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The impact of tropical storms on the accumulation and composition of government debt

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Abstract

This paper investigates the impact of tropical storms on government debt accumulation and decomposition. To this end, we combine quarterly debt data and tropical storm loss data for the period 1993–2013 for the Eastern Caribbean. Our econometric results show that damaging storms cause debt to increase up to three quarters after the event, where this increase can be considerable for damaging enough storms. Much of this increase in debt is due to borrowing from foreign lenders by the central government. At the same time, there is also some shifting of the share of debt toward public corporations, although these tend to react more by financing from domestic sources.

Keywords Tropical storms · Debt

JEL Classification O17 · O44 · Q54

1 Introduction

In the aftermath of a natural disaster, governments need immediate funds for reconstruction, cleanup, and emergency relief and aid in order to ensure a quick recovery. The political pressure to succeed in this regard may be even higher because governments are typically held accountable for any poor post-disaster management (Koetsier 2017; Cavallo and Noy 2009). However, the accompanying likely fall in production in the economy after such an event also induces reductions in government revenues (Melecky and Raddatz 2011), making even less funds available for

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government expenditure. Although in the case of developing countries, which generally have little government savings and catastrophe risk insurance coverage, international aid often can help finance recovery activities. This money is, however, usually disbursed slowly, there is great uncertainty on the amount to be received, and the actual amount received is generally much lower than what is required (Melecky and Raddatz 2011; Borensztein et al. 2009). Many developing countries are thus forced to finance their increases in expenditure through domestic or foreign borrowing (Borensztein et al. 2009). The subsequent higher levels of debt and higher interest rates tend to lead to lower credit scores, resulting in higher budget deficits and causing debt to further increase, creating a vicious cycle which threatens debt sustainability (Koetsier 2017; Borensztein et al. 2009). Importantly in this regard, there is emerging evidence that high levels of debt negatively affect economic growth (Greenidge et al. 2010).[1]

The likelihood that government debt increases in developing countries after natural disasters is generally also supported by the empirical literature.[2] For example, in a study of the macroeconomic impact of major natural disasters across 26 countries Albala-Bertrand (1993) finds that the fiscal deficit, and subsequently government debt, increases. Looking at large-scale extreme weather events, Lis and Nickel (2009) uncover an upsurge in budget deficits in developing countries. Similarly, Melecky and Raddatz (2011) conclude that climate disasters raise the fiscal deficit in low- and middle-income countries, while Melecky and Raddatz (2011) also posit that on average budget deficits go up after climatic disasters in low- and middle-income countries. In a study of large-scale natural disasters in emerging countries, Klomp and de Haan (2015) provide evidence that investors perceive natural disasters as an adverse shock that make government debt less sustainable which in turn may eventually trigger a sovereign default and translate into higher government bond rates making borrowing more expensive. In a subsequent study, Klomp (2017) shows that natural catastrophes increase the probability of a sovereign debt default by about three percentage points, in particular for major earthquakes and storms.

In this paper, we add to the literature on public debt and natural disasters by investigating the impact of tropical storms on government debt in the Eastern Caribbean. The region is arguably apt for the study at hand as its islands are characterized by high debt and low growth, together with high exposure to climate related disaster risk. In fact, the Eastern Caribbean is identified as the most disaster prone region in the world, particularly on account of the frequent number of hurricane strikes. For example, since 1970 natural disaster inflicted damage equivalent to more than 2% of the affected country's GDP can be expected once every two and a half years (Rasmussen 2004). At the same time, the Eastern Caribbean islands have been in an unsustainable debt position for the past two

[1] For example, for the Caribbean Greenidge et al. (2010) show that if debt rises beyond 55% of GDP there is a downward impact on economic growth.

