The Effectiveness of Debt Relief in Mitigating the Macroeconomic Consequences of Natural Disasters

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Abstract

We employ a dynamic panel fixed effects model to assess the macroeconomic consequences of natural disasters in Africa and the effectiveness of debt relief in promoting post-disaster recovery. Our results show that floods and droughts have a negative contemporaneous effect on GDP growth which, in the case of floods, is recovered at the second lag. General debt relief - consisting of debt forgiveness, rescheduling, and significant increases in Official Development Assistance (ODA) - has no impact on economic growth. However, significant increases in ODA in the aftermath of disasters have a positive effect that is increasing in disaster severity, suggesting that it is an effective post-disaster recovery instrument. Debt-to-GDP growth and crop production growth are also considered in the analysis.

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1 Introduction

Africa suffers disproportionately from the destruction of production factors during natural disasters. Over the past 50 years, Africa has experienced more than 2,650 natural disasters, affecting over 500 million citizens and killing more than 900,000 (Guha-Sapir et al., 2015). Although official estimates of financial costs are available for only 10% of disasters, these alone account for over US$300,000,000,000 in damages. Furthermore, while only 20% of all reported disasters worldwide occur in Africa, the continent suffers 60% of all disaster-related deaths (Loretti & Tegegn, 1997). It has been predicted that climate change will increase the probability of these extreme climatic events worldwide, especially intense rainfall and droughts (Edenhofer et al., 2014). Factors such as an over-reliance on agriculture and the low adaptive capacity of rural farmers and institutions leave Africa as one of the regions most vulnerable to climate variability (Challinor et al., 2007).

In conjunction with Africa's vulnerability to weather events, high levels of government debt is a persistent concern for many African economies. According to the World Bank, 33 of the 39 countries in its Heavily Indebted Poor Countries (HIPC) initiative are African countries. High debt levels carry a heightened risk of debt crises if existing debt cannot be rolled over. Additionally, highly indebted governments risk crowding out productive investment and increase the country's susceptibility to changes in commodity prices. Finally, in the aftermath of a disaster, high levels of government debt limit fiscal space, which constrains government spending on mitigation and recovery initiatives. These initiatives include direct humanitarian relief, infrastructure rebuilding or investment in measures to attenuate the severity of a disaster ex-ante such as flood defences.

This paper has two key objectives. The first is to study the effect of natural disasters on macroeconomic variables in Africa. The primary variable of interest is GDP growth, since it captures the economic impact of disasters. Furthermore, we consider debt-to-GDP growth and agricultural crop production growth as additional macroeconomic variables. Debt-to-GDP is included as a proxy for fiscal space while crop production allows us to evaluate the hypothesis that natural disaster related losses are felt most heavily through losses in agricultural output. As many African economies are dependent on agriculture, especially in sub-Saharan Africa, where agriculture accounted for 23% of GDP in 2019 (Goedde et al., 2019), we predict that changes in GDP growth will be positively correlated with changes in crop production.

The second aim is to study the effect of post-disaster debt relief on the rate at which an economy recovers from these natural disasters. In the context of this paper, debt relief refers to debt forgiveness, debt rescheduling and/or increased official development assistance (ODA). All of these policies reduce the need for governments to issue new debt or repay existing debt in the aftermath of a natural disaster. This is expected to ease government constraints on emergency spending, allowing governments to concentrate resources on rehabilitating the economy. This is especially relevant for highly indebted countries, where fiscal constraints are more likely to be binding.

This paper focuses specifically on the impact of floods and droughts using a panel that follows 40 African countries for 35 years from 1978 to 2013. Since debt relief would only be provided for sufficiently large disasters, our data-set includes the 25 floods and 68 droughts above a minimum severity threshold as proposed by Fomby et al. (2013). Similarly, we only study significant instances of debt relief (above 2% of GDP) to avoid capturing any potential seasonal variability. We use three main specifications of debt relief. First, we use a dummy variable that indicates any significant instances of debt restructuring, debt forgiveness, or increases in ODA, both generally and in the immediate aftermath of a disaster. Second, we use the change in ODA as percentage of GDP as a continuous variable while controlling for other types of debt relief. Finally, we interact ODA post-disaster with the severity of the underlying disaster to observe the effectiveness of ODA for different disaster severity levels. Our main model specification is a dynamic panel fixed effects model, although we also include a GMM-style estimation procedure as proposed by Anderson & Hsiao (1982) as a robustness check.

There is an existing body of literature on the effects of natural disasters on output. However, less attention has been paid to public debt levels. Moreover, these results have rarely been reconciled with the literature on debt relief's role in improving economic conditions through creating fiscal space. Our paper builds on these contributions in a number of ways. First, ours is the first to assess the effectiveness of debt relief as a response to natural disasters in the context of Africa, a primarily agrarian and heavily indebted region. Previous studies have focused on the Caribbean (Mejia, 2014) or the world as a whole (Raddatz, 2009). This is significant as we hypothesise that natural disasters affect Africa's developing economies primarily through reduced agricultural production. Second, ours is the first to isolate post-disaster debt relief. This allows us to distinguish the effectiveness of debt relief as an instrument for post-disaster recovery from its general effectiveness as a tool to improve economic growth. Furthermore, by separating debt relief temporally, we proxy for debt relief motivated by the occurrence of a disaster. We expect this post-disaster relief to be more effective in mitigating the negative impacts of disasters over a more general observation of debt relief.

Our results show that floods and droughts have a negative contemporaneous effect on GDP growth. One year after a flood, there is no significant effect on GDP growth, but a flood two years ago has a statistically significant positive effect of comparable magnitude to the negative effect in the contemporaneous period. Droughts appear to have no statistically significant effect on GDP in the following years. We find no significant results for either our debt relief dummy or the general continuous ODA variable. However, we estimate a positive and significant effect for our continuous ODA measure immediately after a disaster. Likewise, we observe a positive and significant effect for the interaction of ODA and disaster severity on GDP growth. These results suggest that debt relief, at least through the channel of ODA, is effective in mitigating the negative macroeconomic consequences of disasters.

The remainder of the paper is structured as follows: Section (2) reviews the key existing literature, Section (3) describes the data, Section (4) presents the empirical strategy and the different specifications estimated, and Section (5) presents the results. This is followed by a discussion of the results in Section (6). Finally, Section (7) provides some brief concluding remarks.

2 Literature Review

2.1 Macroeconomic Impact of Natural Disasters

There is a growing literature on the macroeconomic impact of natural disasters. The most notable paper in this field is that of Fomby et al. (2013), which tracks the annual effect on GDP growth across countries in response to droughts, floods, earthquakes and storms. By employing panel vector auto-regressions in the presence of endogenous variables and exogenous shocks (VARX), they find heterogeneous effects along a variety of dimensions, including the severity of the disaster, the type of disaster and the level of development of the country affected.

Using similar techniques, Raddatz (2009) finds that climate-related disasters reduce GDP per capita by at least 0.6%. Droughts are particularly severe, with cumulative losses of 1 percent of GDP per capita. Mejia (2014) employs a similar methodology to study floods and droughts in the Caribbean, finding that severe floods cause an immediate loss of 3% of output growth while storms cause a loss of 1%.

2.2 The Effectiveness of Debt Relief & Official Development Assistance

2.2.1 Debt Relief

Similarly, there is a rich body of literature that evaluates the effectiveness of debt relief (both restructuring and ODA) at mitigating economic distress in general. Debt restructurings under the auspices of the Paris and London Clubs are relatively common, with 342 recorded instances involving bilateral or commercial creditors between 1970 and 2013 (Das et al., 2012).

A seminal paper in this field is Cassimon & Van Campenhout (2007), which describes the dynamics of fiscal variables following instances of debt relief under the IMF and World Bank's Heavily Indebted Poor Countries (HIPC) scheme. In their study, they find that debt relief reduces contemporaneous government investment, although this is followed by an increase two years later. Moreover, they find that debt relief is a superior method of aid delivery for HIPC countries, compared to traditional mechanisms such as project aid or technical assistance.

However, the literature on the effectiveness of debt relief on economic growth in low-income countries is more mixed. There is no clear evidence that the reduction in the debt stock and improvement in fiscal variables generated through debt relief has a positive impact on growth or investment (Marcelino & Hakobyan, 2014). Chauvin & Kraay (2005) analyse the effect of debt relief to low-income countries between 1989 and 2013, finding debt relief has not raised growth, investment rates or the quality of institutions among recipient countries. On the other hand, Presbitero (2008) reports that debt relief only has a positive impact on relieving debt overhang and triggering economic growth in countries with sound institutions, a condition absent in many sub-Saharan African countries.

2.2.2 Official Development Assistance

A related but independent body of literature analyses the effectiveness of ODA in a similar fashion. ODA comprises a variety of different financial flows, including long term investment projects, soft loans and grants. There are a number of studies that argue that ODA is relatively effective at boosting growth. McGillivray (2005) finds evidence across multiple studies of ODA that aid is positively associated with boosting economic growth and reducing poverty, although it is subject to diminishing returns.

However, there is still limited consensus on this finding. Individual country case studies have often found that ODA can hinder economic development by encouraging rent-seeking behaviour, crowding out domestic exports and reducing pressures for necessary economic reforms. Smith (2010) examines ODA flows to Ethiopia and Sudan, which received the largest share of ODA to sub-Saharan Africa in 2008. They find that these flows have had limited effect on the country as a whole, postulating reasons such as a lack of development policy coherence among organisations and poor governance practices by recipient governments.

2.3 Debt Relief and Natural Disasters

Despite the comprehensive literature on both the macroeconomic consequences of natural disasters and the effectiveness of debt relief and ODA in general, there has been relatively little work on how debt relief mitigates the negative effects of natural disasters. Two notable exceptions to this have been Raddatz (2009) and Mejia (2014), who focus on the macroeconomic implications of natural disasters and the effectiveness of debt relief in mitigating these consequences. Raddatz (2009) performs a global study to estimate the short and long term effect of disasters on GDP, whereas Mejia (2014) focuses on storms and floods in the Caribbean. Both studies find that disasters have negative effects on GDP.

Surprisingly, both authors report that disasters reduce the debt-to-GDP of the affected country. They attempt to decipher this counter-intuitive result by analysing the role of debt relief and ODA. While Mejia (2014) uses a measure of debt relief similar to ours, Raddatz (2009) focuses on the more narrow measure of ODA as a percentage of GDP. Notably, Mejia (2014) finds evidence that debt relief is able to account for the fall in debt-to-GDP ratio in disaster-stricken countries. However, neither Mejia (2014) nor Raddatz (2009) uncovers strong evidence that ODA or debt relief plays a significant role in attenuating the fall in GDP, leaving room for future research in the area.

2.4 Contribution to the Literature

This paper contributes to the existing literature in three main ways. First, by performing a similar analysis on droughts and floods in African countries, we are able to examine the effect of debt relief in a region where the macroeconomic consequences of natural disasters are exceptionally severe. This is because African countries, particularly those in the sub-Saharan region, are heavily reliant on agricultural production, with more than 60% of the population of Sub-Saharan Africa consisting of smallholder farmers (Goedde et al., 2019). We would hence expect droughts and floods to have a particularly severe negative effect on GDP and debt primarily through a reduction in crop production. This differs from the negative effects of disasters in other parts of the world such as the Caribbean, which not only have higher levels of GDP per capita on average, but are also primarily reliant on natural resources and tourism. Natural disasters might thus damage these economies through the one-time destruction of infrastructure instead. This could shed light on why past research has found that debt relief is ineffective in alleviating the consequences of natural disasters.

