	0	0
Cameroon	Q3-14	-12	-4	0	250,000	0	0.0	1.1	0.0	1	0
Chile	Q1-10	10	23	562	2,671,556	40,263,352	0.0	15.7	19.4	0	0
Chile	Q2-14	-13	-7	18	536,942	165,652	0.0	3.0	0.1	0	0
Chile	Q1-15	-7	3	179	193,913	1,852,113	0.0	1.1	0.6	0	0
Chile	Q3-15	6	3	25	682,437	987,794	0.0	3.8	0.3	0	0
China, P.R.: Mainland	Q2-05	4	32	488	29,963,802	4,749,234	0.0	2.3	0.1	1	0
China, P.R.: Mainland	Q3-05	2	28	364	35,047,124	11,933,815	0.0	2.7	0.3	1	0
China, P.R.: Mainland	Q2-06	5	41	362	16,719,033	3,503,728	0.0	1.3	0.1	1	0
China, P.R.: Mainland	Q3-06	5	45	1,563	53,794,624	10,355,126	0.0	4.1	0.3	1	0
China, P.R.: Mainland	Q2-07	11	36	603	108,554,376	6,894,479	0.0	8.2	0.2	1	0
China, P.R.: Mainland	Q2-08	0	18	87,776	49,859,864	119,886,504	0.0	3.8	2.5	1	0
China, P.R.: Mainland	Q3-09	2	16	192	51,605,440	4,329,174	0.0	3.9	0.1	1	0
China, P.R.: Mainland	Q2-10	5	30	4,840	140,182,192	24,912,616	0.0	10.5	0.4	1	0
China, P.R.: Mainland	Q2-11	2	1	524	89,960,408	8,346,171	0.0	6.7	0.1	1	0
China, P.R.: Mainland	Q3-11	2	3	155	30,056,552	6,512,634	0.0	2.2	0.1	1	0
China, P.R.: Mainland	Q2-12	4	8	308	31,285,286	6,330,401	0.0	2.3	0.1	1	0
China, P.R.: Mainland	Q3-13	0	6	754	15,600,417	21,247,892	0.0	1.1	0.3	1	0
China, P.R.: Mainland	Q2-14	0	-6	359	22,459,760	7,341,831	0.0	1.6	0.1	1	0
China, P.R.: Mainland	Q2-16	-2	-5	680	60,914,396	35,098,016	0.0	4.4	0.4	1	0
China, P.R.: Mainland	Q2-20	9	3	329	14,877,324	20,486,084	0.0	1.1	0.2	1	0
China, P.R.: Mainland	Q2-21	-3		399	15,721,015	18,658,024	0.0	1.1	0.1	1	0
Colombia	Q3-05	-4	1	101	474,607	0	0.0	1.1	0.0	1	0
Colombia	Q1-07	20	17	146	1,504,317	0	0.0	3.5	0.0	1	0
Colombia	Q4-07	-10	13	35	1,162,135	0	0.0	2.7	0.0	1	0
Colombia	Q3-08	13	4	76	1,200,091	0	0.0	2.7	0.0	1	0
Colombia	Q2-10	8	18	418	2,791,999	1,342,112	0.0	6.2	0.5	1	0
Colombia	Q2-11	-1	10	138	988,599	1,340,071	0.0	2.2	0.5	1	0

Country	Date	Nominal FX %	Reserves %	Disaster losses, quarter			Disaster losses, % GDP / Pop			EMDE	IDA
	Quarter	4 quarters later	4 quarters later	Death	Affected	USD loss k's	Deaths	Affected	Damage		
Colombia	Q3-11	7	11	135	498,924	1,678,341	0.0	1.1	0.6	1	0
Croatia, Rep. of	Q2-10	18	31	0	300	107,369	0.0	0.0	1.3	0	0
Croatia, Rep. of	Q3-17	-2	9	0	3,580	192,222	0.0	0.1	2.2	0	0
Croatia, Rep. of	Q1-20	7	36	1	78,942	7,689,208	0.0	2.0	81.4	0	0