[2] An exception to the positive relationship between natural disasters and government debt is the study by Noy and Nualsri (2011) which finds that for large natural disaster events in developed countries government expenditure decreases and revenue increases, causing debt to fall.

decades (Fund 2013), where since the mid-1990s average national public debt has almost doubled. The overall government debt was estimated at about 79% of regional GDP in 2012 and has resulted in higher interest costs (Fund 2013). The increase in debt is accounted for by a deterioration in the fiscal balance owing mainly to a rise in government expenditure rather than a decline in revenue (Sahay 2005). Many Caribbean countries also do not benefit from international aid or intentional debt relief after a disaster occurs because of their middle income status, and only a few countries still qualify for concessional borrowing from the World Bank. According to Lugay and Ronald (2014), because of limited fiscal resources and inadequate international aid many Caribbean countries are then forced to borrow in the aftermath of a disaster. Indeed, Lugay and Ronald (2014) claim that in the Eastern Caribbean the occurrence of natural disasters leads to the accumulation of public debt to finance reconstruction as fiscal resources are often times limited and expenditure structures are too rigid to absorb the effects of external shocks. Natural catastrophe shocks are therefore likely a principal and recurrent factor for the rise in public sector debt in the region. Although some countries have made attempts to reduce their public debt through restructuring and fiscal consolidation, there has been little success thus far (Sahay 2005).

There are already a number of existing studies specifically looking at the impact of natural disasters on government debt, or at least government expenditure and revenue, for the Caribbean. More precisely, in their study of the macroeconomic costs of a natural disaster for the region, Heger et al. (2008) uncover that external debt increases in the year after due to a shortage in international aid. Mohan et al. (2018) purport that government expenditure increases by 1.4% points in the year of a hurricane strike. On the other hand, the results of Auffret (2003) suggest that a natural disaster event leads to a moderate decline in government expenditure, while Acevedo-Espinoza (2014) finds that public debt increases with floods. Similarly, in a study of hurricanes, Ouattara and Strobl (2013) demonstrate that hurricane strikes cause an increase in government spending, although the impact on government debt is found to be insignificant. Focusing specifically on the Eastern Caribbean, as we do here, Rasmussen (2004) found that the median public debt increases by a cumulative 6.5% points over three years following a disaster, mainly because of an increase in spending and a small reduction in revenue.

Our paper differs from the existing literature in two main ways. Firstly, compared to other studies that have relied on annual data, we have access to higher frequency, i.e., quarterly information on government debt. This allows us to investigate the short-term effects on debt. As a matter of fact, a growing literature has shown that much of the economic response to natural disasters may be missed if one examines annual data only; see, for example, Mohan and Strobl (2017) and Ishizawa et al. (2019). Secondly, we also are able to decompose debt in terms of its components, namely central government domestic and external debt and public corporation domestic and external debt, providing further insight into the dynamics of the debt response to natural disasters. To undertake our analysis, we combine quarterly data on tropical storm losses as derived from the Caribbean Catastrophe Risk Insurance Facility (CCRIF) catastrophe risk model with government debt and its components for the period 2000–2013 for 8 Eastern Caribbean countries. We then use panel

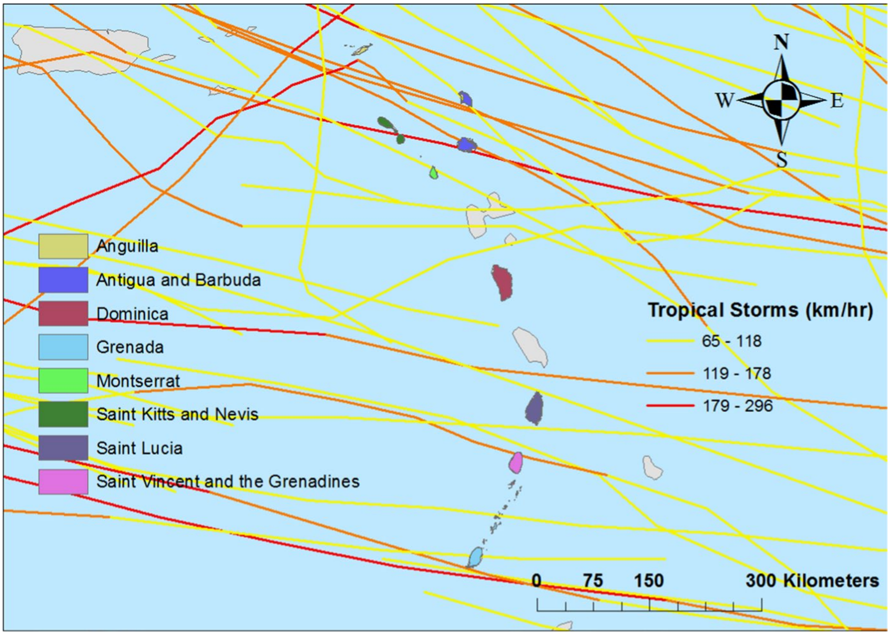

Fig. 1 Eastern Caribbean Island sample and tropical storms (1996–2013)

regression analysis to econometrically quantify the impact of tropical storm losses on the debt to GDP ratio, as well as its decomposition into its components.

