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ABSTRACT

Exogenous Volatility and the Size of Government in Developing Countries*

This paper presents instrumental variables estimates of the effects of GDP per capita volatility on the size of government. We show that for a panel of 157 countries spanning more than half a century rainfall volatility has a significant positive effect on GDP per capita volatility in countries with above median temperatures. In these countries rainfall volatility has also a significant positive reduced-form effect on the GDP share of government. There is no significant reduced-form effect in the sample of countries with below median temperatures where rainfall volatility has no significant effect on GDP per capita volatility. Using rainfall volatility as an instrumental variable in the sample of countries with above median temperatures yields that greater GDP per capita volatility leads to a significantly higher GDP share of government.

JEL Classification: E6, H1 and O1
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1. Introduction

There seems to exist controversy in the literature in regard to the relationship between government size and economic volatility. In a seminal paper, Rodrik (1998) suggests that in order to provide social insurance against random shocks government size increases in response to increases in economic volatility. Important subsequent papers by Fatas and Mihov (2001a, b) employing also instrumental variables for the size of government to address causality, interpreted available empirical evidence as indicating that larger government size causes smaller volatility.[1] Hence, the still lingering issue is whether the original causal interpretation in Rodrik (1998) is correct. In particular, if terms of trade volatility interacted with trade openness causes an increase in the size of government because larger government size is a buffer against economic shocks, then the argument should apply more generally to other, more plausibly exogenous shocks as well.[2]

To address causal effects of volatility on government size, one needs to utilize an exogenous source of variation in volatility. This is particularly important in light of the findings in Fatas and Mihov (2001a, b) indicating that output volatility is endogenous to the

1 See also Andres et al. (2008) and Fatas and Mihov (2012) for more recent studies; and Gali (1994) for an earlier study that compares based on a sample of 22 OECD countries correlations between economic volatility and government size with theoretical predictions from a RBC model.

2 One important issue with terms of trade shocks is that for economically large countries changes in the size of government can have a direct effect on the terms of trade. This, in turn, raises the question of whether from a global welfare point of view a larger government size is optimal in response to terms of trade volatility. See Epifani and Gancia (2009) where the point of terms-of-trade endogeneity to government size is laid out in detail.

size of government. In this paper, to focus on causal effects of volatility on government size, we employ a country-specific standard deviation of rainfall as a source of exogenous volatility. For a panel of 157 countries spanning the period 1950-2009, we document that rainfall volatility has a significant positive effect on GDP per capita volatility in the sample of countries with above median temperatures. In this sample of high-temperature countries, median PPP GDP per capita is below 1500 with an interquartile range of [838; 4089]; the median GDP share of agriculture is above 0.28 with an interquartile range of [0.16; 0.38]. The significant positive effect of rainfall volatility on GDP per capita volatility in the sample of countries with relatively high temperatures should therefore be interpreted in light of the fact that these countries are relatively less developed due to (exogenous) climatic conditions. Figure 1 illustrates graphically this negative link between cross-country differences in temperature and economic development.[3]

The reduced-form analysis shows that: (i) rainfall volatility has a significant positive effect on the GDP share of government in the group of countries with relatively high temperatures; (ii) there are no significant reduced-form effects in the group of countries with relatively low temperatures (where rainfall volatility has no significant effects on GDP per capita volatility). If rainfall volatility has systematic effects on the size of government beyond GDP per capita volatility, then there should be a significant effect of rainfall volatility on government size in the sample where rainfall volatility has no significant effect

3 We are certainly not the first to point to this negative link between temperature and economic development. See, for example, Gallup and Sachs (2000); or Dell et al. (2012) for a recent study that demonstrates a negative within-country effect of temperature on measures of economic development in poor countries.

on GDP per capita volatility. The fact that this is not the case suggests that rainfall volatility has no significant independent effects on government size beyond GDP per capita volatility. Under this exclusion restriction, we can exploit the significant effect of rainfall volatility on GDP per capita volatility in the sample of countries with relatively high temperatures to construct instrumental variables estimates of the causal effects that GDP per capita volatility has on the size of government.

Our instrumental variables regressions yield a significant positive effect of GDP per capita volatility on the GDP share of government consumption expenditures. In a pooled panel estimation the second-stage coefficient on GDP per capita volatility is around 2.4 with a standard error of 1.1. The pooled panel estimations are based on multi-clustered standard errors at the country and time level with control variables including continent dummies, continent-specific time fixed effects, the level of rainfall, as well as other geographic characteristics related to countries' latitude and longitude, their size in square kilometers, and whether the country has access to the sea. We document that the IV estimates are robust to controlling in the panel regressions for country fixed effects or using only cross-sectional data.

It is noteworthy that IV estimates are larger than OLS estimates. In the sample of 157 countries during the 1950-2009 period OLS estimation yields a significant positive coefficient on GDP per capita volatility of around 0.2 with a standard error of around 0.1. In the sample of high-temperature countries the OLS coefficient is also positive but only in some specifications significantly different from zero. The Hausman test rejects the hypothesis that the OLS coefficient is equal to the IV coefficient at the conventional significance levels. One reason for IV estimates being larger than OLS estimates is that the latter suffer from a negative reverse causality bias: according to the literature discussed above larger government size reduces GDP per capita volatility. Hence there is a negative correlation between the right-hand-side regressor (GDP per capita volatility) and the error term that downward biases the OLS estimate. In contrast, because rainfall volatility is exogenous to the size of government, the IV estimates do not suffer from this reverse causality bias, hence, our results are well consistent with those in exiting literature suggesting a stabilizing role of government size.[4]

Methodologically, our paper belongs to a growing body of literature that explores the effects of exogenous climate shocks on economic and political outcomes.[5] While this literature focuses on first moments, we are interested in rainfall volatility, captured by a second moment of rainfall within a time period, as our indicator for exogenous volatility. To the best of our knowledge, this is the first paper to utilize such an approach for explaining the size of government.

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4 Another reason why OLS estimates are smaller than IV estimates could be measurement error. Classical measurement error in GDP per capita volatility will attenuate the least squares estimates towards zero but not the IV estimates.

5 See, for example, Barrios et al. (2010), Brückner and Ciccone (2011), Dell et al. (2012), or Miguel et al. (2004).

Beyond the literature that focuses on the determinants of government size, our results are relevant for studies that explore the stabilizing role of government size. In particular, our finding of a significant positive effect of exogenous volatility on government size implies that benchmark least squares estimates of the (negative) effects of government size on volatility are upward biased. Thus, due to causality running from more economic volatility to larger government size, partial correlations between the size of government and economic volatility will understate the true stabilizing effects of government size.

The rest of the paper proceeds as follows. In the next section, we provide some theoretical background. Section 3 describes the data. This is followed, in Section 4, by a discussion of our estimation approach. Section 5 then contains the empirical analysis, and Section 6 concludes.

2. Theoretical Background

In this section we discuss possible reasons for why economic volatility could lead to larger government size. The first reason is related to government providing social insurance. Formal models linking economic volatility to social insurance, such as Eaton and Rosen (1980), Varian (1980) and Sinn (1995) typically assume ex-ante identical and risk-averse individuals who have the opportunity to design a social insurance scheme prior to the realization of random shocks. While advantages of an insurance mechanism as such in this setting are obvious, whether a government sponsored one is optimal – relative to private insurance – is debatable. To put forward the case for government intervention, one typically has to appeal to contract incompleteness or other market imperfections (Sinn, 1995).

A second reason why economic volatility could lead to larger government size is the provision of public goods. People typically not only care about private consumption but also about the consumption of public goods. When individuals are borrowing-constrained, idiosyncratic income shocks will induce volatility in private consumption (in the absence of insurance); yet, they will not induce volatility in the provision of public goods. Hence, government size that arises from public good provision can provide a utility buffer to risk-averse individuals facing income shocks.[6]

Using dynamic stochastic general equilibrium models, a separate strand of literature has examined the stabilizing properties of government size.[7] This literature considers neither social insurance nor public good provision. Instead, it focuses on the aggregate effects that government expenditures have on the volatilities of output and private consumption. One of the key findings in Andres et al. (2008) is that in the presence of nominal rigidities and costs of capital adjustment the DSGE model with productivity shocks can generate a negative effect of government size on the volatility of output. However, in order to also generate a negative effect of government size on private consumption volatility, rule-of-thumb

6 In the supplementary online appendix, we present a simple model to formalize this idea. The appendix is available for download at https://sites.google.com/site/markusbrucknerresearch/research-papers

7 See, for example, Gali (1994), Andres et al. (2008) or Fatas and Mihov (2012).

consumers are needed. In sum, the results from this literature suggest that larger government size might stabilize the economy and reduce private consumption volatility. Hence, beyond the government's role of providing social insurance and public goods a third reason for larger government size as a consequence of an increase in exogenous volatility is that citizens demand larger government size because of its stabilizing role.

