Climate Change and State-Building in the World's Most Agricultural Countries.*

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Abstract

While the short run negative effects of adverse climate shocks on economic outcomes are well-known, their long run institutional impact is still poorly understood. To clarify this issue, we test the idea that adverse climate conditions push elites unable to commit to future transfers to grant more inclusive political institutions to nonelites endowed with complementary inputs. These reforms convince the nonelites that a sufficient part of the returns on joint elite-nonelite investments will be shared via public good provision and, thus, to cooperate. Consistent with these predictions, data on a panel of 38 most agricultural countries observed over the 1960-2018 period entail that the severity of droughts has a negative and short run direct effect on agricultural output, whereas its institutional impact is positive and persistent. Moreover, reforms towards more inclusive political institutions shift the allocation of tax revenues from military to education expenditures and, thus, exert a positive and delayed impact on agricultural output. These results suggest that policymakers should: (a) consider short and long run effects of climate change; (b) calibrate climate-related policies according to the degree of complementarity of group-specific input/skills; (c) avoid the mechanical transplantation of strong nonelites' political rights in all developing countries.
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1 Introduction

Overwhelming evidence implies that the short run effects of adverse climate shocks on economic outcomes are negative and sizable (Nordhaus, 2019). Yet, our understanding of their long run institutional impact is limited (Contreras, 2016), and it is still confined to the correlations between fiercer climatic conditions and both social unrest and institutional decline documented by a growing body of empirical research focusing on ancient societies (Haldon et al., 2018; Jackson et al., 2018; Van Bavel et al., 2020; Degroot et al., 2021). These jurisdictions are characterized by a limited economic complexity and a vast experience with environmental and institutional changes. Yet, absent a structural model of state-building, it is hard to interpret these links as causal (Zhang et al., 2011; Butzer and Endfield, 2012; D'Alpoim et al., 2016; Arponen et al., 2019; Van Bavel et al., 2019; Degroot et al., 2021).

To help tackle this issue, a recent body of interdisciplinary research has built on historical data on Medieval Europe and Bronze Age Mesopotamia, as well as, on a credible empirical strategy based on a time inconsistency theory of state-building to document the following key results (Boranbay and Guerriero, 2019; Benati et al., 2022; Benati and Guerriero, 2021; 2022a). First, adverse production and, notably, climate conditions pushed elites lacking the credibility to commit to future transfers to grant strong political rights to disenfranchised nonelites endowed with complementary inputs to convince them that a sufficient part of the returns on joint investments would be shared via public good provision. These reforms fostered inter-group cooperation and the provision of public goods, especially those preferred by the nonelites. Second, a milder climate allowed the elites to elicit cooperation under less inclusive political regimes. Because of the key relevance of these results for policy intervention in developing countries, a test of their validity for these economies is necessary.

To construct such a test, we build on recent research on the impact of rainfall on democratization in developing countries (Brückner and Ciccone, 2011; Ciccone and Ismailov, 2022), and we show that the time inconsistency theory of state-building also explains the links between the severity of droughts and democratization in the panel of the 38 among the—42—most agricultural countries for which we can observe all dependent and independent variables over the 1960-2018 period. To illustrate, the severity of droughts, as inversely

captured by the growing season self-calibrating Palmer drought severity index, has a significant and negative effect on a contemporaneous crop production index produced by the World Development Indicators project and a significant, positive and persistent impact on the inclusiveness of the political process measured by the POLITY V constraints on the executive authority score. Moreover, reforms towards more inclusive political institutions shift the allocation of tax revenues from military to education government expenditures and, thus, exert a positive and delayed—of two time periods—impact on agricultural output. Being climate extremes increasingly prevalent because of the ongoing process of global warming (Nordhaus, 2019), we consider the two sets of estimates as a first test of the direct and indirect—i.e., via institutions—effects of climate change (Benati and Guerriero, 2022b).[1]

Even if consistent with the predictions of our theoretical framework, our estimates might be attenuated by measurement errors, or they may be capturing reverse causality and/or unobserved heterogeneity. We evaluate these issues in three steps. First, we notice that the independence from human effort and institutional decisions of our climate variables excludes reverse causation in our analysis of institutional evolution. Moreover, the fact that both the agricultural output and public good provision are unrelated to future institutions is inconsistent with the former driving the latter. Second, we evaluate the severity of measurement error by showing that our conclusions remain the same when we consider a dichotomous proxy for the inclusiveness of the political regime and when we either average climate variables over the entire year or switch to a panel of decennial observations. This last set of estimates confirms that institutions are designed to adapt to both inter-annual fluctuations and multidecadal megadroughts. Finally, we embrace a two-step strategy to assess the role of unobserved heterogeneity. First, we control for the main determinants of democratization identified by the extant literature (Rød et al., 2020). These are economic circumscription (Carneiro, 1970; Mayshar et al., 2017), risk of unrest (Acemoglu and Robinson, 2000; Acemoglu et al., 2019), severity of external threats (Besley and Persson, 2009), economic development (Inglehart and Welzel, 2005), economic performances (Przeworski and Limongi, 1997), degree of economic inequality (Boix, 2003), extent of human capital (Acemoglu et al., 2005), value of

[1] "Climate change refers to a change in the state of the climate that can be identified [...] by changes in the mean and/or the variability of its properties and that persists for an extended period" (IPCC, 2014).

natural resources (Ross, 2001), intensity of religiosity (Potrafke, 2011), and degree of ethnic heterogeneity (Montalvo and Reynal-Querol, 2005). Considering these observable factors together leaves our results almost intact. Second, we calculate that, to attribute the entire relevant estimates to selection effects, selection on unobservable factors would have to be on average more than 28 times greater than selection on all the aforementioned observable factors, which seems unlikely. Ultimately, these tests make difficult to envision that our estimates are driven by mechanisms different from those highlighted by our model and, thus, we take our results as consistent with, if not proving, causality running from climate shocks to the inclusiveness of political institutions and from the latter to public good provision.