The rest of the paper is organized as follows. Section 2 outlines the data and provides summary statistics, while Sect. 3 lays out the methodology. Section 4 describes the results from the econometric estimation. Finally, Sect. 5 concludes the paper.

2 Data and summary statistics

2.1 Government debt

Our study region is the Eastern Caribbean, in particular all countries that are part of the Eastern Caribbean Currency Union, namely Anguilla, Antigua and Barbuda, Grenada, Montserrat, Saint Lucia, Saint Kitts and Nevis, Saint Vincent and the Grenadines, and Dominica. These are depicted in Fig. 1. For these members, the Eastern Caribbean Central Bank (ECCB) has collected data on quarterly government debt and its main components, including public corporation and central government, and external and internal debt since the year 2000. One should note in this regard that, in contrast to the central government which solely has non-market responsibilities, public corporations are government-owned or controlled enterprises, such as a central bank, that engage primarily in commercial activities (IMF 2014). These are often referred to as quasi-fiscal operations, i.e., they carry out government operations at the behest of the government units that control them, which include those related to the financial system, the exchange rate system, and the commercial enterprise sector. Also, in terms of borrowing, typically, loans by public corporations are guaranteed by the central government. External, as opposed to domestic, debt by the central government or public corporations is defined as the actual current liabilities that require payment of principal and/or interest at some point in the future on money owned to nonresidents. We convert the quarterly total, and its 4 component series to 2013 Eastern Caribbean Dollar (EC$) values. For the four individual components, we calculate these as the share of total debt.

2.2 GDP

In order to generate debt ratios, i.e., debt measured as a ratio of GDP, we also need quarterly GDP data for the countries in our sample. Since data on quarterly GDP are not available for Eastern Caribbean countries, we instead proxy GDP with quarterly nightlight intensity data derived from satellite images. Importantly, nightlights have recently found widespread use as a measure of economic activity where other satisfactory proxies are not available; see, for instance, Henderson et al. (2011). Applications of using nightlight data to proxy GDP, and its verification, specifically for the Caribbean can be found in Bertinelli and Strobl (2013) and Ishizawa et al. (2019). As in the aforementioned studies, the nightlight imagery we employ is provided by the Defense Meteorological Satellite Program (DMSP) satellites. In terms of coverage, each DMSP satellite has a 101 minute near-polar orbit at an altitude of about 800 km above the surface of the earth, providing global coverage twice per day, at the same local time each day, with a spatial resolution of about 1 km near the equator. The resulting images provide the percentage of nightlight occurrences for each pixel per year normalized across satellites to a scale ranging from 0 (no light) to 63 (maximum light). Monthly values are then created as simple averages across daily values of grids and are available from 1992 until 2013. We use the stable, cloud-free series for the period 2000 until 2013; see Elvidge et al. (1997). We then aggregate the monthly nightlight intensity at the island level. In order to convert these into monetary values, we also sum them at the annual island level and then calculate the average dollar per unit of nightlight by using all available GDP data, converted to 2013 EC$ values, for each of the islands from the ECCB databank website. The island level monthly EC$ values of nightlights are then used to normalize the total debt data to debt to GDP ratios.

