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The Economic Impact of Natural Disasters in Pacific Island Countries: Adaptation and Preparedness[1]

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Abstract

Pacific island countries are highly vulnerable to various natural disasters which are destructive, unpredictable and occur frequently. The frequency and scale of these shocks heightens the importance of medium-term economic and fiscal planning to minimize the adverse impact of disasters on economic development. This paper identifies the intensity of natural disasters for each country in the Pacific based on the distribution of damage and population affected by disasters, and estimates the impact of disasters on economic growth and international trade using a panel regression. The results show that "severe" disasters have a significant and negative impact on economic growth and lead to a deterioration of the fiscal and trade balance. We also find that the negative impact on growth is stronger for more intense disasters. Going further this paper proposes a simple and consistent method to adjust IMF staff's economic projections and debt sustainability analysis for disaster shocks for the Pacific islands. Better incorporating the economic impact of natural disasters in the medium- and long-term economic planning would help policy makers improve fiscal policy decisions and to be better adapted and prepared for natural disasters.

JEL Classification Numbers: Q51, Q54, O44, H63

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I. MOTIVATION

Pacific island countries (PICs)—i.e., Fiji, Kiribati, Marshall Islands, Micronesia, Palau, Papua New Guinea, Samoa, Solomon Islands, Timor-Leste, Tonga, Tuvalu, and Vanuatu—tend to be highly vulnerable to various natural disasters which are destructive, unpredictable and occur frequently. Between 1950 and 2011, extreme weather-related events in the Pacific Islands region affected approximately 9.2 million people, caused 10,000 deaths and damage of around USD3.2 billion (World Bank, 2017).

Natural disasters have immediate adverse effects on the economy. But they may also reduce long-term growth as the frequent devastation caused by natural disasters disrupts countries' long-term investments and diverts resources away from development to reconstruction. More importantly, as countries in the Pacific region commonly face low GDP growth, high reliance on grants and external loans, and underdevelopment in disaster-resilient infrastructure, the economic impact of natural disasters tends to be larger than for other comparable low-income and emerging economies.

The frequency and scale of these shocks heightens the importance of medium-term economic and fiscal planning to minimize the adverse impact of disasters on economic development. Having a good understanding of the likely impact of natural disasters on the economy is especially important for policy makers. It can help identify the risks to the budget and can help the countries to set realistic medium-term plans. Economies subject to frequent natural disasters should build fiscal buffers to cope with relief and recovery costs—so having a better handle on their likely impact can help quantify the scale of buffer needed. Better decisions can also help policy makers make better decisions by considering the tradeoffs involved in investing in disaster resilient infrastructure versus other development activities.

Better estimates of the economic impact of natural disasters helps economic planning by:

- providing more accurate economic projections that the country's economic policy will be based on;
- ensuring that fiscal policies to safeguard debt sustainability take into account the presence of disaster risk;
- providing more accurate estimates on the necessary fiscal buffers for disaster response; and
- identifying policy priorities such as mitigating future disaster risks by building disaster-resilient roads and bridges, and strengthening building codes.

The rest of paper proceeds as follows: Section II summarizes the literature on the impact of natural disasters on the economy and presents the contribution of this paper. Section III presents key stylized facts on the frequency and intensity of natural disasters in PICs. Section IV analyzes the effects of disasters on growth, the fiscal and trade balance with an explicit consideration of intensity levels of these disasters. Section V proposes a simple and consistent method for the adjustment of economic projections and debt sustainability analysis for the disaster shocks. Section VI summarizes the findings and discusses policy implications. Finally, the appendix includes more detailed explanation on data and some additional estimation results to demonstrate that the results are robust.

II. Literature Review

The empirical literature on the economic impact of natural disasters is not extensive and does not offer conclusive evidence on the impact of natural disasters on growth, although, in general, they are expected to hamper economic growth.[2]

Global Studies

Fomby et al. (2013) was the first to renew interest in work on natural disasters and growth. The authors analyze the impact of four types of natural disasters—droughts, floods, earthquakes, and storms—on GDP per capita growth across 84 countries around the world, 60 of which are developing countries. They find that developing economies are more strongly affected by disasters than advanced economies. They also confirm that economic growth responds differently to different types of disasters. By categorizing disasters based on the intensity of their impact, they also show that, while some moderate disasters might have positive impact on GDP growth, such as moderate floods on agricultural growth, severe disasters of any type always have a negative growth impact.[3]

Loayza et al.'s (2012) findings are largely consistent with that of Fomby et al. (2013), although a different empirical methodology is used. They also find that different types of disaster have varying effects on economic growth, some of which are not always negative. Furthermore, they confirm the notion that severe disasters have a negative impact on growth. Finally, they also find that growth in developing economies is more sensitive than that of advanced countries.

Felbermayr and Groschl (2014) adopt slightly different approach in studying the effect of natural disasters from the previous studies. They measure the intensity of disasters based on the percentile distribution of the physical strength of disasters which is compiled from meteorological information. Despite their unique approach, Felbermayr and Groschl's findings are astonishingly close to that of the previous literature: that is, natural disasters lower growth, and low and middle-income countries experience the highest losses when disasters hit.

Alternatively, the macroeconomic consequences of natural disasters can be assessed by comparing a counterfactual GDP—constructed using the projection of past GDP under a non-disaster scenario—and actual GDP (e.g., Hochrainer, 2009; Cavallo et al., 2013). That is, the impact of natural disaster can be measured as the difference between GDP in disaster years and non-disaster years. They find that the severity of natural disaster matters in determining its impact: i.e., the average negative effects may be small but they can become more pronounced for severe shocks (Hochrainer, 2019), while extremely large disasters have a negative effect on output in both the short and the long run (Cavallo et al., 2013).

More recent literature has aimed to shed light on the impact of natural disaster on specific subgroups of countries based on their geographical location as opposed to their income level.

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[2] See, for example, Dell et al. (2014), Felbermayr and Groschl (2014), and Cavallo and Noy (2011) for a detailed survey on the existing empirical literature on the growth impact of natural disasters and climate shocks.

[3] Specifically, Fomby et al. (2013) measure natural disaster intensity by the sum of the fatalities and 30 percent of the total people affected. A disaster is considered as "moderate" if the intensity measure is greater than 0.01 percent of the population and as "severe" if it is above 1 percent. This practice was first used by Becker and Mauro (2006) as a way to quantify country-specific external shocks.

Acevedo (2014) studies floods and storms in 12 Caribbean countries over 40 years. He finds that both types of disasters have a negative impact on growth in Caribbean island countries. Reviewing studies of storms and droughts in the recent literature, Alano and Lee (2016) corroborate the evidence that disasters dampen economic growth, and suggest that more frequent and extreme disasters due to climate change may have worsening effects on growth in the future.

Pacific Island Studies

Given the remoteness and heterogeneity of the Pacific island countries (PICs), the policy implications from global studies of disasters, most of which do not include these countries in the sample, may not directly apply to the Pacific. Some notable studies have focused on the PICs. Cabezon et al. (2015) assessed the natural disaster impact of five Pacific island countries—Fiji, Samoa, Solomon Islands, Tonga and Vanuatu. The authors study not just the effect of natural disasters on growth alone, but also the effect on government expenditure, tax revenue, and the overall fiscal balance. They find that in the short run natural disasters lower growth and worsen the fiscal position of these economies, although part of the negative effect on the fiscal position is offset by grants from bilateral and multilateral donors. In the long run, a country hit by a natural disaster suffers substantial losses to growth compared to a non-disaster country.

A theoretical study, Marto et al. (2017) present a dynamic small open economy model to explore the macroeconomic impact of natural disasters and to study the debt sustainability concerns in the aftermath of disasters. In application to Vanuatu, they find that disaster causes a loss of productivity and that the inefficiency of the reconstruction process increases the permanent damage to public and private capital. They also find that grants provided by donors play a pivotal role in ensuring public debt sustainability, for example in the aftermath of Cyclone Pam. The finding illustrates the important role of disaster-resilient investment and donors' grants in disaster-vulnerable small developing states.

Contribution of this Paper

This paper contributes to the literature in several respects. First, we study the effect of severe natural disasters using the data specific to the Pacific islands. This can help provide better information to policy makers in the PICs on the impact of natural disasters in their own region which can contribute to better informed policy decisions. Countries in the Pacific share characteristics which are unique compared to the rest of the world—remoteness, fiscal dominance, high dependency on grants and fishing revenues, and vulnerability to natural disasters.

Second, the paper identifies the *intensity* of natural disasters based on the distributions of both the *damage* and *population* affected of the whole sample disasters, and then estimates their impact on economic growth, fiscal position, and international trade using a panel data of PICs. We identify severe natural disasters by specifying a threshold on the distribution of the economic and human cost of disasters. The intensity measure based on the distribution of economic damage or population affected and the identification of severe natural disaster based on this intensity are key innovations. Our paper shares the method based on a measure of the intensity of disasters with Loayza et al. (2012) and Felbermayr and Groschl (2014), although the latter use a different database on natural disasters (physical/meteorological strength) from the others (economic/human cost). Furthermore, we examine whether natural disasters with different levels of intensity have distinct impact on growth by identifying separate dummy variables for each 5th percentile of intensity.

The estimation results show that it is the severe natural disasters that have a significant and negative impact on economic growth. These findings can be explained by the fact that: (i) a small or average size of natural disasters can be handled well by the country; and (ii) the countervailing effects such as donors' support and reconstruction activities in the aftermath of a disaster may offset the negative impact in some cases. We also find the negative effects on economic growth are stronger for more intense disasters. In addition, the results show that severe disasters lead to a deterioration of the fiscal balance owing to a decline in government revenue and increase in government expenditure and in the trade balance due to the subsequent increase of imports and the decline of exports. These findings imply that to achieve sustainable growth, PICs highly vulnerable to natural disasters need to take account of the impact of disaster shock in their medium-term and long-term economic planning.

Last, this paper proposes a simple and consistent method, using our estimation results and the frequency and the intensity of natural disasters, for the adjustment of economic projections and debt sustainability analysis for the disaster shocks. In a similar vein to Hochrainer (2009) and Cavallo et al. (2013), long-term economic projections under the disaster shocks can be made by adjusting the impact of disaster from the non-disaster projections. Our analysis suggests that substantial adjustments for economic projection and debt sustainability analysis are needed for some PICs which are frequently and strongly affected by natural disasters.

III. Stylized Facts: Natural Disasters in PICs

A. Data

Historical data on natural disasters are drawn from the Emergency Events Database (EM-DAT), which was established by the Center for Research on the Epidemiology of Disasters (CRED).[4] EM-DAT provides more than 22,000 mass disasters observations worldwide since 1900. All the disasters included in EM-DAT satisfy one of the following criteria: (i) 10 or more people killed; (ii) 100 or more people affected; (iii) a declaration of a state of emergency; and (iv) a call for international assistance. The sources of the information include UN agencies, non-government organizations, insurance companies, research institutes, and press agencies. For each disaster observation, EM-DAT has information on the disaster year, disaster type, number of occurrence, number of people affected (injured, homeless, or in need of assistance), number of deaths, and an estimate on the total damage in US dollars.[5]

In the following analysis, we include data from 12 PICs: i.e., Fiji, Kiribati, Marshall Islands, Micronesia, Palau, Papua New Guinea, Samoa, Solomon Islands, Timor-Leste, Tonga, Tuvalu, and Vanuatu. Our analysis is restricted to the sample period from 1980 to 2016 as the reporting of natural disasters appeared to be inadequate in the earlier years.

[4] The database is available at: http://www.emdat.be/.

[5] Each observation in the EM-DAT represents a certain type of disaster that happened in the year. However, if that type of disaster happened twice in the same year, it would still be shown as one observation in the database but with two occurrences. Our analysis in this and later sections are based on observations instead of occurrences since macroeconomic variables used in the analysis are observed on an annual basis.

B. Frequency of Natural Disasters in PICs

Table 1 shows the summary statistics of EM-DAT data. Between 1980-2016, 204 natural disaster observations were recorded in the 12 selected countries. That is equivalent to a 46 percent probability of getting hit by disaster in any given year—which demonstrates the high vulnerability of Pacific islands to disasters. According to the data available, natural disasters are more likely to strike countries in the Southern Pacific (e.g., Fiji, Papua New Guinea, Solomon Islands, and Vanuatu) than the Northern Pacific countries (e.g., Palau, Kiribati, and Marshall Islands). On average, a disaster causes 14 percent damage to GDP, and affects 11 percent of population. The most severe disasters in PICs bring economic damages that exceed the country's GDP, and influence the entire population of a country in the disaster year.[6] For instance, Cyclone Nigel caused Vanuatu a damage of 131% of its GDP in 1985, and Kiribati suffered from a severe drought which affected the whole nation's population in 1999.