Second, by disaggregating our debt relief variables and focusing on post-disaster debt relief, we are able to isolate the effectiveness of debt relief in the specific context of alleviating the macroeconomic consequences of natural disasters in the short term. Previous research has only been able to capture the general impact of debt relief in improving growth. Furthermore, by interacting a continuous measure for debt relief, specifically ODA, in the aftermath of disasters with the severity of the underlying disaster, we are able to examine whether the effectiveness of debt relief increases linearly with the size of the relief and/or the size of the disaster.

Third, this paper would help to provide further insight into the debate over the effectiveness of debt relief in general. As highlighted above, debt relief appears to have positive implications on public finances (Cassimon & Van Campenhout, 2007) despite having minimal benefits in mitigating the macroeconomic consequences of disasters (Raddatz (2009); Mejia (2014)). Focusing on a region where both high levels of unsustainable debt and natural disasters are acute problems provides a compelling backdrop to address this discrepancy.

3 Data

Our paper examines natural disasters in 40 African countries between 1978 and 2013. The countries studied for each dependent variable can be found in figures (4), (5), and (6).

3.1 Natural Disasters

The data on natural disasters comes from the EM-DAT International Disasters Database, which is compiled by the Centre for Research on the Epidemiology of Disasters. A disaster is included in EM-DAT if it satisfies at least one of the following criteria: i) at least 10 people were killed, ii) at least 100 people were affected, or iii) a state of emergency was declared or a call for international assistance was made. We focus on droughts and floods in Africa. For each country-year, we sum up the total number of deaths and the total number of individuals affected by severe floods and severe droughts separately. We then create two distinct continuous severity indices, $Severity^F_{i,t}$ for floods and $Severity^D_{i,t}$ for droughts, according to the following intensity measure proposed by Fomby et al. (2013).

$$Severity^j_{i,t} = \frac{TotalDeaths^j_{i,t} + 0.3 * TotalAffected^j_{i,t}}{Population_{i,t}}$$

where $j \in \{F, D\}$ indicates the disaster type. Country-year observations with floods or droughts that are not severe, along with observations without any floods or droughts, are thus assigned the value 0. To be considered severe in our paper, floods must affect more than 1% of the population according to our severity measure and droughts must affect more than 10% respectively. We use the total number of affected and total deaths as our proxy for the scale of the disaster rather than measures such as economic cost. This helps to capture the initial size of the disaster, which is exogenous conditional on geographical fixed effects, rather than the subsequent consequences of the disasters, which are likely to be endogenous to the emergency response capabilities and institutions of countries.

3.2 Macroeconomic Variables

To quantify the macroeconomic consequences of natural disasters, we study three main variables. First, GDP growth. Second, debt-to-GDP growth. Third, crop production growth, which measures agricultural production for each year relative to the base period 2004-2006. It includes all crops except fodder crops. While GDP growth and crop production growth are obtained from the respective World Bank Development Indicators, debt-to-GDP growth is obtained from the IMF Global Debt Database.

Furthermore, these variables are expressed in terms of growth rates instead of levels due to evidence of non-stationarity. By conducting Fisher-type unit-root tests, which are appropriate for finite and unbalanced dynamic panels with potential gaps in the individual time series (Fisher (1954); Choi (2001)), we conclude that all our dependent variables are non-stationary. On the other hand, when expressed in growth rates, we can reject the joint null hypothesis of all panels containing a unit root for each variable. By performing individual Phillips-Perron tests for each panel, we also find that we can reject the null hypothesis of non-stationarity for the majority of the panels. Hence, using the growth rates of the dependent variables instead of levels appears to be a suitable solution to achieve stationarity and thereby consistency of dynamic panel estimators. Results for the unit-root tests on the levels and growth rates of the dependent variables in levels are presented in Tables (17), (18), and (19) in the appendix.

3.3 Controls

We include controls for internal conditions that are determinants of GDP, debt-to-GDP and agricultural production. These indicators of economic development and political stability are also expected to correlate with a country's preparedness for disasters and therefore with our severity indices. The internal conditions are life expectancy, for which we use the World Bank Development Indicators; political system, for which we use the polity2 autocracy-democracy index from the Polity IV database; and wars. To compile our dataset on wars, we combine the Correlates of War dataset for intra-state wars with the dataset on inter-state wars by Reiter (2020). All wars or conflicts with above 1000 battle deaths are assigned the value 1 in our dummy variable. After controlling for country fixed effects, we expect that these variables should be largely orthogonal to the effect of natural disasters on the dependent variables, but they should still help us reduce variability in the data. Finally, we control for average rainfall using the yearly mean of monthly average rainfall data from the World Bank Climate Change Knowledge Portal, since this would be correlated with the probabilities of countries suffering from severe weather events.

3.4 Debt Relief

Debt relief refers to any policy that reduces the need for governments to issue new debt or repay existing debt in the aftermath of a disaster, freeing up resources for them to concentrate on rehabilitating the economy. This category refers to significant increases in Official Development Assistance and sovereign debt restructurings. Both debt reduction (reduction in nominal value of debt) and debt rescheduling (lengthening of maturities) are considered sovereign debt restructurings because they involve a reduction in the present value of creditor claims, or a "haircut".

We follow the definition of a sovereign debt restructuring proposed by Das et al. (2012) as "an exchange of outstanding sovereign debt instruments, such as loans or bonds, for new debt instruments or cash through a legal process". Importantly, since we are focusing on the role of debt relief in the aftermath of natural disasters, we similarly concentrate on distressed debt restructurings, which occur at terms less favourable than the original bond or loan terms. Finally, since we are considering policy measures that the international community can take to mitigate against natural disasters, we focus on debt restructurings that affect foreign creditors. These creditors include foreign governments (Paris Club), commercial banks (London Club) and foreign bondholders (sovereign bond restructurings).

We use three main variables of debt relief. First, we use a dummy variable that indicates any instances of debt restructuring, debt forgiveness or significant increases in Official Development Assistance. To focus on economically significant instances of debt relief, we assign the dummy a value of 1 whenever the debt restructuring affected debt is greater than 2% of GDP or ODA grew by more than 2% of GDP. Second, we use the increase in ODA as a percentage of GDP, above the 2% threshold, as a continuous variable. For both of these variables, we also include an additional variable that represents when debt relief or increases in ODA occurred either in the year of or following the disaster. Finally, we include an interaction of continuous ODA and disaster severity to analyse any non-linearity in the effectiveness of ODA. Henceforth, these are the debt relief and ODA variables to which this paper is referring.

Data on debt restructuring and debt forgiveness is compiled from multiple sources. For Paris Club agreements, we use the Sovereign Debt Restructuring dataset by Das et al. (2012) for years 1978-2010 and the Paris Club website for years 2010-2013. For commercial debt relief agreements, we use the haircut dataset compiled by Cruces & Trebesch (2013). Finally, for ODA, we use the World Bank Global Development Finance and the OECD.Stat databases.

3.5 Summary Statistics

We have provided the summary statistics of each of our variables in the table below. In particular, out of 1,472 country-year observations, 395 of them saw some significant instance of debt relief, of which 62 were in the immediate aftermath of a severe flood or drought. Similarly, 280 instances saw a significant increase of ODA, of which 32 were in the aftermath of a severe flood or drought.

Summary statistics (for non-zero values)

	mean	median	min	max	sd	#non-zero values
gdpGrowth	.04	.04	-.50	1.50	.08	1337
Debt/GDP growth	.04	0.00	.47	-.91	9.10	1176
Crop Prod Growth	.04	0.03	.16	-.54	2.48	1452
ContODA2	.06	0.04	0	.63	.04	280
interact	.01	0.007	0	.06	.003	32
DroughtSeverity	0.21	0.21	0	.32	.05	68
FloodSeverity	0.03	0.02	0	.10	.01	25
avg_rain	88.87	87.13	3.99	273.52	50.25	1436
DR2all	.33	0	0	1	.47	395
Debt Affected (% of GDP)	.13	0.06	0	1.45 1	.19	235
war	.11	0	0	1	.31	1472
lifeExp	52.06	51.92	26.17	68.70	6.14	1472
polity2	-1.67	-3	-10	9	5.61	1443

Table 1: Summary statistics

4 Model

This section describes the empirical strategy employed to estimate the macroeconomic consequences of natural disasters, specifically droughts and floods, in Africa. We begin by developing our main model, which we later expand to include debt relief before concluding with some of its limitations.

4.1 Macroeconomic Consequences of Natural Disasters

To estimate the macroeconomic consequences of natural disasters, we consider the following model:

$$\boldsymbol{y}_{i,t} = \boldsymbol{\alpha}_i + \boldsymbol{\delta}_t + \boldsymbol{\eta}\boldsymbol{y}_{i,t-1} + \sum_{j=0}^{2} \left(\boldsymbol{\gamma}_{D,j} Severity^D_{i,t-j} + \boldsymbol{\gamma}_{F,j} Severity^F_{i,t-j}\right) + \boldsymbol{\beta}_1' \boldsymbol{X}_{1i,t} + \boldsymbol{\epsilon}_{i,t} \quad (1)$$

$$\boldsymbol{y}_{i,t} = \begin{bmatrix} GDPGrowth_{i,t} \\ DebtGDPGrowth_{i,t} \\ CropProdGrowth_{i,t} \end{bmatrix} \quad \boldsymbol{X}_{1i,t} = \begin{bmatrix} lifeExpect_{i,t} \\ avgrain_{i,t} \\ war_{i,t} \\ polity_{i,t} \end{bmatrix} \quad Severity^j_{i,t} = \frac{TotalDeaths^j_{i,t} + 0.3 * TotalAffected^j_{i,t}}{population_{i,t}}$$

where $i = 1, \ldots, N$ indicates countries and $t = 1, \ldots, T$ years, $\boldsymbol{\alpha}_i$ is a country-specific intercept including country Fixed Effects, $\boldsymbol{\delta}_t$ is a year-specific Fixed Effect that is common to all countries within year t, and $\boldsymbol{\epsilon}_{it}$ is a vector of idiosyncratic error terms. $\boldsymbol{y}_{i,t}$ is a vector including our dependent variables of interest GDP growth, debt-to-GDP growth and the growth rate of Crop Production, and $\boldsymbol{\eta} = \begin{bmatrix} \eta_{11} & 0 & 0 \\ 0 & \eta_{22} & 0 \\ 0 & 0 & \eta_{33} \end{bmatrix}$. Hence, we run three regressions per specification, if not explicitly stated otherwise.