Croatia, Rep. of	Q4-20	-7	22	8	149,407	7,037,208	0.0	3.7	81.3	0	0
Czech Rep.	Q2-13	0	35	15	1,300,000	1,040,877	0.0	12.4	0.5	0	0
Dominican Rep.	Q4-07	-7	-12	162	141,333	173,186	0.0	1.5	0.4	1	0
Dominican Rep.	Q4-16	-3	12	21	2,792,048	0	0.0	26.5	0.0	1	0
Ecuador	Q1-08	0	-22	41	289,122	1,359,273	0.0	2.0	2.1	1	0
Ecuador	Q2-16	0	30	673	389,511	2,438,717	0.0	2.4	2.9	1	0
Ethiopia, The Federal Dem. Rep. of	Q2-20	-20		12	1,229,854	0	0.0	1.0	0.0	1	1
Gambia, The	Q3-10	-5	-3	9	38,961	0	0.0	2.0	0.0	1	1
Ghana	Q3-07	-18	24	56	332,600	0	0.0	1.4	0.0	1	1
Ghana	Q2-17	-8	-11	0	1,000,000	0	0.0	3.3	0.0	1	1
Guyana	Q1-05	-6	5	34	274,774	696,977	0.0	0.0	26.9	0	1
Guyana	Q1-06	-6	5	0	35,000	245,341	0.0	0.0	8.8	0	1
Hungary	Q2-19	-10	10	0	150,000	0	0.0	1.5	0.0	0	0
India	Q3-05	-4	15	1,692	23,482,560	5,619,572	0.0	2.0	0.5	1	0
India	Q3-07	-15	15	1,811	37,643,000	530,921	0.0	3.2	0.0	1	0
India	Q3-11	-7	-5	670	12,579,269	2,129,802	0.0	1.0	0.1	1	0
India	Q4-13	-2	9	161	13,605,000	1,451,573	0.0	1.1	0.1	1	0
India	Q3-14	-6	11	595	5,204,000	20,351,672	0.0	0.4	1.0	1	0
India	Q3-15	-1	6	373	14,600,137	0	0.0	1.1	0.0	1	0
India	Q3-17	-10	0	652	19,912,856	2,229,061	0.0	1.5	0.1	1	0
India	Q3-18	2	8	631	23,291,024	3,324,452	0.0	1.7	0.1	1	0
India	Q2-19	-9	18	212	20,000,060	2,071,934	0.0	1.4	0.1	1	0
India	Q2-20	2	21	2,048	19,342,502	24,684,620	0.0	1.4	0.9	1	0
Indonesia	Q2-06	3	26	6,129	3,230,806	4,580,470	0.0	1.4	0.0	1	0

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Indonesia	Q3-09	8	39	1,361	2,851,590	3,219,330	0.0	1.2	0.0	1	0
Israel	Q4-13	-11	5	4	2,003,000	0	0.0	24.9	0.0	0	0
Japan	Q1-11	1	15	19,846	368,820	273,218,368	0.0	0.3	4.7	0	0
Japan	Q2-16	-9	-1	65	425,232	70,722,800	0.0	0.3	1.2	0	0
Japan	Q2-18	3	5	251	1,520,817	14,859,616	0.0	1.2	0.2	0	0
Madagascar, Rep. of	Q1-07	17	41	88	255,511	338,750	0.0	1.3	3.7	1	1
Madagascar, Rep. of	Q1-08	-15	3	105	533,166	81,556	0.0	2.6	0.8	1	1
Madagascar, Rep. of	Q1-12	-6	-14	112	335,599	127,466	0.0	1.5	1.3	1	1
Madagascar, Rep. of	Q1-17	0	39	81	434,253	23,879	0.0	1.7	0.2	1	1
Mauritania, Islamic Rep. of	Q3-07	12	-34	3	54,120	0	0.0	1.7	0.0	1	1
Mexico	Q4-05	-2	3	43	2,954,571	11,239,144	0.0	2.8	1.1	1	0
Mexico	Q4-07	-21	9	22	1,600,000	4,234,370	0.0	1.5	0.4	1	0
Mexico	Q3-10	-9	24	46	1,385,075	5,234,236	0.0	1.2	0.5	1	0
Mexico	Q3-17	-3	1	492	1,459,460	9,911,978	0.0	1.2	0.8	1	0