Table 1. EM-DAT Summary Statistics

Total Observations: 204

	Natural Disaster	**Damage** (% of GDP)			**Population Affected** (% of total population)		
	Likelihood per year[1)]	Mean	Median	Maximum	Mean	Median	Maximum
Fiji	70.3%	1.8%	1.3%	10.1%	6.3%	0.8%	39.7%
Kiribati	10.8%	n/a	n/a	n/a	25.7%	0.8%	100.0%
Marshall Islands	16.2%	n/a	n/a	n/a	10.5%	1.1%	38.3%
Micronesia	24.3%	1.8%	1.8%	3.5%	24.4%	5.7%	97.8%
Palau	2.7%	n/a	n/a	n/a	n/a	n/a	n/a
Papua New Guinea	81.1%	0.3%	0.1%	1.3%	1.2%	0.4%	32.7%
Samoa	27.0%	47.7%	21.0%	161.8%	2.5%	1.6%	6.7%
Solomon Islands	51.4%	8.0%	8.0%	14.0%	5.7%	1.1%	53.8%
Timor-Leste	21.6%	0.1%	0.1%	0.1%	1.3%	0.1%	10.1%
Tonga	29.7%	9.7%	4.9%	28.2%	21.0%	3.4%	100.0%
Tuvalu	16.2%	n/a	n/a	n/a	42.6%	42.0%	42.6%
Vanuatu	56.8%	42.8%	18.0%	131.2%	11.9%	5.3%	87.0%
PICs	34.0%	14.4%	1.7%	161.8%	10.7%	1.3%	100.0%

Note: 1) Likelihood of natural disaster is computed by the probability that at least one disaster occurs in a given year.
Source: EM-DAT; IMF staff calculations

The Pacific islands are also subject to different types of natural disasters—storms, floods, earthquakes, and droughts. Less frequent disasters are combined into the "Others" category: e.g., volcanic activity, epidemic, landslide, mass movement, and wildfire. Storms and floods occur more frequently in the Southern Pacific (e.g., Fiji, Papua New Guinea, Solomon Islands, Tonga, and Vanuatu), whereas droughts are relatively common in the Northern Pacific (e.g., Marshall Islands, Micronesia, and Timor-Leste) (Figure 1).

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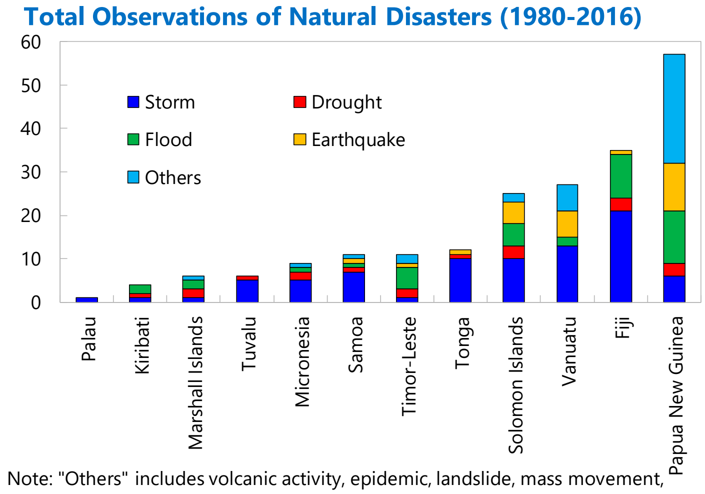
[6] We truncated the impact on a country's population to 100 percent in cases which looked erroneous and reported a population effect of greater than the country's population.

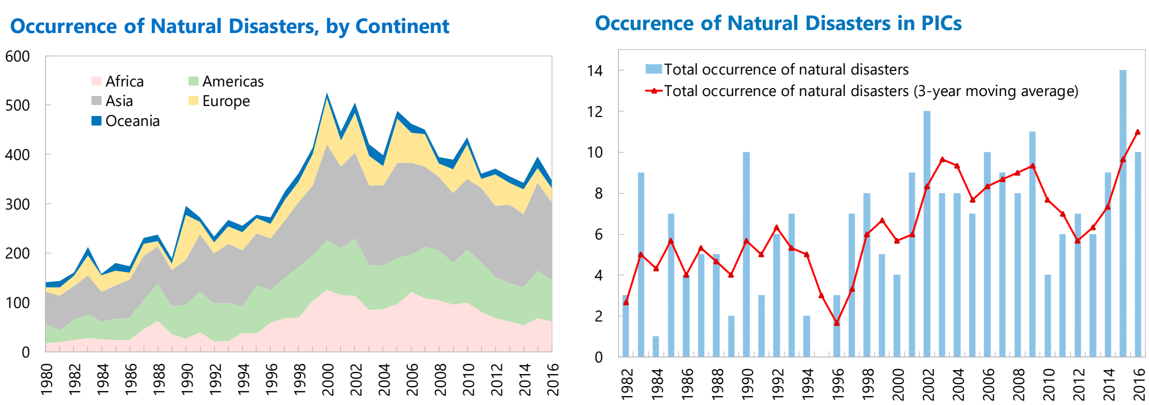
Figure 1. Natural Disaster in PICs, by country and type



Note: "Others" includes volcanic activity, epidemic, landslide, mass movement, and wildfire.

The EM-DAT data interestingly suggest that the frequency of world-wide natural disasters per year peaked in the early 2000s and has been on a declining trend since then (left panel of Figure 2). However, the Pacific region exhibits an opposite trend: i.e., the number of natural disasters has been gradually increasing starting from 1996 (right panel of Figure 2).[7]

Figure 2. Trends in Occurrence of Natural Disaster



C. Intensity of Natural Disasters in PICs

The frequency of natural disasters sometimes cannot provide sufficient information on the economic impact of natural disasters as some countries are affected frequently by disasters but they may occur in remote, lightly populated areas and so may only have a small effect on the economy. For instance, in Papua New Guinea (PNG), the likelihood of natural disasters per year is as high as 81 percent, while the average population affected is relatively low at 1 percent of total population because PNG is large and sparsely populated (Table 1). In Samoa,

[7] This may reflect the improvement in recording natural disasters. However, it is not easy to conclude that the upward trend in the occurrence of natural disasters in PICs is mainly attributable to improved data recording due to: (i) a clear increasing trend since 2010 which is quite recent year; and (ii) a decreasing trend in the occurrence of world-wide natural disasters since 2000.

in contrast, there is a 27 percent chance of a natural disaster each year, yet the average damage from its disasters is large at 48 percent of GDP, reflecting the high density of population and infrastructure. Therefore, it is important to consider both the frequency (or probability) and the intensity of economic damage (i.e., estimated damage[8] or population affected) of natural disasters to measure the economic impact of disasters.[9]

In the literature, the general assumption has been that disasters which affect more of the population also have a bigger economic impact. In line with this general assumption, the previous literature analyzing the growth impact of natural disasters constructed a measure of natural disaster intensity using information only on population affected with larger weights on death than affected (Fomby et al, 2013; IMF, 2003; Becker and Mauro, 2006). However, historical data show that different types of disasters affect a country's population and economy differently, and the size of the population affected is not always directly related to total damage incurred. Based on EM-DAT, drought tends to affect a greater proportion of the population than other types of disaster, but when measuring the damage in US dollars, storms incur the most damage (Table 2). In other words, a disaster that has a widespread impact on population does not necessarily lead to a higher economic loss. Hence, using only population affected as a measure for disaster intensity can be misleading.

Estimated damage in US dollars would be an alternative measure for disaster intensity, but the data availability is limited in EM-DAT. The data limitation poses challenges to select a single indicator as the measure of natural disaster intensity. Among all the recorded disasters during the sample period, only 51 disasters contain the information on estimated damage, and it is not enough for our empirical analysis (by contrast there are 116 observations on population affected). Thus, this paper departs from the previous literature and introduces a new measure to estimate the intensity of economic impact of natural disasters, using both population affected (including fatalities) and total damage which are available from EM-DAT.

Table 2. Average Damage per Disaster, by type (1980-2016)

	Estimated Damage (USD million)	Population Affected (number of person)
Storm	62.5	36,629
Drought	45.0	290,931
Flood	26.8	27,177
Earthquake	21.0	3,942
Others	70.8	9,992

Note: "Others" includes volcanic activity, epidemic, landslide, mass movement, and wildfire.

To measure the intensity of natural disasters, we construct a natural disaster ranking based on the percentiles of estimated damage and population affected from natural disasters. This measure helps to identify which disasters have a significant impact on the economy by

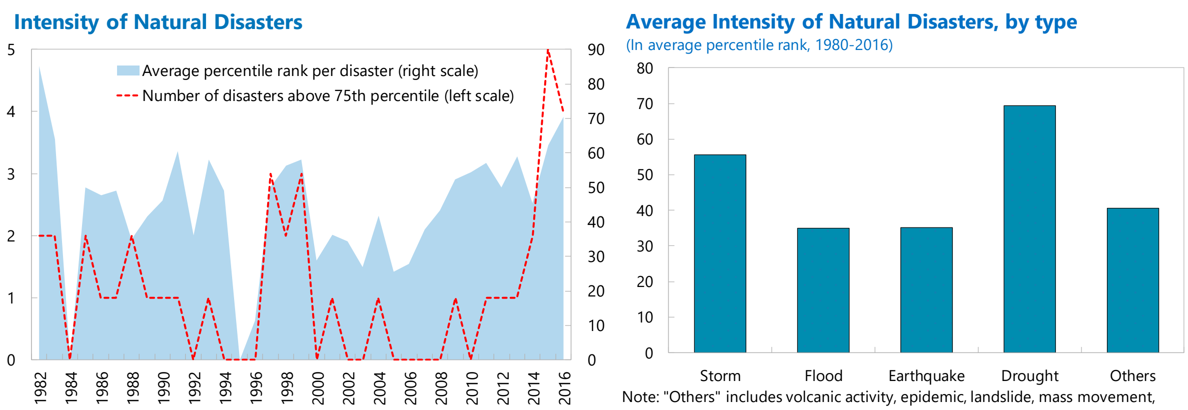
[8] Estimated damage includes both direct damage and indirect losses from natural disasters.

[9] Thus, our proposed method to incorporate the economic impact of natural disaster in macroeconomic projections and debt sustainability analysis considers both the probability and the intensity of natural disasters (Section V).

utilizing both damage and population affected data. Among all 204 observations in the sample period, 124 observations have at least one of damage or population affected data, and 43 observations have both, while the remaining 80 observations do not contain any information on either damage or population affected. First, we rank 51 disasters that contain damage information in percentiles (a higher percentile means a higher damage-to-GDP ratio). Similarly, 116 disasters with population affected information are also ranked in percentiles. Since total damage is likely to be more directly related to the economic loss from disasters, we select the percentile based on damage as its primary disaster percentile rank in case of 51 disaster observations which contain damage information. For 73 observations which contain only the information on population affected, we use the percentile from population affected. That is, each disaster has a percentile rank first based on total damage, and second based on population affected. From now on, we define the intensity of natural disaster based on the percentile ranks calculated by the abovementioned way.

Figure 3 presents the trends in the average intensity of natural disasters in PICs. While we could not find any clear upward trend in the intensity over the whole sample period, we note a significant increase in the average percentile of the disasters and the number of severe natural disasters since 2008 (left panel of Figure 3). The most intense disasters in PICs are likely to be storm or drought (right panel of Figure 3). The damage from storms has been severe in the Southern PICs, while the population affected from drought has been relatively large and widespread in the Northern PICs.

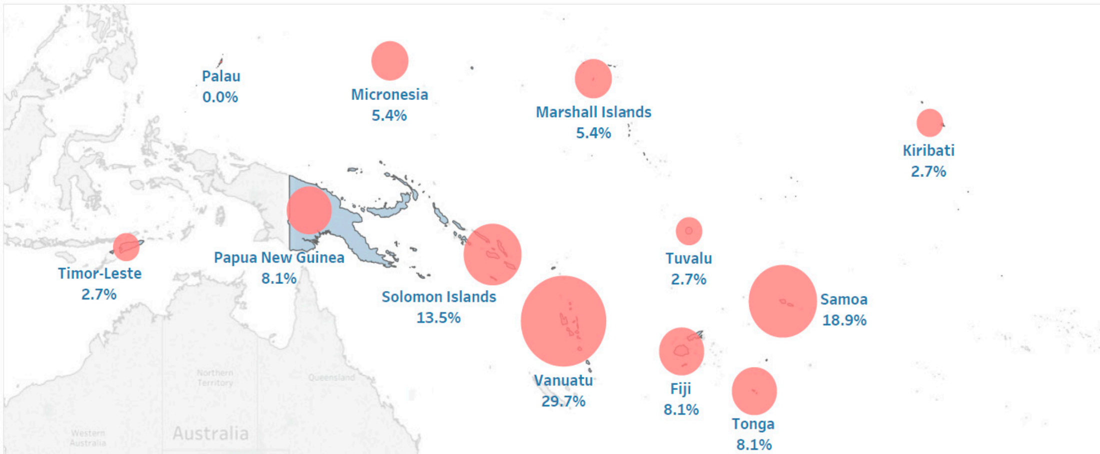
Figure 3. Trends in Natural Disaster Intensity in PICs



Note: "Others" includes volcanic activity, epidemic, landslide, mass movement, and wildfire.

As most of existing studies found that only severe natural disasters have a significantly adverse impact on the economy, we define "severe" as a natural disaster above a certain threshold which was chosen at 75th percentile in our analysis. Figure 4 summarizes the probability per year for each PIC being exposed to severe natural disaster—measured by the average probability per year that each country experiences the natural disaster above 75th percentile over the sample period (1980-2016). A bigger bubble size demonstrates higher probability, indicating that Vanuatu, Samoa, and Solomon Islands are among the PICs that are most likely to bear the most adverse economic cost from severe disasters. We also note a significant increase since 2008 in the number of severe disasters (left panel of Figure 3).