Over and above the aforementioned body of literature on climate change and state-building in pre-industrial societies, our analysis is related to three main strands of the burgeoning literature on the determinants of democratization. First, we contribute to a growing strand of research on the impact of adverse climate conditions on the inclusiveness of the political process in the most agricultural societies by explicitly considering the role of the time inconsistency issues created by the elites' inability to promise direct transfers and, thus, always assure the nonelites' participation. Unlike North and Weingast (1989), Barzel and Kiser (1991) and Myerson (2008), and similar to Boranbay and Guerriero (2019) and Benati and Guerriero (2022b), we highlight that public good provision is the main commitment device in the elites' hands, documenting its empirical relevance for the most agricultural societies. While doing so, we also provide a formal justification for the empirical regularity that democratization episodes tend to be preceded by a temporary dip in income (Acemoglu et al., 2019). Finally, we also compare the explanatory power of our theoretical framework with that of the main alternative economics and political science theories of state-building and, notably, those emphasizing the role of conflicts (Rød et al., 2020).

Our paper delivers three key contributions. First, we document that our time inconsistency theory of state-building can also shed light on democratization in the world's most agricultural societies. Focusing on this sample allows us to exploit a large variation across time and space on economies sufficiently simple to credibly link geography to institutional formation (Benati and Guerriero, 2022b). Second, by showing that fiscal policies connect time inconsistency issues with the political order (Guerriero and Righi, 2022), we stress that

climate change is an understudied determinant of the state's fiscal capacity (Benati and Guerriero, 2022b). Finally, we build on our results to draw three key policy implications for developing countries. First, policymakers should consider direct and indirect effects of climate change. Second, they should calibrate climate-related policies according to the degree of complementarity of the group-specific inputs. Finally, they should avoid the mechanical transplantation of strong nonelites' political rights in all developing countries.

The paper proceeds as follows. In section 2, we illustrate the key intuitions of our time inconsistency theory of state-building emphasizing the role of production and, notably, climate conditions. Next, we detail in section 3 the testable predictions produced by our theoretical framework, and we test them in section 4. Finally, we conclude in section 5, and we report figures and (extra) tables in the (Internet) appendix.

2 Time Inconsistency Theory of State-Building

Benati and Guerriero (2021; 2022a,b) formally assume that elites and nonelites try to cooperate in an economic activity—e.g., farming—delivering an output only if the nonelites incur a costly investment. The value of the output is larger the more favorable are the production conditions, e.g., the milder is the climate.[2] The elites keep the untaxed output because of, for instance, their ability to politically control the distribution of arable lands, the credit necessary to buy seeds and fertilizers and the social programs directed to farmers (Treisman, 2020; Lansford, 2021). Yet, they cannot commit to direct transfers to the nonelites. This assumption builds on the literature on the time inconsistency issues inherent to politics (North and Weingast, 1989; Barzel and Kiser, 1991; Fleck and Hanssen, 2006; Myerson, 2008; Boranbay and Guerriero, 2019), and it is justified in our sample by the fact that contracts tend to be enforced by courts controlled by the same elites promising not to renege on transfers (Shen-Bayh, 2018).[3] The elites can, however, entice the nonelites by enacting a more inclusive political process, which allows them to select the tax rate and organize public good provision (Boranbay and Guerriero, 2019; Guerriero and Righi, 2022).[4]

[2]The formal proofs of the model discussed in this section can be found in section 3 of Benati et al. (2022)

[3]Utter (2021), for instance, documents that, in the aftermath of the 1977-1992 civil war, the Mozambique's government created Community Courts as a tool of political control by the elites.

[4]Benati et al. (2022) also allow the elites to punish the nonelites for suspected shirking by weakening their use rights to the input, e.g., shortening land tenure (Guerriero, 2016a; 2021). For a limited, but not too

Being both nonelites and elites risk neutral, the investment payoff of the latter equals the sum of untaxed output and the utility from public good consumption, whereas the investment payoff of the former equals the utility from public good consumption net of the investment cost. When the investment return is limited—but not so small to avoid any cooperation—and, thus, the elites' time inconsistency issues are severe, the nonelites cooperate only when they have been granted the more inclusive political process and, in turn, the power to fully tax the output and produce their preferred public good (Levi, 1988; Blanton and Fargher, 2008; 2016).[5] These choices maximize their utility from public good provision. When, instead, the investment return becomes sufficiently large, the elites do not need to give up control over fiscal policies and they pick a tax rate falling with the output value.

3 Empirical Predictions

The elites' capacity to elicit an otherwise unattainable cooperation via democratization, and in turn, public good provision clarifies why we consider this mechanism the key feature of state-building (Benati and Guerriero, 2022a). A large investment return induces cooperation even under autocracy. Ultimately, our time inconsistency theory delivers the following three testable predictions on climate change, agricultural production and democratization:

Predictions: *The inclusiveness of the political process increases with the severity of adverse climate shocks; 2. The nonelites' utility from public good provision increases with the inclusiveness of the political process. 3. Adverse climate shocks have both a direct and negative impact and an indirect and positive institutional effect on agricultural output.*

tiny, investment return, the protection of the nonelites' property rights must be complete to assure their participation in investment. When the investment return is large, the elites can also weaken the nonelites' use rights to strengthen their own, provided that the value of the extra public good provision necessary to assure the nonelites' participation is sufficiently small because of a very observable output. Testing these predictions for a sample of most agricultural countries is a key avenue for future research.

[5]These reforms are favored by the nonelites' accumulation of a culture of cooperation, i.e., internalized reward from cooperating in economic activities (Boranbay and Guerriero, 2019; Guerriero, 2020; Benati and Guerriero, 2022b). Intuitively, a larger implicit payoff from cooperation credibly signals the nonelites' commitment to invest even in activities inducing a small payoff and, thus, a limited public good provision. When the investment return is sufficiently large, over-accumulation of culture is unnecessary to signal participation. Benati and Guerriero (2022b) confirm these predictions in a subsample of the countries listed in table 1.