2.3 Tropical storm losses

In order to capture hurricane damage, we use the estimates generated from the CCRIF hurricane loss model. More specifically, we use losses derived from CCRIF's Second-Generation Hazard and Loss Estimation Model (2G Model), which uses storm- and site-specific characteristics to calculate local winds and storm surge in response to a hurricane strike (Facility 2012). The local wind speed and storm surge estimates from the models are then translated into damage using local exposure data and damage functions. The exposure data consist of locally-estimated

Table 1 Summary statistics

Variable	Mean	SD	Min	Max
DEBT	4.7086	2.9891	0.000	13.5452
CGDD	0.3361	0.1603	0.0102	0.8315
CGED	0.4170	0.1742	0.0679	0.7937
PCDD	0.0771	0.0670	0.0000	0.4132
PCED	0.1698	0.2118	0.0081	0.7613
DAMAGE	0.0004	0.0034	0.0000	0.0522
DAMAGE (>0)	0.0032	0.0091	6.00e−07	0.0522

(30 arc-seconds) asset values at risk and allow the generation of estimated losses in monetary terms by considering asset exposure and explicit damage functions. More precisely, for each 30 arc-second grid cell, the number of dwelling units is computed from population data, land cover information is used to infer construction types and non-residential exposure, infrastructure estimates are based on the density and distribution of building types, while the agricultural component in the loss estimation is constructed using land cover data and agriculture contribution to country GDP. Each asset class including residential, non-residential, and infrastructure is then subject to damage functions associated with each type. Inputs into these damage functions are the maximum wind speed and storm surge experienced for a storm at the grid cell's centroid, providing monetary losses for each cell for each storm. Finally, all grid cell asset losses are aggregated at the national level for each storm. We then convert losses to ratios of the total exposure of total national assets, as given within the 2G Model.

We have access to the output of this model from 1996 until 2013. Over this period, 31 tropical storms caused at least some damage in the 8 islands in our sample. We depict the storm tracks along with their wind speeds in three categories, in Fig. 1. As can be seen, the direction and the strength of storms are largely unpredictable spatially.

2.4 Summary statistics

Combining our total debt, its components and the hurricane damage data, provides us with a nearly balanced quarterly panel covering the period 2000–2013 for the 8 Eastern Caribbean countries.[3] We provide summary statistics for our variables in Table 1. As can be seen, the quarterly debt to GDP ratio is about 471%, equivalent to an annual debt to GDP ratio in the region of about 118%. There is considerable variation, however, with some islands at some point in time with zero debt, while others experienced debt up to 1354% of quarterly GDP (i.e., an annual level of 338%).

[3] The panel is nearly balanced because there is no debt data for Saint Lucia for the first three quarters of 2000.

Looking at the decomposition of debt, one finds that on average in our sample the central government holds most of the debt, i.e., a little over three quarters. Within this central government debt, the external component tends to be somewhat larger, with a mean of slightly over 55%. Within the public corporation debt, the external share tends, in contrast, to be larger, at nearly 70%. Across all components, the share of central government external debt is thus highest, while that of domestic public corporation is lowest. In the Eastern Caribbean, about 58% of total debt is owed to nonresidents.

In terms of hurricane damage, on average about 0.04% of total assets is destroyed each quarter in the region, although with considerable variation (0.03%). In reality, a nonzero damage quarter occurs in 12% of our sample, implying a return period of a damaging hurricane about every two years in the region. The average amount of assets exposed to damage during such a storm is only about 0.3%, but was witnessed to be as high as 5.2% (Grenada during Hurricane Ivan in 2004).

3 Econometric methodology

In econometrically estimating the impact of hurricane losses on government debt, we employ the following specification:

$$\mathrm{DEBT}_{iqt} = \alpha_0 + \sum_{q=0}^{Q} \beta_m \mathrm{DAMAGE}_{iqt} + \mu_i + \lambda_t + \pi_q + \mathrm{TREND}_{it} + \epsilon_{iqt} \tag{1}$$

where DEBT is the government debt to GDP ratio in country i in quarter q in year t and DAMAGE is the hurricane damage to exposure ratio. One should note that in terms of the effect of the latter on the former, we allow for both contemporaneous and lagged impacts of up to M months. We additionally control for island-specific time-invariant effects μ, year and quarter specific common shocks λ and π, as well as island-specific time trends TREND. One may want to note that since the damage variable is based on a tropical storm's physical features, and time-invariant exposure maps, it is arguably exogenously constructed. Moreover, while at least in theory economic agents may place assets within countries with the knowledge of what areas are more or less likely to be affected by damaging storms, after we account for island-specific fixed effects, one is arguably left with random realizations from the local distribution of potential hurricane damage. Finally, in order to allow for arbitrary cross-sectional and serial correlation we calculate standard errors following Hoechle (2007).