3. Data

Rainfall Volatility. Our primary measure of rainfall volatility is the 10-year standard deviation of rainfall growth. This country-level variable is constructed as

$\sigma_{i,t} = (0.1 \sum_{j=1}^{10} (Rain_{i,t-j+1} - \mu_{i,t})^2)^{0.5}$, where $Rain_{it}$ is the change in the log of rainfall in country *i* between year *t*-1 and *t*, and $\mu_{i,t} = 0.1 \sum_{j=1}^{10} Rain_{i,t-j+1}$ is the average rainfall growth over a 10-year interval in country *i* in a period ending in year *t*. In order to examine the robustness of our findings to the volatility measure used, we will also present estimates that are based on calculating the standard deviation of rainfall over the entire 1950-2009 period.

The annual rainfall data are from Matsuura and Willmott (2009). These data are available from 1900 onwards and are based on gauge station observations. The data come at a high resolution (0.5°x0.5° latitude-longitude grid), and each rainfall observation in a given grid is constructed by interpolation of rainfall observed by all stations operating in that grid. We aggregate rainfall data to the country level by assigning grids to the geographic areas of countries.

Size of Government. Our main measure of the size of government is the share of government consumption expenditures in GDP. The data are from the Penn World Table, version 7.0 (Heston et al., 2011). Using exactly the same formula as above, we construct real GDP per capita volatility; the data source is PWT 7.0. Appendix Tables 1A and 1B provide some key summary statistics as well as a list of the countries in the sample.

Other Data. Data on countries' longitude and latitude and an indicator variable for whether the country is landlocked are from Head et al. (2010). Data on countries' land area are from WDI (2011). Data on temperature are from Matsuura and Willmott (2009).

4. Estimation Framework

We use a two-stage least squares estimation framework to examine the causal effects of GDP per capita volatility on the size of government. The baseline second-stage equation is:

(1) $$G_{it}=\alpha GDPVolatility_{it} + \Gamma X_{it} + d_{tc} + z_{it}$$

where G_{it} is the share of government consumption expenditures in GDP of country i in period t; $GDPVolatility_{it}$ is a measure of the volatility of GDP per capita; d_{tc} are continent-time fixed effects. X_{it} is a vector of control variables that includes the level of rainfall, temperature, the volatility of temperature, geographic controls (latitude, longitude, landlocked, country area) and continent dummies (Africa, Asia, America, Europe, Pacific).

The corresponding first-stage equation is given by:

(2) $GDPVolatility_{it} = \beta RainfallVolatility_{it} + \Lambda X_{it} + \tau_{tc} + e_{it}$

where $RainfallVolatility_{it}$ is a country-specific measure of rainfall volatility. In both equations (1) and (2) the error terms are clustered at the country and time level, using the Cameron et al. (2011) multi-cluster estimator. Clustering at the country level corrects the standard errors for arbitrary serial correlation. This type of clustering also ensures that in the pooled panel regressions we correctly adjust the standard errors of variables which vary only in the cross-section of countries. Using pooled panel (rather than cross-sectional) regressions with standard errors clustered at the country level is therefore a conservative approach which ensures that standard errors are not artificially low due to repeated within-country observations. The clustering at the time level adjusts standard errors for arbitrary spatial correlation.

A necessary condition for two-stage least squares estimation to yield a consistent estimate of α in equation (1) is that there is a highly significant first-stage fit between rainfall volatility and GDP per capita volatility in equation (2). We will show in Section 5 that this is the case for the group of countries with above median temperatures (and more generally in countries with relatively high temperatures). Hence the instrumental variables analysis will be limited to the subset of high-temperature countries.

Since rainfall volatility is plausibly exogenous to time-invariant country characteristics that determine both GDP per capita volatility and the size of government, we do not control in our baseline panel regressions for country fixed effects. In the baseline regressions the estimated effects are therefore identified from both cross-country and time-series variation. It is often argued that the omission of country fixed effects in least squares estimation reduces credibility that the identified effects reflect a causal relationship.[8] The typical argument is that in the cross-section there are a multitude of variables, related, for example, to differences in countries' colonial experience that affect current institutions, which in turn affect both GDP per capita volatility and the size of government. However, due to the exogeneity of rainfall volatility, these omitted variables do not lead to inconsistent instrumental variables estimates in the pooled panel model.

As an alternative to our benchmark estimation framework, we will present estimates from cross-sectional regressions that use averages over the entire 1950-2009 period; and estimates from the panel model that includes country fixed effects. This allows us to examine whether the identified relationship in the pooled panel model holds across countries as well as within countries.

5. Empirical Results

5.1 Least Squares Estimates

8 See, for example, Acemoglu et al. (2008).

Before discussing the results from our instrumental variables analysis we present in Table 1 least squares estimates for the sample of 157 countries spanning the period 1950-2009. Column (1) shows least squares estimates from a simple bivariate regression of the GDP share of government consumption on GDP per capita volatility. The estimated coefficient on GDP per capita volatility is around 0.26 and has a standard error of around 0.08. Hence a simple bivariate regression shows that government size is significantly positively related to economic volatility.

In columns (2)-(5) of Table 1 we document that the least squares estimates of the relationship between volatility and government size barely change when including additional control variables. Column (2) adds time fixed effects that capture shocks common across all countries. In column (3) we add continent fixed effects to account for average differences in politico-economic development across continents. In column (4) we interact the time fixed effects with continent fixed effects so that the common time shocks are continent specific. And in column (5) we add geographic variables that are specific to each country; such as country area, latitude and longitude, and whether the country is landlocked.[9] The estimated least squares coefficient on GDP per capita continues to be around 0.2 with a standard error that is below 0.1.

In column (6) of Table 1 we show that the least squares estimates are robust to excluding outliers. We control for the same set of variables as in column (5) but exclude

9 Table 1 of the supplementary online appendix shows that the correlations between rainfall volatility and these fixed geographic country characteristics are small.

observations that according to the Hadi (1992) procedure are identified as outliers at the 5 percent level. The Hadi (1992) procedure belongs to the class of robust outlier detection methods that are based on the multidimensional distribution of parameters. It uses the vector of variable medians and the covariance matrix to identify the subset of observations with the smallest Mahalanobis distance. The least squares coefficient in column (6), where outliers are excluded based on the Hadi (1992) procedure, is around 0.23 and has a standard error of around 0.09. Thus excluding outliers continues to yield a significant positive least squares coefficient on GDP per capita volatility.

The least squares estimates are unlikely to capture the causal effects of GDP per capita volatility on government size. The literature on the stabilizing role of government, see Section 2, suggests that larger government size reduces the volatility of GDP per capita. A priori, we thus expect least squares estimation to lead to an understatement of the causal effect of GDP per capita volatility on government size due to reverse causality. Furthermore, classical measurement error in the volatility of GDP per capita will attenuate least squares estimates towards zero. It is well known that measurement errors in national accounts statistics are a serious issue, especially in developing countries (Heston, 1994; Deaton, 2005). Finally, inconsistency arising from omitted variables is a concern in least squares estimation as GDP per capita volatility is an endogenous variable. For example, Acemoglu et al. (2003) have shown that institutions affect countries' GDP per capita volatility, and Stein et al. (1999) have documented a significant relationship between institutions and government size. The sign and size of inconsistency in least squares estimation arising from omitted variables is difficult to pin down but the above discussion makes it clear that least squares estimation is unlikely to identify the causal effect of GDP per capita volatility on government size. In the next section we present results from an instrumental variables approach that overcomes all three sources of inconsistency.

5.2 Instrumental Variables Estimates

5.2.1 First Stage

We begin the instrumental variables analysis by discussing the effects of rainfall volatility on GDP per capita volatility. A necessary condition for instrumental variables regressions to yield consistent estimates is a precise first-stage fit between the instrument and the endogenous regressor. Rainfall volatility is likely to have significant positive effects on GDP per capita volatility in poor and largely agrarian economies; however in industrialized economies, where the agricultural sector is small and irrigation is well developed, GDP per capita volatility is unlikely to be significantly affected by rainfall volatility. We, therefore, need to separate countries to account for the heterogeneous effect of rainfall volatility on GDP per capita volatility. A key challenge that complicates this task is that countries' level of economic development is endogenously determined, and is possibly causally related to government size, see e.g., the review article by Besley and Persson (2013).

A well-known fact from the literature on climate and economic development is that warmer countries tend to have on average lower levels of economic development (e.g. Gallup and Sachs, 2000).[10] Figure 1 illustrates this relationship for the sample at hand. The left-hand figure plots the cross-country relationship between the log of the 1950-2009 average PPP GDP per capita and temperature; the right-hand figure plots the relationship between the 1950-2009 average GDP share of agriculture and temperature.[11] The unconditional relationship between countries' PPP GDP per capita and temperature is clearly negative: the coefficient (Huber robust standard error) on temperature is -0.09 (0.01) and the R-squared in this simple bivariate regression is above 0.32. The unconditional relationship between the GDP share of agriculture and temperature is on the other hand positive: the coefficient (Huber robust standard error) on temperature is around 0.7 (0.1) and the R-squared is above 0.17. Column (1) of Table 2 shows that these relationships are robust to controlling for continent fixed effects as well as geographic characteristics of countries such as latitude and longitude, country area, and an indicator variable that is unity for landlocked countries. Columns (2)-(6) show that these cross-country relationships also remain significant for more recent years.