Specifying the model in growth rates has the advantage that country-specific fixed effects in levels are canceled out by first-differencing. However, economic theory (e.g. Solow (1956)) predicts that economic growth depends on fundamental country-specific factors. We model these fundamentals in two ways. First, we assume that there are time-invariant country-specific components (country Fixed Effects) denoted by $\boldsymbol{\alpha}_i$, where for each of our dependent variables:

$$E(\epsilon_{i,t}|\alpha_i, \delta_t, y_{i,1}, \ldots, y_{i,T}, \boldsymbol{X}_{1i}) \neq 0$$

Second, we include a vector of country-specific time-varying variables $\boldsymbol{X}_{1i,t}$ along with the first lag of the dependent variable $\boldsymbol{y}_{i,t-1}$ to account for time-varying country-specific determinants of economic growth. Further, we assume that there are time-variant components that affect all countries in the same way, i.e. common economic developments, denoted by $\boldsymbol{\delta}_t$ and from now on referred to as year Fixed Effects. We follow Acemoglu et al. (2019) in modelling $\boldsymbol{\alpha}_i$ as Fixed Effects instead of assuming the more restrictive Random Effects (RE), since Fixed Effects models are consistent under Random Effects but not vice versa.

We include one lag of the respective dependent variable into our model. This has two main purposes. First, it controls for the fact that countries may be less prepared for natural disasters depending on their economic situation, which would then lead to more severe disasters. Second, the lag of the dependent variable also captures a range of economic factors that affect the growth and preparedness of a country, which in turn has ramifications on the severity indices for floods and droughts. For example, lagged GDP growth would be a determinant of contemporaneous GDP growth. At the same time, it captures information on whether there was an economic crisis, which would potentially negatively affect a country's healthcare expenditures and thereby lead to a higher number of deaths. To determine the lag length, we observe the Partial Autocorrelation Function (PACF) of each dependent variable country time series, the results of which can be seen in table (10) in the Appendix. Evidence from Chauvet & Potter (2013), convention in the wider econometric literature and the country time series PACF results all support our decision to use an AR(1) specification for GDP growth. Our estimates are robust to including one more lag than suggested by the PACF; these result can be seen in appendix tables (14), (15), and (16). Furthermore, the correlation table in the appendix table (9) rules out potential concerns of multi-collinearity between our lagged dependent variables and the lagged disasters.

Finally, we include our set of control variables $\boldsymbol{X}_{1i,t}$, as described in the data section, along with year dummy variables to non-parametrically control for year-specific growth shocks common to all countries in our sample. Jointly controlling for country FE and year FE should be sufficient to ensure exogeneity of drought and flood severity. We also permit correlation in the error terms within country and across years by employing heteroskedasticity and autocorrelation robust standard errors clustered at country level.

4.2 The Effectiveness of Debt Relief in the Aftermath of Natural Disasters

In order to evaluate the effectiveness of Debt Relief in the aftermath of floods and droughts in Africa, we expand Model (1) with a vector of Debt Relief variables $\boldsymbol{X}_{2,it}$. This gives us Model (2) below. The exact components of this vector will vary between different specifications, as described by Table (2). All other components of these specifications are defined as in Model (1).

$$\boldsymbol{y}_{i,t} = \boldsymbol{\alpha}_i + \boldsymbol{\delta}_t + \boldsymbol{\eta}\boldsymbol{y}_{i,t-1} + \sum_{j=0}^{2} \left(\boldsymbol{\gamma}_{D,j} Severity^{D}_{i,t-j} + \boldsymbol{\gamma}_{F,j} Severity^{F}_{i,t-j}\right) + \boldsymbol{\beta_1'}\boldsymbol{X}_{1i,t} + \boldsymbol{\beta_2'}\boldsymbol{X}_{2i,t} + \boldsymbol{\epsilon}_{i,t} \qquad (2)$$

(1) Binary Debt Relief	(2) Continuous ODA	(3) Continuous ODA interacted with Severity
$\boldsymbol{X}_{2i,t} = \begin{bmatrix} DR2all_{i,t} \\ DR2allpostD_{i,t} \end{bmatrix}$	$\boldsymbol{X}_{2i,t} = \begin{bmatrix} ContODA2_{i,t} \\ ContODA2postD_{i,t} \\ DAperGDP_{i,t} \end{bmatrix}$	$\boldsymbol{X}_{2i,t} = \begin{bmatrix} ContODA2_{i,t} \\ ContODA2interact_{i,t} \\ DAperGDP_{i,t} \end{bmatrix}$

$$ContODA2interact_{i,t} = ContODA2_{i,t} \times max(\{DroughtSeverity_{i,t-j}, FloodSeverity_{i,t-j}\}_{j=0}^{1})$$

Table 2: Different Debt Relief Specifications

Specification 1 (binary debt relief) is used to evaluate the effect of debt relief on the macroeconomic dependent variables. This variable $DR2all_{i,t}$ takes on the value 1 for all instances of debt restructuring where the total debt affected is at least 2% of GDP and significant increases of ODA above 2% of GDP. The second key independent variable of this specification is $DR2allpostD_{i,t}$ which is 1 if that instance of debt relief was in the year of, or the year following, a severe disaster in the affected country.

Specification 2 (continuous ODA) extends this analysis to exploit the continuous data of ODA received by countries. The first independent variable in this specification ($ContODA2_{i,t}$) is the change in ODA as a percentage of GDP. Thus, this measures the impact of large ODA growth on the dependent variables in general. The second variable ($ContODA2postD_{i,t}$) is the change in ODA as a percentage of GDP if there was a severe disaster in the same or previous year. This specification also controls for the total amount of debt affected[2] by Paris or London Club agreements that year ($DAperGDP_{i,t}$). This is a continuous variable and is useful because the amount of debt under negotiation might affect the decisions of governments to provide ODA and determine our dependent variables.

Specification 3 (ODA $\times$ disaster severity) identifies the effect of $ContODA2_{i,t}$ on the dependent variables, as in specification 2. The difference now is that the main variable of interest in this specification is the interaction variable between $ContODA2postD_{i,t}$ and the severity of the disaster associated with that ODA. Thus, this specification allows us to identify how the effect of post-disaster ODA depends on disaster severity.

4.3 Limitations

Given the dynamic structure of our model, we have to relax the strict exogeneity assumption (exogeneity at all lags and leads of the included regressors) by instead assuming weak exogeneity for all i and t and our

[2] This is distinct from the actual size of the haircut, which is a percentage of the total debt affected

three dependent variables. This implies the following condition

$$E\left(\epsilon_{i,t} | y_{i,t-1}, \ldots, y_{i,1}, \{FloodSeverity_{i,s}, DroughtSeverity_{i,s}, \boldsymbol{X}_{1i,s}, \boldsymbol{X}_{2i,s}\}_{s=1}^{t}, \alpha_i, \delta_t\right) = 0$$

This standard assumption when dealing with linear dynamic panel models requires that disasters, debt relief and the lag of the dependent variable (e.g. past GDP) are orthogonal to contemporaneous and future shocks to the dependent variable and that the error terms $\epsilon_{i,t}$ are serially uncorrelated. Economically, it imposes that the countries that are hit by natural disasters and/or receive debt relief are on similar long-run balanced growth paths (captured by α_i) relative to countries with similar levels of past growth rates (captured by $y_{i,t-1}$) (Acemoglu et al., 2019). If not explicitly stated otherwise, we estimate all our models using the within-estimator which technically requires strict exogeneity as it demeans the entire model to cancel out the country FE α_i. The failure of strict exogeneity in our dynamic panel induces an asymptotic bias of order $1/T$, known as the Nickell bias, to our main specifications. Given that T is fairly large with on average 32 observations per country, this is likely to be small (Acemoglu et al. (2019); Nickell (1981); Alvarez & Arellano (2003)).

In subsection (5.5), we further elaborate on this issue and estimate several different GMM-type specifications as proposed by Anderson & Hsiao (1982). Due to weak instrument problems with debt-to-GDP growth and crop production growth, we conduct this robustness check for our GDP growth results only. Results are reported in table (11) in the appendix.

5 Results

We first estimate the effects of floods and droughts on three key macroeconomic variables: GDP growth, debt-to-GDP growth and crop production growth. This is then repeated with the first two specifications of debt relief to understand whether debt relief or significant increases in ODA are effective in mitigating these economic consequences. Finally, we interact the continuous ODA variable with disaster severity to understand how ODA effectiveness depends on disaster severity. The results focus on the dynamic effect of the natural disasters over the subsequent 2 periods.

5.1 Macroeconomic Consequences of Droughts and Floods

Floods and droughts can affect growth through multiple channels, such as the destruction of capital, disruption of supply chains or loss of livelihoods. Furthermore, resources which could have been used to encourage growth may have to be diverted to assist economic recovery of affected communities/sectors. The estimated macroeconomic consequences of floods and droughts in African countries between 1978-2013 based on model (1) are shown in Table (3).

5.1.1 GDP Growth

Floods and droughts both have a negative contemporaneous effect on GDP growth. However, while the economy appears to recover from floods after two periods, droughts appear to cause a persistent shock to the level of GDP. Floods have no significant effect on GDP growth one year after the first impact, but have

Fixed Effects Regression			
	(1)	(2)	(3)
VARIABLES	GDP growth	Debt to GDP growth	Crop Production Growth
L.Y	0.189**	-0.0306	-0.297***
	(0.0844)	(0.0459)	(0.0371)
DroughtSeverity	-0.0681*	0.351	-0.404***
	(0.0367)	(0.223)	(0.115)
L.DroughtSeverity	0.111	-0.518	0.404**
	(0.0683)	(0.458)	(0.191)
L2.DroughtSeverity	-0.0521	0.378	-0.0265
	(0.0450)	(0.312)	(0.184)
FloodSeverity	-0.492***	-4.147	-0.527
	(0.174)	(4.101)	(0.928)
L.FloodSeverity	0.0843	-1.548	-0.0349
	(0.177)	(2.499)	(0.529)
L2.FloodSeverity	0.312**	12.37	0.501
	(0.131)	(11.49)	(0.608)
Observations	1,254	1,092	1,313
R-squared	0.169	0.098	0.194
Number of countries	40	36	40
Controls $\boldsymbol{X}_{1i,t}$	Yes	Yes	Yes
Country FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes

Cluster standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3: The Macroeconomic consequences of Droughts and Floods

a statistically significant positive effect after two periods, of comparable magnitude to the negative effect in the initial period. This implies that when a severe flood hits, a country falls below its balanced growth path, remains below it for one period and then makes some recovery back to its previous balanced growth path in the second year after the flood. On the other hand, droughts appear to have no statistically significant effect on GDP in the following years. This implies that the drought causes the country to fall below its balanced growth path and remain there at least for two years or until a positive shock or policy intervention occurs. Since GDP growth does not fall any further in subsequent periods, this suggests that droughts do not have long-run multiplier effects following the initial economic downturn.

To account for this post-flood recovery, we posit three possible explanations. First, floods can increase soil quality and improve crop yields. Second, increased construction and infrastructure spending to rebuild after the flood can stimulate economic activity. Third, productivity may increase when firms replace low quality capital destroyed by the flood with higher quality substitutes.

Our estimates suggest that a drought of median severity reduces GDP growth by 1.391 percentage points in the year of the first impact. The coefficient on GDP growth year one year later is positive but insignificant. For a flood of median severity, GDP growth decreases by 0.773 percentage points in the first year, followed by a recovery of 0.4903 percentage points. The effects for median disasters at different lags are reported in table (8) in the appendix.