Namibia	Q1-08	-15	29	42	65,000	0	0.0	3.2	0.0	1	0
Namibia	Q1-09	31	34	92	350,000	0	0.0	16.9	0.0	1	0
Namibia	Q1-10	8	-20	8	110,000	0	0.0	5.2	0.0	1	0
Namibia	Q1-11	-12	4	108	500,000	15,612	0.0	23.4	0.0	1	0
New Zealand	Q3-10	4	21	0	300,002	8,723,726	0.0	6.9	6.0	0	0
New Zealand	Q1-11	7	2	181	301,500	19,515,598	0.0	6.9	13.4	0	0
New Zealand	Q2-11	-3	-9	1	345	3,903,120	0.0	0.0	2.7	0	0
New Zealand	Q4-16	2	16	2	50	4,755,498	0.0	0.0	2.7	0	0
Pakistan	Q1-05	-1	-7	613	7,008,950	44,957	0.0	4.0	0.0	1	0
Pakistan	Q4-05	-2	17	73,338	5,128,309	7,792,473	0.0	2.9	0.0	1	0
Pakistan	Q3-10	-1	17	2,045	20,363,496	12,750,062	0.0	10.5	0.0	1	0
Pakistan	Q3-11	-8	-23	509	5,400,755	3,252,600	0.0	2.7	0.0	1	0
Pakistan	Q3-12	-10	-42	518	5,050,564	3,186,657	0.0	2.5	0.0	1	0
Pakistan	Q3-14	-2	35	271	2,530,755	2,472,413	0.0	1.2	0.0	1	0

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Peru	Q3-07	4	41	593	658,331	846,874	0.0	2.3	0.7	1	0
Peru	Q1-08	-13	-8	40	450,012	0	0.0	1.6	0.0	1	0
Peru	Q4-11	6	31	66	812,626	0	0.0	2.8	0.0	1	0
Peru	Q1-17	1	-1	200	2,188,505	3,820,565	0.0	6.9	1.9	1	0
Philippines	Q4-04	6	14	1,760	1,792,199	183,138	0.0	2.1	0.1	1	0
Philippines	Q3-06	11	43	301	4,124,441	365,065	0.0	4.7	0.2	1	0
Philippines	Q4-06	19	47	1,486	3,654,208	116,187	0.0	4.2	0.1	1	0
Philippines	Q3-07	-4	19	21	1,397,462	1,388	0.0	1.6	0.0	1	0
Philippines	Q2-08	-7	8	718	6,293,909	544,146	0.0	6.9	0.3	1	0
Philippines	Q3-08	-1	16	96	966,195	62,002	0.0	1.1	0.0	1	0
Philippines	Q3-09	8	26	1,115	11,094,766	1,206,417	0.0	11.9	0.6	1	0
Philippines	Q4-10	0	21	161	4,432,145	433,712	0.0	4.7	0.2	1	0
Philippines	Q2-11	3	10	109	3,674,884	72,177	0.0	3.8	0.0	1	0
Philippines	Q3-11	5	9	241	4,553,526	575,134	0.0	4.7	0.3	1	0
Philippines	Q4-11	7	11	1,502	2,576,056	285,969	0.0	2.7	0.1	1	0
Philippines	Q3-12	-4	2	191	5,448,453	112,799	0.0	5.6	0.0	1	0
Philippines	Q4-12	-7	-1	1,961	6,596,632	1,153,847	0.0	6.7	0.5	1	0
Philippines	Q3-13	-3	-5	98	4,253,024	2,842,203	0.0	4.3	1.2	1	0
Philippines	Q4-13	-1	-4	7,628	20,629,264	12,757,200	0.0	20.7	5.2	1	0
Philippines	Q1-14	0	1	85	1,196,447	19,521	0.0	1.2	0.0	1	0
Philippines	Q3-14	-4	1	144	7,184,837	1,131,799	0.0	7.1	0.4	1	0
Philippines	Q4-14	-5	1	102	4,733,644	162,643	0.0	4.7	0.1	1	0
Philippines	Q4-15	-5	0	99	3,189,341	429,075	0.0	3.1	0.2	1	0
Philippines	Q3-16	-5	-6	47	2,593,473	17,355	0.0	2.5	0.0	1	0