4 Evidence

While it is natural to relate the millennial institutional evolution of ancient societies to recurring climate changes (Benati and Guerriero, 2022a), it is less obvious to evaluate whether our model can rationalize the institutional discontinuities that have shaped developing countries in the much shorter post-colonial period. To tackle this issue, we follow Ciccone and Ismailov (2022) and Benati and Guerriero (2022b), and we study the interplay among the severity of droughts, the agricultural production, inclusiveness of the political process and public good provision in the world's most agricultural countries. To elaborate, we focus on 38 among the—42—countries with agriculture, forestry, and fishing value added as a share of the GDP averaged over the 1960-2020 period in the top quintile of the relative distribution. For these countries, we can observe all dependent and independent variables over the maximum available sample, i.e., 2242 observations spanning the 1960-2018 period (see table 1).[6] Three are the key reasons behind this choice. First, the value added of the primary sector displays a mean value abundantly and significantly—at 1%—larger within our sample than outside, i.e., 35.4% vs. 9.8%. Hence, differently from other jurisdictions, the most agricultural countries mainly deal with economic activities primarily shaped by the availability of soil moisture. Second, as documented by Ciccone and Ismailov (2022), these jurisdictions display significantly fewer irrigation infrastructures. Therefore, the institutional impact of droughts must be larger in these countries than elsewhere. Finally, after the 1960s, these jurisdictions witnessed a series of exceptional institutional discontinuities (Benati and Guerriero, 2022b). Consistent with these three remarks, Benati and Guerriero (2022b) document that the institutional impact of the availability of soil moisture is statistically significant only in the sample of the most agricultural countries.

4.1 Anecdotal Evidence

Malawi is a case in point. After the 1964 independence, president Banda autocratically ruled the country until staple production was ruined by the beginning of the 1990s unprecedented droughts (Lansford, 2021), i.e., our inverse measure of the severity of droughts felt from 1.6 in 1989 to -6.3 in 1992. Landless peasants cultivated government estates and em-

[6] We substitute a missing observation with the closest data point. This choice does not affect our conclusions.

ployed fertilizers and seeds acquired thanks to public credit (Chinsinga, 2017). The resulting economic downfall pushed Banda to hold a general referendum on structural reforms, which paved the way to the 1994 general elections, a new constitution and a shift of the allocation of tax revenues towards the provision of education (Treisman, 2020; Chinsinga, 2017), whose expenditures in percentage of the GDP and in deviation from the military expenditures—again as a percentage of GDP—rose from 2 in 1993 to 4.5 in 1996. As part of the 2010 Green Belt Initiative, traditional leaders were coopted as state agents and started to mediate between the government and local communities in the allocation of land and loans to the rightless farmers (Chinsinga, 2017). Accordingly, our measure of the inclusiveness of political institutions rose from a value of 2 in 1993 to 5 over the 1994-2000 period.

The institutional trajectory of Mozambique follows a similar pattern. After gaining independence in 1975, an almost 20-years long civil war raged on (Lansford, 2021; Treisman, 2020), until the end of the 1980s harsh droughts forced the two main political parties to start negotiating an agenda for conflict resolution and political reforms. Such a bargaining phase culminated in the 1990 promulgation of the new pluralistic constitution and the 1992 peace treaty (Treisman, 2020). A process of army demobilization was, then, started, leading to the 1994 general elections and, in turn, a period of economic growth characterized by the redistribution of the nationalized lands to the rightless farmers. In our data, the drop in our inverse measure of drought severity from 1.4 in 1986 to -4.9 in 1992 was followed by a rise in the proxy for the inclusiveness of the political process from the value of 3 recorded between 1986 and 1993 to the value of 4 observed over the 1994-2012 period and the contemporary increase in the difference between the expenditures on education and the military expenditures, both in percentage of the GDP, from -1.5 in 1994 to 4.8 in 2012.

4.2 Empirical Evidence: Measurement

While anecdotal evidence is informative, empirical evidence is more convincing. To evaluate the model testable predictions, we need appropriate proxies for adverse agricultural production shocks, inclusiveness of political institutions and nonelites' payoff from public good consumption as well as a credible identification strategy.

4.2.1 Severity of Droughts

A large agricultural economics literature suggests that extremes in the growing season climate factors and, notably, droughts explain most of the yield anomalies at the global scale (Vogel et al., 2019; Zhao et al., 2017). Hence, we focus on the "self-calibrating Palmer drought severity index" averaged between May and September, which is the growing season period common to most of the tropical and temperate countries in the sample, i.e., *SC-PDSI* (see table 2 and I of the Internet appendix for definition and sources of each variable). This choice is consistent with the aforementioned literature on the origins of the state (Boranbay and Guerriero, 2019; Guerriero, 2020; Benati and Guerriero, 2021; 2022a; Benati et al., 2022). To account, moreover, for the fact that the growing season of tropical regions tends to last the entire year, we document that our results are similar when we turn to the self-calibrating Palmer drought severity index averaged over the entire year, i.e., *SC-PDSI-Y* (see table II of the Internet appendix). Finally, we reach similar conclusions when we consider the long run interplay among climate change, democratization and public good provision by averaging our proxies over decennial subperiods (see table III of the Internet appendix).

The variable *SC-PDSI* is an inverse measure of the severity of droughts—i.e., periods over which the supply of moisture fails to meet its demand (Redmond, 2002), captures seasonal to longer time scales surface aridity anomalies as well as water storage variations and it is based on nonlinear combination of surface air temperature and precipitation (Dai, 2021). Its values range between -10—i.e., extreme droughts—and 10, i.e., extremely wet conditions (Dai, 2021), and 0 picks a situation of normal soil moisture. The underlying data are calculated by Dai (2021) for each month from 1850 on and over the global land areas at a 2.5-degree spatial resolution. While Palmer (1965) originally mixed air temperature and rainfall through parameters derived from U.S. Great Plains data, Dai (2021) exploits local features obtained from regional surface meteorological forcing data for all the cell in his sample. Operationally, we, first, average for each time-period in the sample the monthly observations over either the May to September period or the entire year and then, we calculate country means weighted by the contribution of each cell to the country area.

To control for the linear effect of temperature and rainfall, we also consider their averages

over either the May to September period or the entire year, i.e., either *Rainfall* and *Temperature* or *Rainfall-Y* and *Temperature-Y*. To calculate these variables, we rely on monthly observations produced by the CRU CY dataset for the entire globe at the 0.5 spatial resolution from 1901 on. Again, we, first, average these data points for each time period in the sample over either the May to September period or the entire year and, then, we calculate country means weighted by the contribution of each cell to the country area (Harris et al., 2020). Focusing on these linear effects only, as proposed by Brückner and Ciccone (2011) and Ciccone and Ismailov (2022), would not account for the fact that extreme climate events, like tropical storms, can greatly affect both the rainfall and the temperature without significantly relieving droughts by re-establishing soil moisture (Moreland, 1993).