We are also interested in estimating the impact of hurricane damage on the components of debt. Since the individual components of debt are calculated as shares of total debt, they will necessarily be related to each other. In order to take account of this, we use a panel SURE regression model for a system of equations; see Wooldridge (2002):

Table 2 Impact on debt to GDP ratio

	(1)	(2)	(3)
DAMAGE_t	25.29*	27.08**	27.14*
	(2.58)	(8.80)	(3.23)
DAMAGE_{t-1}		45.94*	46.66*
		(22.73)	(2.26)
DAMAGE_{t-2}		17.41*	18.39*
		(22.74)	(2.38)
DAMAGE_{t-3}		8.07	9.118
		(12.12)	(0.73)
DAMAGE_{t-4}		2.53	3.657
		(8.79)	(0.39)
DAMAGE_{t-5}			5.658
			(0.49)
DAMAGE_{t-6}			12.65
			(1.70)
DAMAGE_{t-7}			5.878
			(0.67)
DAMAGE_{t-8}			−0.950
			(−0.15)
Obs.	445	445	445
R^2	0.51	0.52	0.52

(a) ** and * indicate 1 and 5% significant levels, respectively; (b) all regressions include year and month dummy indicators, as well as country specific time trends. (c) Standard errors allowing for arbitrary cross-sectional and serial correlation in parentheses

$$\frac{\text{DEBT}_{jiqt}}{\sum_{j=1}^{J}\text{DEBT}_{jiqt}} = \alpha_0 + \sum_{q=0}^{Q}\beta_{jq}\text{DAMAGE}_{jiqt} + \mu_i + \lambda_t + \pi_q + \text{TREND}_{it} + \epsilon_{jimt}, \quad j = 1, \dots, J \tag{2}$$

where DEBT_{jiqt} refers to the four debt components, CGDD, CGED, PCDD, and PCED measured as a share of total debt DEBT, and the other controls are as in Eq. (1).

4 Results

4.1 Debt accumulation

We show the results of estimating Eq. (1) in Table 2, in the first column only allowing for a contemporaneous effect. As can be seen, damage due to a tropical storm immediately increases the debt to GDP ratio in an affected Eastern Caribbean

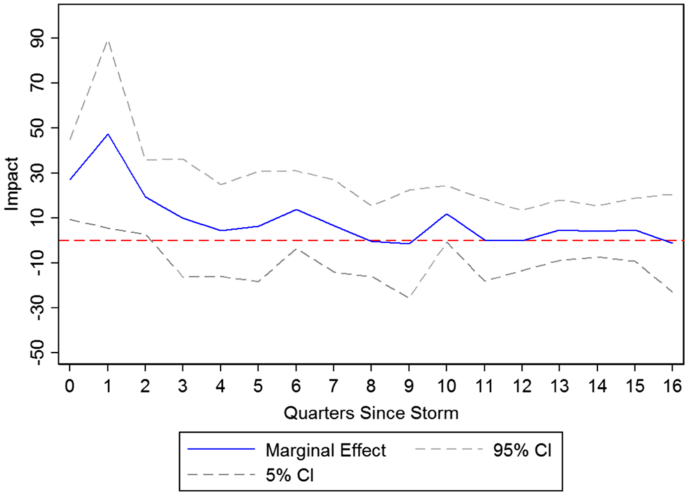

Fig. 2 Long-term impact on debt to GDP ratio

country. Taken at face value, the estimated coefficient suggests that an average damaging hurricane, causing an asset loss ratio of 0.32%, and causes the debt to GDP ratio to increase by 8.1%. The largest observed loss ratio in our sample of 5.2% would cause the debt ratio to rise by 132%.

We next allow for lagged effects of up to a year after the event, as shown in the second column of Table 2. Accordingly, the positive impact on debt of a damaging storm persists up until two quarters, after which it becomes insignificant. One may want to note in this regard that the effect is largest in the quarter following the storm, and smallest in the last impacted quarter. For an average damaging tropical storm, this cumulative effect over the three quarters translates into a 28.9% rise in debt.