Table 3 shows that much in accordance with the relationship discussed above between development and cross-country differences in temperature, rainfall volatility only

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10 See also Dell et al. (2012) for a recent empirical study that demonstrates a negative within-country effect of temperature on economic growth and other measures of development in poor countries.

11 The ongoing lively debate on the climate effect on the productivity in agriculture, see, Fisher et al. (2012) or Mendelson et al. (1994), is of tangential relevance here, first, because it primarily addresses the US context, and also because in our setting temperature levels are just designed to proxy for the overall development level (see Dell et al., 2012, for a similar perspective).

has a significant first-stage effect on GDP per capita volatility in the group of countries with relatively high temperatures. In columns (1) and (2) of Table 3 we report estimates for the sample of countries in the bottom 25th and 50th temperature percentiles. In this group of countries with relatively cold temperatures, rainfall volatility has no significant effect on GDP per capita volatility. This is true in the largest possible sub-sample, where all observations are used to estimate the relationship between rainfall volatility and GDP per capita volatility (Panel A), and in the sub-sample that excludes observations identified as outliers by the Hadi procedure (Panel B). On the other hand, columns (3) and (4) of Table 3 show that for countries in the top 25th and 50th temperature percentiles, rainfall volatility has a highly significant positive effect on GDP per capita volatility. For the sample of countries with above median temperature levels, the coefficient on rainfall volatility is significant at the 1 percent level when outliers are excluded (5 percent level when outliers are included). For the sample of countries in the top 25th temperature percentile the coefficient on rainfall volatility is significant at the 1 percent level regardless of whether outliers are excluded or included. We now turn to discussing the reduced-form estimates.

5.2.2 Reduced Form

Table 4 presents the reduced-form estimates of the relationship between rainfall volatility and the GDP share of government consumption expenditures. In order to facilitate comparison to the first-stage estimates Table 4 is structured in exactly the same way as Table 3. In columns

(1) and (2) we report estimates for the group of countries with relatively low temperatures, i.e. countries in the bottom 25th and 50th temperature percentiles. In columns (3) and (4) we report estimates in the group of countries with relatively high temperatures, i.e. countries in the top 50th and 25th temperature percentiles.

The reduced-form analysis shows that rainfall volatility has a significant positive effect on the GDP share of government consumption expenditures in countries with relatively high temperatures. The coefficient on rainfall volatility for the group of countries with above median temperatures is positive and significantly different from zero at the 1 percent level, see column (3) of Table 4. This is true regardless of whether observations are excluded, which are identified as outliers by the Hadi procedure (Panel B), or whether these observations are included (Panel A). Column (4) of Table 4 shows that also in the group of countries in the top 25th temperature percentile the coefficient on rainfall volatility is positive and significantly different from zero at the 1 percent level.

Another important result from the reduced-form analysis is that rainfall volatility has no significant effects on the GDP share of government consumption expenditures in the group of countries with relatively low temperatures. Columns (1) and (2) of Table 4 show estimates for the group of countries in the bottom 25th and 50th temperature percentiles, respectively. There are no significant reduced-form effects of rainfall volatility in the low-temperature countries regardless of whether we include or exclude outliers.

5.2.3 Second Stage

The first-stage and reduced-form analysis revealed that rainfall volatility has only a significant positive effect on government size and GDP per capita volatility in the group of countries with above median temperatures. In countries with below median temperatures there is no significant first-stage effect on GDP per capita volatility; nor is there a significant reduced-form effect on government size. This latter result suggests that rainfall volatility only affects the size of government through its effect on GDP volatility.[12] If rainfall volatility has significant effects on government size beyond GDP per capita volatility, then we would expect rainfall volatility to also have a significant effect on government size in the sample of low-temperature countries. This, however, is not the case as discussed in the previous section.

In Table 5 we present the second-stage estimates of our benchmark two-stage least squares regressions where the instrumental variable for GDP per capita volatility is rainfall volatility. Rainfall volatility has no significant first-stage effects on GDP per capita volatility in the group of countries with below median temperatures, so it makes no sense to report second-stage estimates for this sub-group of countries.[13] This is because a necessary

12 In Tables 2 and 3 of the supplementary online appendix we document that rainfall volatility has no significant effects on countries' GDP shares of net official development aid or civil war incidence.

13 In Table 4 of the supplementary online appendix we document that rainfall volatility has also no significant first-stage or reduced-form effects in OECD countries. This is consistent with the results in Sections 5.2.1

condition for consistent two-stage least estimation is that rainfall volatility is a relevant instrument for GDP per capita volatility. In other words, the first-stage effect of rainfall volatility on GDP volatility needs to be sufficiently precise. When instruments are weak, two-stage least squares estimation produces inconsistent estimates and hypothesis tests with large size distortions (Stock and Yogo, 2005). This makes it clear that the two-stage least squares analysis must be limited to the sample of countries with relatively high temperatures, where rainfall volatility has a highly significant effect on GDP volatility. Panel A of Table 5 thus presents estimates for the group of countries in the top 25th temperature percentile while Panel B presents estimates for the group of countries in the top 50th temperature percentile.

The main finding from the two-stage least squares regressions is that the second-stage coefficient on GDP per capita volatility is positive and significantly different from zero at the conventional significance levels. In column (1) of Table 5 the estimated coefficient (standard error) on GDP per capita volatility is around 2.0 (0.8) for the group of countries in the top 25th temperature percentile. For the group of countries in the top 50th temperature percentile the second-stage coefficient (standard error) on GDP per capita volatility is around 2.6 (1.4). We can reject the hypothesis that the second-stage coefficient is equal to zero at the 5 and 10 percent significance level, respectively. Using the interaction between rainfall volatility and temperature as an instrument in the first-stage yields a slightly more precise fit, see column

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and 5.2.2 that rainfall volatility has significant effects on GDP per capita volatility and the size of government only in relatively poor countries.

(2). In that case we can reject the hypothesis that the second-stage coefficient on GDP per capita volatility is equal to zero at the 1 and 5 percent significance level, respectively.

It is interesting to note that the least squares coefficient on GDP per capita volatility is also positive in the sub-group of countries with relatively high temperatures (see column (3) of Table 5). Quantitatively, the LS coefficient is however substantially smaller than the IV coefficient. This is consistent with the discussion in Section 5.1 that least squares estimation leads to an understatement of the causal effect of GDP per capita volatility on government size due to the latter variable having a negative effect on the former. The generalized Hausman test rejects the null hypothesis that the IV coefficient is equal to the LS coefficient at the 1 percent significance level. Hence, also in the statistical sense there is evidence that least squares estimation leads to an understatement of the causal effect that GDP per capita volatility has on government size.

In columns (4)-(6) of Table 5 we show that the above results are robust to excluding outliers. In fact, the exclusion of outliers leads to more precise estimates. For the group of countries in the top 25th temperature percentile we can reject the hypothesis that the second-stage coefficient on GDP per capita volatility is equal to zero at the 1 percent significance level. For the group of countries in the top 50th temperature percentile we can reject the null hypothesis that the second-stage coefficient on GDP per capita volatility is equal to zero at the 5 percent significance level. Quantitatively, the second-stage coefficients in the sub-sample that excludes outliers are very similar to the second-stage coefficients obtained in columns (1) and (2) where outliers are not excluded.

In terms of instrument relevance, we note that once outliers are excluded, the Kleibergen-Paap F-statistic is above 10. This is true for the sub-sample of countries in the top 25th temperature percentile as well as in the sub-sample of countries in the top 50th temperature percentile. According to Staiger and Stock (1997) we can, therefore, reject that the IV estimates are based on weak instruments.

5.3 Robustness

5.3.1 Country Fixed Effects Estimates

The pooled panel regressions that we have presented so far used both across and within-country variations to identify the effects of GDP per capita volatility on government size. The discussion in Section 2 suggests that the positive effect of GDP per capita volatility on government size should also be present when we use only within-country variation. We, therefore, present here IV estimates from panel regressions that control for country fixed effects. In these fixed effects regressions, the estimated effect of GDP per capita volatility on government size is identified by deviations from country mean. Cross-country differences in average 1950-2009 GDP per capita volatility and government size do not affect the estimated slope coefficient in the country fixed effects regression.

Table 6 presents instrumental variables estimates from panel regressions that include country fixed effects in addition to continent-specific time fixed effects, as well as temperature and rainfall level controls. In columns (1)-(3) we present estimates for the group of countries in the top 25th temperature percentile. In columns (4)-(6) we present estimates for the group of countries in the top 50th temperature percentile. We exclude observations that are identified by the Hadi (1992) procedure as outliers at the 5 percent level. In the top panel of Table 6 we report the estimated second-stage coefficients that capture the average marginal effects of within-country changes in GDP per capita volatility on the GDP share of government consumption expenditures. In the bottom panel of Table 6 we report the first-stage coefficients that capture the average marginal effects of within-country changes in rainfall volatility on GDP per capita volatility.