4.2.2 Agricultural Production

To evaluate the power of our inverse measure of drought severity to explain variation in agricultural output, we relate it to a real crop production index, i.e., *Production*. The score *Production* reports the agricultural production for each year from 1960 on relative to the base value of 100 assigned to the 2004-2006 period, excludes fodder crops and is available at the country level from the World Development Indicators project.

4.2.3 Inclusiveness of the Political Process and Public Good Provision

To proxy the inclusiveness of political institutions, we consider both its main multivalued measure and the most used metrics classifying regimes into democracies and nondemocracies (Guerriero, 2020; Acemoglu et al., 2019). The former is the Polity V Project constraints on executive score, i.e., *Democracy*. This variable refers to the strength of the institutionalized constraints on the decision-making power of chief executives, whether individual or collective. Such limitations may be imposed by any accountability group. In Western democracies these are usually legislatures. Other kinds of accountability groups are the ruling party in a one-party state, councils of nobles or powerful advisors in monarchies, the military in coup-prone polities and an independent judiciary in many states. Thus, our measurement concern is with the checks and balances between the various parts of the decision-making process. A seven-category scale is used with a value of one picking unlimited authority by the executive and a value of seven gauging executive parity or subordination, i.e., accountability

groups have effective authority equal to or greater than the executive in most areas of activity. As stressed by Acemoglu et al. (2019), *Democracy* might be subject to measurement error and changes in its cardinal values could only correspond to ordinal switches or, even, no institutional evolution. To tackle this issue, we also consider the dichotomous regime classification proposed by Acemoglu et al. (2019), i.e., *Dem-D*. This dummy equals one only if several sources classify a jurisdiction as a democracy, and it is available up to the 2010. Finally, to evaluate the persistent effect of climate shocks, we compute the difference between the value that *Democracy* (*Dem-D*) assumes in, respectively, t+2, t+4 and t+9 and the value recorded in t-1, i.e., Δ*3-Dem*, Δ*5-Dem* and Δ*10-Dem* (Δ*3-Dem-D*, Δ*5-Dem-D* and Δ*10-Dem-D*). Relying on these alternative variables induces a loss of degrees of freedom.

Finally, we proxy a rise in the nonelites' payoff from public good consumption with the difference between the government expenditures on education and those on the military, both expressed as a percentage of the GDP and available from the World Development Indicators from 1960 on, i.e., *Public-Good*. Intuitively, while a powerful military helps the elites maintain control over scarce resources, schooling raises the nonelites' returns from both economic cooperation and civic participation (North et al. 2009).[7]

4.3 Empirical Evidence: Estimating Equation

Our empirical approach is organized in two steps. First, we show that country and year fixed effects Ordinary Least Squares—OLS—estimates confirm the two testable predictions. Second, we use these results to construct tests implying that the possible endogeneity biases are negligible. Starting from the first exercise, we follow Ciccone and Ismailov (2022) and Benati and Guerriero (2022b), and we run by OLS panel models of the type:

$$Y_{c,t} = \alpha_c + \beta_t + \gamma' \mathbf{X}_{c,t} + \delta' \mathbf{Z}_{c,t} + \varepsilon_{c,t}, \tag{1}$$

where $Y_{c,t}$ is either *Production*, a proxy for democratization or *Public-Good*. α_c, instead, incorporates country fixed effects controlling for time-independent determinants of $Y_{c,t}$. These are the colonial heritage (Acemoglu and Robinson, 2000), geographic traits, such as rugged-

[7] To illustrate, Wang et al. (2022) document that the contribution of increased educational attainment to the US agricultural output growth between 1948 and 2017 is about eight percentage points.

ness, land suitability for agriculture and pasture and the irrigation potential (Litina, 2016; Bentzen et al., 2016), and predetermined shocks like the out-of-Africa exodus of humankind as well as the agricultural revolution (Ashraf and Galor, 2013; Olsson and Paik, 2016). β_t encapsulates year dummies picking up global climate shocks and macro events like epidemics, which modulate the incentives to escape the Malthusian trap (Voigtländer and Voth, 2009). Ultimately, the coefficients attached to our inverse proxy for drought severity evaluate the effects of short run climate shocks on the intensity of democratization and the extent of agricultural production once we have controlled for both their long run and aggregate determinants, which are encapsulated respectively in the country and year fixed effects.

$X_{c,t}$ gathers either *Rainfall*, *Temperature*, *SC-PDSI* and, possibly, two of its lags or *Rainfall-Y*, *Temperature-Y*, *SC-PDSI-Y* and, possibly, two of its lags. When the dependent variable is either *Production* or *Public-Good*, we also include in $X_{c,t}$ a proxy for democratization sometimes together with two of its lags. Since we do not observe all the geographic determinants of the return on farming and democratization, we also consider the inclusiveness of the political process when studying *Public-Good*, and we focus on the coefficient attached to this variable to assess our second testable prediction.

$Z_{c,t}$ possibly includes the observable factors discussed in section 4.5.3.

Should the error $\varepsilon_{c,t}$ be heteroskedastic and/or correlated over time because, of for instance, the autoregressive structure of the self calibrating Palmer drought severity index (Dai, 2021; Palmer, 1965), the standard errors of our estimates would be biased (Angrist and Pischke, 2009). To assess this issue, we experiment with errors clustered at the level of the Asian, Oceania, Sub-Saharan African, Saharan African and South American regions and we reach similar conclusions (see table IV of the Internet appendix).