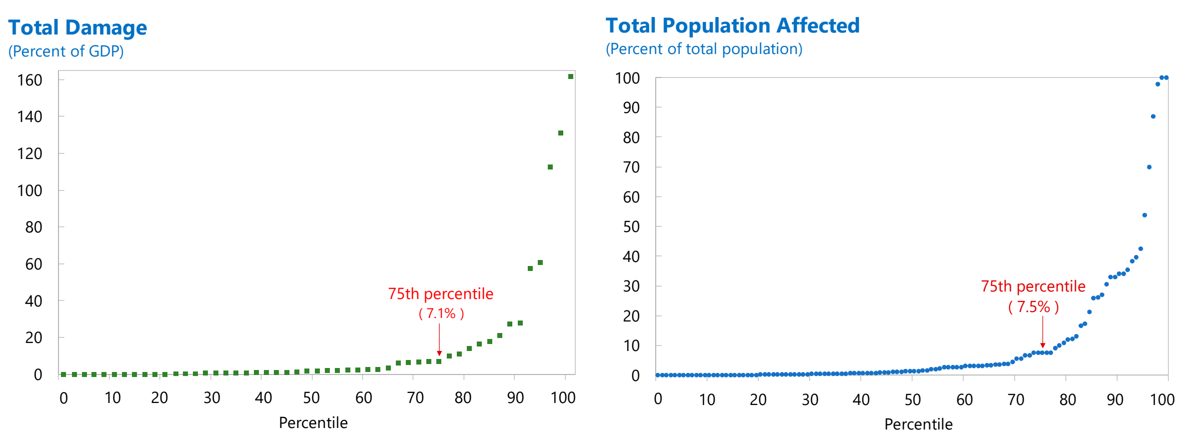
Figure 4. Probability of Severe Natural Disasters in PICs



Note: The size of circle denotes the probability that each country is hit by a severe (above 75th percentile) natural disaster.

The choice of 75th percentile as a threshold is mainly based on the significance of estimated coefficients of natural disasters on GDP growth. The regression analysis in Section IV finds that natural disaster above 75th percentile shows statistically significant impact on GDP growth. Figure 5—the distribution of damage in percent of GDP and population affected in percent of total population – provides another rationale for the choice of threshold at 75th percentile, which is a turning point between 70th to 80th percentiles, with the economic impact becoming significant at around 75th percentile.[10] This turning point corresponds to an impact of 7.1 percent in terms of damage-to-GDP ratio and 7.5 percent in terms of population affected-to-total population ratio.

Figure 5. Distribution of Damage and Population Affected



Furthermore, the level of damage and population affected change fast above 75th percentile in that disasters in 85-90th percentile have a significantly larger economic impact than disasters in 75-80th percentile. Therefore, it is meaningful to distinguish the difference in the economic

[10] 25th and 50th percentiles correspond to 0.3 and 1.9 percent in the damage-to-GDP ratio and 0.2 and 1.3 percent in the population affected-to-total population ratio. However, 75th percentiles in the damage-to-GDP ratio and in the population affected-to-total population ratio correspond to 7.1 percent and 7.5 percent, respectively.

impact of natural disasters above 75th percentile in more detail, given that each PIC suffers from disasters of different intensity. Table 3 provides a more detailed breakdown on the disasters above 75th percentile. For example, Fiji, Solomon Islands, and Vanuatu suffer the most frequently from 75-80th percentile severe disasters while PNG experiences more often 80-85th percentile disasters.

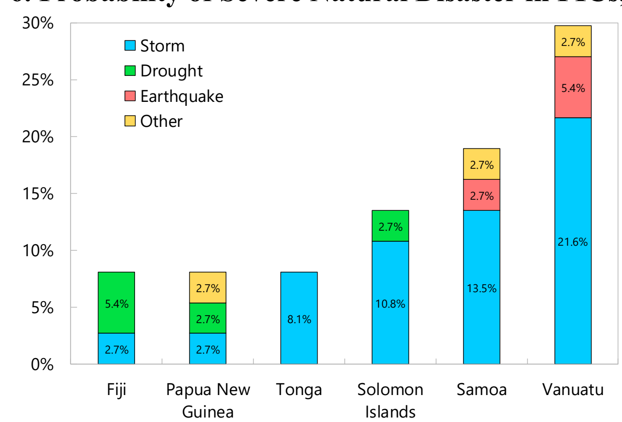
Table 3. Probability of Severe Natural Disasters in PICs, by each 5th percentile

	75-80	*80-85*	*85-90*	*90-95*	*95-100*	*Total*
Fiji	5.4%	0.0%	0.0%	2.7%	0.0%	8.1%
Kiribati	0.0%	0.0%	0.0%	0.0%	2.7%	2.7%
Marshall Islands	0.0%	2.7%	0.0%	2.7%	0.0%	5.4%
Micronesia	0.0%	0.0%	0.0%	2.7%	2.7%	5.4%
Palau	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Papua New Guinea	0.0%	8.1%	0.0%	0.0%	0.0%	8.1%
Samoa	0.0%	2.7%	5.4%	5.4%	5.4%	18.9%
Solomon Islands	5.4%	5.4%	2.7%	0.0%	0.0%	13.5%
Timor-Leste	0.0%	2.7%	0.0%	0.0%	0.0%	2.7%
Tonga	2.7%	0.0%	0.0%	5.4%	0.0%	8.1%
Tuvalu	0.0%	0.0%	0.0%	0.0%	2.7%	2.7%
Vanuatu	10.8%	2.7%	8.1%	2.7%	5.4%	29.7%
PICs Average	2.0%	2.0%	1.4%	1.8%	1.6%	8.8%

Source: EM-DAT; IMF staff calculations

Figure 6 presents the probability that each PIC is hit by severe natural disasters in a given year. Among all PICs, Vanuatu, Samoa and Solomon Islands are the top three countries that suffer the most severe natural disasters. In these three countries, storms are the most frequent disaster type.

Figure 6. Probability of Severe Natural Disaster in PICs, by type



Note: "Others" includes volcanic activity, epidemic, landslide, mass movement, and wildfire.

IV. Econometric Analysis: Economic Impact of Natural Disasters

This section analyzes the effects of natural disasters on economic growth and international trade using a panel regression method. In particular, we look at the impact of disasters on GDP, GDP per capita, fiscal balance, and trade balance.

The empirical analysis uses the data on natural disasters (estimated damage, population affected, and disaster type) from EM-DAT and macroeconomic variables (GDP, GDP per capita, fiscal balance, trade balance, population, inflation, trade openness, and terms of trade) from the IMF World Economic Outlook (WEO) database. The detailed descriptions and sources of the data used in the analysis are presented in Appendix Table A. The analysis covers the 12 PICs and is restricted to the period 1995-2016 owing to data availability.[11] Our sample countries are limited to 12 PICs which are relatively homogeneous in the development stage (mostly low-income countries), in the geographical location (Pacific islands), and in the size of economy (mostly small states).

The panel regression method of 12 PICs can be justified in our analysis in two respects. First, country-specific econometric analysis is not feasible due to data limitations. The reliable macroeconomic data is available only for the recent decades at best in most PICs. In addition, data observations on severe natural disasters in a single country may not be sufficient for reliable estimation. The second rationale is that the economic impact of disasters can vary across areas within a given country based on which area of the country was affected by the disaster (e.g., rural or urban areas). For this reason, pooling a wide range of natural disaster events across countries and areas would cover various cases of disasters and yield more reliable estimates of the future average economic impact of natural disasters in the Pacific region.

A. Empirical Specification

To investigate the impact of natural disasters on growth and trade, we set up the estimation as below by adopting a similar specification as Dell et al. (2012), Felbermayr and Gröschl (2014) and Loayza et al. (2012).

$$\Delta y_{it} = \beta \, ND_{it} + \alpha_1 \, y_{it-1} + \alpha_2 \, \boldsymbol{X}_{it-1} + FE_i + FE_t + \varepsilon_{it} \qquad (1)$$

where y_{it} is log(GDP) (or log(GDP per capita), trade balance/GDP, trade balance/GDP); ND_{it} is natural disaster dummy variable that takes 1 if damage-to-GDP is above 75th percentile, or affected people-to-total population is above 75th percentile for the case that damage data is not available;[12] $\boldsymbol{X}_{it}$ includes various control variables such as population, inflation, trade openness, and terms of trade growth of Australia and the U.S. interacted with the trade share with these two countries to capture global trade activity closely related to the Pacific islands.[13] FE_i is a country fixed effect, included to take account of country-specific heterogeneity; and FE_t is a year-specific fixed effect, included to consider global macroeconomic shocks. The subscripts *i* and *t* denote country and year, respectively.

The specification estimates the impact of "severe" (above 75th percentile) natural disaster on the economy, reflect the findings of previous literature that only severe natural disasters are found to have a significant adverse effect on growth (e.g., Fomby et al. 2013; Loayza et al. 2012). As explained in the previous section, our primary measure of natural disaster intensity is damage-to-GDP ratio where data is available for both damage and population affected (see

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[11] The panel data are unbalanced since some variables are not available for the whole period of all 12 countries.
[12] We also adopt different thresholds (70th and 80th percentiles) for robustness checks and find qualitatively similar results (see Tables B.4 and B.5).
[13] Due to data limitation for PICs, we could not include richer set of control variables on structural, domestic policy, and external factors which also may be related to GDP growth and other dependent variables. Instead country and year fixed effects are expected to capture some of cross-country and time-variant heterogeneity.

(continued…)

Section III.C for more details on the definition of the severe natural disaster dummy variable).[14] Endogeneity concerns between natural disasters and dependent variables (GDP, GDP per capita, fiscal balance, and trade balance) are mitigated in our specification because dummy variables (on damage or population affected based on thresholds) are used as explanatory variables instead of using the damage or population affected itself—which are more likely to be correlated with dependent variables.

The choice of thresholds for a severe natural disaster at 75th percentile is based on two criteria: (i) the significant increase around 70-80th percentiles in both damage-to-GDP ratio and affected people-to-total population ratio (Figure 3 in Section III.C); and (ii) the significance of estimated coefficients on the natural disaster on GDP growth. For the latter, we estimated equation (1) on the impact of natural disasters on the GDP growth for a series of severe disaster dummies with a 5th percentile grid starting from 50th percentile, and then select the lowest percentile that the estimated coefficient of natural disaster dummy variable becomes statistically significant (at the 5 percent significance level).[15]

We also extend the specification to more detailed natural disaster dummy variables based on the percentile intensity of natural disasters. This extended model is set up to confirm if there is nonlinearity in the economic impact of natural disasters by intensity this has often been found for example in the effect of public debt on growth (e.g., Cecchetti et al., 2011). By assigning separate dummy variables for each 5th percentile range above 75th percentile intensity, our regression specification is set up as:

$$\Delta y_{it} = \sum_{k=1}^{5} \beta^k \, ND_{it}^k + \alpha_1 \, y_{it-1} + \alpha_2 \, \boldsymbol{X}_{it-1} + FE_i + FE_t + \varepsilon_{it} \tag{2}$$

where superscript k differentiates each 5th percentile range above 75th percentile: i.e., $ND_{it}^1 = 1$ if natural disaster intensity belongs in 75-80th percentile, and $ND_{it}^2 = 1$ for 80-85th percentile intensity and so on.

Due to potential sources of bias that can cause inconsistency in the coefficients of panel regression, two different methods were adopted to estimate the effects of natural disaster on growth in PICs: fixed effects (FE) panel regression and the first difference generalized method of moments (FDGMM) dynamic panel regression (Arellano and Bond 1991).[16] Both results were similar suggesting that our results are robust.

B. Effect of Natural Disasters on Growth

We first analyze the effect of natural disaster on economic growth. Table 4 presents the estimation results on the impact of natural disasters on GDP growth based on equations (1)-(2). Specifications [1] and [3] include only the dummy variables on severe natural disasters and

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[14] The results are broadly consistent with a different specification for the natural disaster intensity: e.g., the intensity measure based on higher percentiles in case both damage and population affected are available.

[15] More rigorously, we can adopt a threshold regression method proposed by Hansen (1999) to determine a threshold level. However, we instead chose the way above as the focus of this paper is to measure the average size of economic impact of severe natural disaster instead of identifying the threshold level itself.

[16] Due to the small number of countries, system GMM, which is another method for the estimation of parameters, is not adopted in the estimation. It is commonly known that the system GMM method is appropriate for data that constitutes a short time series and a large number of individuals (Blundell and Bond 1998).

initial level of log(GDP) as explanatory variables, while specifications [2] and [4] control for other variables (population, inflation, trade openness, and terms of trade growth of Australia and the U.S.). We report the estimation results from both the FE and FDGMM panel regression.

The results from the FE model are presented in the left four columns of Table 4. We find that the adverse growth effect of severe natural disasters is statistically significant in most specifications.

First, in the estimation for the overall natural disaster dummy for above 75th percentile (specifications ([1] and [2]), the coefficient of natural disaster dummy is estimated to be negative and statistically significant at the 5 percent significance level. The magnitude of impact is estimated to be -1.7 to -1.9 percent, implying that a severe natural disaster tends to reduce GDP growth by on average 1.8 percent, which is consistent with the literature. However, caution is needed in interpreting the estimated coefficients on natural disasters: (i) the negative impact of severe disasters on growth is likely to be underestimated as the disaster dummy variable is defined as 1 only for above 75th percentile disaster years which in turn disaster dummy is set as 0 for both non-disaster years and below 75th disaster percentile disaster years; (ii) the negative impact of severe disaster can be underestimated if there are lagged effects from previous years' disasters (i.e., lasting effects beyond the disaster year);[17] and (iii) the negative impact of severe disaster can be either overestimated or underestimated if another disaster occurs in successive years—the specification of this paper cannot fully disentangle the impact of successive disasters.