Philippines	Q4-16	0	1	32	2,941,137	202,219	0.0	2.8	0.1	1	0
Philippines	Q1-17	-4	0	30	1,850,857	26,355	0.0	1.7	0.0	1	0
Philippines	Q4-17	-5	-3	164	2,948,739	149,600	0.0	2.8	0.0	1	0
Philippines	Q3-18	4	14	105	7,740,750	162,037	0.0	7.1	0.0	1	0

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Philippines	Q4-18	4	11	194	1,269,363	479,881	0.0	1.2	0.1	1	0
Philippines	Q4-19	5	25	140	6,633,053	184,154	0.0	6.0	0.1	1	0
Philippines	Q4-20	-6	-1	185	4,796,000	1,146,454	0.0	4.3	0.4	1	0
Philippines	Q4-21	-8		519	11,781,749	1,070,438	0.0	10.3	0.3	1	0
Romania	Q3-05	6	20	75	52,571	1,667,889	0.0	0.5	1.1	0	0
Samoa	Q3-09	5	39	148	5,584	169,206	0.0	0.0	23.3	1	1
Samoa	Q4-12	-3	0	12	12,703	169,530	0.0	0.0	22.7	1	1
Seychelles	Q4-04	0	63	3	4,830	46,482	0.0	5.9	2.6	0	0
Seychelles	Q1-13	-3	45	0	3,000	11,683	0.0	3.3	1.1	0	0
Seychelles	Q1-14	-12	4	0	4,435	0	0.0	4.9	0.0	0	0
Solomon Islands	Q2-14	-9	-1	47	52,000	29,669	0.0	0.0	2.3	1	1
Sri Lanka	Q4-04	2	24	35,405	1,219,306	2,039,778	0.2	6.3	5.0	1	1
Sri Lanka	Q4-06	-1	24	25	333,002	4,355	0.0	1.7	0.0	1	1
Sri Lanka	Q4-07	-4	-27	0	250,000	0	0.0	1.2	0.0	1	1
Sri Lanka	Q2-08	-6	-54	34	412,582	0	0.0	2.0	0.0	1	1
Sri Lanka	Q4-08	-1	109	15	360,000	0	0.0	1.8	0.0	1	1
Sri Lanka	Q4-09	3	34	3	360,000	0	0.0	1.8	0.0	1	1
Sri Lanka	Q2-10	4	42	28	606,072	140,922	0.0	2.9	0.3	1	1
Sri Lanka	Q1-11	-14	-15	65	1,285,324	650,520	0.0	6.2	1.1	1	1
Sri Lanka	Q4-12	-2	5	53	516,021	74,186	0.0	2.5	0.1	1	1
Sri Lanka	Q4-14	-9	-11	41	1,100,020	0	0.0	5.2	0.0	1	1
Sri Lanka	Q2-16	-5	31	203	301,602	1,463,230	0.0	1.4	1.9	1	1
Sri Lanka	Q2-17	-3	33	293	879,932	464,437	0.0	4.1	0.6	1	1
Sri Lanka	Q4-19	-2	-26	29	395,967	0	0.0	1.8	0.0	1	1
Sri Lanka	Q4-21	-45		30	236,004	0	0.0	1.1	0.0	1	1
Sudan	Q3-07	-6	36	150	565,335	423,437	0.0	1.8	0.6	1	1
Sudan	Q3-13	-23	-3	76	500,133	8,794	0.0	1.4	0.0	1	1
Sudan	Q2-20	-88		155	875,013	282,691	0.0	2.0	0.5	1	1

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Tanzania, United Rep. of	Q3-16	-3	35	17	139,601	558,466	0.0	0.3	1.2	1	1
Thailand	Q4-05	13	29	55	700,000	145,360	0.0	1.1	0.1	1	0
Thailand	Q3-06	10	31	164	2,212,413	14,430	0.0	3.3	0.0	1	0
Thailand	Q3-08	1	29	18	839,573	21,748	0.0	1.2	0.0	1	0
Thailand	Q4-08	4	25	21	732,584	16,100	0.0	1.1	0.0	1	0
Thailand	Q4-10	-4	2	258	8,970,653	445,581	0.0	13.1	0.1	1	0