4.4 Empirical Evidence: Basic Empirical Results

Table 3 documents three key facts about the interplay among climate change, agricultural production and democratization, which are consistent with the first model testable prediction. First, the severity of droughts is the main climatic determinant of the agricultural output whereby a shift from an extreme drought—i.e., *SC-PDSI* = - 10—to extremely wet conditions—i.e., *SC-PDSI* = 10—is related to a significant—at 1%—0.39-standard-deviation

rise in the real crop production index (column (1)). Second, more adverse farming conditions, as determined by severe droughts, induce reforms towards a more inclusive political process (columns (2) and (3)). To elaborate, the effect of the drought severity is only contemporaneous and a jump from extreme wet to extreme dry conditions is associated with a significant—at 5%—0.54-standard-deviation increase in the strength of the constraints on the executive (column (3)). Similarly, a one-standard-deviation fall in *Temperature* is linked to a significant—at 1%—0.65-standard-deviation rise in *Democracy*. Finally, the institutional effect of soil moisture is permanent as revealed from the significant—at 5% or better—and negative coefficient on *SC-PDSI* in the regressions with dependent variables the changes in the constraints on the executive over three, five and ten years (columns (4) to (6)). The samples in columns (5) and (6) are smaller since we don't have data from 2021 on.

Turning to the mechanisms of state-building, the key channel linking droughts to cooperative investments is the shift towards the provision of public goods preferred by the nonelites, which can only be assured by democratization. Notably, a reform from unlimited executive authority to executive parity is related to a significant—at 1%—0.65-standard-deviation rise in the difference between education and military government expenditures (column (1) of table 4). This piece of evidence is consistent with the second testable prediction.

Finally and consistent with the third testable prediction, a rise in the growing season soil moisture has the short run direct effect of increasing agricultural output and the long run indirect impact of curbing it by discouraging democratization and the consequent expansion of the provision of the public goods preferred by the nonelites (column (2) of table 4). Crucially, the relationship between *Democracy* and *Production* is the strongest after two periods, whereas the effect of the drought severity on the agricultural output is only contemporaneous and larger in the specification considering *Democracy* and its lags (compare column (2) of table 4 with column (1) of table 3). Evidence available upon request reveals that the link between *Democracy* and *Production* survives even after eight years from the initial shock.

4.5 Empirical Evidence: Gaining More Insights About Causality

Even if all our OLS estimates are consistent with our model testable predictions, they might be attenuated by measurement error, may be picking the effect of reverse causality

and/or may be capturing unobserved heterogeneity. We evaluate these three issues in turn.

4.5.1 Evaluating Measurement Error

We begin with considering alternative proxies for the inclusiveness of the political process and alternative measures of climate extremes. While columns (1) to (4) of table 5 clarify that the message of our empirical exercise remains intact when we consider the aforementioned discrete measures of the inclusiveness of political institutions, tables II and III of the Internet appendix entail that the conclusions of our analysis remain substantially unaffected when we average climate variables over the entire year and when we average our proxies over the six decennial subperiods in which our sample can be divided, respectively. The first of these last two exercises assures that our results do not rest on our choice of focusing on the growing season, whereas the second one evaluates the possibility that society would find more difficult to adapt to multidecadal megadrought. This does not seem to be the case in our data.

4.5.2 Evaluating Reverse Causality

While the independence from both human effort and institutional decisions of climate factors excludes reverse causation in our analysis of institutional formation, a more direct test is, instead, necessary to rule out that agricultural product and/or public good provision drive the constraints on the executive. To construct such a test, we follow Angrist and Pischke (2009), and we expand the specifications in columns (1) and (2) of table 4 to include in $X_{c,t}$ the proxy for the inclusiveness of political institutions lead one year, i.e., *Democracy*(+1). If reverse causality was an issue, then one would expect even stronger correlations between current values of public good provision and/or the agricultural product and future values of *Democracy* since both factors would plausibly shape democratization with a lag. As columns (5) and (6) of table 5 immediately reveal, this is not what we observe in our data.

4.5.3 Evaluating Unobserved Heterogeneity

We follow a two-step strategy to assess the role of unobserved heterogeneity.

First, we control for the other key determinants of inclusive political institutions identified by the competing theories of state-building. We consider ten alternatives. First, we evaluate the idea that the environmental circumscription, which is the difference between the productivity of a jurisdiction's territory and that of the surrounding areas, represents

a deterrent to exit and unrest (Carneiro, 1970; Mayshar et al., 2017). To capture this dimension, we include the value of *Production* over the average of the values that *Production* assumes in the countries neighboring the jurisdiction, i.e., *Circumscription*. Smaller values of this proxy, which are suggestive of worse production conditions within a country relative to neighboring countries, should be related to stronger elites' needs to introduce a more inclusive political process to appease the nonelites. Second, Acemoglu and Robinson (2000) claim that the elites' willingness to share with nonelites their decision-making power and, notably, their control over fiscal policies rises with the risk of unrest.[8] Accordingly, we build on data from the Correlates of War project, and we incorporate into the analysis a dummy for the experience of intra-state wars, i.e., *Internal-Conflicts*. Third, an expanding literature suggests that producing common interest goods, such as fighting external wars, is conducive to forceful nonelites' political rights (Besley and Persson, 2009). Building on these remarks, we consider a dummy for inter-state wars again obtained through data from the Correlates of War project, i.e., *External-Conflicts*. Together, *Internal-Conflicts* and *External-Conflicts* also control for political instability and mass activism (Rød et al., 2020). Fourth, we consider the institutional effect of modernization by incorporating in the analysis the log GDP per capita in constant 2015 USD collected from the World Development Indicators (Inglehart and Welzel, 2005), i.e., *Income*. Fifth, we evaluate the hypothesis that worse short-term performances, like a higher inflation level—i.e., *Inflation*, may have deleterious effects on democratization (Przeworski and Limongi, 1997). Sixth, Boix (2003) claims that economic inequality magnifies the redistributive impact of democracy, decreasing the likelihood of a peaceful transition from an authoritarian to a democratic regime. As a result, we consider the Gini index reported by the World Development Indicators, i.e., *Inequality*. Seventh, we test whether high levels of educational attainment are a prerequisite for democratization by evaluating the ratio of total enrollment to tertiary education, regardless of age, to the population of the relative age group produced by the World Development Indicators (Acemoglu et al., 2005), i.e., *Human-Capital*. Eighth, to understand whether large levels of non-produced output, and thus, a weaker disincentive effect of autocracy dilute the elites' willingness to

[8]Since the opportunity cost of contesting authoritarian rule falls with transitory negative shocks to the farming conditions, the latter might absorb the institutional effect of unrest (Ciccone and Ismailov, 2022). Results available upon request show, however, that internal conflicts are unrelated to the severity of droughts.

democratize (Ross, 2001), we incorporate in $Z_{c,t}$ the total natural resources rents as a percentage of GDP calculated by the World Development Indicators, i.e., *Natural-Resources*. Ninth, we assess the Huntington's (1996) claim that the Islamic religion's doctrine is less conducive to democratization by considering the percentage of Muslims in the total population collected from the composition of religious and ethnic groups project, i.e., *Muslims*. Finally, we ponder on the hypothesis that more heterogeneous populations are also more conflicting and less culturally prone to cooperating in the establishment of more inclusive political institutions (Montalvo and Reynal-Querol, 2005). To illustrate, we add to $Z_{c,t}$ the historical ethnic fractionalization index produced by the EUI Research Data, i.e., *Heterogeneity*.