Second, in the estimation with separate disaster dummy variables for each 5th percentile (specifications ([3] and [4]), the coefficient is negative for all 5th percentiles except for the highest 5th percentile, but it is significant only for the ranges of 75-80th and 85-90th percentiles. At the same time, the absolute value of coefficient does not change much between 75th to 90th percentiles, implying that the negative growth impact tends to be similar for severe disasters above 75th percentile. This result justifies our specification for severe natural disasters using a threshold based on the distribution of damage or population affected.[18]

Lastly, the result confirms our expected sign on the control variables for GDP growth. We first find that the negative relation between GDP growth and initial GDP levels is significant at the 1 or 5 percent significance level in all specifications, implying that there is income convergence across countries after controlling for other factors affecting GDP growth. In addition, the estimated coefficients on lagged log(population) and terms of trade growth of the U.S. are positive and statistically significant at the 1 or 5 percent level in all specifications (while on the other hand the coefficients on terms of trade growth of Australia are estimated to be insignificant): that is, GDP grows faster in the country-year of larger population as well as in the year of higher terms of trade of growth of the U.S. and in the country of higher trade

[17] For robustness, we also estimated a separate regression with inclusion of lagged disaster dummy variables as additional explanatory variables to capture the lagged growth effects from natural disaster. However, the estimated lagged effects were found to be small and insignificant. The result was not reported in the paper but it can be provided upon request.

[18] However, the adverse impact of disaster weakens at the highest 10th percentiles. This finding may be related to the measurement issue of natural disaster intensity as the large proportion of the highest 10th percentile belongs to the disaster events only with the data on population affected in which the intensity measure is less likely to capture the actual economic impact.

share with the U.S.—implying an influential role of the U.S. in the world economy. The estimated coefficients of lagged log(inflation) and lagged trade openness are negative but they are estimated to be statistically insignificant.

It is noteworthy that the FDGMM model (right four columns) presents the similar results in both sign and magnitude with FE model. The Arellano-Bond test on serial correlation of first-differenced errors in FDGMM model shows that there is only first order and no second order serial correlation. Thus, lagged GDP growth was included as explanatory variables to capture the autoregressive dynamics of growth. We find that the estimated coefficients of lagged GDP growth are positive and statistically significant at the 1 or 5 percent level in all specifications—indicating GDP grows faster in the country of higher GDP growth in the previous year.

Table 5 presents the impact of natural disaster on GDP per capita growth. Similar to the estimation on GDP growth (Table 4), we find that: (i) severe natural disasters have a significant adverse impact on GDP per capita growth; (ii) a negative growth impact tends to be larger for more severe disasters; and (iii) there is a significant negative relation between GDP per capita growth and initial GDP per capita levels while there is a significant positive relation between GDP per capita growth and terms of trade of growth of the U.S.

The estimation results are also robust to different econometric specifications. For instance, the negative impact of natural disaster on GDP growth and GDP per capita growth applies to:

- different fixed effects specifications: region-year fixed effects (controlling for economic shocks separately for Southern and Northern Pacific regions) instead of year-specific fixed effects (controlling for common economic shocks for all countries);[19]
- separate severe natural disaster dummy variables for different types of natural disaster (storm, flood, drought, earthquake, and other);[20] and
- different thresholds for severe natural disaster dummy variables: lower/higher thresholds than the 75th percentile (e.g., 70th or 80th percentiles).

The results presented in Tables B.1 and B.2 show that the specification of region-year fixed effects has similar sign and magnitude of coefficients with a larger *R*-squared than that of year fixed effects. This implies that there might be some significant difference in the economic effects of natural disasters between Southern Pacific and Northern Pacific. Southern PICs are more closely related to Australia and New Zealand while Northern PICs have relatively close relationships with the U.S. and Asian countries. Also, Southern PICs are more exposed to storms and floods while Northern PICs suffer mostly from droughts.

Table B.3 reports the results in the estimation with separate disaster dummy variables for different types of disasters. We find that the impact of natural disasters on GDP and GDP per capita growth varies across different types of disasters in significance and magnitude although all types have a negative impact on growth. For instance, droughts, earthquakes and

[19] Separate dummy variables are assigned for Southern PICs (Fiji, PNG, Samoa, Solomon Islands, Tonga, Tuvalu, and Vanuatu) and Northern PICs (Kiribati, Marshall Islands, Micronesia, Palau, and Timor-Leste) since they may substantially differ in terms of both economic or trade relationships with Australia and the U.S. and the relative exposure to different types of natural disasters.

[20] Some of existing studies found that different types of disaster have distinct effects on economic growth (e.g., Fomby et al., 2013; Loayza et al., 2012). However, the dummy variable for flood is not included in our estimation because no flood event above 75th percentile occurred over the sample period in the Pacific region.

“other” categories have a significant negative impact on growth in several specifications while storms have a negative impact on growth without statistical significance. The insignificant coefficients for storms and droughts may have resulted from wider ranges of growth impact for these more frequent disaster types.

Tables B.4 and B.5 present the estimation results for the specification of overall natural disaster dummy variable using 70th or 80th percentile thresholds which maintain the signs but smaller magnitudes of coefficients as those of the 75th percentile threshold. This finding implies that our main findings do not rely critically on the level of thresholds if the threshold level is high enough to identify severe natural disaster events.

Table 4. Impact of Natural Disasters on GDP

Dependent variable: GDP growth

	FE				FDGMM			
	Above 75th percentile		Each 5th percentile		Above 75th percentile		Each 5th percentile	
	[1]	[2]	[3]	[4]	[1]	[2]	[3]	[4]
ND(Above 75th percentile)	-1.650*	-1.914**			-1.712**	-1.695**		
	(0.780)	(0.853)			(0.777)	(0.719)		
ND(75-80th percentile)			-2.889***	-3.256**			-2.821***	-2.710***
			(0.897)	(1.060)			(0.763)	(0.967)
ND(80-85th percentile)			-2.331	-1.558			-2.408*	-2.717
			(1.316)	(0.924)			(1.349)	(1.948)
ND(85-90th percentile)			-2.736*	-3.279*			-2.913**	-3.221**
			(1.273)	(1.705)			(1.169)	(1.546)
ND(90-95th percentile)			-0.234	-1.753			-0.129	-0.633
			(1.030)	(2.090)			(1.132)	(1.627)
ND(95-100th percentile)			0.153	1.131			-0.085	0.175
			(2.530)	(2.682)			(2.396)	(2.304)
Lagged log(GDP)	-4.816**	-5.975***	-4.688**	-5.824***	-4.574***	-6.245***	-4.437***	-5.813***
	(1.989)	(1.150)	(2.034)	(1.182)	(1.352)	(1.101)	(1.348)	(1.218)
Lagged log(Population)		11.51***		12.14**		8.957***		5.561**
		(3.400)		(3.946)		(2.937)		(2.440)
Lagged log(Inflation)		-0.272		-0.254		-0.244		-0.292*
		(0.202)		(0.206)		(0.178)		(0.176)
Lagged Trade openness		-0.030		-0.030		-0.033		-0.035
		(0.032)		(0.033)		(0.028)		(0.029)
Terms of trade growth of AUS		-0.346		-0.360		-0.393		-0.406
× Share of trade with AUS		(0.271)		(0.263)		(0.306)		(0.298)
Terms of trade growth of USA		1.592***		1.623***		1.766***		1.653***
× Share of trade with USA		(0.353)		(0.336)		(0.339)		(0.339)
Lagged GDP growth					0.144**	0.149**	0.145**	0.172***
					(0.072)	(0.060)	(0.072)	(0.064)
Observations	242	213	242	213	232	201	232	201
R^2-within	0.150	0.243	0.157	0.253				
A-B AR(2) test (*p*-value)[1)]					0.548	0.404	0.503	0.302
Number of countries	12	12	12	12	12	12	12	12

Notes: 1) Arellano-Bond test with a null hypothesis that the first-differenced errors exhibit no second order serial correlation; 2) Numbers in parentheses are robust standard errors clustered at country level; 3) *, **, and *** indicate coefficient estimates significantly different from zero at the 10%, 5%, and 1% levels, respectively; 4) Constant, country and year fixed effects are included in all specifications.

Table 5. Impact of Natural Disasters on GDP Per Capita

Dependent variable: GDP per capita growth

	FE				FDGMM			
	Above 75th percentile		Each 5th percentile		Above 75th percentile		Each 5th percentile	
	[1]	[2]	[3]	[4]	[1]	[2]	[3]	[4]
ND(Above 75th percentile)	-1.560*	-1.824*			-1.733**	-1.933**		
	(0.726)	(0.868)			(0.784)	(0.769)		
ND(75-80th percentile)			-2.878***	-3.125***			-2.864***	-2.645***
			(0.801)	(0.942)			(0.618)	(0.646)
ND(80-85th percentile)			-1.900	-1.295			-2.018*	-1.088
			(1.087)	(0.863)			(1.179)	(1.016)
ND(85-90th percentile)			-2.736*	-3.414			-3.008**	-3.324*
			(1.361)	(1.946)			(1.383)	(1.743)
ND(90-95th percentile)			-0.667	-1.808			-0.939	-1.185
			(1.023)	(2.105)			(1.176)	(1.652)
ND(95-100th percentile)			0.879	1.447			0.293	0.363
			(2.692)	(2.785)			(2.533)	(2.436)
Lagged log(GDP per capita)	-6.131***	-6.474***	-5.999**	-6.310***	-5.871***	-6.311***	-5.663***	-6.481***
	(1.880)	(1.339)	(1.960)	(1.359)	(1.393)	(1.382)	(1.382)	(1.404)
Lagged log(Population)		4.995		5.937		1.967		3.303
		(3.332)		(4.180)		(2.681)		(3.510)
Lagged log(Inflation)		-0.218		-0.196		-0.213		-0.174
		(0.170)		(0.175)		(0.154)		(0.154)
Lagged Trade openness		-0.027		-0.027		-0.035		-0.032
		(0.031)		(0.031)		(0.027)		(0.028)
Terms of trade growth of AUS		-0.430		-0.443		-0.373		-0.479
× Share of trade with AUS		(0.285)		(0.274)		(0.299)		(0.298)
Terms of trade growth of USA		1.723***		1.761***		1.755***		1.949***
× Share of trade with USA		(0.400)		(0.375)		(0.297)		(0.346)
Lagged GDP per capita growth					0.144**	0.167**	0.144*	0.145**
					(0.070)	(0.066)	(0.075)	(0.059)
Observations	236	213	236	213	224	199	224	199
R^2-within	0.171	0.250	0.178	0.261				
A-B AR(2) test (p-value)[1)]					0.469	0.267	0.418	0.284
Number of countries	12	12	12	12	12	12	12	12

Notes: 1) Arellano-Bond test with a null hypothesis that the first-differenced errors exhibit no second order serial correlation; 2) Numbers in parentheses are robust standard errors clustered at country level; 3) *, **, and *** indicate coefficient estimates significantly different from zero at the 10%, 5%, and 1% levels, respectively; 4) Constant, country and year fixed effects are included in all specifications.

C. Effect of Natural Disasters on the Fiscal Balance

In addition to the impact on growth, a natural disaster is likely to have an impact on the fiscal balance via a decrease in government revenues and an increase in government expenditures. Government revenues are expected to decrease in the aftermath of large natural disasters due to lower GDP growth especially from disruptions in the agriculture and tourism sectors. As PICs are highly dependent on grants which are volatile and unpredictable, we used the data on government revenues which exclude grants from overall government revenues. On the other hand, government expenditures may increase in the disaster year to support the economic recovery from the damages of a disaster.

Table 6 describes the impact of natural disasters on the fiscal balance-to-GDP ratio. Similar to Tables 4 and 5, only the dummy variables on severe natural disasters and initial level of fiscal balance-to-GDP are included as explanatory variables in specifications [1] and [3], while other control variables are considered in specifications [2] and [4]. Both the FE and FDGMM panel regression results are reported.

The estimation results find that a severe natural disaster may lead to a reduction of fiscal balance-to-GDP ratio by on average 1.1 to 1.5 percent depending model specifications (Table

6, specifications [1] and [2] of the FE and FDGMM models. However, the coefficients on severe natural disaster dummy are estimated to be insignificant, partly because there are other important country-specific factors that may affect the fiscal situation of the country—for example some development expenditures may fall in the aftermath or a disaster or expenditures may switch from development to reconstruction rather than expanding overall. Explicit consideration of these other country-specific factors was not feasible in our paper due to data limitations. Nonetheless, our results do show that the adverse impact of natural disasters on the fiscal balance is large and statistically significant for 80-85th percentile in specification [3] of the FE model and in specifications [3] and [4] of the FDGMM model, while the positive impact is not statistically significant for some other percentiles, which implies some nonlinearity in the impact of natural disaster on the fiscal balance.

The negative impact on the fiscal balance could result from either a decrease in government revenues or an increase in government expenditures, which can be tested by a separate estimation on the effects of a natural disaster on government revenues and expenditures (Tables B.6 and B.7). The estimation finds expected sign—severe natural disaster causing a decrease in revenues and an increase in expenditures—but the estimated coefficients are statistically insignificant.