5.1.2 Debt-to-GDP Growth

We find no statistically significant effects of natural disasters on debt-to-GDP growth. This is surprising, given that theoretically one would expect a country to increase its borrowing following a natural disaster in order to stimulate economic recovery. One possible explanation for this result might be driven by the role of debt relief, which we will evaluate in the subsequent section.

5.1.3 Crop Production

This paper aims to test the hypothesis that a key source of post-disaster economic slowdown in Africa has been the reduction in agricultural production due to the destruction of crops and livestock. Our results show a statistically significant contemporaneous negative effect of severe droughts on crop production, followed by a positive effect of similar magnitude one year afterwards. This demonstrates that crop production rapidly recovers to its previous trajectory once the drought is over. This is in line with economic theory, since we would expect agricultural production to be restored as soon as rainfall returns to its original levels.

On the other hand, we observe no effect of severe floods on crop production. This implies that droughts reduce economic growth, at least partially, through the agricultural sector, whereas floods do so through other channels. The former result makes sense, considering that the FAO finds that in developing countries, the agricultural sector absorbs around 80% of all the direct impacts of droughts. Possible alternative channels through which floods affect the economy include the destruction of infrastructure and machinery or the reduction in aggregate demand due to losses in livelihood.

5.2 The Role of Debt Relief & ODA

In order to study how international economic policy can alleviate these negative macroeconomic consequences, we now examine the role of debt relief. Additionally, controlling for debt relief might provide further insight into the dynamic behaviour of the macroeconomic variables following disasters. Theoretically, debt relief should have a positive impact on GDP growth but an ambiguous effect on debt-to-GDP growth. For the former, it should allow the country to mitigate the economic losses of the disaster by providing aid directly or by increasing fiscal space. For the latter, while debt relief, particularly debt forgiveness, should decrease debt, this increased fiscal space might incentivise governments to borrow even more after disasters in order to rehabilitate the economy.

5.2.1 Debt Relief

Table (4) shows the results of the specification using a dummy variable for debt relief (restructurings and ODA). Here, DR(all) represents all instances of debt relief while DR(post disaster) represents only instances of debt relief in the period of or directly after the disaster. Neither the debt relief nor the post-disaster debt

Fixed Effects Regression - Debt Relief

VARIABLES	(1) GDP growth	(2) Debt to GDP growth	(3) Crop Production Growth
L.Y	0.187**	-0.0293	-0.310***
	(0.0854)	(0.0484)	(0.0372)
DR(all)	0.000382	-0.0215	0.0134
	(0.00442)	(0.0223)	(0.00967)
DR(post disaster)	0.00662	-0.0546	-0.000825
	(0.00669)	(0.0736)	(0.0259)
DroughtSeverity	-0.0743**	0.407*	-0.415***
	(0.0346)	(0.215)	(0.119)
L.DroughtSeverity	0.127**	-0.471	0.427**
	(0.0583)	(0.467)	(0.191)
L2.DroughtSeverity	-0.0484	0.354	-0.0240
	(0.0442)	(0.311)	(0.191)
FloodSeverity	-0.510***	-4.103	-0.619
	(0.173)	(4.091)	(0.934)
L.FloodSeverity	0.101	-1.218	0.378
	(0.185)	(2.224)	(0.408)
L2.FloodSeverity	0.291*	12.42	0.442
	(0.148)	(11.43)	(0.693)
Observations	1,245	1,088	1,247
R-squared	0.165	0.098	0.210
Number of countries	40	36	40
Controls $\boldsymbol{X}_{1i,t}$	Yes	Yes	Yes
Country FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes

Cluster standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4: The Effectiveness of Debt Relief

relief variables are significantly different from zero for any of the three regressions. Most surprisingly, they suggest that debt-to-GDP growth is not affected at all by instances of debt relief. One possible explanation for this observation is that debt relief may create the fiscal space for countries to increase borrowing even more, potentially to rehabilitate the economy, thus negating its positive impacts. This hypothesis is promising given that the inclusion of debt relief now results in a statistically significant positive impact of contemporaneous droughts on debt-to-GDP growth. This evidence suggests that governments take on more debt during severe droughts to facilitate economic recovery. Further, we now observe a significant recovery of GDP growth one year after the first impact of a drought. GDP growth and Crop Production growth are now subject to similar dynamics in instances of severe droughts.

A possible explanation for the lack of significant point estimates for the coefficients of debt relief in this specification is that the debt relief variable is a binary measure. This is an artefact of data limitations with debt restructuring. As no data exists on the actual size of the haircuts imposed on creditors[3] by Paris Club restructuring and forgiveness agreements[4], we are unable to use a continuous variable for all forms of debt relief, preventing us from exploiting all the variation in the data. To investigate if this is the case, we perform the same analysis with using ODA, for which we have continuous data.

5.3 Continuous ODA

Unlike the debt relief dummy, ODA as a continuous variable gives statistically significant results. We disaggregate the effect of ODA into its general (*ContODA2*) and post-disaster (*ContODA2postD*) components. In our model, we also control for debt affected by London or Paris Club debt restructuring negotiated agreements. Our results indicate that significant increases in ODA in general have no statistically significant impact on GDP growth, but a large and significant effect in reducing debt-to-GDP growth. This suggests that ODA has limited effectiveness as an instrument to raise economic growth. Instead, it appears that increases in ODA inflows are either used by the government to repay existing debt or cause governments to substitute away from fiscal spending to repay this debt.

On the other hand, significant increases in ODA, when provided in the year of or immediately after a severe disaster, have significant positive effects on GDP growth. Furthermore, the previous result on debt-to-GDP growth disappears. This suggests that ODA, when provided in the year of or immediately after a severe disaster, is effective as a short-term post-disaster recovery instrument. Unlike when it is used in times of relative stability, increases in ODA are not associated with reduced levels of debt. This key finding contrasts with existing literature by Mejia (2014) and Raddatz (2009), who find that ODA in general does not mitigate the economic consequences of natural disasters.

[3] The haircut refers to reduction in the net present value of debt suffered by creditors
[4] Only data on the total amount of debt affected is publicly available

Fixed Effects Regression - ODA

	(1)	(2)	(3)
VARIABLES	GDP Growth	Debt-to-GDP Growth	Crop Production Growth
L.Y	0.184**	-0.0298	-0.313***
	(0.0860)	(0.0470)	(0.0370)
ContODA2	-0.0969	-0.417***	-0.0651
	(0.112)	(0.147)	(0.140)
ContODA2postD	0.269*	-1.030	0.227
	(0.153)	(1.562)	(0.295)
Debt Affected	-0.00589	-0.322*	-0.0415
	(0.0224)	(0.178)	(0.0334)
DroughtSeverity	-0.0704**	0.374*	-0.423***
	(0.0326)	(0.214)	(0.118)
L1.DroughtSeverity	0.115**	-0.458	0.423**
	(0.0519)	(0.467)	(0.203)
L2.DroughtSeverity	-0.0506	0.354	-0.0313
	(0.0418)	(0.308)	(0.199)
FloodSeverity	-0.533***	-4.317	-0.692
	(0.177)	(4.227)	(0.960)
L1.FloodSeverity	0.0803	-0.693	0.404
	(0.193)	(2.009)	(0.378)
L2.FloodSeverity	0.215	13.08	0.378
	(0.203)	(11.51)	(0.736)
Observations	1,231	1,074	1,233
R-squared	0.169	0.105	0.208
Number of countries	40	36	40
Controls $\boldsymbol{X}_{1i,t}$	Yes	Yes	Yes
Country FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 5: The Effectiveness of ODA

5.4 Interaction between ODA and Disaster Severity

To investigate the relationship between the effectiveness of post-disaster ODA and the severity of the respective disaster further, we now interact the continuous measure of general ODA with a measure of the maximum severity of all disasters a country experienced in either the year in which ODA increases occurred or the previous year. In Table (6), we present the estimates of Model (2) using specification (3) for the debt relief vector $\boldsymbol{X}_{2i,t}$ as presented in Table (2). The estimated results are based on 35 instances of significant increases in ODA following disasters. To obtain more precise estimates and due to the limited data availability, we initially do not distinguish between floods and droughts when estimating the coefficients.

We find a significant positive estimate for the effect of the interaction of ODA and severity on GDP growth. This suggests that, for a given level of ODA, the effectiveness of post disaster ODA increases in the severity of the underlying disasters. By the same logic, for a given disaster, the effectiveness of ODA increases in its level. The estimated coefficient of the effect of ODA on GDP growth is given by $(-0.0959 + 1.6277 * MaxSeverity_{i,t}) * ODA_{i,t}$, where $MaxSeverity_{i,t} = max(\{DroughtSeverity_{i,t-j}, FloodSeverity_{i,t-j}\}_{j=0}^{1})$.

To illustrate these results, we compare a country experiencing a significant increase in ODA inflows after a drought of median severity (0.204) under two different scenarios. In the first scenario, the country receives the median post-disaster increase in ODA (0.0461). Under the second scenario, the same country receives the 75th-percentile increase of post-disaster ODA (0.0641). According to our estimates, increasing ODA from the median to the 75th-percentile in the aftermath of a drought of median severity increases GDP growth by 0.426 percentage points. Similarly, by repeating the experiment with a country after a drought of a severity at the 75th-percentile, we find that increasing ODA from the median to the 75th-percentile now increases GDP growth by 0.710 percentage points. Given that GDP grows on average by 4% in our data set, these numbers are of significant magnitude. Furthermore, by using this measure of post-disaster ODA, we recover the previously observed rebound of GDP growth 2 years after a flood, which had turned insignificant once continuous ODA was included.

However, since droughts typically affect a higher number of people than floods, it is worthwhile to repeat the estimation separately for floods and droughts. Results are reported in Table (7) in the Appendix. This gives us a less precise estimate due to reduced sample size, but is more reliable for discussing the effects droughts specifically. By performing the same thought experiment as above in using the interaction of continuous drought severity with continuous ODA, we find that an increase of post-disaster ODA from the median to the 75th-percentile is now associated with a 0.4177 percentage point increase in GDP growth in the aftermath of a median severe drought, and with a 0.6320 percentage point increase in the aftermath of a drought with a severity level at the 75th-percentile. On the other hand, since there are only 9 such instances in the aftermath of severe floods, we cannot interpret these results for floods alone.

5.4.1 Debt to GDP growth

With Debt-to-GDP growth as dependent variables, we again find that ODA in general tends to decrease the Debt-to-GDP ratio growth. In the aftermath of a disaster, we now find a significant coefficient on the interaction term of post-disaster ODA and severity. Following a drought of median severity, increasing ODA from the post-disaster median level to the 75th-percentile increases debt-to-GDP growth by 0.7207 percentage points (from 1.84114 to 2.5618), based on the results in (7). Following a drought with a severity level at the 75th-percentile, the same increase in ODA is associated with a 1.2913 percentage point increase in debt-to-GDP growth.

As a robustness check, we run the same regression with different levels of severity. Our results do not change significantly and are hence robust to various specifications. The results of these regressions are located in tables (12) and (13) in the Appendix.