Considering all these proxies together leaves our estimates almost intact (columns (7) and (8) of table 5). Furthermore, while internal and external conflicts, human capital, natural resources and the diffusion of Islamic values are unrelated to the degree of democratization, *Circumscription* and *Heterogeneity* (*Income*, *Inflation* and *Inequality*) are significantly and positively (negatively) related to the inclusiveness of the political process. Accordingly, only the coefficients on *Inflation* and *Inequality* are consonant with the extant theories of state-building. This evidence further emphasizes the importance of considering climate change in the analysis of institutional formation in developing and, notably, agricultural countries.

Second, we calculate the index proposed by Bellows and Miguel (2009) to measure how much stronger selection on unobservables, relative to selection on observables, must be to explain away the entire estimated effects. To see how it is calculated, consider a regression with a restricted set of controls and one with a full set of controls. Next, denote the estimate of the coefficient attached to the variable of interest from the first regression λ_R, where R stands for "restricted," and that from the second regression λ_F, where F stands for "full." Then, the index equals the absolute value of $\lambda_F/(\lambda_R - \lambda_F)$. To elaborate, the lower the absolute value of $(\lambda_R - \lambda_F)$ is, the less the estimate of the coefficient attached to the variable of interest is affected by selection on observables, and the stronger selection on unobservable factors needs to be to explain away the entire effect. Similarly, the higher the absolute value of λ_F is, the greater is the effect that needs to be explained away by selection on unobservables. We consider the specifications reported in column (3) of table 3 and column (1) of table 4 as the restricted regressions and those incorporating the extra controls discussed

above and reported in columns (7) and (8) of table 5 as the full regressions, and we list the indexes calculated from the regressions with dependent variable *Democracy* and *Public-Good*, respectively, in columns (1) and (2) of table 6. The key observations are that no index is lower than one and their average equals 28.1. As a consequence, to attribute the entire estimates to selection effects, selection on unobservable factors would have to be on average more than 28 times greater than selection on all observables, which is unlikely.

4.6 Empirical Evidence: Discussion

Overall, these tests make difficult to envision that our estimates are driven by mechanisms different from those we model and, thus, we take our results as consistent with, if not proving, causality running from climate shocks to political rights and from the latter to public goods.

5 Concluding Comments

Our analysis suggests that climate change has an asymmetric impact on institutional evolution whereby severe droughts induce reforms towards more inclusive political institutions and a shift towards the fiscal policies preferred by the nonelites, whereas favorable climate conditions assure inter-groups cooperation under a less inclusive political regime and, thus, a stricter elites' control over taxation and public good provision. Our conclusions, together with recent evidence on the pivotal role of institutions in guiding the adaptation of developing countries to climate change via cooperation (Yomo et al., 2020; Mubaya and Mafongoya, 2017; Agrawal, 2010), entail three key policy implications for developing jurisdictions.

First, severe droughts have the short run effect of penalizing economic activities but, in the long run, they can favor an otherwise unattainable cooperation between groups endowed with complementary inputs/skills. Therefore, after major adverse climate shocks, policymakers should focus on assessing the degree of complementarity of the input/skills of differently powered groups. When this is large, cooperation must be elicited by favoring their participation in joint investments and, in turn, the endogenous introduction of strong nonelites' political rights. When, instead, group-specific inputs/skills are substitute, policymakers should stimulate the sectors fostering inputs/skill complementarity if this strategy does not entail too large misallocations (Guerriero, 2021). This first implication of our analysis offers

an encouraging perspective through which assess the full-scale impact of the present-day crises and take steps to turn dramatic short run shocks in future success. Second, provided that the production conditions generate a sufficiently large output to share, less inclusive political regimes can incentivize joint investments (Benati et al, 2022; Benati and Guerriero, 2021). This second implication, together with the first one, speaks against the mechanical transplantation of strong nonelites' political rights in all developing countries (Guerriero, 2016). Moreover, it squares with recent evidence on the fact that an inclusive political process can assure cooperative investments in the short run, but might become irrelevant, if not detrimental, when social and/or technological innovations deprive these joint endeavors of their role (Boranbay and Guerriero, 2019; Guerriero, 2020). Finally, our analysis suggests that it is desirable to properly combine natural and social sciences when evaluating short and long run impacts of major climate shocks. Such an interdisciplinary approach requires detailed data on regional climate change, institutional evolution and economic outcomes but also convincing theoretical models of the interplay among these variables increasing the credibility of the empirical analyses of state-building (Jackson et al., 2018; Van Bavel et al, 2019; Turner et al., 2012; Allan et al., 2016; Carleton and Hsiang, 2016).

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Tables

Table 1: The Sample — Most Agricultural Countries

Afghanistan, Bangladesh, Benin, Burkina Faso, Burundi, Cambodia, Central African Republic, Chad, Congo Democratic Republic, Cote d'Ivoire, Ethiopia, Gambia, Ghana, Guinea-Bissau, Guyana, India, Kenya, Kyrgyz Republic, Lao, Liberia, Malawi, Mali, Mozambique, Myanmar, Nepal, Niger, Pakistan, Papua New Guinea, Rwanda, Sierra Leone, Somalia, Sudan, Syria, Tanzania, Togo, Uganda, Uzbekistan, Vietnam.

Note: 1. The 38 among the—42—countries with agriculture, forestry, and fishing value added as a share of the GDP averaged over the 1960-2020 period in the top quintile of the relative distribution and for which we observe all the variables that we use over their maximum common available sample, i.e., 1960-2018.