In the final column of Table 2, we investigate if there were any further lagged effects by including lags of up to two years after the event, but the results remain unchanged in that storms increase debt until two quarters and then no longer are statistically significant. In order to see whether there may be potentially any debt reduction in the longer term, we also included up to 4 years worth of lags and, for convenience sake, we show the estimated coefficients and the 95% confidence bands in Fig. 2. Accordingly, the pattern remains the same, after the first two quarters, storms no longer cause governments in the Eastern Caribbean to increase their debt ratio, but there is also no evidence that the debt increase is reversed further down the line.

4.2 Debt composition

Our data allow us to examine how the increase in total debt up to 8 months after a storm is financed. To this end, we provide the results of estimating Eq. (2) in Table 3, where each column contains the estimated coefficients on the various debt shares from the system of equations. Accordingly, in the quarter when the storm strikes and, as we show above, debt increases, the central government debt

Table 3 Impact on debt decomposition

	(CGDD)	(CGED)	(PCDD)	(PCED)
$DAMAGE_t$	− 7.91**	6.79**	1.65	0.28
	(2.57)	(1.61)	(1.59)	(0.87)
$DAMAGE_{t-1}$	− 3.49**	1.78*	2.22*	1.26*
	(0.97)	(0.90)	(0.91)	(0.51)
$DAMAGE_{t-2}$	− 3.91**	1.40	2.71**	1.23**
	(1.05)	(0.82)	(0.83)	(0.46)
$DAMAGE_{t-3}$	− 1.73	0.52	1.74*	0.49
	(1.00)	(0.69)	(0.71)	(0.39)
$DAMAGE_{t-4}$	0.91	− 0.19	0.25	− 0.34
	(0.79)	(0.50)	(0.53)	(0.28)
Obs.	445	445	445	445
R^2	0.43	0.43	0.43	0.43

(a) ** and * indicate 1 and 5% significant levels, respectively; (b) all regressions include year and month dummy indicators, as well as country specific time trends. (c) Standard errors in parentheses

composition shifts from domestic to external debt financing. For a mean storm, this quantitative shifting is about 2.2% from resident to nonresident debtors. In contrast, in the immediate aftermath of the storm public corporations share to total debt does not change significantly.

One quarter after the damaging event, there is substantial reshuffling of debt composition among the 4 categories. More specifically, while the relative importance of debt by the central government owed to resident lenders continues to fall and that to foreign lenders to rise, in relative terms now debt by public corporations, both domestically and externally, increases. This shifting of relative debt from the central government domestic category continues in the second quarter, although now only toward the public corporation categories. By the third quarter, there is only a small increase in the share of domestic debt in public corporations, where the insignificance of the damage ratio variable across the three other categories probably means a shift close to equal across them. One year after the storm, there is no longer any significant effects on the decomposition of total debt.[4]

We can also use our estimated (significant) coefficients to create a visual picture of the evolution of changes in the debt composition over time after a damaging tropical storm. More specifically, we assume an Eastern Caribbean country with a mean decomposition of debt among the four categories. We then use the estimated coefficients to calculate how a storm with a damage ratio of one standard deviation above the mean, i.e. 1.2%, changes the relative shares over the four quarter period in which we found a significant impact.[5] The results of this exercise are shown in

[4] We also experiment with further lags, but there similarly were no longer any significant effects.

[5] Given that the significant coefficient changes do not exactly offset each other, we readjust these to make sure that they do.