Fixed Effects Regression - Interaction

VARIABLES	(1) GDP growth	(2) Debt to GDP growth	(3) Crop Production growth
L.Y	0.184**	-0.0307	-0.311***
	(0.0857)	(0.0475)	(0.0371)
ContODA2	-0.0959	-0.570***	-0.0716
	(0.110)	(0.184)	(0.140)
interactContODA2	1.627**	3.760*	2.014
	(0.710)	(2.085)	(1.272)
DA_perGDP	-0.00562	-0.325*	-0.0413
	(0.0221)	(0.182)	(0.0334)
DroughtSeverity	-0.0732**	0.389*	-0.427***
	(0.0351)	(0.205)	(0.120)
L.DroughtSeverity	0.102*	-0.604	0.401*
	(0.0522)	(0.452)	(0.204)
L2.DroughtSeverity	-0.0464	0.376	-0.0278
	(0.0433)	(0.306)	(0.196)
FloodSeverity	-0.531***	-4.455	-0.693
	(0.179)	(4.328)	(0.977)
L.FloodSeverity	0.140	-0.986	0.452
	(0.198)	(2.258)	(0.405)
L2.FloodSeverity	0.374**	12.67	0.521
	(0.158)	(11.32)	(0.680)
Observations	1,231	1,074	1,233
R-squared	0.170	0.104	0.208
Number of countries	40	36	40
Controls $\boldsymbol{X}_{1i,t}$	Yes	Yes	Yes
Country FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 6: The Interaction between Effectiveness of ODA and the Severity of Disasters

5.5 GMM Estimation

As discussed in (4.3), the failure of the strict exogeneity assumption induces the Nickell bias in our main specifications estimated using the within-estimator. This is due to the demeaning of the regressors. We address this issue by estimating our model (2) with the most efficient debt relief specification (3) using the GMM-type estimator as proposed by Anderson & Hsiao (1982). As the second and higher lags of debt-to-GDP growth and Crop Production growth do not qualify as valid instruments due to a lack of relevance (F-statistics well below 10), we only perform this robustness analysis for GDP growth as the dependent variable. As a first step, Anderson & Hsiao (1982) propose cancelling out the Fixed Effects α_i by taking first differences. In the second step, $\Delta gdpGrowth_{t-1} = gdpGrowth_{t-1} - gdpGrowth_{t-2}$ is instrumented by

$gdpGrowth_{t-2}$. This instrument for GDP growth is relevant, as can be seen by checking the F-statistics reported in table (11). In order to obtain exogeneity and thereby validity of the instrument, we need to make sure that no included regressor is part of the functional form of the instrumental variable. To satisfy the exogeneity assumption, we estimate two GMM-type estimators presented in columns (1) and (2) of Table (11) in the Appendix. For comparison, the results of the within estimator are presented in column (3).

In column (1), we obtain exogeneity of the instrument by omitting the second lag of the severity indices from the regression. The regression presented in column (1) exactly follows the procedure described above by using $gdpGrowth_{t-2}$ as the instrumental variable. Comparing columns (1) and (3), our results do not change in a meaningful way by using the consistent estimator as proposed by Anderson & Hsiao (1982). However, using this approach, we are not able to consistently estimate the coefficients on the second lags of our disasters. To do so, we propose a slight variation of the Anderson & Hsiao (1982) estimator. Specifically, we use $gdpGrowth_{t-3}$ as an instrumental variable. Our results presented in column (2) suggest that the inclusion of the lagged severity indices in combination with using y_{t-3} as the instrumental variable results in the coefficient for the continuous interaction of ODA and disaster severity becoming insignificant. Further, we lose significance at the second lag of Flood Severity compared to the within-estimator presented in column (3).

Interestingly, the GMM approach tends to find larger contemporaneous effects of disasters and smaller lagged effects than the within-estimator. The only exception to this is the coefficient on the first lag of Flood Severity when omitting its second lag in column (1). This is not surprising, given that previous results suggest a significant positive effect of the second lag of Flood Severity, which may now be partly captured by the coefficient on the first lag in (1).

This robustness check provides weak evidence for the robustness of the positive relationship between the effectiveness of ODA in the aftermath of disasters and the severity of the underlying disasters. Furthermore, it provides evidence that the contemporaneous effects of natural disasters are not driven by endogeneity of lagged GDP.

6 Discussion

6.1 Role of Debt Relief

Our paper has found that debt relief, at least through the channel of increases in post-disaster ODA, has a significant effect on alleviating the negative macroeconomic consequences of natural disasters in the short-run. Studying its effects has important policy implications, particularly because weak state capacity to collect taxes and limited insurance markets in Africa mean that countries often have to rely on international borrowing to respond effectively to natural disasters. In addition, high levels of indebtedness in the region mean that attempts at reconstruction may be crowded out by existing debt repayments.

6.1.1 Possible Explanations

Although we have identified the macroeconomic effects of debt relief on natural disasters, we have not specified an exact mechanism through which debt relief mitigates the consequences of natural disasters. We propose a number of possible explanations that merit further research.

First, debt relief could have a direct impact on increasing the resources available for governments to respond to disasters. The losses in human life and economic damage caused by natural disasters reduces the tax revenues of governments, which in turn reduces the amount of resources available to rehabilitate the economy. ODA flows can substitute for this shortfall by providing emergency relief, aid and social safety nets directly to citizens. Debt restructuring programmes have a similar effect by reducing the necessary interest rate repayments of governments, preventing debt service from crowding out investment (Marcelino & Hakobyan, 2014) and allowing them to devote more resources on rehabilitation.

Second, debt relief could increase fiscal space, which refers to the amount of budgetary resources available to countries to implement fiscal policy without jeopardising fiscal sustainability (Kose et al., 2018). In contrast to the first channel, this represents an indirect mechanism by boosting the efficacy of existing fiscal policy and allowing governments to draw on more resources through international borrowing.

If a country already has high levels of debt before the crisis and the natural disaster is sufficiently large, international investors may anticipate that the borrowing needed to fully recover from the disaster would increase the debt-to-GDP ratio of the country to unsustainable levels. Near the fiscal limit, investors may demand a risk premium to compensate for the possibility of default. Klomp (2015) finds that natural disasters significantly increase the sovereign default premium paid by bond holders. In turn, this raises borrowing costs and makes it even more difficult for countries to recover from the disaster.

Extending debt relief in the immediate aftermath of the disaster hence relieves the country's debt burden and reduces the default risk. In turn, this brings the government away from its fiscal limit (Ostry et al., 2010). Investors will not charge a risk premium for subsequent borrowing because the country's debt will still be sustainable, allowing it to access international funds in order to rebuild. In support of this hypothesis, Melecky & Raddatz (2015) find evidence that countries with higher debt market development, which improves their ability to borrow at low cost, suffer smaller real consequences from disasters while seeing their deficits rise higher. Clearly, international borrowing is a preferable method of increasing existing revenues to smooth the effects of disasters, compared to increasing taxes or reducing expenditures.

Alternatively, improved fiscal space can increase the effectiveness of the government's fiscal policy response. Huidrom et al. (2016) find that fiscal space is correlated with the fiscal multiplier, or the change in activity for a dollar increase in government spending. For example, the fiscal multiplier over the two-year horizon is close to 0.5 for countries at the 10th percentile of debt-to-GDP ratios but is negative at the 90th percentile. Thus, by increasing fiscal space, debt relief could allow countries to respond more extensively and more effectively to natural disasters.

6.1.2 Continuous vs Dummy Variables

In our results, we find that ODA growth post-disasters has a direct effect on increasing GDP growth. On the other hand, we do not observe this same impact with our debt relief variable, which captures both significant increases in ODA and incidents of debt restructuring. This is surprising, since we would expect both ODA and debt restructuring to have a positive impact on the economy through the same channels highlighted above. To explain this observation, we highlight two possible reasons.

First, the debt relief variable is a dummy, which may be unable to capture threshold effects. Limited data availability regarding the actual size of the haircuts imposed on creditors by Paris Club restructuring and forgiveness agreements mean that we are unable to use a continuous variable for all forms of debt relief. This is important because we would not expect low values of debt relief to have a significant impact on the economy. As observed in section (5), ODA only has a significant effect on GDP growth when we truncate the variable to represent increases of more than 2% in the immediate aftermath of a disaster. Similarly, debt relief in periods of relative stability may have different or reduced effects on the economy, compared to debt relief following a severe drought or flood. This is in line with findings by Chauvin & Kraay (2005), who show that general untargeted debt relief has little effect on economic performance in low-income countries. This is largely because many instances of debt restructuring are small compared with other forms of development aid. Ideally, we would like to capture the effect of debt relief as a disaster response mechanism, when it is implemented on a large scale, rather than a general macroeconomic stabilisation tool.

6.2 Role of ODA

Second, it is also possible that ODA itself is a more effective form of debt relief than debt restructuring agreements. The literature on the effectiveness of ODA in general is still mixed and this paper cannot comment on the relative benefits of ODA compared to debt restructuring. However, we can postulate some mechanisms by which ODA has a different impact on countries, potentially through more appropriate channels, in the aftermath of disasters.

The primary difference between ODA and debt restructuring lies in the fact that ODA involves direct transfers to both governments and the necessary recipients. It covers a variety of funds, including soft loans and project grants, which are often used for reconstruction efforts following disasters. On the other hand, the effects of sovereign debt rescheduling and forgiveness will only be translated into increased on-the-ground resources for afflicted populations insofar as the government uses them effectively. In the context of Sub-Saharan Africa, with relatively weak authoritarian governments that are ranked among worst in the world in terms of institutional quality and corruption, this cannot be guaranteed. Sudden dramatic increases in fiscal space might lead to leakages and inefficiencies rather than additional disaster recovery spending.

Alternatively, the issue could be one of timing, since debt restructuring agreements might not be immediately forthcoming or might be small in comparison to the size of the disasters. This is because debt restructuring via the London and Paris Clubs is a multi-step process involving numerous rounds of negotiations between the sovereign government and the creditors. In particular, London Club agreements require unanimity among all creditors for successful finalisation, which could be difficult because deals could involve up to 1,000 banks across numerous countries. Indeed, Trebesch (2010) finds that around 30% of London Club agreements saw intra-creditor disputes which led to delays of 3 months or more in implementing the restructuring.

Finally, debt restructuring might actually increase borrowing costs by prompting credit-rating downgrades. This arises because it implicitly confirms that the debtor country has an unsustainable debt burden (Bulow & Rogoff, 1989). In support of this hypothesis, Cruces & Trebesch (2013) find that restructurings which have a higher haircut (debtor losses) are associated with higher future borrowing costs (bond yield spreads) and longer periods of capital market exclusion. The negative impact of debt relief on a country's reputation in international financial markets might outweigh the positive effects of reduced debt overhang, meaning that its borrowing costs might actually rise upon receiving debt relief.

6.3 Limitations

We recognise that there are certain limitations in our methodological approach. These could represent valuable opportunities for further research.

First, our research only studies the short-term effectiveness of debt relief in alleviating the macroeconomic consequences of natural disasters. In the medium- to long-run, there might be moral hazard concerns if increases in debt relief lead to governments becoming more fiscally irresponsible ex-ante and eschewing important structural reforms. Additionally, it is possible that large increases in debt relief might overwhelm the fiscal capacity of traditionally weak Sub-Saharan African governments, resulting in inefficiencies and leakages due to corruption. Finally, ODA increases may generate inflationary pressure that erodes the purchasing power of citizens. Further research is hence needed to fully evaluate if debt relief should be adopted as a primary policy instrument.