Table 2: Summary of Variables

	Variable	Definition and Sources	Statistics
Farming Product:	*Production*:	Crop production index relative to the base period 2004-2006. Source: World Bank, https://databank.worldbank.org/	56.167 (30.516)
Inclusiveness of political institutions:	*Democracy*:	POLITY V constraints on the executive authority score. Source: https://www.systemicpeace.org/csprandd.html	3.045 (1.898)
	Δ*3-Dem*:	Difference between *Democracy* in t+2 and *Democracy* in t-1. Source: https://www.systemicpeace.org/csprandd.html	0.079 (1.209)
	Δ*5-Dem*:	Difference between *Democracy* in t+4 and *Democracy* in t-1. Source: https://www.systemicpeace.org/csprandd.html	0.137 (1.463)
	Δ*10-Dem*:	Difference between *Democracy* in t+9 and *Democracy* in t-1. Source: https://www.systemicpeace.org/csprandd.html	0.282 (1.848)
	Dem-D:	Dummy for a democratic political regime. Source: http://economics.mit.edu/faculty/acemoglu/data/ddcg	0.230 (0.421)
	Δ*3-Dem-D*:	Difference between *Dem-D* in t+2 and *Dem-D* in t-1. Source: http://economics.mit.edu/faculty/acemoglu/data/ddcg	0.017 (0.283)
	Δ*5-Dem-D*:	Difference between *Dem-D* in t+4 and *Dem-D* in t-1. Source: http://economics.mit.edu/faculty/acemoglu/data/ddcg	0.031 (0.334)
	Δ*10-Dem-D*:	Difference between *Dem-D* in t+9 and *Dem-D* in t-1. Source: http://economics.mit.edu/faculty/acemoglu/data/ddcg	0.063 (0.419)
Public good provision:	*Public-Good*:	Difference between government expenditure on education as a percentage of the GDP and the military expenditure as a percentage of the GDP. Source: World Bank, https://databank.worldbank.org/	0.909 (3.549)
Climate change:	*SC-PDSI*:	Mean growing season self-calibrating Palmer drought severity index. Source: https://rda.ucar.edu/datasets/ds299.0/	- 0.570 (1.753)
	Rainfall:	Mean growing season monthly precipitation in mm. Source: CRU Country File, https://crudata.uea.ac.uk/	141.007 (117.775)
	Temperature:	Mean growing season temperature in degrees Celsius. Source: CRU Country File, https://crudata.uea.ac.uk/	25.029 (4.229)
Extra controls:	*Circumscription*:	Production over its average in neighboring countries. Source: World Bank, https://databank.worldbank.org/index	1.106 (0.620)
	Internal-Conflicts:	Dummy for intra-state wars. Source: Correlates of War Project, https://correlatesofwar.org/data-sets/COW-war	0.031 (0.173)
	External-Conflicts:	Dummy for inter-state wars. Source: Correlates of War Project, https://correlatesofwar.org/data-sets/COW-war	0.045 (0.207)
	Income:	Log GDP per capita in constant 2015 USD. Sources: World Bank, https://databank.worldbank.org/index	6.414 (0.657)
	Inflation:	Annual inflation calculated through the GDP deflator in percentage. Sources: World Bank, https://databank.worldbank.org/index	40.889 (580.535)
	Inequality:	Gini index. Sources: World Bank, https://databank.worldbank.org/index	40.561 (8.038)
	Human-Capital:	Ratio of total enrollment to tertiary education, regardless of age, to the population of the relative age group. Source: World Bank, https://databank.worldbank.org/	4.684 (7.045)
	Natural-Resources:	Total natural resources rents as a percentage of GDP. Source: World Bank https://databank.worldbank.org/	8.729 (7.117)
	Muslim:	Percentage of Muslims on total population. Source: CREG project and CIA factbook, https://clinecenter.illinois.edu/ and https://www.cia.gov	36.180 (35.265)
	Heterogeneity:	Historical ethnic fractionalisation index. Source: http://hdl.handle.net/1814/64606	0.618 (0.244)

Note: 1. The last column reports the mean value and, in parentheses, the standard deviation of each variable. Both are computed building on the samples used in tables 3 to 6.

Table 3: Climate Change, Agricultural Production and Democratization

	(1)	(2)	(3)	(4)	(5)	(6)
	The dependent variable is:					
	Production	*Democracy*	*Democracy*	*Δ3-Dem*	*Δ5-Dem*	*Δ10-Dem*
SC-PDSI	0.588	- 0.038	- 0.051	- 0.037	- 0.055	- 0.094
	(0.188)***	(0.023)*	(0.021)**	(0.019)**	(0.023)**	(0.030)***
SC-PDSI(-1)		- 0.017				
		(0.021)				
SC-PDSI(-2)		- 0.032				
		(0.020)				
Rainfall	0.007	0.001	0.001	0.003	0.003	0.006
	(0.014)	(0.002)	(0.002)	(0.001)**	(0.002)*	(0.002)***
Temperature	- 0.182	- 0.256	- 0.267	0.001	0.019	0.049
	(0.879)	(0.099)***	(0.098)***	(0.089)	(0.108)	(0.137)
	OLS					
Within R^2	0.79	0.28	0.27	0.05	0.07	0.14
Number of Observations	2242	2242	2242	2242	2166	1976

Notes: 1. Standard errors in parentheses. *** denotes significant at the 1% confidence level; **, 5%; *, 10%.
2. All specifications include country and year fixed effects.

Table 4: Micro Mechanisms of State-Building

	(1)	(2)
	The dependent variable is:	
	Public-Good	*Production*
Democracy	0.105	0.024
	(0.041)***	(0.373)
Democracy(-1)		0.004
		(0.503)
Democracy(-2)		0.832
		(0.373)**
SC-PDSI	0.043	0.604
	(0.040)	(0.201)***
SC-PDSI(-1)		0.061
		(0.189)
SC-PDSI(-2)		0.0005
		(0.180)
Rainfall	- 0.002	0.006
	(0.003)	(0.014)
Temperature	0.284	- 0.026
	(0.187)	(0.880)
	OLS	
Within R^2	0.07	0.80
Number of Observations	2242	2242

Notes: 1. Standard errors in parentheses. *** denotes significant at the 1% confidence level; **, 5%; *, 10%.
2. All specifications include country and year fixed effects.