Table 6. Impact of Natural Disasters on Fiscal Balance

Dependent variable: Fiscal balance-to-GDP change

	FE				FDGMM			
	Above 75th percentile		Each 5th percentile		Above 75th percentile		Each 5th percentile	
	[1]	[2]	[3]	[4]	[1]	[2]	[3]	[4]
ND(Above 75th percentile)	-1.089	-1.419			-1.494	-1.371		
	(2.332)	(2.784)			(1.927)	(1.818)		
ND(75-80th percentile)			2.075	2.155			1.803	3.473
			(3.710)	(3.531)			(3.467)	(3.187)
ND(80-85th percentile)			-13.90*	-12.94			-14.27**	-12.12**
			(7.717)	(7.344)			(6.938)	(5.757)
ND(85-90th percentile)			-0.801	-2.030			-0.345	-0.886
			(1.780)	(2.640)			(1.678)	(1.794)
ND(90-95th percentile)			2.376	2.372			1.751	0.979
			(3.782)	(4.445)			(4.656)	(4.663)
ND(95-100th percentile)			7.153	6.585			7.578	6.549
			(8.169)	(8.585)			(7.886)	(5.824)
Lagged Fiscal balance-to-GDP	-0.278***	-0.260***	-0.282***	-0.266***	-0.352***	-0.363***	-0.362***	-0.367***
	(0.065)	(0.073)	(0.063)	(0.070)	(0.038)	(0.067)	(0.038)	(0.065)
Lagged log(Population)		-17.15		-19.63*		-20.19**		-20.46***
		(9.949)		(10.53)		(8.272)		(7.519)
Lagged log(Inflation)		0.242		0.200		0.399		0.363
		(0.510)		(0.482)		(0.482)		(0.473)
Lagged Trade openness		0.005		0.000		0.003		0.004
		(0.049)		(0.046)		(0.032)		(0.031)
Terms of trade growth of AUS		-0.879		-0.844		-0.638		-0.546
× Share of trade with AUS		(1.365)		(1.302)		(0.910)		(0.860)
Terms of trade growth of USA		1.581		1.555		1.652		1.601
× Share of trade with USA		(2.188)		(2.068)		(1.121)		(1.130)
Lagged Fiscal balance-to-GDP change					0.017	-0.007	0.035	-0.000
					(0.156)	(0.134)	(0.128)	(0.109)
Observations	227	206	227	206	213	189	213	189
R^2-within	0.281	0.295	0.325	0.336				
A-B AR(2) test (p-value)[1)]					0.433	0.128	0.643	0.086
Number of countries	12	12	12	12	12	12	12	12

Notes: 1) Arellano-Bond test with a null hypothesis that the first-differenced errors exhibit no second order serial correlation; 2) Numbers in parentheses are robust standard errors clustered at country level; 3) *, **, and *** indicate coefficient estimates significantly different from zero at the 10%, 5%, and 1% levels, respectively; 4) Constant, country and year fixed effects are included in all specifications.

D. Effect of Natural Disasters on the Trade Balance

Lastly, a natural disaster is also expected to have a substantial impact on the international trade via an increase in imports and a disruption of exports. Imports can increase in the aftermath of severe natural disasters as: (i) the reconstruction of destroyed infrastructure would involve imports of construction materials from abroad; and (ii) some of donor supports (grants and concessional loans) can be spent on the purchase of foreign products. Furthermore, natural disasters can lead to a disruption of exports due to for example, damage to crops, and the destruction of transportation and hotels. Jones and Olken (2010) find that climate shocks have a significant negative impact on the exports of poor countries and agricultural exports, with a less severe impact on manufacturing exports.

Table 7 describes the estimation results on the impact of natural disasters on the trade balance-to-GDP ratio, using both the FE and FDGMM panel regression methods. Specifications [1] and [3] includes only the dummy variables on severe natural disasters and initial level of trade balance-to-GDP as explanatory variables, while specifications [2] and [4] introduce other control variables.[21]

The estimation results find that a severe natural disaster has a statistically significant impact on international trade reducing the trade balance by on average 3 to 5 percent depending model specifications (Table 7, specifications [1] and [2]). Moreover, the adverse impact of natural disasters on the trade balance is statistically significant for 85-90th, and 95-100th percentiles in some specifications in the FE and FDGMM models, implying some nonlinearity in the impact of a natural disaster on the trade balance.

The negative impact on the trade balance could result from either an increase in imports or decrease in exports, which can be tested by a separate estimation on the impact of natural disaster on imports and exports (Tables B.8 and B.9). The estimation finds that severe natural disasters tend to have a significant impact on imports raising imports by on average 3~4 percent while the effect on exports is not statistically significant but is of the right sign—causing a reduction in exports. Thus, the results overall are consistent with a worsening of the trade balance.

[21] We do not include financial supports (grants or loans) from donors as separate explanatory variables although these variables may have impacts on imports and the trade balance since the separate inclusion of grants did not affect the results significantly. This way implies that the impact of disaster on the trade balance also includes the impact on imports via the increase in donor supports.

Table 7. Impact of Natural Disasters on Trade Balance

Dependent variable: Trade balance-to-GDP change

	FE				FDGMM			
	Above 75th percentile		Each 5th percentile		Above 75th percentile		Each 5th percentile	
	[1]	[2]	[3]	[4]	[1]	[2]	[3]	[4]
ND(Above 75th percentile)	-4.214*	-5.487**			-4.846**	-4.847***		
	(2.070)	(2.432)			(1.991)	(1.675)		
ND(75-80th percentile)			-1.615	-2.876			-2.451	-3.146
			(2.976)	(3.194)			(2.135)	(2.362)
ND(80-85th percentile)			-2.298	-3.546			-2.614	-3.173
			(3.986)	(3.646)			(2.864)	(2.634)
ND(85-90th percentile)			-1.882	-2.436			-2.668*	-2.823*
			(1.753)	(1.802)			(1.397)	(1.604)
ND(90-95th percentile)			-1.569	-3.334			-2.931	-3.363
			(5.108)	(5.592)			(3.954)	(5.113)
ND(95-100th percentile)			-18.38	-18.95*			-17.65*	-15.13**
			(12.19)	(10.32)			(9.710)	(6.975)
Lagged Trade balance-to-GDP	-0.351***	-0.209	-0.351***	-0.213*	-0.312***	-0.401***	-0.312***	-0.393***
	(0.050)	(0.121)	(0.050)	(0.111)	(0.085)	(0.055)	(0.079)	(0.058)
Lagged log(Population)		-4.572		-8.953		-4.315		-7.001
		(6.216)		(7.417)		(4.827)		(5.524)
Lagged log(Inflation)		-0.212		-0.285		0.086		0.059
		(0.571)		(0.569)		(0.541)		(0.549)
Lagged Trade openness		0.023		0.022		-0.023		-0.022
		(0.045)		(0.041)		(0.036)		(0.035)
Terms of trade growth of AUS		-0.772		-0.767		-0.262		-0.289
× Share of trade with AUS		(0.675)		(0.688)		(0.547)		(0.563)
Terms of trade growth of USA		1.219		1.099		0.381		0.353
× Share of trade with USA		(2.762)		(2.670)		(2.217)		(2.190)
Lagged Trade balance-to-GDP change					0.194***	0.169***	0.192***	0.169***
					(0.058)	(0.050)	(0.058)	(0.050)
Observations	236	213	236	213	224	200	224	200
R^2-within	0.270	0.223	0.296	0.256				
A-B AR(2) test (*p*-value)[1)]					0.195	0.128	0.213	0.125
Number of countries	12	12	12	12	12	12	12	12

Notes: 1) Arellano-Bond test with a null hypothesis that the first-differenced errors exhibit no second order serial correlation; 2) Numbers in parentheses are robust standard errors clustered at country level; 3) *, **, and *** indicate coefficient estimates significantly different from zero at the 10%, 5%, and 1% levels, respectively; 4) Constant, country and year fixed effects are included in all specifications.

V. Use in Macroeconomic Projection and Debt Sustainability Analysis: Adjustment for Natural Disasters

IMF (2016) suggests that the long-term baseline macroeconomic projections for the countries which are highly vulnerable to natural disasters should be based not just on the outlook in non-disaster years, but should also factor in an average adverse impact from probable disasters. Internalization of the disaster shocks into macroeconomic projections would help countries prepare more realistic medium-term and long-term plans and policies. This, together with a focus on resilience building and disaster risk reduction, could help reduce the human and economic cost of disasters.

The assessment of the debt sustainability analysis for low-income countries also needs to include the adjusted long-term projections and to consider the risk of experiencing a very large disaster as an alternative scenario (IMF, 2017). The "large disaster" scenario should consider a one-off shock to public debt, GDP growth, and export growth in the year of shock, based on data covering natural disasters during 1950-2015. The paper also allows for tailoring the scenario to country-specific circumstances.

Following the key recommendations from these papers, we propose a simple and consistent method using our estimation results, and the frequency and intensity of natural disasters for the adjustment of economic projections on GDP growth, the fiscal and trade balance. We further extend the method to identify the one-off "large disaster" alternative scenario for the analysis on debt sustainability.

A. Macroeconomic Projection

The long-term baseline macroeconomic projections for each year need to be adjusted for the expected impact of natural disasters. For example, Vanuatu was hit by Cyclone Pam in 2015 which destroyed about 60 percent of GDP. As a result, GDP growth decreased by about 2 percent (2.3 percent in 2014; 0.2 percent in 2015) in the year of the cyclone, while at the same time the fiscal deficit increased by around 5 percent (5.0 percent in 2014; 9.6 percent in 2015) and the trade deficit increased by about 10 percent (24.2 percent in 2014; 34.8 percent in 2015).[22] Although this kind of large disaster does not occur often (say, once in 20 years), the economic projections and debt sustainability would be somewhat unrealistic without considering the large expected economic effects of the disaster.

We propose that the baseline economic projection (the non-disaster projection) can be adjusted by the product of the average impact per natural disaster and the probability of a natural disaster in a given year—which is approximated by the annual expected impact of a disaster—as below:

Long-term baseline adjustment per year	=	Expected impact per disaster (region-common)	×	Probability of disaster per year (country-specific)

The expected impact per natural disaster is drawn from the estimated coefficients from the previous section (Section IV). In addition, to keep consistency in the measurement of severe natural disasters in the calculation of expected impact and probability, the probability of disaster is computed based on the natural disasters above 75th percentile. It should be also noted that by construction, the baseline adjustment will vary across countries according to the difference in the probability of severe natural disasters. Consequently, a relatively large adjustment is expected to be required for Samoa, Solomon Islands, and Vanuatu which are frequently hit by severe natural disasters.

Table 8 presents the suggested adjustment for growth projection per year for each PIC, based on the above method. Specifications [1]-[4] correspond to the adjustments using the estimated coefficients of specifications [1]-[4] in the FE and FDGMM models from Table 4. Relatively large reductions in growth are suggested for Vanuatu (0.49~0.64 percentage points), Samoa (0.22~0.36), and Solomon Islands (0.22~0.38). As we discussed earlier, the difference in the magnitude of baseline adjustment is determined by the historical probability

[22] For the calculation of the macroeconomic impact of Cyclone Pam in Vanuatu by the difference of economic variables between 2014 (pre-cyclone) and 2015 (cyclone-year), the impact on GDP growth can be underestimated while that on the fiscal balance and the trade balance can be overestimated since the government's several large infrastructure projects started in 2015. The countries tend to record relatively higher GDP growth along with larger fiscal deficit and trade deficit during the infrastructure boom. This can offset some of adverse growth impacts of the cyclone and it is likely to lead to deterioration in the fiscal and trade balance (along with an increase in government expenditures and imports).

that each country has been hit by severe natural disasters—which, in our analysis, is measured by the average probability over the sample period (1980-2016) that each country experienced disasters above 75th percentile. Also, it should be noted that the adjustment for GDP growth may have even wider ranges because of wide standard error bands in estimating the coefficients.

Similarly, Table 9 presents the suggested adjustment for GDP per capita growth per year. Specifications [1]-[4] correspond to the adjustments using the estimated coefficients of specifications [1]-[4] in the FE and FDGMM models from Table 5. The adjustments for GDP growth and GDP per capita growth are largely consistent with a similar magnitude. The results imply that the country which is highly exposed to natural disasters can easily fall behind further in growth in terms of both GDP and GDP per capita compared to other developing countries.

Table 8. Baseline Adjustment for Natural Disaster Impact on GDP

(percentage point)

	FE				FDGMM			
	Above 75th percentile		Each 5th percentile		Above 75th percentile		Each 5th percentile	
	[1]	[2]	[3]	[4]	[1]	[2]	[3]	[4]
Fiji	-0.13	-0.16	-0.16	-0.22	-0.14	-0.14	-0.16	-0.16
Kiribati	-0.04	-0.05	0.00	0.03	-0.05	-0.05	0.00	0.00
Marshall Islands	-0.09	-0.10	-0.07	-0.09	-0.09	-0.09	-0.07	-0.09
Micronesia	-0.09	-0.10	0.00	-0.02	-0.09	-0.09	-0.01	-0.01
Palau	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Papua New Guinea	-0.13	-0.16	-0.19	-0.13	-0.14	-0.14	-0.20	-0.22
Samoa	-0.31	-0.36	-0.22	-0.25	-0.32	-0.32	-0.23	-0.27
Solomon Islands	-0.22	-0.26	-0.36	-0.35	-0.23	-0.23	-0.36	-0.38
Timor-Leste	-0.04	-0.05	-0.06	-0.04	-0.05	-0.05	-0.07	-0.07
Tonga	-0.13	-0.16	-0.09	-0.18	-0.14	-0.14	-0.08	-0.11
Tuvalu	-0.04	-0.05	0.00	0.03	-0.05	-0.05	0.00	0.00
Vanuatu	-0.49	-0.57	-0.60	-0.65	-0.51	-0.50	-0.61	-0.64

Notes: Adjustments are calculated by the product of estimated coefficients in Table 4 and the correspoding probability of each dummy variable of natural disasters.