Second, to determine the severity of droughts and floods, we use the total number of individuals affected as a proxy. However, it is unclear how reliable this proxy is for severity, since it does not capture heterogeneity in how badly affected different people were. A concentrated disaster that severely affects a proportion of the population may result in larger economic damage than a shallow disaster that affects most of the population only mildly.

Third, we do not distinguish between the first year of a disaster and subsequent years in our analysis. This is significant because severe droughts often last for multiple years. The effect of a drought in its second or third year might be distinct from its impact in the first year.

7 Conclusion

This paper has investigated the macroeconomic consequences of severe droughts and floods in Africa between 1978 and 2013 using a dynamic panel fixed effects model. Furthermore, it has assessed the effectiveness of debt relief, particularly Official Development Assistance, in mitigating these adverse consequences. As a robustness check, we also include an Anderson-Hsiao style GMM estimation procedure.

Our paper has found evidence to suggest that significant increases in Official Development Assistance in the aftermath of natural disasters have a positive impact on GDP growth. Furthermore, larger increases in ODA have greater cumulative effects on the economy, especially for more severe disasters. On the other hand, general, untargeted increases in ODA do not appear to have an impact on raising economic growth. This suggests that ODA can be an effective short-term policy instrument to alleviate the negative macroeconomic consequences of floods and droughts. This is a key contribution to the literature, as existing studies have only examined the effect of ODA in general, rather than focusing on ODA flows that were a) sufficiently large and b) specifically targeted at the disaster.

In our sample of 92 severe disasters, large increases of ODA greater than 2% of GDP only occurred on 32 occasions. Similarly, Becerra et al. (2010) finds that ODA flows still appear to be small relative to the size of the economies and the economic cost of the disaster. There is hence room for a larger and improved policy response from the international community to bolster recovery efforts of highly-indebted developing nations in the aftermath of natural disasters. However, more research needs to be done to ascertain if this positive effect holds in the long-run as well. Issues such as moral hazard and the potential inflationary consequences of ODA must also be taken into consideration to fully evaluate the effectiveness of ODA.

Debt relief, which comprises ODA, debt forgiveness and debt rescheduling, is thus effective in mitigating the effects of natural disasters through at least one channel. It is unclear, however, if debt forgiveness and debt rescheduling are similarly effective in this regard. While ODA and debt restructuring act in similar ways to restore economic growth, particularly through reducing debt overhang and increasing fiscal space, we have also identified areas in which the two policies act in different ways and might have different degrees of effectiveness. Improved data on the size of the haircuts imposed on creditors by Paris Club agreements is necessary for further research in this area.

These findings are particularly important due to the significant impact of droughts and floods in lowering GDP growth immediately upon impact. These negative effects are observed largely through reduced agricultural production for droughts but not for floods. Although the economy appears to recover to the steady-state growth path within 2 years of a flood, the negative economic repercussion of droughts seem to be more persistent. Furthermore, when controlling for debt relief, we observe that severe droughts increase debt-to-GDP growth considerably. This suggests that African governments should be particularly concerned about preparing for droughts, both due to its human impact and its economic consequences. Countries vulnerable to droughts, such as those in the region of the parched Sahel desert, would be advised to maintain sustainable levels of debt in years of relative tranquility. This would prevent them from approaching their fiscal limit and being at risk of default when a severe drought hits. Alternatively, policies such as insurance coverage or disaster funds could also be employed to similar effect, although the feasibility of establishing such funds may be doubtful in African countries with relatively underdeveloped financial markets.

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A Appendix

A.1 Full Results

Fixed Effects Regression - Separate Floods and Droughts Interaction

VARIABLES	(1) GDP growth	(2) Debt to GDP growth	(3) Crop Production growth
L.Y	0.184**	-0.0307	-0.310***
	(0.0858)	(0.0473)	(0.0371)
ContODA2	-0.0981	-0.478***	-0.0855
	(0.111)	(0.142)	(0.142)
interactDrought	1.613**	4.294*	1.914
	(0.703)	(2.408)	(1.238)
interactFlood	7.699	-192.0*	42.61
	(6.205)	(106.3)	(38.44)
DA_perGDP	-0.00596	-0.311*	-0.0434
	(0.0223)	(0.170)	(0.0336)
DroughtSeverity	-0.0720**	0.349	-0.419***
	(0.0350)	(0.208)	(0.124)
L.DroughtSeverity	0.102*	-0.614	0.403*
	(0.0521)	(0.446)	(0.204)
L2.DroughtSeverity	-0.0471	0.399	-0.0323
	(0.0430)	(0.309)	(0.198)
FloodSeverity	-0.544***	-3.888	-0.775
	(0.176)	(4.370)	(0.816)
L.FloodSeverity	0.0988	0.285	0.177
	(0.205)	(1.521)	(0.308)
L2.FloodSeverity	0.334**	13.86	0.250
	(0.154)	(11.16)	(0.852)
avg_rain	0.000330**	-0.000295	0.00183***
	(0.000140)	(0.00167)	(0.000607)
war	-0.0494***	0.0193	-0.0429**
	(0.00845)	(0.0449)	(0.0164)
lifeExp	0.00219***	-0.00720	0.00123*
	(0.000452)	(0.00447)	(0.000656)
polity2	0.000603	0.000428	0.00102
	(0.000535)	(0.00335)	(0.000790)
Constant	-0.123***	0.522**	-0.186***
	(0.0316)	(0.200)	(0.0667)
Observations	1,231	1,074	1,233
R-squared	0.170	0.108	0.209
Number of countries	40	36	40

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 7: Separate Drought and Floods Interaction

Effects of Median disasters on GDP growth

Lag / Disaster	Flood	Drought
L0.MedDis	-.0077	-.0139
L1.MedDis	0.0013 (insign.)	0.0228 (insign.)
L2.MedDis	.0049	-0.0107 (insign.)

Effects of Median disasters on Debt to GDP growth

Lag / Disaster	Flood	Drought
L0.MedDis	-0.0652 (insign.)	0.0718 (insign.)
L1.MedDis	-0.0243 (insign.)	-0.1059 (insign.)
L2.MedDis	0.1945 (insign.)	0.0774 (insign.)

Effects of Median disasters on Crop Production Growth

Lag / Disaster	Flood	Drought
L0.MedDis	-0.0083 (insign.)	-0.0825
L1.MedDis	-0.0005 (insign.)	0.0826
L2.MedDis	0.0079 (insign.)	-0.0054 (insign.)

Median FloodSeverity = 0.0157; Median DroughtSeverity = 0.2044

Table 8: The macroeconomic consequences of natural disasters

The above table shows the effect of a median flood or drought on the 3 main dependent variables. For instance, a increase in drought severity of 1 (as measured by the amount of the population affected) leads to a 1.3 percentage points fall in contemporaneous GDP growth (top right result).

A.2 Robustness Checks Results

Exogenous Variables	L.GDP growth	Debt to GDP	Crop Production
L.FloodSeverity	-0.0109	0.0096	0.0067
L2.FloodSeverity	0.0127	-0.0043	0.0498
L.DroughtSeverity	-0.0464	0.0367	0.0050
L2.DroughtSeverity	-0.0182	0.0118	0.0346

Table 9: Correlations of Exogenous Variables and Lagged Dependent Variables

Lags	GDP growth	Debt to GDP growth	Crop Production growth
0	56.1	89.5	71.4
1	43.9	10.5	19
2	–	–	9.6

Table 10: Persistence of PACF (% of Country Series)

GMM and FE with GDP Growth as dependent variable

VARIABLES / IV	(1) $gdpGrowth_{t-2}$	(2) $gdpGrowth_{t-3}$	(3) Within-estimator
LD.gdpGrowth	0.147*	-0.211	0.184**
	(0.0832)	(0.214)	(0.0857)
D.ContODA2	-0.102	-0.110	-0.0959
	(0.123)	(0.115)	(0.110)
D.interactContODA2	1.723**	0.861	1.627**
	(0.680)	(0.565)	(0.710)
D.DA_perGDP	-0.0166	-0.0133	-0.00562
	(0.0314)	(0.0235)	(0.0221)
D.DroughtSeverity	-0.0954**	-0.113***	-0.0732**
	(0.0472)	(0.0393)	(0.0351)
LD.DroughtSeverity	0.0898*	0.0321	0.102*
	(0.0518)	(0.0525)	(0.0522)
L2D.DroughtSeverity		-0.0565	-0.0464
		(0.0433)	(0.0433)
D.FloodSeverity	-0.706***	-0.604***	-0.531***
	(0.252)	(0.204)	(0.179)
LD.FloodSeverity	-0.177	-0.149	0.140
	(0.213)	(0.193)	(0.198)
L2D.FloodSeverity		0.299	0.374**
		(0.222)	(0.158)
Observations	1,221	1,183	1,231
R-squared	-0.061	0.206	0.170
Number of countries	40	40	40
First-stage F-statistic	65.85	12.75	NA
Controls $\boldsymbol{X}_{1i,t}$	Yes	Yes	Yes
Country FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Method	GMM	GMM	FE

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 11: The Dependence between Effectiveness of ODA and the Severity of Disasters - GMM

Note: First-stage F-statistics are based on a simple OLS regression of $\Delta gdpGrowth_{t-1}$ on the respective IV to facilitate interpretability. In bivariate regressions, $F > 10$ satisfies the relevance condition (see for instance Stock & Watson (2015)).