The main finding from instrumental variables regressions that control for country fixed effects is that there is a significant positive within-country effect of GDP per capita volatility on government size. For the group of countries in the top 25th temperature percentile the second-stage coefficient on GDP per capita volatility is around 1.7 and significantly different from zero at the 1 percent significance level (see columns (1) and (2) of Table 6). For the group of countries in the top 50th temperature percentile the second-stage coefficient on GDP per capita volatility is above 2.7 and also significantly different from zero at the 1 percent significance level (see columns (4) and (5) of Table 6).

The LS coefficients in the panel regressions that include country fixed effects are significantly smaller than the IV coefficients. Column (3) of Table 6 shows that the LS coefficient on GDP per capita volatility is significantly negative for the sample of countries in the top 25th temperature percentile. Column (6) of Table 6 shows that the LS coefficient on GDP per capita volatility is positive but insignificant for the sample of countries in the top 50th temperature percentile. The Hausman test rejects the hypothesis that the IV coefficient is equal to the LS coefficient at the 1 percent significance level for both samples. Hence, also the within-country evidence suggests that least squares estimation leads to an understatement of the causal effect that GDP per capita volatility has on government size.

5.3.2 Cross-Country Estimates

In this section we present instrumental variables estimates from cross-sectional regressions that use averages over the entire 1950-2009 period. Cross-sectional estimation leads to a substantial reduction in the number of observations as there are only 78 countries in the data set with below median temperatures. Nevertheless, results from this analysis may still be of interest as cross-sectional regressions over long time periods capture long-run relationships.

Table 7 shows the results from instrumental variables regressions that are based on cross-sectional data averages for the entire 1950-2009 period. The cross-sectional regressions control for continent fixed effects and geographic variables that are specific to each country such as country area, latitude and longitude, and whether the country is landlocked, as well as temperature and rainfall level controls. In columns (1)-(3) we present cross-sectional estimates for the group of countries in the top 25th temperature percentile. In columns (4)-(6) we present cross-sectional estimates for the group of countries in the top 50th temperature percentile. We exclude observations that are identified by the Hadi (1992) procedure as outliers at the 5 percent level. In the top panel of Table 7 we report the estimated second-stage coefficients that capture the average marginal effects of cross-country changes in GDP per capita volatility on the GDP share of government consumption expenditures. In the bottom panel we report the first-stage coefficients that capture the average marginal effects of cross-country changes in rainfall volatility on GDP per capita volatility.

The main finding from the cross-sectional instrumental variables regressions is that there is a significant positive cross-country effect of GDP per capita volatility on government size. For the group of countries in the top 25th temperature percentile the second-stage coefficient on GDP per capita volatility is around 1.6 and significantly different from zero at the 1 percent significance level (see columns (1) and (2) of Table 7). For the group of countries in the top 50th temperature percentile the second-stage coefficient on GDP per capita volatility is around 1.4 and also significantly different from zero at the conventional significance levels (see columns (4) and (5) of Table 7).

The LS coefficients in the cross-sectional regressions are significantly smaller than the IV coefficients. Column (3) of Table 7 shows that the LS coefficient on GDP per capita volatility is around 0.5 and significantly different from zero at the 5 percent level for the sample of countries in the top 25th temperature percentile. Column (6) of Table 7 shows that the LS coefficient on GDP per capita volatility is also around 0.5 and significantly different from zero at the 5 percent level for the sample of countries in the top 50th temperature percentile. The Hausman test rejects the hypothesis that the IV coefficient is equal to the LS coefficient at the 1 (10) percent significance level for the group of countries in the top 25th (50th) temperature percentile. Hence, the cross-country evidence also suggests that least squares estimation leads to an understatement of the causal effect that GDP per capita volatility has on government size.

In Figures 2 and 3 we illustrate graphically the reduced-form and first-stage regression underlying the two-stage least squares estimation in the sample of countries in the top 50th temperature percentile (i.e. column (4) of Table 7). The figures show scatter plots of the residual relationships by conditioning on the same set of control variables as in Table 7. As can be seen from Figure 2, the reduced-form relationship between rainfall volatility and the GDP share of government consumption expenditures is significantly positive and robust to the exclusion of countries that according to the Hadi (1992) procedure are identified as outliers at the 5 percent level. Figure 3 shows that this is also the case for the first-stage relationship between rainfall volatility and GDP per capita volatility.

5.3.3 Other Types of Government Expenditures

An ideal measure for a risk mitigating portion of government spending would be income transfers programs, specifically welfare and social security. However, especially since our focus is on developing countries, the relevant proxies are not useful, for the following reasons. First, data on such scarcely exist; second, they are not reliable, because much of economic activity goes unreported (see e.g., Ahmed et al., 1991); third, in most developing countries, governments tend to rely on public employment, inkind transfers, and public-works programs as the means to broaden safety nets -- all of which show up in government consumption expenditures (Rodrik, 1998). For these reasons, the use of government consumption expenditures as the main measure for government size may well be more advantageous for our purposes; indeed, the measure has been commonly employed in the relevant literature. In this section, we consider additional and more disaggregated types of government spending that may have an effect on the social safety net. These results are meant to supplement those obtained for our main measure of interest, government consumption.

In Table 8 we report instrumental variables estimates of the effects that GDP per capita volatility has on other types of government spending, such as public gross fixed capital formation, public education expenditures, and public health expenditures. We obtain data on these types of government expenditures from the WDI (2011). Time-series observations for these government expenditure items are very sparse for the group of high temperature countries where our instrument produces a significant first-stage fit with GDP per capita volatility. Hence, we present here estimates from cross-section regressions that relate, as in

Section 5.3.2, countries' sample average government expenditure GDP shares to their GDP per capita volatilities. As in the previous tables columns (1)-(3) show results for the group of countries in the top 25th temperature percentile, and columns (4)-(6) show estimates for the group of counties in the top 50th temperature percentile.

The instrumental variables estimates in Panel A of Table 8 show that there is also a significant positive effect of GDP per capita volatility on government size in the cross-section of countries when using as dependent variable the GDP shares of public gross fixed capital formation, public education expenditures, and public health expenditures. For the GDP share of public gross fixed capital formation the second-stage coefficient (standard error) on GDP per capita volatility is around 1.0 (0.6) in column (1) and around 1.3 (0.7) in column (4); we can reject the hypothesis that these coefficients are equal to zero at the 10 and 5 percent level, respectively. For the GDP share of public education expenditures the second-stage coefficient (standard error) on GDP per capita volatility is around 0.5 (0.1) in column (2) and around 0.4 (0.2) in column (5); we can reject the hypothesis that these coefficients are equal to zero at the 1 and 5 percent level, respectively. For the GDP share of public health expenditures the second-stage coefficient (standard error) on GDP per capita volatility is around 0.2 (0.1) in column (3) and around 0.4 (0.1) in column (6); for both of these coefficients can we reject the hypothesis that they are equal to zero at the 1 percent level.

It is noteworthy that the LS coefficients are positive and significantly different from zero for the majority of regressions (see Panel B of Table 8). However, the LS coefficients are smaller than the IV coefficients. The Hausman test rejects for the majority of specifications the hypothesis that the LS coefficient is equal to the IV coefficient. We conclude that the LS estimation leads to an understatement of the effect of GDP per capita volatility also when using the GDP shares of public gross fixed capital formation, public education expenditures, or public health expenditures as alternative measures of government size.

5.3.4 Effects in Sub-Saharan Africa

In Table 9 we explore whether the instrumental variables estimates of the effects that GDP per capita volatility has on government size are different for sub-Saharan African countries. A number of recent studies have argued that poor sub-Saharan African countries are especially vulnerable to adverse climatic conditions (e.g. Barrios et al., 2010; Dell et al., 2012). Sub-Saharan Africa also differs from other developing regions in a number of other aspects that might lead to a differential response of government size to GDP per capita volatility. For example, the majority of sub-Saharan African countries are characterized by very high levels of ethnic diversity which have been linked to poor policy choices and low economic growth (see e.g. Easterly and Levine, 1997).

The instrumental variables estimates in Table 9 show that there is no evidence of a significant different effect of GDP per capita volatility on government size in sub-Saharan African countries. In column (1) of Table 9 we report second-stage estimates for the group of countries in the top 25th temperature percentile from an interaction model that includes in addition to GDP per capita volatility an interaction term between GDP per capita volatility and an indicator variable that is unity for sub-Saharan African countries. The instruments are rainfall volatility and rainfall volatility interacted with the sub-Saharan African indicator variable. The second-stage coefficient on GDP per capita volatility is positive and significantly different from zero at the 5 percent level. On the other hand, the interaction term is insignificant. This suggests that the second-stage effects of GDP per capita volatility on government size are not significantly different in sub-Saharan African countries. In terms of instrument relevance, we note that according to the tabulations in Stock and Yogo (2005), for the case of two instruments and two endogenous regressors, the Kleibergen Paap F-statistic of 7.07 allows us to reject the hypothesis that the IV size distortion is larger than 10 percent (the most stringent criteria) at the 5 percent significance level. In column (4) of Table 9 we repeat the analysis from the interaction model for the group of countries in the top 50th temperature percentile and find similar second-stage results. In terms of instrument relevance, the Kleibergen Paap F-statistic is 4.60; according to Stock and Yogo (2005) we can therefore reject the hypothesis that the IV size distortion is larger than 15 percent (the second most stringent criteria) at the 5 percent significance level.