Table 9. Baseline Adjustment for Natural Disaster Impact on GDP Per Capita

(percentage point)

	FE				FDGMM			
	Above 75th percentile		Each 5th percentile		Above 75th percentile		Each 5th percentile	
	[1]	[2]	[3]	[4]	[1]	[2]	[3]	[4]
Fiji	-0.13	-0.15	-0.17	-0.22	-0.14	-0.16	-0.18	-0.18
Kiribati	-0.04	-0.05	0.02	0.04	-0.05	-0.05	0.01	0.01
Marshall Islands	-0.08	-0.10	-0.07	-0.08	-0.09	-0.10	-0.08	-0.06
Micronesia	-0.08	-0.10	0.01	-0.01	-0.09	-0.10	-0.02	-0.02
Palau	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Papua New Guinea	-0.13	-0.15	-0.15	-0.11	-0.14	-0.16	-0.16	-0.09
Samoa	-0.30	-0.35	-0.19	-0.24	-0.33	-0.37	-0.25	-0.25
Solomon Islands	-0.21	-0.25	-0.33	-0.33	-0.23	-0.26	-0.35	-0.29
Timor-Leste	-0.04	-0.05	-0.05	-0.04	-0.05	-0.05	-0.05	-0.03
Tonga	-0.13	-0.15	-0.11	-0.18	-0.14	-0.16	-0.13	-0.14
Tuvalu	-0.04	-0.05	0.02	0.04	-0.05	-0.05	0.01	0.01
Vanuatu	-0.46	-0.54	-0.55	-0.62	-0.52	-0.57	-0.62	-0.60

Notes: Adjustments are calculated by the product of estimated coefficients in Table 5 and the correspoding probability of each dummy variable of natural disasters.

Tables 10 and 11 present the suggested adjustment for the fiscal balance-to-GDP ratio and trade balance-to-GDP ratio per year, respectively. Specifications [1]-[4] correspond to the adjustments using the estimated coefficients of specifications [1]-[4] in the FE and FDGMM models from Tables 6 and 7. Relatively large reductions in the fiscal balance are suggested for Vanuatu (0.32~0.44 percentage points), Samoa (0.21~0.28), and Solomon Islands (0.15~0.20) in the specification of overall disaster dummy variable for above 75th percentile, whereas based on each 5th percentile the results for most countries are for a positive adjustment—again suggesting non-linearity of the results. However, for the fiscal balance there are insignificant coefficients with wide standard error bands in the estimation. In addition, relatively large reduction in the trade balance is suggested for Vanuatu (1.25~1.63 percentage points), Samoa (0.80~1.43), and Solomon Islands (0.26~0.74), though the magnitude shows some difference across specifications.

The analysis finds that the nonnegligible adjustments in the baseline projections on growth, and the fiscal and trade balance are needed for some countries, which are likely to be struck by severe natural disasters frequently. If a country does not incorporate the expected impact of a natural disaster in its economic projections, this would likely result in systematic errors and over-optimism bias which could result in misleading economic planning in the medium- or long-term.

Table 10. Baseline Adjustment for Natural Disaster Impact on Fiscal Balance

(percentage point)

	FE				FDGMM			
	Above 75th percentile		Each 5th percentile		Above 75th percentile		Each 5th percentile	
	[1]	[2]	[3]	[4]	[1]	[2]	[3]	[4]
Fiji	-0.09	-0.12	0.18	0.18	-0.12	-0.11	0.14	0.21
Kiribati	-0.03	-0.04	0.19	0.18	-0.04	-0.04	0.20	0.18
Marshall Islands	-0.06	-0.08	-0.31	-0.29	-0.08	-0.07	-0.34	-0.30
Micronesia	-0.06	-0.08	0.26	0.24	-0.08	-0.07	0.25	0.20
Palau	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Papua New Guinea	-0.09	-0.12	-1.13	-1.05	-0.12	-0.11	-1.16	-0.98
Samoa	-0.21	-0.27	0.10	0.02	-0.28	-0.26	0.10	0.03
Solomon Islands	-0.15	-0.19	-0.66	-0.64	-0.20	-0.19	-0.68	-0.49
Timor-Leste	-0.03	-0.04	-0.38	-0.35	-0.04	-0.04	-0.39	-0.33
Tonga	-0.09	-0.12	0.18	0.19	-0.12	-0.11	0.14	0.15
Tuvalu	-0.03	-0.04	0.19	0.18	-0.04	-0.04	0.20	0.18
Vanuatu	-0.32	-0.42	0.23	0.14	-0.44	-0.41	0.24	0.36

Notes: Adjustments are calculated by the product of estimated coefficients in Table 6 and the correspoding probability of each dummy variable of natural disasters.

Table 11. Baseline Adjustment for Natural Disaster Impact on Trade Balance

(percentage point)

	FE				FDGMM			
	Above 75th percentile		Each 5th percentile		Above 75th percentile		Each 5th percentile	
	[1]	[2]	[3]	[4]	[1]	[2]	[3]	[4]
Fiji	-0.34	-0.44	-0.39	-0.39	-0.13	-0.25	-0.21	-0.26
Kiribati	-0.11	-0.15	-0.13	-0.13	-0.50	-0.51	-0.48	-0.41
Marshall Islands	-0.23	-0.30	-0.26	-0.26	-0.10	-0.19	-0.15	-0.18
Micronesia	-0.23	-0.30	-0.26	-0.26	-0.54	-0.60	-0.56	-0.50
Palau	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Papua New Guinea	-0.34	-0.44	-0.39	-0.39	-0.19	-0.29	-0.21	-0.26
Samoa	-0.80	-1.04	-0.92	-0.92	-1.24	-1.43	-1.33	-1.24
Solomon Islands	-0.57	-0.74	-0.65	-0.66	-0.26	-0.41	-0.35	-0.42
Timor-Leste	-0.11	-0.15	-0.13	-0.13	-0.06	-0.10	-0.07	-0.09
Tonga	-0.34	-0.44	-0.39	-0.39	-0.13	-0.26	-0.22	-0.27
Tuvalu	-0.11	-0.15	-0.13	-0.13	-0.50	-0.51	-0.48	-0.41
Vanuatu	-1.25	-1.63	-1.44	-1.44	-1.43	-1.72	-1.59	-1.56

Notes: Adjustments are calculated by the product of estimated coefficients in Table 7 and the correspoding probability of each dummy variable of natural disasters.

B. Debt Sustainability Analysis

The analysis of debt sustainability should also consider the risk of suffering an extremely large disaster as possibilities (or as an alternative scenario)—even if the probability of this event is not very high. The most extreme disaster event the country has experienced historically can be used as a proxy for the exceptionally major future natural disaster event which the country can be exposed to. To keep consistency with adjustment in the baseline macroeconomic projection, the one-time adjustment under an alternative scenario is computed as the largest-disaster impact adjustment subtracting the baseline adjustment which was already adjusted for the year.[23]

$$\text{One-time adjustment} = \text{Largest-disaster adjustment} - \text{Baseline adjustment}$$

$$\text{Largest-disaster adjustment} = \text{Expected impact per disaster} \times \left(\frac{\text{Largest damage}}{\text{Average damage}}\right)$$

For the calculation of a large-disaster adjustment, the average estimated impact is multiplied by the ratio of the country-specific damage-to-GDP (or population affected-to-total population) of the largest disaster and the average values of these variables of severe natural disasters in the Pacific region. The one-time adjustment varies across countries according to the scale of damage of the largest natural disaster in a given country. Consequently, a relatively large one-time adjustment tends to be required for Kiribati, Micronesia, Samoa, Tonga, and Vanuatu, which have suffered exceptionally severe natural disasters over the past four decades (1980-2016).

Table 12 presents the suggested alternative scenario for GDP growth, GDP per capita growth, the fiscal balance-to-GDP ratio, and the trade balance-to-GDP ratio for each PIC, based on the above method. Specifications [1] and [2] correspond to the necessary one-time adjustment using the estimated coefficients of specifications [1] and [2] in the FE model from Tables 4 to 7. One-time large reduction in GDP growth is suggested as an alternative

[23] By doing this, we can avoid a double adjustment for natural disaster in the year of one-time adjustment.

scenario for Samoa (4.9~5.6 percentage points), Kiribati (4.6~5.4), Tonga (4.6~5.3), Micronesia (4.5~5.2), and Vanuatu (3.7~4.3) based on their past experiences of exceptionally large impact of some disasters. Similarly, these countries tend to have extremely large disaster shock which is likely to lead to a significant decline in GDP per capita growth. At the same time, relatively large declines in the fiscal balance-to-GDP ratio and the trade balance-to-GDP ratio should be also considered as alternative scenarios for these countries. That is, the one-time adjustments for the fiscal balance-to-GDP ratio are suggested for Samoa (3.1~4.1 percentage points), Kiribati (3.1~4.0), Tonga (3.0~3.9), Micronesia (2.9~3.8), and Vanuatu (2.3~3.1), while those for the trade balance-to-GDP ratio are proposed for Samoa (12.9~16.8), Kiribati (11.9~15.5), Tonga (11.8~15.4), Micronesia (11.6~15.1), and Vanuatu (10.2~13.4).

The natural disaster shock under this alternative scenario for the debt sustainability analysis is expected to help the country can internalize the risk of large decline in growth and significant increase of the fiscal and trade deficit, and further its impact on debt sustainability.

Table 12. Alternative Scenario for Extreme Natural Disaster Impact on GDP, Fiscal and Trade

(percentage point)

	Largest Disaster		FE: Above 75th percentile							
	Damage	Population	GDP		GDP Per Capita		Fiscal Balance/GDP		Trade Balance/GDP	
	(% GDP)	(% tot. pop)	[1]	[2]	[1]	[2]	[1]	[2]	[1]	[2]
Fiji	10.1%	39.7%	-1.72	-2.00	-1.62	-1.92	-1.10	-1.45	-4.60	-6.02
Kiribati	n/a	100.0%	-4.64	-5.38	-4.38	-5.13	-3.05	-3.98	-11.91	-15.52
Marshall Islands	n/a	38.3%	-1.70	-1.98	-1.60	-1.89	-1.10	-1.44	-4.49	-5.86
Micronesia	3.5%	97.8%	-4.49	-5.21	-4.24	-4.97	-2.94	-3.84	-11.60	-15.13
Palau	n/a	n/a	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Papua New Guinea	1.3%	32.7%	-1.40	-1.62	-1.31	-1.55	-0.88	-1.17	-3.76	-4.93
Samoa	161.8%	6.7%	-4.86	-5.64	-4.57	-5.40	-3.12	-4.10	-12.88	-16.84
Solomon Islands	14.0%	53.8%	-2.30	-2.67	-2.15	-2.56	-1.45	-1.92	-6.20	-8.12
Timor-Leste	0.1%	10.1%	-0.43	-0.50	-0.40	-0.48	-0.27	-0.36	-1.16	-1.52
Tonga	28.2%	100.0%	-4.55	-5.28	-4.29	-5.04	-2.96	-3.88	-11.82	-15.42
Tuvalu	n/a	42.6%	-1.95	-2.26	-1.84	-2.16	-1.27	-1.67	-5.04	-6.58
Vanuatu	131.2%	87.0%	-3.70	-4.30	-3.46	-4.13	-2.30	-3.07	-10.20	-13.38

Notes: Adjustments are calculated by the product of estimated coefficients in specifications [1] and [2] of Tables 4-7 and the correspoding probability of each dummy variable of natural disasters.

VI. Conclusions

Many PICs are highly vulnerable to various natural disasters. The frequency and magnitude of such disasters are too high to ignore in the macroeconomic analysis. The aim of this paper is to provide a consistent approach to enable IMF staff and policy-makers to incorporate the impact such disasters into the macroeconomic projections and debt sustainability analysis.

This paper identifies the intensity of natural disasters based on the distributions of damage and population affected, and then estimates their impact on economic growth, fiscal positions, and international trade using a panel data of PICs. Focusing on PICs, the main contributions of this paper are: (i) to identify key facts on the frequency and intensity of natural disasters; (ii) to measure the average economic impact of natural disasters by a panel regression method; and (iii) to propose a simple and consistent method to take account for the economic impact of natural disasters in the macroeconomic projections and debt sustainability analysis.

The economic impact of a natural disaster can be determined mainly by the frequency and the intensity of disasters as well as the type of disasters. However, as illustrated in the literature, only severe natural disasters appear to have a significant impact on the economy, and so this paper uses the frequency and the intensity of severe disasters (above 75th percentile) and estimates the economic impact of those disasters. We find the following:

- Among PICs, Vanuatu, Samoa, and Solomon Islands are the most vulnerable countries to severe natural disasters. The disaster type that these countries are affected by the most frequently is storms with some likelihood of earthquake, drought and other types varying across countries;
- Severe natural disasters have a significant and negative impact on economic growth and may lead to deterioration in the fiscal and trade balance;
- The negative impact on economic growth is stronger for more intense natural disasters.

These findings imply that to achieve sustainable growth, PICs vulnerable to natural disasters need to take account of the impact of disaster shocks in their medium-term and long-term economic planning.

This paper proposes a simple and consistent method, using our estimation results and the frequency and the intensity of natural disasters, to adjust economic projections and debt sustainability analysis for disaster shocks. Our analysis suggests that substantial adjustments are needed for some PICs which are frequently and strongly affected by natural disasters.

However, caution is required to apply the method in this paper too mechanically. First, the estimated impact of natural disasters is imprecise given gaps in data availability. Secondly, related to the first issue, the potentially diverse effects of disasters stemming from country-specific economic factors are not fully captured in our regional panel regression, and need to be considered when applying our method to each country. Thirdly, the econometric analysis used in this paper can measure only the partial impact of natural disasters in the sense that the separate estimation on the impact of natural disaster on growth, the fiscal balance, and the trade balance cannot capture the potential interactions among these variables. Finally, our analysis is based on past experience which may not be a good guide to the future, especially where climate change is important and is likely to change the frequency and nature of disasters going forward. Therefore, judgement also remains important in the application of this method to each particular country.