FE Regression - 0.75% Flood Severity
7.5% Drought Severity Threshold

	(1)	(2)	(3)
VARIABLES	GDP growth	Debt to GDP growth	Crop Production
L.Y	0.183**	-0.0299	-0.318***
	(0.0832)	(0.0474)	(0.0329)
ContODA2	-0.0927	-0.581***	-0.0800
	(0.109)	(0.190)	(0.141)
interactContODA2	1.604**	3.991*	2.130*
	(0.690)	(2.101)	(1.238)
DA_perGDP	-0.00874	-0.321*	-0.0384
	(0.0225)	(0.182)	(0.0336)
DroughtSeverity	-0.0625*	0.250	-0.405***
	(0.0344)	(0.203)	(0.118)
l1.DroughtSeverity	0.110**	-0.535	0.373**
	(0.0541)	(0.424)	(0.177)
l2.DroughtSeverity	-0.0583	0.378	-0.0383
	(0.0425)	(0.302)	(0.181)
FloodSeverity	-0.475***	-4.861	-0.610
	(0.171)	(4.236)	(0.958)
l1.FloodSeverity	0.154	-1.390	0.725
	(0.206)	(2.357)	(0.511)
l2.FloodSeverity	0.348**	13.71	0.596
	(0.159)	(11.15)	(0.728)
Constant	-0.119***	0.524***	-0.188**
	(0.0317)	(0.190)	(0.0698)
Observations	1,261	1,074	1,263
R-squared	0.165	0.107	0.214
Number of countries	40	36	40

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 12: Severity Index Lowered by 25%

FE Regression - 0.5% Flood Severity
5% Drought Severity Threshold

VARIABLES	(1) GDP growth	(2) Debt to GDP growth	(3) Crop Production
L.Y	0.182**	-0.0305	-0.321***
	(0.0832)	(0.0476)	(0.0336)
ContODA2	-0.0922	-0.576***	-0.0716
	(0.109)	(0.186)	(0.140)
interactContODA2	1.588**	3.542*	2.012
	(0.669)	(1.885)	(1.239)
DA_perGDP	-0.00892	-0.320*	-0.0372
	(0.0225)	(0.180)	(0.0335)
DroughtSeverity	-0.0453	0.0795	-0.396***
	(0.0387)	(0.321)	(0.127)
L1.DroughtSeverity	0.0909	-0.353	0.312*
	(0.0561)	(0.385)	(0.173)
L2.DroughtSeverity	-0.0343	0.398	0.0766
	(0.0458)	(0.353)	(0.165)
FloodSeverity	-0.498***	-4.823	-0.539
	(0.173)	(4.297)	(0.962)
L1.FloodSeverity	0.149	-1.314	0.552
	(0.218)	(2.349)	(0.535)
L2.FloodSeverity	0.362**	13.19	0.469
	(0.162)	(10.97)	(0.741)
Constant	-0.123***	0.520***	-0.195***
	(0.0326)	(0.182)	(0.0712)
Observations	1,261	1,074	1,263
R-squared	0.164	0.106	0.215
Number of countries	40	36	40

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 13: Severity Index Lowered by 50%

GDP Growth FE Regression - 1 to 3 lags

VARIABLES	(1) GDP growth	(2) GDP growth	(3) GDP growth
L.Y	0.207**	0.194**	0.191**
	(0.0811)	(0.0851)	(0.0854)
L2.Y		0.0205	0.0168
		(0.0173)	(0.0263)
L3.Y			0.0777***
			(0.0220)
ContODA2	-0.114	-0.107	-0.107
	(0.122)	(0.123)	(0.127)
interactContODA2	1.775**	1.127*	0.909
	(0.744)	(0.664)	(0.696)
DA_perGDP	-0.00497	-0.00234	-0.00946
	(0.0237)	(0.0236)	(0.0223)
DroughtSeverity	-0.0529	-0.0263	-0.0522*
	(0.0416)	(0.0288)	(0.0268)
L1.DroughtSeverity	0.0955	0.0755	0.0882**
	(0.0575)	(0.0492)	(0.0418)
L2.DroughtSeverity	-0.0291	-0.0125	-0.00365
	(0.0575)	(0.0452)	(0.0409)
FloodSeverity	-0.543***	-0.557***	-0.507***
	(0.173)	(0.180)	(0.183)
L1.FloodSeverity	0.168	0.115	0.146
	(0.256)	(0.261)	(0.245)
L2.FloodSeverity	0.365	0.351	0.331
	(0.238)	(0.225)	(0.223)
Constant	-0.157***	-0.162***	-0.146***
	(0.0501)	(0.0471)	(0.0429)
Observations	946	915	882
R-squared	0.177	0.179	0.178
Number of countries	40	40	40

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 14: GDP growth with 1 to 3 lags

Debt to GDP Growth FE Regression - 1 to 3 lags

VARIABLES	(1) Debt to GDP Growth	(2) Debt to GDP Growth	(3) Debt to GDP Growth
L.Y	-0.00206	-0.00487	-0.0111
	(0.0356)	(0.0365)	(0.0357)
L2.Y		-0.0296	-0.0363
		(0.0289)	(0.0262)
L3.Y			-0.0557*
			(0.0314)
ContODA2	-0.794***	-0.773***	-0.621**
	(0.241)	(0.241)	(0.234)
interactContODA2	4.868**	4.218	3.757
	(2.274)	(2.534)	(2.721)
DA_perGDP	-0.294*	-0.317*	-0.311*
	(0.165)	(0.173)	(0.169)
DroughtSeverity	0.381	0.351	0.161
	(0.246)	(0.297)	(0.297)
L1.DroughtSeverity	-0.627	-0.630	-0.835
	(0.480)	(0.543)	(0.630)
L2.DroughtSeverity	0.328	0.354	0.667
	(0.336)	(0.346)	(0.455)
FloodSeverity	-3.653	-4.282	-4.701
	(4.448)	(4.748)	(4.927)
L1.FloodSeverity	-0.0880	-1.554	-1.052
	(1.917)	(2.898)	(2.519)
L2.FloodSeverity	14.85	15.04	19.55
	(13.08)	(13.05)	(16.11)
Constant	0.716***	0.777***	0.757***
	(0.248)	(0.273)	(0.264)
Observations	826	792	759
R-squared	0.115	0.119	0.131
Number of countries	36	36	36

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 15: Debt to GDP growth with 1 to 3 lags

Crop Production Growth FE Regression - 1 to 3 lags

VARIABLES	(1) Crop Production	(2) Crop Production	(3) Crop Production
L.Y	-0.259***	-0.308***	-0.339***
	(0.0317)	(0.0457)	(0.0506)
L2.Y		-0.172***	-0.222***
		(0.0433)	(0.0485)
L3.Y			-0.162**
			(0.0664)
ContODA2	-0.000800	-0.0185	-0.0233
	(0.140)	(0.135)	(0.133)
interactContODA2	2.600	2.105	2.205
	(1.561)	(1.614)	(1.716)
DA_perGDP	-0.0354	-0.0302	-0.0314
	(0.0369)	(0.0359)	(0.0370)
DroughtSeverity	-0.423***	-0.382***	-0.496***
	(0.156)	(0.138)	(0.134)
l1.DroughtSeverity	0.385*	0.352*	0.462**
	(0.205)	(0.196)	(0.213)
l2.DroughtSeverity	0.0614	0.0332	-0.0166
	(0.202)	(0.182)	(0.174)
FloodSeverity	-0.680	-0.785	-0.897
	(1.049)	(1.057)	(1.006)
l1.FloodSeverity	0.844*	0.568	0.579
	(0.501)	(0.509)	(0.551)
l2.FloodSeverity	0.768	0.721	0.523
	(0.897)	(0.840)	(0.879)
Constant	-0.228**	-0.231**	-0.224**
	(0.0897)	(0.0895)	(0.0921)
Observations	956	931	902
R-squared	0.185	0.206	0.234
Number of countries	40	40	40

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 16: Crop Production growth with 1 to 3 lags

A.3 Unit Root Tests

In order to evaluate the required stationarity assumption, we first plot the individual series per country. Figures (1), (2), and (3) show the individual time series for each of our dependent variables in levels. GDP growth is clearly non-stationary, which is fully validated by the unit-root test as proposed by Choi (2001). This Fisher-type unit-root test allows for unbalanced panels with potential lags in the individual time series. The reported P-Statistic is Inverse Chi-Squared distributed and requires the number of panels to be finite.

Under the H_0, all panels contain a unit root. By specifying trend option, we allow for either Random Walk with or without drift. Table (17) reports the results of the unit-root tests on levels. For GDP, we cannot reject the H_0 for any lag, which is in line with the visual evidence provided by Figure (1). For Debt to GDP, we reject the null hypothesis the all panels contain a unit root only when including 3 lags into the ADF regression. Observing the graphs in Figure (2) and noting that we are jointly testing whether all individual series contain a unit root and we only reject when including 3 lags, but not when including 2 or 4 lags, we conclude that there generally is a unit root. For Crop Production, we reject the H_0 that all panels contain a unit root when including 1 lag and no lags at all. Looking at Figure (3) provides sufficiently strong evidence to conclude that there is a unit root in general.

GDP

test-type	lags	P-statistic (Inverse chi-squared(80))	p-value	Decision
ADF, trend	0	P = 29.5391	1.0000	All panels contain unit root
ADF, trend	1	P = 27.0818	1.0000	All panels contain unit root
ADF, trend	2	P = 94.5860	0.1268	All panels contain unit root
ADF, trend	3	P = 27.1281	1.0000	All panels contain unit root
ADF, trend	4	P = 19.5968	1.0000	All panels contain unit root

Debt to GDP

test-type	lags	P-statistic (Inverse chi-squared(76))	p-value	Decision
ADF, trend	0	P = 78.5250	0.3988	All panels contain unit root
ADF, trend	1	P = 59.5496	0.9177	All panels contain unit root
ADF, trend	2	P = 60.1167	0.9092	All panels contain unit root
ADF, trend	3	P = 108.3379	0.0088	At least one panel is stationary
ADF, trend	4	P = 43.1037	0.9991	All panels contain unit root

Crop Production

test-type	lags	P-statistic (Inverse chi-squared(84))	p-value	Decision
ADF, trend	0	P = 211.7810	0.0000	At least one panel is stationary
ADF, trend	1	P = 118.8971	0.0073	At least one panel is stationary
ADF, trend	2	P = 73.0978	0.7963	All panels contain unit root
ADF, trend	3	P = 64.9399	0.9390	All panels contain unit root
ADF, trend	4	P = 55.4433	0.9932	All panels contain unit root

H_0 : All panels contain a unit-root, H_1 : At least one panel is stationary

Table 17: Fisher-type unit-root tests on levels

On the other hand, we are able to firmly reject the null hypothesis of all panels containing a unit root when expressing each variable in terms of growth rates, as seen in Table (18). Additionally, we also find that we can reject the null hypothesis of a unit root for a large majority of the panels for each variable at the 5% significance level using individual Phillips-Perron tests. We use Phillips-Perron tests to correct for the possibility of heteroskedasticity and autocorrelation in the error terms. The specific results of these individual tests can be found in Table (19) below.

GDP growth

test-type	lags	P-statistic (Inverse chi-squared(82))	p-value	Decision
ADF, trend	0	P = 812.7051	0.0000	At least one panel is stationary
ADF, trend	1	P = 419.4898	0.0000	At least one panel is stationary
ADF, trend	2	P = 227.1581	0.0000	At least one panel is stationary
ADF, trend	3	P = 237.3280	0.0000	At least one panel is stationary
ADF, trend	4	P = 150.7665	0.0000	At least one panel is stationary

Debt to GDP growth

test-type	lags	P-statistic (Inverse chi-squared(76))	p-value	Decision
ADF, trend	0	P = 685.9097	0.0000	At least one panel is stationary
ADF, trend	1	P = 333.8619	0.0000	At least one panel is stationary
ADF, trend	2	P = 197.1992	0.0000	At least one panel is stationary
ADF, trend	3	P = 157.9119	0.0000	At least one panel is stationary
ADF, trend	4	P = 95.7685	0.0624	At least one panel is stationary

Crop Production growth

test-type	lags	P-statistic (Inverse chi-squared(84))	p-value	Decision
ADF, trend	0	P = 1579.9489	0.0000	At least one panel is stationary
ADF, trend	1	P = 796.6214	0.0000	At least one panel is stationary
ADF, trend	2	P = 497.4499	0.0000	At least one panel is stationary
ADF, trend	3	P = 292.7840	0.0000	At least one panel is stationary
ADF, trend	4	P = 171.4482	0.0000	At least one panel is stationary

H_0 : All panels contain a unit-root, H_1 : At least one panel is stationary

Table 18: Fisher-type panel unit-root tests on growth rates

Variables	**Percentage of Stationary Panels**
GDP Growth	80.5%
Debt-to-GDP Growth	89.5%
Crop Production Growth	97.6%