An alternative approach to examining whether the effects of GDP per capita volatility on government size are different for sub-Saharan African countries is to split the sample. The disadvantage of this approach is that it is associated with a loss of statistical power due to the smaller number of observations in each sub-sample. Nevertheless, the estimated second-stage coefficient on GDP per capita volatility for the sub-sample of sub-Saharan African countries in the top 25th temperature percentile is around 2.8 and significant at the 5 percent level (column (2)). For the sub-sample of countries outside of sub-Saharan Africa in the top 25th temperature percentile the second-stage coefficient is around 2.9 and significant at the 5 percent level (column (3)). Moving to the top 50th temperature percentile shows that the second-stage coefficient on GDP per capita volatility is around 2.0 for both sub-Saharan African countries as well as for countries outside sub-Saharan African.

We conclude from Table 9 that there is no evidence of a significant difference in the effects that GDP per capita volatility has on government size between relatively warm (and poor) sub-Saharan African countries and other such countries located outside of sub-Saharan Africa.

6. Conclusions

This paper explored the effects of exogenous economic volatility on the size of government. A main novelty relative to existing empirical work was the use of rainfall volatility as an instrument for GDP per capita volatility. This enabled a cleaner identification of the causal effect of GDP per capita volatility on government size as a consequence of the plausible exogeneity of rainfall volatility to countries' politico-economic conditions.

The first-stage and reduced-form analysis showed that greater rainfall volatility leads to significantly larger government size and GDP per capita volatility in countries with above median temperatures. In contrast, in countries with below median temperatures, rainfall volatility has no significant effects on GDP per capita volatility. Given that countries with more temperate climates are on average more industrialized than warmer countries, where due to underdevelopment the agricultural sector is relatively large, the insignificant effect of rainfall volatility on GDP per capita volatility is not surprising. However, and importantly, rainfall volatility has no significant effects on government size in the group of countries with colder climates, which is consistent with the underlying assumption (exclusion restriction) in the instrumental variables estimation that rainfall volatility only affects government size through its effect on GDP per capita volatility.

The instrumental variables estimates showed that greater economic volatility causes a larger GDP share of government consumption expenditures. An important implication of these findings for the literature examining the effects of government size on economic volatility in developing countries is that failure to account for a causal effect of the latter on the former will lead to an understatement of the true stabilizing effect of government size.

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Table 1. GDP Volatility and the Size of Government
(Least Squares Estimates)

	GDP Share of Government Consumption Expenditures					
	(1)	(2)	(3)	(4)	(5)	(6)
						Excl. Outliers
GDP p.c. Volatility	0.255*** (0.084)	0.238*** (0.083)	0.197*** (0.076)	0.191** (0.076)	0.190*** (0.071)	0.228*** (0.086)
Year FE	No	Yes	Yes	Yes	Yes	Yes
Continent FE	No	No	Yes	Yes	Yes	Yes
Year-Continent FE	No	No	No	Yes	Yes	Yes
Geography Controls	No	No	No	No	Yes	Yes
Observations	6899	6899	6899	6899	6899	6554

Note: The method of estimation is least squares. The dependent variable is the GDP share of government consumption expenditures. Huber robust standard errors (in parentheses) are multi-clustered at the country and year level. The geography control variables are latitude, longitude, the log of country area, and an indicator variable that is unity for countries without sea access. Column (6) excludes observations that according to the Hadi (1992) procedure are identified as outliers at the 5 percent level. *Significantly different from zero at the 10 percent significance level, ** 5 percent significance level, *** 1 percent significance level.

Table 2. Temperature and Economic Development

	(1)	(2)	(3)	(4)	(5)	(6)
	1950-2009 Average	1970	1980	1990	2000	2009
	Panel A: Log PPP GDP per capita					
Temperature	-0.049***	-0.055**	-0.058***	-0.043***	-0.033***	-0.037***
	(0.009)	(0.012)	(0.011)	(0.011)	(0.012)	(0.012)
Observations	157	130	130	144	157	157
	Panel B: GDP Share of Agricultural Value Added					
Temperature	0.520***	0.663**	0.757***	0.505***	0.441***	0.443***
	(0.146)	(0.262)	(0.213)	(0.178)	(0.151)	(0.145)
Observations	131	79	95	117	131	131
	Control Variables in Panels A and B					
Continent FE	Yes	Yes	Yes	Yes	Yes	Yes
Geography Controls	Yes	Yes	Yes	Yes	Yes	Yes

Note: The method of estimation is least squares. The dependent variable in Panel A is the log of PPP GDP per capita; Panel B the GDP share of agricultural value added. Huber robust standard errors are shown in parentheses. The geography control variables are latitude, longitude, the log of country area, and an indicator variable that is unity for countries without sea access. *Significantly different from zero at the 10 percent significance level, ** 5 percent significance level, *** 1 percent significance level.

Table 3. Rainfall Volatility and GDP Volatility

	GDP p.c. Volatility			
	(1)	(2)	(3)	(4)
	Bottom 25th Temp. Percentile	Bottom 50th Temp. Percentile	Top 50th Temp. Percentile	Top 25th Temp. Percentile
		Panel A: All Observations		
Rainfall Volatility	-0.017	-0.053	0.066**	0.107***
	(0.053)	(0.041)	(0.026)	(0.032)
Observations	1836	3470	3429	1812
		Panel B: Excluding Outliers		
Rainfall Volatility	-0.013	-0.013	0.075***	0.099***
	(0.055)	(0.033)	(0.023)	(0.028)
Observations	1705	3242	3312	1762
		Control Variables in Panels A and B		
Year-Continent FE	Yes	Yes	Yes	Yes
Geography Controls	Yes	Yes	Yes	Yes
Temp. and Rainfall Level Controls	Yes	Yes	Yes	Yes
Temperature Volatility Control	Yes	Yes	Yes	Yes

Note: The method of estimation is least squares. The dependent variable is the volatility of real GDP per capita. In column (1) the estimates are for the group of countries with temperatures below the bottom 25th percentile; columns (2), (3), and (4) below the bottom 50th percentile, above the top 50th percentile, and above the top 25th percentile, respectively. GDP per capita volatility is measured as the 10-year standard deviation of GDP per capita growth. Rainfall volatility is measured as the 10-year standard deviation of rainfall growth. Huber robust standard errors (in parentheses) are multi-clustered at the country and year level. Panel B excludes observations that according to the Hadi (1992) procedure are identified as outliers at the 5 percent level. The geography control variables are latitude, longitude, the log of country area, and an indicator variable that is unity for countries without sea access. *Significantly different from zero at the 10 percent significance level, ** 5 percent significance level, *** 1 percent significance level.

Table 4. Rainfall Volatility and the Size of Government

GDP Share of Government Consumption Expenditures				
	(1)	(2)	(3)	(4)
	Bottom 25th Temp. Percentile	Bottom 50th Temp. Percentile	Top 50th Temp. Percentile	Top 25th Temp. Percentile
	Panel A: All Observations			
Rainfall Volatility	0.004	-0.107	0.237***	0.245***
	(0.052)	(0.066)	(0.066)	(0.042)
Observations	1836	3470	3429	1812
	Panel B: Excluding Outliers			
Rainfall Volatility	-0.014	-0.093	0.239***	0.255***
	(0.047)	(0.061)	(0.067)	(0.046)
Observations	1705	3242	3312	1762
	Control Variables in Panels A and B			
Year-Continent FE	Yes	Yes	Yes	Yes
Geography Controls	Yes	Yes	Yes	Yes
Temp. and Rainfall Level Controls	Yes	Yes	Yes	Yes
Temperature Volatility Control	Yes	Yes	Yes	Yes

Note: The method of estimation is least squares. The dependent variable is the GDP share of government consumption expenditures. In column (1) the estimates are for the group of countries with temperatures below the bottom 25th percentile; columns (2), (3), and (4) below the bottom 50th percentile, above the top 50th percentile, and above the top 25th percentile, respectively. Rainfall volatility is measured as the 10-year standard deviation of rainfall growth. Huber robust standard errors (in parentheses) are multi-clustered at the country and year level. Panel B excludes observations that according to the Hadi (1992) procedure are identified as outliers at the 5 percent level. The geography control variables are latitude, longitude, the log of country area, and an indicator variable that is unity for countries without sea access. *Significantly different from zero at the 10 percent significance level, ** 5 percent significance level, *** 1 percent significance level.