Appendix A: Data

Table A. Data Description and Source

Variable	Description	Source
Natural disaster dummy	1 if Damage-to-GDP ratio or population affected-to-total population is above 75th percentile; 0 otherwise	EM-DAT
GDP	Real GDP	IMF World Economic Outlook
GDP per capita	Real GDP per capita	IMF World Economic Outlook
Government revenue	(General government revenue-Grant)/Nominal GDP×100	IMF World Economic Outlook
Government expenditure	General government expenditure/Nominal GDP×100	IMF World Economic Outlook
Fiscal balance	(Government revenue-Expenditure)/Nominal GDP×100	IMF World Economic Outlook
Import	Import/Nominal GDP×100	IMF World Economic Outlook
Export	Export/Nominal GDP×100	IMF World Economic Outlook
Trade balance	(Export-Import)/Nominal GDP×100	IMF World Economic Outlook
Population	Total population	IMF World Economic Outlook
Inflation	1+CPI inflation	IMF World Economic Outlook
Trade openness	(Import+Export)/Nominal GDP×100	IMF World Economic Outlook
Terms of trade	Export price/import price×100	IMF World Economic Outlook
Trade share with U.S. or Australia	(Import and export with U.S or Australia)/total trade×100 in 2010[1)]	UN Comtrade

Notes: 1) Due to data availability, data in different years are used for some countries (PNG, 2011; Timor-Leste, 2013; Tuvalu, 2008) while parner countries' (U.S. or Australia) data are used for Marshall Islands.

Appendix B: Robustness

Table B.1. Impact of Natural Disasters on GDP: Region-Year Fixed Effect

Dependent variable: GDP growth

	FE				FDGMM			
	Above 75th percentile		Each 5th percentile		Above 75th percentile		Each 5th percentile	
	[1]	[2]	[3]	[4]	[1]	[2]	[3]	[4]
ND(Above 75th percentile)	-1.529	-1.864**			-1.710**	-1.683***		
	(0.987)	(0.752)			(0.806)	(0.589)		
ND(75-80th percentile)			-3.051**	-3.264***			-2.952***	-2.478***
			(1.016)	(0.906)			(0.822)	(0.696)
ND(80-85th percentile)			-2.058	-1.580			-2.163	-1.461
			(1.691)	(1.087)			(1.485)	(1.156)
ND(85-90th percentile)			-2.342***	-2.626*			-2.437***	-2.688**
			(0.737)	(1.310)			(0.589)	(1.065)
ND(90-95th percentile)			0.320	-1.852			-0.268	-1.184
			(1.608)	(2.279)			(1.366)	(1.604)
ND(95-100th percentile)			0.029	1.988			0.026	1.035
			(2.873)	(2.705)			(2.573)	(1.988)
Lagged log(GDP)	-5.070**	-6.731***	-5.032**	-6.573***	-4.452***	-6.171***	-4.377***	-5.996***
	(2.009)	(1.643)	(2.001)	(1.612)	(1.267)	(1.215)	(1.248)	(1.163)
Lagged log(Population)		13.78***		14.77***		11.11***		11.18***
		(4.355)		(4.615)		(3.972)		(4.205)
Lagged log(Inflation)		-0.299		-0.290		-0.350**		-0.350**
		(0.213)		(0.221)		(0.165)		(0.165)
Lagged Trade openness		-0.027		-0.027		-0.032		-0.031
		(0.033)		(0.033)		(0.028)		(0.028)
Terms of trade growth of AUS		-0.524		-0.527		-0.675		-0.662
× Share of trade with AUS		(0.399)		(0.382)		(0.429)		(0.414)
Terms of trade growth of USA		1.369***		1.389***		1.544***		1.550***
× Share of trade with USA		(0.372)		(0.323)		(0.326)		(0.292)
Lagged GDP growth					0.125	0.137**	0.125	0.138**
					(0.079)	(0.066)	(0.079)	(0.068)
Observations	242	213	242	213	232	201	232	201
R^2-within	0.247	0.329	0.254	0.340				
A-B AR(2) test (*p*-value)[1)]					0.910	0.935	0.872	0.881
Number of countries	12	12	12	12	12	12	12	12

Notes: 1) Arellano-Bond test with a null hypothesis that the first-differenced errors exhibit no second order serial correlation; 2) Numbers in parentheses are robust standard errors clustered at country level; 3) *, **, and *** indicate coefficient estimates significantly different from zero at the 10%, 5%, and 1% levels, respectively; 4) Constant, country and region-year fixed effects are included in all specifications.

Table B.2. Impact of Natural Disasters on GDP Per Capita: Region-Year Fixed Effect

Dependent variable: GDP per capita growth

	FE				FDGMM			
	Above 75th percentile		Each 5th percentile		Above 75th percentile		Each 5th percentile	
	[1]	[2]	[3]	[4]	[1]	[2]	[3]	[4]
ND(Above 75th percentile)	-1.305	-1.704*			-1.568**	-1.620**		
	(0.941)	(0.785)			(0.759)	(0.662)		
ND(75-80th percentile)			-3.201***	-3.326***			-3.187***	-2.829***
			(0.885)	(0.894)			(0.620)	(0.557)
ND(80-85th percentile)			-1.488	-1.096			-1.637	-0.931
			(1.516)	(1.088)			(1.394)	(1.182)
ND(85-90th percentile)			-2.129**	-2.513			-2.263***	-2.645**
			(0.697)	(1.420)			(0.689)	(1.242)
ND(90-95th percentile)			0.138	-1.941			-0.549	-1.415
			(1.775)	(2.324)			(1.417)	(1.669)
ND(95-100th percentile)			1.212	2.563			0.888	1.646
			(2.916)	(2.782)			(2.448)	(1.879)
Lagged log(GDP per capita)	-6.903***	-7.189***	-6.791***	-7.044***	-6.016***	-6.614***	-5.928***	-6.459***
	(2.099)	(1.854)	(2.083)	(1.819)	(1.631)	(1.605)	(1.611)	(1.546)
Lagged log(Population)		6.492		7.932		5.575		6.146
		(4.384)		(4.946)		(4.474)		(4.903)
Lagged log(Inflation)		-0.266		-0.252		-0.299*		-0.296*
		(0.199)		(0.207)		(0.153)		(0.154)
Lagged Trade openness		-0.022		-0.022		-0.029		-0.028
		(0.031)		(0.032)		(0.027)		(0.027)
Terms of trade growth of AUS		-0.588		-0.588		-0.714*		-0.691*
× Share of trade with AUS		(0.422)		(0.401)		(0.434)		(0.416)
Terms of trade growth of USA		1.489***		1.516***		1.718***		1.727***
× Share of trade with USA		(0.396)		(0.329)		(0.328)		(0.295)
Lagged GDP per capita growth					0.121	0.133*	0.118	0.132*
					(0.080)	(0.068)	(0.080)	(0.068)
Observations	236	213	236	213	224	199	224	199
R^2-within	0.276	0.341	0.285	0.354				
A-B AR(2) test (*p*-value)[1)]					0.886	0.849	0.835	0.758
Number of countries	12	12	12	12	12	12	12	12

Notes: 1) Arellano-Bond test with a null hypothesis that the first-differenced errors exhibit no second order serial correlation; 2) Numbers in parentheses are robust standard errors clustered at country level; 3) *, **, and *** indicate coefficient estimates significantly different from zero at the 10%, 5%, and 1% levels, respectively; 4) Constant, country and region-year fixed effects are included in all specifications.

Table B.3. Impact of Natural Disasters on GDP and GDP Per Capita: Disaster Type

Dependent variable:	*GDP growth*				*GDP per capita growth*			
	FE		FDGMM		FE		FDGMM	
	[1]	[2]	[3]	[4]	[1]	[2]	[3]	[4]
ND(Storm)	-0.374	-0.585	-0.197	-0.333	-0.328	-0.396	-0.124	-0.209
	(1.100)	(1.351)	(1.079)	(1.096)	(1.086)	(1.369)	(1.067)	(1.112)
ND(Drought)	-1.338	-2.006*	-1.687*	-1.555	-1.472	-1.988*	-1.862*	-2.019**
	(1.162)	(1.055)	(0.940)	(1.048)	(1.146)	(1.052)	(0.986)	(1.023)
ND(Earthquake)	-5.250**	-4.782**	-5.235***	-4.840**	-5.186**	-5.229**	-5.665***	-5.804***
	(1.710)	(2.101)	(1.634)	(1.953)	(1.732)	(2.103)	(1.780)	(2.050)
ND(Other)	-3.725**	-1.004	-4.112***	-2.581	-2.122	-0.615	-2.683*	-2.043
	(1.676)	(2.856)	(1.452)	(2.368)	(1.784)	(2.833)	(1.606)	(2.530)
Lagged log(GDP)	-4.759**	-6.059***	-4.519***	-6.274***				
	(2.067)	(1.182)	(1.379)	(1.152)				
Lagged log(GDP per capita)					-6.062**	-6.599***	-5.859***	-6.449***
					(2.023)	(1.350)	(1.453)	(1.427)
Lagged log(Population)		10.72***		7.918***		4.074		0.892
		(3.228)		(2.585)		(3.001)		(2.179)
Lagged log(Inflation)		-0.300		-0.274		-0.251		-0.251
		(0.201)		(0.182)		(0.170)		(0.159)
Lagged Trade openness		-0.028		-0.032		-0.025		-0.033
		(0.033)		(0.029)		(0.031)		(0.028)
Terms of trade growth of AUS		-0.369		-0.414		-0.457		-0.401
× Share of trade with AUS		(0.269)		(0.303)		(0.281)		(0.294)
Terms of trade growth of USA		1.595***		1.761***		1.732***		1.760***
× Share of trade with USA		(0.358)		(0.354)		(0.406)		(0.325)
Lagged GDP growth			0.149**	0.152**				
			(0.075)	(0.059)				
Lagged GDP per capita growth							0.144**	0.167**
							(0.069)	(0.065)
Observations	242	213	232	201	236	213	224	199
R^2-within	0.162	0.251			0.181	0.259		
A-B AR(2) test (*p*-value)[1)]			0.601	0.449			0.522	0.282
Number of countries	12	12	12	12	12	12	12	12

Notes: 1) Arellano-Bond test with a null hypothesis that the first-differenced errors exhibit no second order serial correlation; 2) Numbers in parentheses are robust standard errors clustered at country level; 3) *, **, and *** indicate coefficient estimates significantly different from zero at the 10%, 5%, and 1% levels, respectively; 4) Constant, country and year fixed effects are included in all specifications.

Table B.4. Impact of Natural Disasters on GDP: Different Disaster Thresholds

Dependent variable: GDP growth

	ND threshold: 70th percentile				ND threshold: 80th percentile			
	FE		FDGMM		FE		FDGMM	
	[1]	[2]	[3]	[4]	[1]	[2]	[3]	[4]
ND(Above 70th percentile)	-1.160	-1.643*	-1.270	-1.656**				
	(0.794)	(0.851)	(0.788)	(0.721)				
ND(Above 80th percentile)					-1.191	-1.356	-1.285	-1.543**
					(0.906)	(1.013)	(0.895)	(0.780)
Lagged log(GDP)	-4.834**	-5.930***	-4.585***	-5.844***	-4.843**	-5.980***	-4.616***	-5.908***
	(1.977)	(1.170)	(1.345)	(1.116)	(1.978)	(1.117)	(1.299)	(1.067)
Lagged log(Population)		11.17***		7.202***		11.46***		7.454***
		(3.420)		(2.555)		(3.493)		(2.668)
Lagged log(Inflation)		-0.302		-0.316		-0.272		-0.287
		(0.214)		(0.196)		(0.199)		(0.182)
Lagged Trade openness		-0.030		-0.036		-0.029		-0.035
		(0.032)		(0.028)		(0.033)		(0.028)
Terms of trade growth of AUS		-0.331		-0.274		-0.328		-0.270
× Share of trade with AUS		(0.282)		(0.305)		(0.290)		(0.312)
Terms of trade growth of USA		1.622***		1.596***		1.592***		1.568***
× Share of trade with USA		(0.361)		(0.256)		(0.369)		(0.265)
Lagged GDP growth			0.144**	0.172***			0.141*	0.173***
			(0.072)	(0.064)			(0.073)	(0.063)
Observations	242	213	232	201	242	213	232	201
R^2-within	0.145	0.241			0.144	0.235		
A-B AR(2) test (*p*-value)[1)]			0.559	0.288			0.619	0.373
Number of countries	12	12	12	12	12	12	12	12

Notes: 1) Arellano-Bond test with a null hypothesis that the first-differenced errors exhibit no second order serial correlation; 2) Numbers in parentheses are robust standard errors clustered at country level; 3) *, **, and *** indicate coefficient estimates significantly different from zero at the 10%, 5%, and 1% levels, respectively; 4) Constant, country and year fixed effects are included in all specifications.