Table 19: Phillips Perron individual unit-root tests on growth rates

A.4 Plots of Macroeconomic Variables

A.4.1 Levels

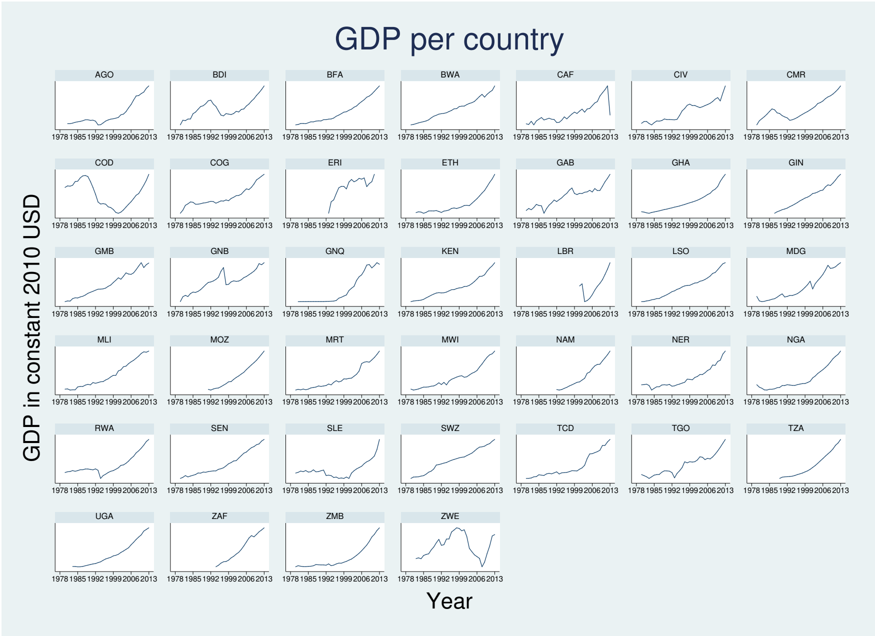

Figure 1: Non-stationary GDP per country

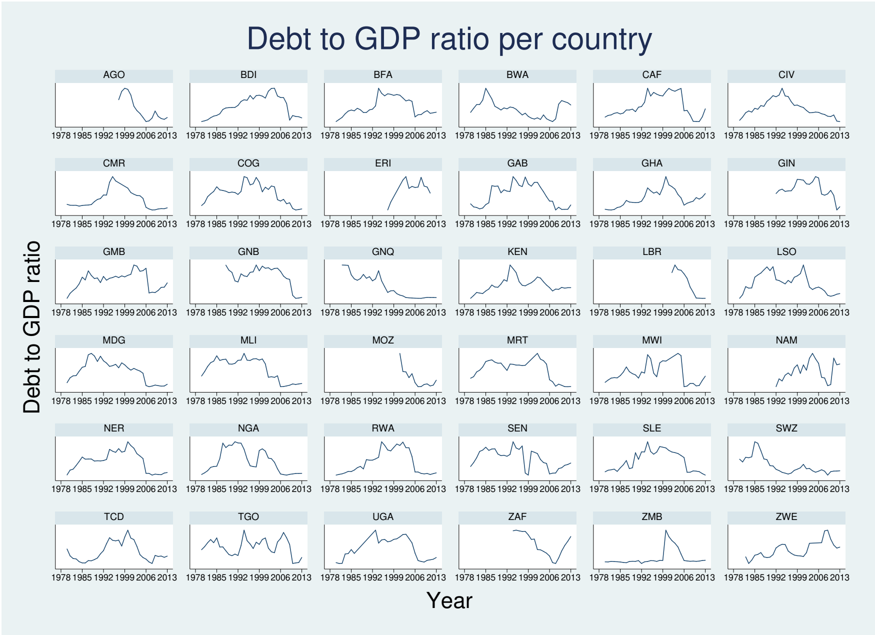

Figure 2: Debt to GDP ratio per country

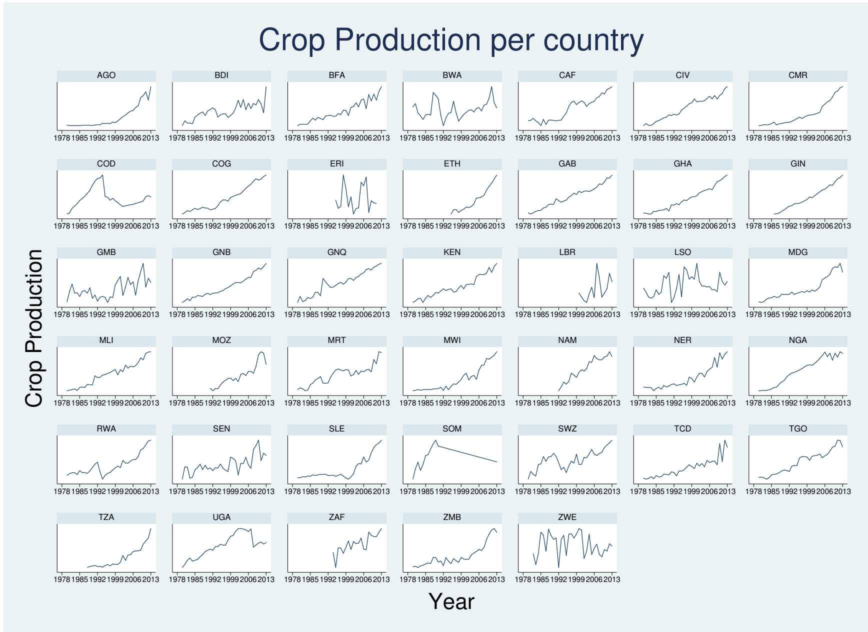

Figure 3: Crop Production per country

A.4.2 Growth Rates

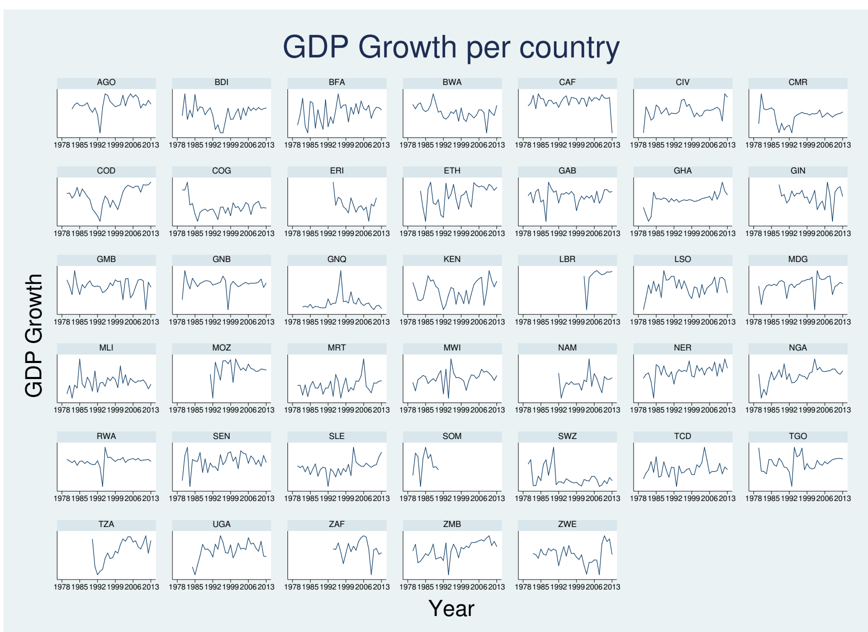

Figure 4: GDP growth per country

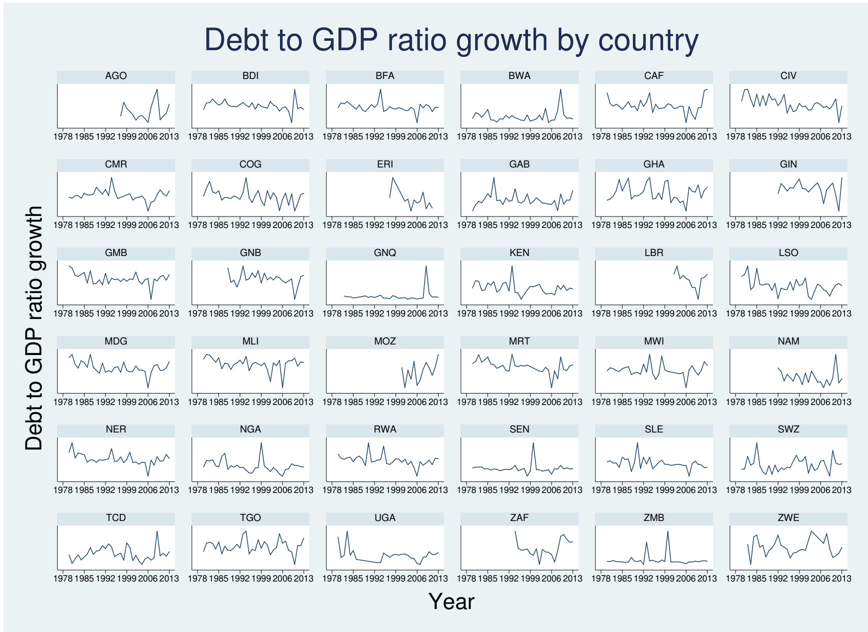

Figure 5: Debt to GDP ratio growth per country

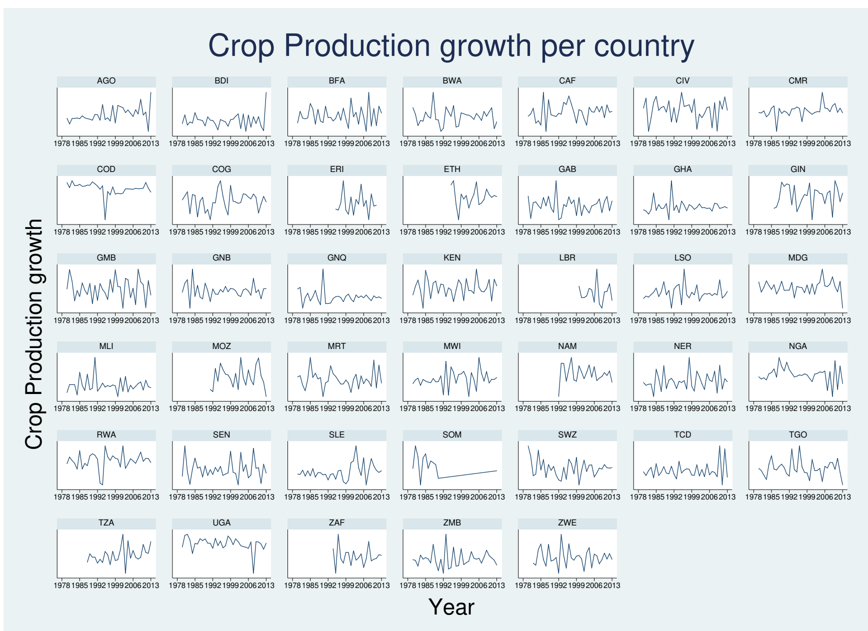

Figure 6: Crop Production growth per country