Table 5: GDP Volatility and Government Size
(Baseline Instrumental Variables Estimates)

	GDP Share of Government Consumption Expenditures					
	(1)	(2)	(3)	(4)	(5)	(6)
	2SLS	2SLS	LS	2SLS	2SLS	LS
				Excluding Outliers	Excluding Outliers	Excluding Outliers
	Panel A: Top 25th Temperature Percentile					
GDP p.c. Volatility	1.976** (0.773)	1.974*** (0.769)	0.117 (0.092)	2.200*** (0.774)	2.211*** (0.764)	0.159 (0.107)
Endog Test, p-value	0.004	0.004		0.004	0.003	
	First Stage GDP p.c. Volatility					
Rainfall Volatility	0.107*** (0.033)			0.099*** (0.028)		
Rainfall Volatility* Temperature		0.004*** (0.001)			0.004*** (0.001)	
Kleibergen Paap F-Stat	10.715	10.939		12.697	13.267	
Observations	1812	1812	1812	1762	1762	1762
	Panel B: Top 50th Temperature Percentile					
GDP p.c. Volatility	2.621* (1.398)	2.590** (1.302)	0.090 (0.087)	2.374** (1.052)	2.381** (0.999)	0.180* (0.097)
Endog Test, p-value	0.010	0.007		0.009	0.007	
	First Stage GDP p.c. Volatility					
Rainfall Volatility	0.066** (0.026)			0.075*** (0.023)		
Rainfall Volatility* Temperature		0.003*** (0.001)			0.003*** (0.001)	
Kleibergen Paap F-Stat	6.450	7.277		10.012	10.811	
Observations	3429	3429	3429	3312	3312	3312
	Control Variables in Panels A and B					
Year-Continent FE	Yes	Yes	Yes	Yes	Yes	Yes
Geography Controls	Yes	Yes	Yes	Yes	Yes	Yes
Temp. and Rainfall Level Controls	Yes	Yes	Yes	Yes	Yes	Yes
Temp. Volatility Control	Yes	Yes	Yes	Yes	Yes	Yes

Note: The dependent variable is the GDP share of government consumption expenditures. The method of estimation in columns (1), (2), (4) and (5) is two-stage least squares; columns (3) and (6) least squares. Huber robust standard errors (shown in parentheses) are multi-clustered at the country and year level. Panel A reports estimates for the group of countries with temperatures above the top 25th percentile; Panel B reports estimates for the group of countries with temperatures above the top 50th percentile. Columns (4)-(6) exclude observations that according to the Hadi (1992) procedure are identified as outliers at the 5 percent level. The geography control variables are latitude, longitude, the log of country area, and an indicator variable that is unity for countries without sea access. *Significantly different from zero at the 10 percent significance level, ** 5 percent significance level, *** 1 percent significance level.

Table 6: GDP Volatility and Government Size
(Robustness Country Fixed Effects)

	GDP Share of Government Consumption Expenditures					
	(1)	(2)	(3)	(4)	(5)	(6)
	2SLS	2SLS	LS	2SLS	2SLS	LS
	Excluding Outliers	Excluding Outliers	Excluding Outliers	Excluding Outliers	Excluding Outliers	Excluding Outliers
	Top 25th Temperature Percentile			Top 50th Temperature Percentile		
GDP p.c. Volatility	1.736*** (0.434)	1.766*** (0.472)	-0.029* (0.016)	2.709*** (0.794)	2.989*** (0.963)	0.002 (0.012)
Endog Test, p-value	0.000	0.000		0.000	0.000	
	First Stage GDP p.c. Volatility					
Rainfall Volatility	0.062*** (0.012)			0.036*** (0.010)		
Rainfall Volatility* Temperature		0.002*** (0.0005)			0.001*** (0.0003)	
Kleibergen Paap F-Stat	26.361	22.651		13.808	10.979	
Observations	1762	1762	1762	3312	3312	3312
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Continent-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Temp. and Rain Level Controls	Yes	Yes	Yes	Yes	Yes	Yes
Temp. Volatility Control	Yes	Yes	Yes	Yes	Yes	Yes

Note: The dependent variable is the GDP share of government consumption expenditures. The method of estimation in columns (1), (2), (4) and (5) is two-stage least squares; columns (3) and (6) least squares. Huber robust standard errors (shown in parentheses) are multi-clustered at the country and year level. Columns (1)-(3) report estimates for the group of countries with temperatures above the top 25th percentile; columns (4)-(6) report estimates for the group of countries with temperatures above the top 50th percentile. Observations that according to the Hadi (1992) procedure are identified as outliers at the 5 percent level are excluded from the regression. *Significantly different from zero at the 10 percent significance level, ** 5 percent significance level, *** 1 percent significance level.

Table 7: GDP Volatility and Government Size
(Robustness Cross Section Regression)

	GDP Share of Government Consumption Expenditures					
	(1)	(2)	(3)	(4)	(5)	(6)
	2SLS	2SLS	LS	2SLS	2SLS	LS
	Excluding Outliers	Excluding Outliers	Excluding Outliers	Excluding Outliers	Excluding Outliers	Excluding Outliers
	Top 25th Temperature Percentile			Top 50th Temperature Percentile		
GDP p.c. Volatility	1.559*** (0.577)	1.590*** (0.555)	0.534** (0.221)	1.355*** (0.763)	1.379** (0.692)	0.545** (0.270)
Endog Test, p-value	0.009	0.007		0.109	0.079	
	First Stage GDP p.c. Volatility					
Rainfall Volatility	0.157*** (0.042)			0.150*** (0.038)		
Rainfall Volatility* Temperature		0.006*** (0.002)			0.006*** (0.001)	
Kleibergen Paap F-Stat	14.133	14.981		15.577	18.889	
Observations	37	37	37	74	74	74
Continent FE	Yes	Yes	Yes	Yes	Yes	Yes
Geography Controls	Yes	Yes	Yes	Yes	Yes	Yes
Temp. and Rain Level Controls	Yes	Yes	Yes	Yes	Yes	Yes
Temp. Volatility Control	Yes	Yes	Yes	Yes	Yes	Yes

Note: The dependent variable is the GDP share of government consumption expenditures. The method of estimation in columns (1), (2), (4) and (5) is two-stage least squares; columns (3) and (6) least squares. Huber robust standard errors are listed in parentheses. Columns (1)-(3) report estimates for the group of countries with temperatures above the top 25th percentile; columns (4)-(6) report estimates for the group of countries with temperatures above the top 50th percentile. Observations that according to the Hadi (1992) procedure are identified as outliers at the 5 percent level are excluded from the regression. *Significantly different from zero at the 10 percent significance level, ** 5 percent significance level, *** 1 percent significance level.

Table 8: GDP Volatility and Government Size
(Robustness Other Types of Government Expenditures)

GDP Share of Expenditures:	Public Capital	Public Education	Public Health	Public Capital	Public Education	Public Health
	(1)	(2)	(3)	(4)	(5)	(6)
	Excluding Outliers	Excluding Outliers	Excluding Outliers	Excluding Outliers	Excluding Outliers	Excluding Outliers
	Top 25th Temperature Percentile			Top 50th Temperature Percentile		
	Panel A: 2SLS					
GDP p.c. Volatility	1.035*	0.465***	0.222***	1.294**	0.368**	0.376***
	(0.640)	(0.139)	(0.061)	(0.660)	(0.185)	(0.135)
Endog Test, p-value	0.206	0.055	0.088	0.037	0.159	0.012
	First Stage GDP p.c. Volatility					
Rainfall Volatility	0.186***	0.202***	0.202***	0.149***	0.145***	0.145***
	(0.055)	(0.053)	(0.053)	(0.047)	(0.041)	(0.041)
Kleibergen Paap F-Stat	11.549	14.517	14.517	9.984	12.667	12.667
	Panel B: LS					
GDP p.c. Volatility	0.395**	0.203**	0.107**	0.248	0.125*	0.128***
	(0.167)	(0.084)	(0.044)	(0.177)	(0.076)	(0.048)
	Control Variables in Panels A and B					
Continent FE	Yes	Yes	Yes	Yes	Yes	Yes
Geography Controls	Yes	Yes	Yes	Yes	Yes	Yes
Temp. and Rain Level Controls	Yes	Yes	Yes	Yes	Yes	Yes
Temp. Volatility Control	Yes	Yes	Yes	Yes	Yes	Yes
Observations	30	34	34	60	68	68

Note: The dependent variable in columns (1) and (4) is the GDP share of public gross fixed capital formation; columns (2) and (5) the GDP share of public education expenditures; columns (3) and (6) the GDP share of public health expenditures. The method of estimation in Panel A is two-stage least squares; Panel B least squares. Huber robust standard errors are listed in parentheses. Columns (1)-(3) report estimates for the group of countries with temperatures above the top 25th percentile; columns (4)-(6) report estimates for the group of countries with temperatures above the top 50th percentile. Observations that according to the Hadi (1992) procedure are identified as outliers at the 5 percent level are excluded from the regression. *Significantly different from zero at the 10 percent significance level, ** 5 percent significance level, *** 1 percent significance level.