Table 5: Gaining More Insights About Causality

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	The dependent variable is:							
	Dem-D	*Δ3-Dem-D*	*Δ5-Dem-D*	*Δ10-Dem-D*	*Public-Good*	*Production*	*Democracy*	*Public-Good*
Democracy					0.091	0.155		0.107
					(0.079)	(0.503)		(0.041)***
Democracy(-1)						- 0.002		
						(0.504)		
Democracy(-2)						0.829		
						(0.373)**		
Democracy(+1)					0.017	- 0.145		
					(0.079)	(0.373)		
SC-PDSI	- 0.017	- 0.010	- 0.014	- 0.017	0.043	0.602	- 0.037	0.029
	(0.006)***	(0.005)**	(0.006)**	(0.008)**	(0.040)	(0.201)***	(0.021)*	(0.039)
SC-PDSI(-1)						0.060		
						(0.189)		
SC-PDSI(-2)						- 0.002		
						(0.180)		
Rainfall	0.0005	0.001	0.001	0.001	- 0.002	0.006	0.001	- 0.0003
	(0.0004)	(0.0004)	(0.0004)	(0.0006)	(0.003)	(0.014)	(0.002)	(0.003)
Temperature	- 0.047	0.007	0.005	0.020	0.285	- 0.033	- 0.306	0.342
	(0.026)*	(0.023)	(0.028)	(0.036)	(0.187)	(0.880)	(0.097)***	(0.184)*
Extra Controls	NO	NO	NO	NO	NO	NO	YES	YES
	OLS							
Within R^2	0.16	0.04	0.05	0.09	0.07	0.80	0.32	0.13
# of Observations	1938	1862	1786	1596	2242	2242	2242	2242

Notes: 1. Standard errors in parentheses. *** denotes significant at the 1% confidence level; **, 5%; *, 10%.
2. All specifications include country and year fixed effects, except those in columns (7) and (8) that also incorporate *Circumscription*, *Internal-Conflicts*, *External-Conflicts*, *Income*, *Inflation*, *Inequality*, *Human-Capital*, *Natural-Resources*, *Muslim* and *Heterogeneity*.

Table 6: Using Selection on Observables to Assess the Bias from Unobservables

	(1)	(2)
		The dependent variable is
	Democracy	*Public-Good*
The index is calculated for		
SC-PDSI	2.6	
Democracy		53.5

Note: 1. The restricted set of controls includes those employed in the specifications reported in column (3) of table 3 and column (1) of table 4, whereas the "full set" of covariates incorporates those used in the specifications listed in columns (7) and (8) of table 5. The sample size always equals 2242.

APPENDIX (FOR ONLINE PUBLICATION)

I Supplementary Tables

Table I: Summary of Variables

Climate change:	*SC-PDSI-Y*:	Self-calibrating Palmer drought severity index averaged over the entire year. Source: https://rda.ucar.edu/datasets/ds299.0/	- 0.558 (1.564)
	Rainfall-Y:	Monthly precipitation in mm averaged over the entire year. Source: CRU Country File, https://crudata.uea.ac.uk/	98.151 (64.180)
	Temperature-Y:	Temperature in degrees Celsius averaged over the entire year. Source: CRU Country File, https://crudata.uea.ac.uk/	23.222 (5.731)

Note: 1. The last column reports the mean value and, in parentheses, the standard deviation of each variable. Both are computed building on the sample used in table II.

Table II: Self-calibrating Palmer Drought Severity Index Averaged Over the Entire Year

	(1)	(2)	(3)	(4)
	The dependent variable is:			
	Democracy	Δ*10-Dem*	*Public-Good*	*Production*
Democracy			0.103	0.019
			(0.041)***	(0.373)
Democracy(-1)				- 0.030
				(0.503)
Democracy(-2)				0.849
				(0.373)**
SC-PDSI-Y	- 0.051	- 0.125	0.039	0.942
	(0.025)**	(0.036)***	(0.047)	(0.261)***
SC-PDSI-Y(-1)				- 0.223
				(0.250)
SC-PDSI-Y(-2)				- 0.072
				(0.220)
Rainfall-Y	0.002	0.009	- 0.005	- 0.050
	(0.003)	(0.004)**	(0.006)	(0.027)*
Temperature-Y	- 0.351	0.091	0.114	- 0.585
	(0.103)***	(0.143)	(0.196)	(0.924)
	OLS			
Within R^2	0.28	0.14	0.07	0.80
Number of Observations	2242	1976	2242	2242

Notes: 1. Standard errors in parentheses. *** denotes significant at the 1% confidence level; **, 5%; *, 10%.
2. All specifications include country and year fixed effects.

Table III: Decennial Fluctuations in Droughts

	(1)	(2)
		The dependent variable is:
	Democracy	*Public-Good*
Democracy		0.126
		(0.138)
SC-PDSI	- 0.194	0.179
	(0.098)**	(0.185)
Rainfall	0.014	- 0.001
	(0.011)	(0.020)
Temperature	- 0.668	0.902
	(0.458)	(0.857)
		OLS
Within R^2	0.38	0.11
Number of Observations	228	228

Notes: 1. Standard errors in parentheses. *** denotes significant at the 1% confidence level; **, 5%; *, 10%.
2. All specifications include country and year fixed effects.

Table IV: Standard Errors Clustered at the Regional Level

	(1)	(2)
		The dependent variable is:
	Democracy	*Public-Good*
Democracy		0.105
		(0.135)
SC-PDSI	- 0.051	0.043
	(0.009)***	(0.017)*
Rainfall	0.001	- 0.002
	(0.002)	(0.003)
Temperature	- 0.267	0.284
	(0.174)	(0.192)
		OLS
Within R^2	0.27	0.07
Number of Observations	2242	2242

Notes: 1. Standard errors clustered at the regional level in parentheses. The regions that we consider are Oceania, Asia, Saharan Africa, Sub-Saharan Africa and South America. *** denotes significant at the 1% confidence level; **, 5%; *, 10%.
2. All specifications include country and year fixed effects.