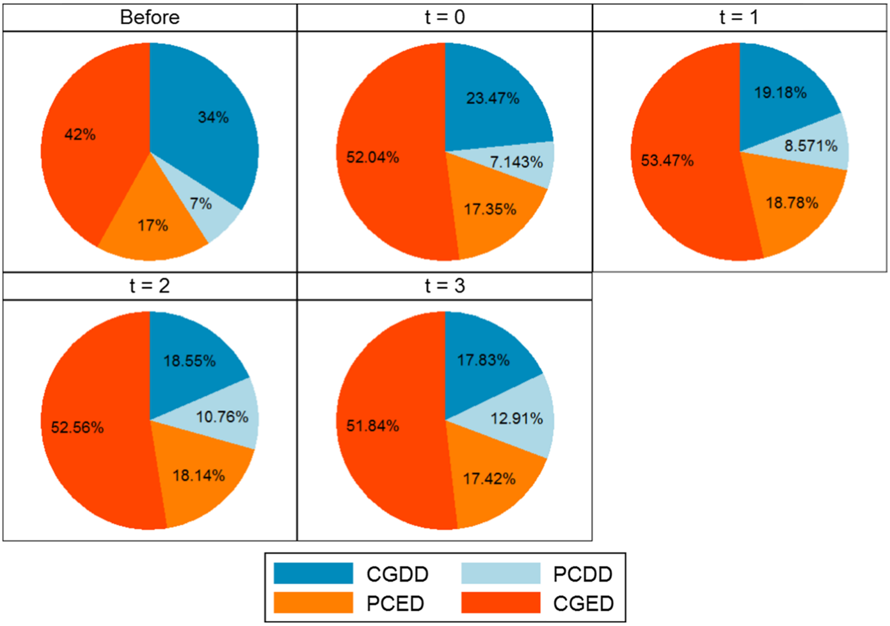

Fig. 3 Debt decomposition after storm

Fig. 3. Accordingly, our hypothetical mean Eastern Caribbean country starts out with debt that consists of 59% external debt, of which 42% points are due to the central government and the remaining 17% points attributable to money owed by the public corporations. Of the 41% domestic debt, 34% points are from the central government and 7% points due to the public corporations. Overall, the central government has more than three quarters (76%) of total debt.

In the quarter that a damaging storm strikes the external debt by both the central government and public corporations increase, by a little over 10% points for the former and only 0.35% for the latter. While the proportion of debt due to public corporation domestic debt also increases marginally (0.143% points), the domestic central government debt share clearly falls by over 10%. A quarter after the storm, there is a further drop in the share of domestic debt held by the central government by 4.19% points. This fall in the share is relatively equally distributed as increases in the central government external debt (1.39% points), and public corporation domestic (1.43% points) and external (1.43%) borrowing. In the second quarter after the storm, there are only marginal debt decomposition changes. In particular, the importance of money owed by the central government to foreign lenders is marginally reversed by 0.91% points. Similarly, both public corporation external and central government domestic debt share have slightly fallen. The relative fall in these three debt categories hence resulted in greater importance in the public corporation domestic debt by 2.19% points. Finally, the third quarter, where according to our results above there was no longer an effect on overall debt, the pattern continues, with marginal drops in the shares of central government external and domestic and public corporation external debt, and subsequent relative rise in money owed to domestic lenders by the public corporations.

Following from this computational exercise, the overall pattern of changes in debt composition after a storm can be summarized as follows. The largest part of the rise in debt is absorbed by the taking on of external debt by the central government. This may not be surprising given that, in the face of a sudden need of post-disaster financing, governments often rely on foreign lending bodies, such as the IMF or the World Bank. There is also an increase in the share of public corporation debt. However, in contrast to the central government most of this increase comes from borrowing from domestic lenders. While three quarters after a tropical storm strikes we find that there was no impact on the overall debt level, there was still some marginal reshuffling of debt between the four debt components for another quarter.

5 Conclusion

We investigate the impact of tropical storms on the accumulation of public debt and its decomposition using the case study of the Eastern Caribbean, a region characterized by high debt and tropical storm risk. Using a panel of quarterly data on debt and tropical storm damage over a 14-year period, we show that damaging storms cause public debt to increase only up to three quarters after the event, although potentially considerably so for very damaging storms. A large part of this debt increase is attributable to the taking on of loans from foreign rather than local lenders by the central government. This may not be surprising given that local credit markets may be particularly constrained after the damage a tropical storm causes, and often foreigner lenders, such as the IMF and World Bank, have to jump in to provide relief. We also discover that after a storm there is some shifting of lending away from the central government toward public corporations, although somewhat surprisingly the increase in debt due to these entities was mostly toward domestic lenders.

More generally, our results underline the need for disaster financing in the first few months after a disaster hits. Taking on debt to do so is arguably worrisome for countries that are already highly indebted, such as the island economies in the Eastern Caribbean. The reliance on foreign lenders in this regard hints potentially at the lack of financial development, or at least at the financial constraints faced after the damages of these events.

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