Table 9: GDP Volatility and Government Size
(Robustness Sub-Saharan Africa vs. Other Regions)

	GDP Share of Government Consumption Expenditures					
	(1)	(2)	(3)	(4)	(5)	(6)
	2SLS	2SLS	2SLS	2SLS	2SLS	2SLS
		SSA Only	Excluding SSA		SSA Only	Excluding SSA
	Excluding Outliers	Excluding Outliers	Excluding Outliers	Excluding Outliers	Excluding Outliers	Excluding Outliers
	Top 25th Temperature Percentile			Top 50th Temperature Percentile		
GDP p.c. Volatility	2.540**	2.795**	2.863**	2.444**	1.986*	1.992
	(0.979)	(1.294)	(1.361)	(1.060)	(1.058)	(1.58)
GDP p.c. Volatility* SSA Indicator	-0.720			-0.429		
	(1.063)			(0.822)		
Endog Test, p-value	0.014	0.030	0.015	0.051	0.089	0.165
Kleibergen Paap F-Statistic	7.072	4.891	4.950	4.601	5.108	3.438
Year-Continent FE	Yes	Yes	Yes	Yes	Yes	Yes
Geography Controls	Yes	Yes	Yes	Yes	Yes	Yes
Temp. and Rainfall Level Controls	Yes	Yes	Yes	Yes	Yes	Yes
Temp. Volatility Control	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1762	819	943	3312	1429	1883

Note: The dependent variable is the GDP share of government consumption expenditures. The method of estimation is two-stage least squares. The instrumental variables in columns (1) and (3) are rainfall volatility and the interaction between rainfall volatility and an indicator variable that is unity for sub-Saharan African countries. The instrumental variable in columns (2), (3), (5), and (6) is rainfall volatility. Columns (1)-(3) report estimates for the group of countries with temperatures above the top 25th percentile; columns (4)-(6) report estimates for the group of countries with temperatures above the top 50th percentile. Columns (2) and (5) report estimates for sub-Saharan African countries. Columns (3) and (6) report estimates for countries outside sub-Saharan Africa. Observations that according to the Hadi (1992) procedure are identified as outliers at the 5 percent level are excluded from all regressions. Huber robust standard errors (shown in parentheses) are multi-clustered at the country and year level. *Significantly different from zero at the 10 percent significance level, ** 5 percent significance level, *** 1 percent significance level.

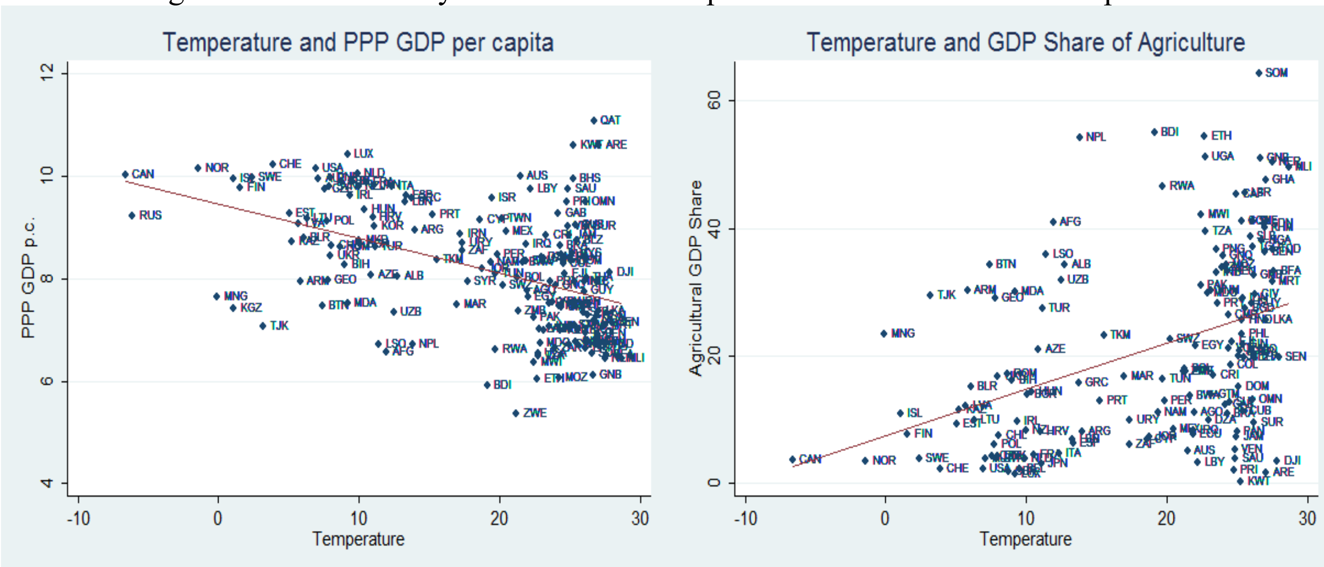
Appendix Table 1A. List of Countries

Country	Rain Volatility	Government Size	GDP Volatility	Country	Rain Volatility	Government Size	GDP Volatility
Afghanistan	0.22	0.09	0.15	Kyrgyzstan	0.25	0.13	0.08
Albania	0.19	0.08	0.06	Laos	0.11	0.17	0.04
Algeria	0.34	0.12	0.09	Latvia	0.18	0.13	0.03
Angola	0.13	0.33	0.09	Lebanon	0.18	0.12	0.28
Argentina	0.14	0.09	0.05	Lesotho	0.23	0.05	0.07
Armenia	0.25	0.08	0.03	Liberia	0.13	0.07	0.25
Australia	0.23	0.10	0.02	Libya	0.44	0.17	0.12
Austria	0.14	0.10	0.02	Lithuania	0.20	0.09	0.06
Azerbaijan	0.24	0.08	0.13	Luxembourg	0.27	0.07	0.04
Bahamas	0.22	0.10	0.07	Macedonia	0.22	0.13	0.03
Bangladesh	0.18	0.02	0.04	Madagascar	0.19	0.08	0.05
Belarus	0.19	0.10	0.06	Malawi	0.23	0.10	0.11
Belgium	0.22	0.11	0.02	Malaysia	0.11	0.05	0.05
Belize	0.17	0.16	0.05	Mali	0.15	0.11	0.07
Benin	0.18	0.10	0.05	Mauritania	0.31	0.21	0.09
Bhutan	0.18	0.17	0.07	Mexico	0.21	0.03	0.04
Bolivia	0.09	0.07	0.05	Moldova	0.25	0.08	0.10
Bosnia&Herz.	0.19	0.09	0.15	Mongolia	0.23	0.16	0.08
Botswana	0.32	0.10	0.09	Morocco	0.30	0.04	0.06
Brazil	0.09	0.10	0.04	Mozambique	0.19	0.07	0.05
Bulgaria	0.19	0.09	0.05	Namibia	0.42	0.07	0.05
Burkina Faso	0.13	0.14	0.06	Nepal	0.13	0.09	0.03
Burundi	0.13	0.18	0.07	Netherlands	0.22	0.17	0.02
Cambodia	0.16	0.06	0.08	New Zealand	0.16	0.09	0.03
Cameroon	0.10	0.06	0.06	Nicaragua	0.16	0.19	0.10
Canada	0.07	0.10	0.02	Niger	0.25	0.15	0.07
Central Afr. Rep.	0.08	0.19	0.04	Nigeria	0.10	0.02	0.08
Chad	0.19	0.51	0.09	Norway	0.15	0.08	0.02
Chile	0.14	0.07	0.06	Oman	0.55	0.07	0.09
Colombia	0.07	0.04	0.03	Pakistan	0.31	0.09	0.03
Comoros	0.35	0.33	0.05	Panama	0.15	0.19	0.05
Congo, Dem. Rep.	0.06	0.05	0.12	Papua New Guinea	0.15	0.22	0.08
Congo, Rep. of	0.10	0.11	0.07	Paraguay	0.18	0.05	0.04
Costa Rica	0.10	0.18	0.04	Peru	0.07	0.05	0.06
Cote d'Ivoire	0.17	0.07	0.05	Philippines	0.16	0.05	0.04
Croatia	0.16	0.10	0.09	Poland	0.22	0.09	0.05
Cuba	0.31	0.26	0.06	Portugal	0.28	0.05	0.04
Cyprus	0.30	0.10	0.08	Puerto Rico	0.21	0.09	0.04
Czech Republic	0.18	0.14	0.05	Qatar	0.98	0.15	0.08
Denmark	0.23	0.10	0.02	Romania	0.21	0.09	0.06
Djibouti	0.58	0.29	0.15	Russia	0.07	0.11	0.09
Dominican Rep.	0.22	0.09	0.05	Rwanda	0.14	0.32	0.14
Ecuador	0.15	0.07	0.04	Sao Tome and Principe	0.22	0.25	0.07
Egypt	0.47	0.10	0.04	Saudi Arabia	0.30	0.08	0.06
El Salvador	0.18	0.11	0.03	Senegal	0.17	0.07	0.05
Equatorial Guinea	0.13	0.16	0.19	Sierra Leone	0.08	0.05	0.07
Eritrea	0.25	0.43	0.09	Slovenia	0.14	0.07	0.05
Estonia	0.18	0.12	0.09	Solomon Islands	0.18	0.32	0.08
Ethiopia	0.10	0.07	0.06	Somalia	0.41	0.14	0.08
Fiji	0.20	0.11	0.06	South Africa	0.21	0.05	0.03
Finland	0.16	0.10	0.03	Spain	0.20	0.07	0.04
France	0.16	0.11	0.02	Sri Lanka	0.16	0.09	0.04
Gabon	0.12	0.04	0.09	Sudan	0.15	0.10	0.1
Gambia, The	0.25	0.18	0.07	Suriname	0.18	0.25	0.1
Georgia	0.17	0.08	0.09	Swaziland	0.27	0.08	0.08
Ghana	0.17	0.12	0.12	Sweden	0.15	0.11	0.02
Greece	0.17	0.09	0.04	Switzerland	0.21	0.05	0.03
Guatemala	0.10	0.10	0.03	Syria	0.35	0.09	0.09
Guinea	0.09	0.10	0.04	Taiwan	0.22	0.19	0.03
Guinea-Bissau	0.17	0.13	0.15	Tajikistan	0.24	0.12	0.13
Guyana	0.16	0.15	0.11	Tanzania	0.19	0.07	0.04
Haiti	0.24	0.17	0.05	Thailand	0.12	0.07	0.05
Honduras	0.19	0.17	0.05	Togo	0.18	0.10	0.07
Hungary	0.22	0.12	0.03	Tunisia	0.38	0.04	0.05
Iceland	0.20	0.08	0.05	Turkey	0.14	0.05	0.05
India	0.13	0.10	0.03	Turkmenistan	0.25	0.13	0.11
Indonesia	0.17	0.08	0.05	Uganda	0.16	0.14	0.05
Iran	0.22	0.12	0.09	Ukraine	0.18	0.08	0.10
Iraq	0.34	0.14	0.26	United Arab Emirates	0.50	0.07	0.05
Ireland	0.14	0.07	0.03	United Kingdom	0.14	0.10	0.02
Israel	0.35	0.16	0.05	United States	0.09	0.10	0.02
Italy	0.19	0.10	0.02	Uruguay	0.27	0.06	0.06
Jamaica	0.22	0.13	0.04	Uzbekistan	0.27	0.23	0.06
Japan	0.13	0.11	0.03	Vanuatu	0.25	0.29	0.08
Jordan	0.48	0.10	0.10	Venezuela	0.09	0.05	0.06
Kazakhstan	0.19	0.07	0.08	Vietnam	0.15	0.11	0.04
Kenya	0.30	0.04	0.04	Yemen	0.33	0.09	0.06
Korea, Republic of	0.24	0.10	0.04	Zambia	0.15	0.15	0.09
Kuwait	0.75	0.10	0.13				