Table B.5. Impact of Natural Disasters on GDP Per Capita: Different Disaster Thresholds

Dependent variable: GDP per capita growth

	ND threshold: 70th percentile				ND threshold: 80th percentile			
	FE		FDGMM		FE		FDGMM	
	[1]	[2]	[1]	[2]	[1]	[2]	[1]	[2]
ND(Above 70th percentile)	-1.072	-1.551*	-1.272	-1.633**				
	(0.750)	(0.853)	(0.793)	(0.766)				
ND(Above 80th percentile)					-1.079	-1.279	-1.297	-1.548*
					(0.875)	(1.064)	(0.921)	(0.859)
Lagged log(GDP per capita)	-6.127***	-6.433***	-5.878***	-6.263***	-6.155***	-6.480***	-5.910***	-6.317***
	(1.875)	(1.356)	(1.347)	(1.397)	(1.855)	(1.306)	(1.325)	(1.351)
Lagged log(Population)		4.714		1.645		4.944		1.826
		(3.295)		(2.649)		(3.361)		(2.756)
Lagged log(Inflation)		-0.246		-0.246		-0.217		-0.218
		(0.182)		(0.166)		(0.168)		(0.153)
Lagged Trade openness		-0.027		-0.035		-0.026		-0.034
		(0.031)		(0.027)		(0.031)		(0.027)
Terms of trade growth of AUS		-0.415		-0.354		-0.412		-0.350
× Share of trade with AUS		(0.297)		(0.311)		(0.303)		(0.317)
Terms of trade growth of USA		1.751***		1.779***		1.723***		1.753***
× Share of trade with USA		(0.400)		(0.301)		(0.415)		(0.312)
Lagged GDP per capita growth			0.139**	0.168**			0.141**	0.169***
			(0.071)	(0.065)			(0.070)	(0.065)
Observations	236	213	224	199	236	213	224	199
R^2-within	0.166	0.248			0.165	0.242		
A-B AR(2) test (*p*-value)[1)]			0.519	0.247			0.554	0.321
Number of countries	12	12	12	12	12	12	12	12

Notes: 1) Arellano-Bond test with a null hypothesis that the first-differenced errors exhibit no second order serial correlation; 2) Numbers in parentheses are robust standard errors clustered at country level; 3) *, **, and *** indicate coefficient estimates significantly different from zero at the 10%, 5%, and 1% levels, respectively; 4) Constant, country and year fixed effects are included in all specifications.

Table B.6. Impact of Natural Disasters on Government Revenue: Year Fixed Effect

Dependent variable: Government revenue-to-GDP change

	FE				FDGMM			
	Above 75th percentile		Each 5th percentile		Above 75th percentile		Each 5th percentile	
	[1]	[2]	[3]	[4]	[1]	[2]	[3]	[4]
ND(Above 75th percentile)	0.838	0.482			0.799	0.566		
	(2.073)	(2.386)			(1.779)	(1.109)		
ND(75-80th percentile)			0.354	1.005			0.604	2.131
			(1.693)	(2.103)			(1.625)	(1.641)
ND(80-85th percentile)			-7.795*	-6.451			-7.621**	-5.148**
			(4.070)	(3.742)			(3.389)	(2.596)
ND(85-90th percentile)			0.696	-0.961			0.676	-0.433
			(0.784)	(1.125)			(0.719)	(0.643)
ND(90-95th percentile)			2.915	1.231			2.594	0.473
			(2.938)	(4.073)			(3.094)	(3.343)
ND(95-100th percentile)			10.52	10.77			11.84	10.30
			(11.68)	(10.87)			(11.12)	(7.026)
Lagged Revenue-to-GDP	-0.140*	-0.119	-0.152**	-0.134*	-0.176*	-0.220***	-0.205***	-0.248***
	(0.073)	(0.076)	(0.063)	(0.065)	(0.093)	(0.082)	(0.056)	(0.062)
Lagged log(Population)		-5.287		-3.998		-4.637		-1.996
		(6.265)		(6.469)		(4.716)		(2.939)
Lagged log(Inflation)		0.699**		0.725***		0.730**		0.705***
		(0.283)		(0.228)		(0.319)		(0.259)
Lagged Trade openness		0.002		-0.000		-0.022		-0.023
		(0.050)		(0.050)		(0.045)		(0.045)
Terms of trade growth of AUS		-0.406		-0.370		-0.112		-0.007
× Share of trade with AUS		(0.741)		(0.705)		(0.416)		(0.385)
Terms of trade growth of USA		-0.080		-0.086		-0.155		-0.266
× Share of trade with USA		(1.298)		(1.210)		(0.692)		(0.704)
Lagged Revenue-to-GDP change					0.073	0.036	0.116	0.090
					(0.132)	(0.166)	(0.084)	(0.094)
Observations	228	206	228	206	214	190	214	190
R^2-within	0.145	0.173	0.203	0.237				
A-B AR(2) test (*p*-value)[1)]					0.438	0.326	0.343	0.965
Number of countries	12	12	12	12	12	12	12	12

Notes: 1) Arellano-Bond test with a null hypothesis that the first-differenced errors exhibit no second order serial correlation; 2) Numbers in parentheses are robust standard errors clustered at country level; 3) *, **, and *** indicate coefficient estimates significantly different from zero at the 10%, 5%, and 1% levels, respectively; 4) Constant, country and year fixed effects are included in all specifications.

Table B.7. Impact of Natural Disasters on Government Expenditure: Year Fixed Effect

Dependent variable: Government expenditure-to-GDP change

	FE				FDGMM			
	Above 75th percentile		Each 5th percentile		Above 75th percentile		Each 5th percentile	
	[1]	[2]	[3]	[4]	[1]	[2]	[3]	[4]
ND(Above 75th percentile)	1.565	1.525			1.223	0.976		
	(1.748)	(1.903)			(1.531)	(1.611)		
ND(75-80th percentile)			-2.314	-1.899			-2.091	-1.976
			(2.772)	(1.758)			(2.744)	(2.067)
ND(80-85th percentile)			5.649	6.106			5.572	5.857**
			(4.342)	(4.242)			(3.733)	(2.962)
ND(85-90th percentile)			1.300	1.012			0.946	0.369
			(1.310)	(2.218)			(1.205)	(1.826)
ND(90-95th percentile)			-0.185	-2.369			-0.837	-2.332
			(3.056)	(2.878)			(3.013)	(2.864)
ND(95-100th percentile)			3.907	4.938			3.042	2.655
			(4.485)	(3.085)			(3.772)	(2.316)
Lagged Expenditure-to-GDP	-0.293***	-0.299***	-0.291***	-0.299***	-0.359***	-0.335***	-0.356***	-0.330***
	(0.058)	(0.072)	(0.058)	(0.069)	(0.067)	(0.074)	(0.069)	(0.071)
Lagged log(Population)		18.54**		22.42**		16.91**		19.40***
		(8.365)		(8.715)		(7.282)		(7.367)
Lagged log(Inflation)		0.578		0.651		0.416		0.479
		(0.446)		(0.468)		(0.447)		(0.454)
Lagged Trade openness		0.000		0.001		-0.044		-0.046
		(0.035)		(0.035)		(0.029)		(0.029)
Terms of trade growth of AUS		0.644		0.643		0.617		0.619
× Share of trade with AUS		(0.697)		(0.669)		(0.462)		(0.446)
Terms of trade growth of USA		-2.052		-1.995		-1.524**		-1.547**
× Share of trade with USA		(1.489)		(1.405)		(0.729)		(0.690)
Lagged Expenditure-to-GDP change					0.133	0.083	0.125	0.067
					(0.151)	(0.141)	(0.148)	(0.139)
Observations	232	211	232	211	220	196	220	196
R^2-within	0.262	0.278	0.273	0.294				
A-B AR(2) test (*p*-value)[1)]					0.174	0.708	0.222	0.891
Number of countries	12	12	12	12	12	12	12	12

Notes: 1) Arellano-Bond test with a null hypothesis that the first-differenced errors exhibit no second order serial correlation; 2) Numbers in parentheses are robust standard errors clustered at country level; 3) *, **, and *** indicate coefficient estimates significantly different from zero at the 10%, 5%, and 1% levels, respectively; 4) Constant, country and year fixed effects are included in all specifications.

Table B.8. Impact of Natural Disasters on Import: Year Fixed Effect

Dependent variable: Import-to-GDP change

	FE				FDGMM			
	Above 75th percentile		Each 5th percentile		Above 75th percentile		Each 5th percentile	
	[1]	[2]	[3]	[4]	[1]	[2]	[3]	[4]
ND(Above 75th percentile)	3.100	4.480*			3.773**	4.105***		
	(1.755)	(2.279)			(1.775)	(1.562)		
ND(75-80th percentile)			-1.125	-0.050			-0.351	0.341
			(3.092)	(3.111)			(1.921)	(2.055)
ND(80-85th percentile)			0.0307	0.903			0.630	0.855
			(4.702)	(4.513)			(3.865)	(3.609)
ND(85-90th percentile)			0.567	1.274			1.487	1.890
			(1.659)	(2.030)			(1.346)	(2.160)
ND(90-95th percentile)			1.273	4.911			2.399	4.982
			(4.380)	(3.884)			(3.321)	(3.522)
ND(95-100th percentile)			19.91	19.72*			19.32**	16.65**
			(11.21)	(9.560)			(8.970)	(6.578)
Lagged Import-to-GDP	-0.328***	-0.120	-0.329***	-0.132	-0.297***	-0.407***	-0.299***	-0.390***
	(0.070)	(0.239)	(0.071)	(0.216)	(0.068)	(0.109)	(0.063)	(0.114)
Lagged log(Population)		3.339		6.601		3.359		5.095
		(9.072)		(10.22)		(6.666)		(7.301)
Lagged log(Inflation)		0.0470		0.102		-0.210		-0.199
		(0.577)		(0.617)		(0.573)		(0.605)
Lagged Trade openness		-0.100		-0.092		0.067		0.057
		(0.138)		(0.123)		(0.089)		(0.090)
Terms of trade growth of AUS		1.282		1.249		0.894		0.900
× Share of trade with AUS		(0.812)		(0.837)		(0.615)		(0.633)
Terms of trade growth of USA		-2.288		-2.201		-1.582		-1.597
× Share of trade with USA		(2.929)		(2.853)		(2.339)		(2.330)
Lagged Import-to-GDP change					0.147**	0.129***	0.145**	0.131***
					(0.071)	(0.043)	(0.071)	(0.045)
Observations	236	213	236	213	224	200	224	200
R^2-within	0.256	0.232	0.292	0.278				
A-B AR(2) test (*p*-value)[1)]					0.574	0.705	0.619	0.771
Number of countries	12	12	12	12	12	12	12	12

Notes: 1) Arellano-Bond test with a null hypothesis that the first-differenced errors exhibit no second order serial correlation; 2) Numbers in parentheses are robust standard errors clustered at country level; 3) *, **, and *** indicate coefficient estimates significantly different from zero at the 10%, 5%, and 1% levels, respectively; 4) Constant, country and year fixed effects are included in all specifications.

Table B.9. Impact of Natural Disasters on Export: Year Fixed Effect

Dependent variable: Export-to-GDP change

	FE				FDGMM			
	Above 75th percentile		Each 5th percentile		Above 75th percentile		Each 5th percentile	
	[1]	[2]	[3]	[4]	[1]	[2]	[3]	[4]
ND(Above 75th percentile)	-1.219	-1.007			-1.133	-0.730		
	(0.847)	(0.992)			(0.753)	(0.930)		
ND(75-80th percentile)			-2.938**	-2.926*			-2.706**	-2.747**
			(1.252)	(1.586)			(1.081)	(1.195)
ND(80-85th percentile)			-2.450	-2.644			-2.245	-2.495*
			(1.960)	(1.823)			(1.654)	(1.442)
ND(85-90th percentile)			-1.164	-1.162			-1.034	-0.733
			(1.376)	(1.760)			(1.137)	(1.632)
ND(90-95th percentile)			-0.407	1.577			-0.659	1.624
			(3.077)	(3.385)			(2.844)	(3.082)
ND(95-100th percentile)			1.303	0.768			1.569	1.567
			(1.286)	(1.393)			(1.151)	(1.030)
Lagged Export-to-GDP	-0.244***	-0.299***	-0.243***	-0.293***	-0.299***	-0.372***	-0.299***	-0.380***
	(0.032)	(0.037)	(0.031)	(0.038)	(0.022)	(0.054)	(0.021)	(0.050)
Lagged log(Population)		-1.234		-2.352		-1.113		-2.432
		(7.027)		(6.316)		(6.228)		(5.281)
Lagged log(Inflation)		-0.165		-0.183		-0.180		-0.184
		(0.256)		(0.246)		(0.240)		(0.236)
Lagged Trade openness		0.012		0.011		0.026		0.029
		(0.019)		(0.020)		(0.022)		(0.022)
Terms of trade growth of AUS		0.510**		0.483**		0.572**		0.536**
× Share of trade with AUS		(0.207)		(0.194)		(0.249)		(0.237)
Terms of trade growth of USA		-1.070**		-1.103**		-1.145***		-1.167***
× Share of trade with USA		(0.476)		(0.432)		(0.413)		(0.356)
Lagged Export-to-GDP change					0.126	0.166	0.127	0.178
					(0.101)	(0.112)	(0.097)	(0.113)
Observations	236	213	236	213	224	200	224	200
R^2-within	0.209	0.262	0.219	0.277				
A-B AR(2) test (*p*-value)[1)]					0.516	0.930	0.536	0.871
Number of countries	12	12	12	12	12	12	12	12

Notes: 1) Arellano-Bond test with a null hypothesis that the first-differenced errors exhibit no second order serial correlation; 2) Numbers in parentheses are robust standard errors clustered at country level; 3) *, **, and *** indicate coefficient estimates significantly different from zero at the 10%, 5%, and 1% levels, respectively; 4) Constant, country and year fixed effects are included in all specifications.

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