Thailand	Q1-11	-2	-1	65	716,126	412,430	0.0	1.0	0.1	1	0
Thailand	Q3-11	1	2	831	10,500,000	52,041,596	0.0	15.3	15.0	1	0
Thailand	Q3-13	-4	-6	61	3,500,000	727,375	0.0	5.0	0.2	1	0
Thailand	Q4-16	10	18	18	786,343	176,807	0.0	1.1	0.0	1	0
Thailand	Q1-17	10	19	96	1,800,000	1,193,926	0.0	2.5	0.3	1	0
Thailand	Q3-17	3	3	23	1,028,560	366,535	0.0	1.5	0.1	1	0
Thailand	Q4-17	0	2	31	990,498	1,671	0.0	1.4	0.0	1	0
Thailand	Q1-19	-3	7	7	720,885	0	0.0	1.0	0.0	1	0
Thailand	Q4-20	-10	-5	36	1,105,582	56,538	0.0	1.5	0.0	1	0
Trinidad and Tobago	Q4-18	0	-9	0	150,000	4,312	0.0	10.0	0.0	0	0
Uganda	Q3-07	5	17	29	718,045	100	0.0	2.4	0.0	1	1
United States	Q3-05		-7	1,848	800,201	214,637,680	0.0	0.3	1.5	0	0
United States	Q2-08		8	57	11,000,868	18,502,424	0.0	3.6	0.1	0	0
United States	Q1-16		-1	73	85,000,320	11,309,551	0.0	26.1	0.1	0	0
United States	Q3-17		0	199	652,810	181,715,600	0.0	0.2	1.0	0	0
Venezuela, Rep. Bolivariana de	Q3-21	51098936		46	1,400,100	0	0.0	5.0	0.0	1	0
Vietnam	Q3-06	0	89	206	1,522,045	918,940	0.0	1.8	1.2	1	0
Vietnam	Q4-06	0	75	168	1,226,360	676,502	0.0	1.5	0.8	1	0
Vietnam	Q3-07	-3	6	170	1,101,560	453,077	0.0	1.3	0.5	1	0
Vietnam	Q4-07	-8	2	156	546,042	931,562	0.0	0.6	1.1	1	0
Vietnam	Q3-09	-8	-24	219	3,217,315	1,070,836	0.0	3.7	1.1	1	0
Vietnam	Q4-10	-7	9	186	1,489,833	886,062	0.0	1.7	0.9	1	0

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Vietnam	Q3-11	0	40	109	900,000	284,931	0.0	1.0	0.3	1	0
Vietnam	Q3-13	-1	50	132	1,871,596	842,612	0.0	2.1	0.7	1	0
Vietnam	Q4-13	-1	32	83	2,252,849	1,108,022	0.0	2.5	0.8	1	0
Vietnam	Q4-16	0	34	117	2,038,076	623,435	0.0	2.2	0.4	1	0
Vietnam	Q3-17	-3	37	77	717,574	2,476,562	0.0	0.8	1.5	1	0
Vietnam	Q4-17	-2	13	206	4,411,538	1,193,926	0.0	4.7	0.7	1	0
Vietnam	Q4-20	1	15	289	2,025,784	1,577,713	0.0	2.1	0.8	1	0
Zambia	Q1-07	16	60	4	1,518,755	0	0.0	12.2	0.0	1	1
Zambia	Q1-09	19	88	31	614,814	0	0.0	4.6	0.0	1	1
Zambia	Q1-20	-18	-13	0	701,500	0	0.0	3.7	0.0	1	1
Zimbabwe	Q1-17	0	-63	251	113,023	225,652	0.0	0.8	1.3	1	0
Zimbabwe	Q1-19	1189	-39	654	270,186	0	0.0	1.8	0.0	1	0

Both EMDE and IDA countries are classified in accordance with the World Bank's country and lending group classification (https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups). EMDE comprise all countries except high income countries.