Appendix Table 1B. Summary Statistics

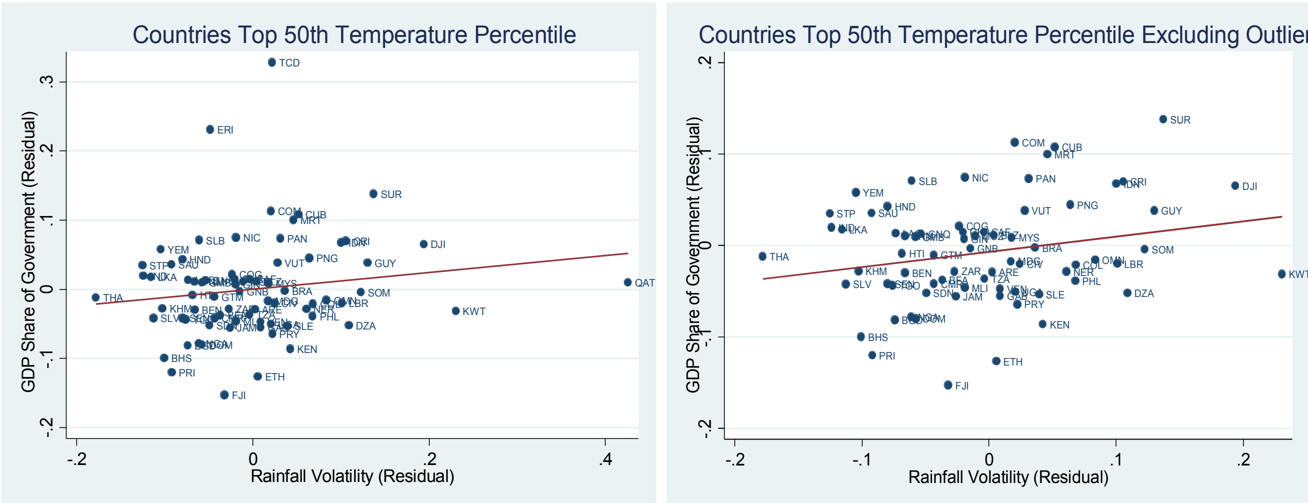
	Mean	Overall Stdv.	Between Stdv.	Within Stdv.	Observations
Rainfall Volatility	0.205	0.123	0.121	0.058	6899
GDP per capita Volatility	0.055	0.047	0.036	0.033	6899
GDP Share of Government Consumption	0.113	0.078	0.073	0.033	6899

Figure 1. Cross-Country Differences in Temperature and Economic Development



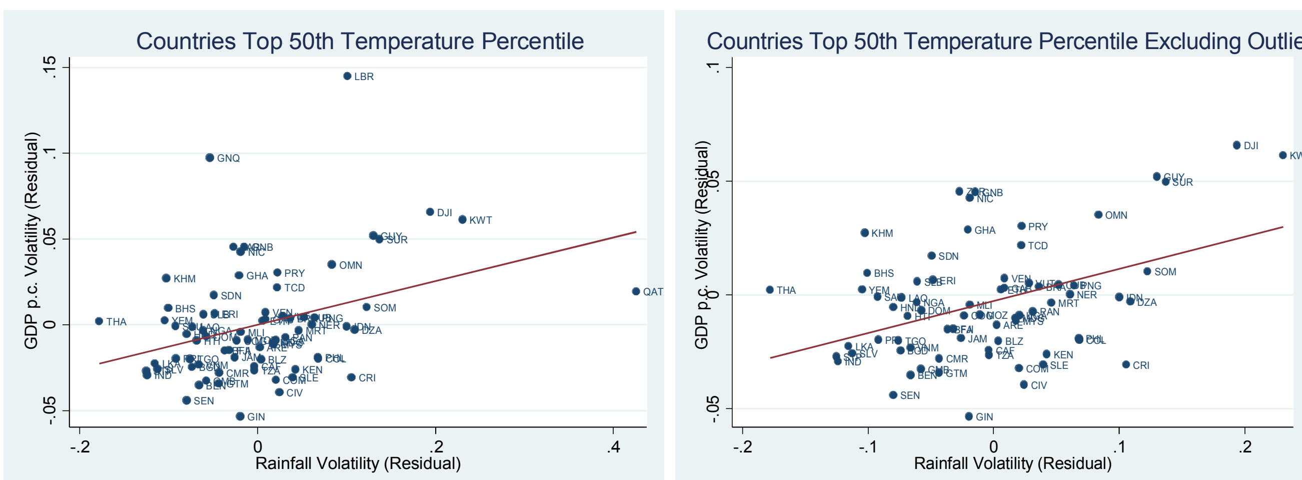
Note: The left-hand figure shows a cross-country scatter plot of the relationship between temperature and the log of PPP GDP per capita. The right-hand figure shows a cross-country scatter plot of the relationship between temperature and the agricultural GDP share. All variables are calculated as an average over the 1950-2009 period.

Figure 2. Rainfall Volatility and Government Size



Note: The figure shows a scatter plot of the (residual) relationship between government size and rainfall volatility (both calculated over the 1950-2009 period). The residuals are generated using as right-hand-side controls continent fixed effects, latitude, longitude, the log of country area, an indicator variable that is unity for countries without sea access, the level of temperature, the level of rainfall, and the volatility of temperature. The left-hand side figure shows this relationship for the sample of countries in the top 50th temperature percentile; the right-hand side figure shows this relationship for the sample of countries in the top 50th temperature percentile excluding observations that according to the Hadi (1992) procedure are identified as outliers at the 5 percent level.

Figure 3. Rainfall Volatility and GDP Volatility



Note: The figure shows a scatter plot of the (residual) relationship between GDP per capita volatility and rainfall volatility (both calculated over the 1950-2009 period). The residuals are generated using as right-hand-side controls continent fixed effects, latitude, longitude, the log of country area, an indicator variable that is unity for countries without sea access, the level of temperature, the level of rainfall, and the volatility of temperature. The left-hand side figure shows this relationship for the sample of countries in the top 50th temperature percentile; the right-hand side figure shows this relationship for the sample of countries in the top 50th temperature percentile excluding observations that according to the Hadi (1992) procedure are identified as outliers at the 5 percent level.