Ecology, trade and states in pre-colonial Africa

Fenske, James

University of Oxford, Department of Economics

December 2010

ECOLOGY, TRADE AND STATES IN PRE-COLONIAL AFRICA

JAMES FENSKE[†]

ABSTRACT. I test Bates' view that trade across ecological divides promoted the development of states in pre-colonial Africa. My main result is that sub-Saharan societies in ecologically diverse environments had more centralized pre-colonial states. I use spatial variation in rainfall to control for possible endogeneity. I construct artificial societies and present narrative evidence to show the results are not due to conquest of trading regions. I also test mechanisms by which trade may have caused states, and find that trade supported class stratification between rulers and ruled.

1. INTRODUCTION

The states that existed in Africa before colonial rule continue to shape its modern development. Pre-colonial state centralization is positively correlated with modern cross-country differences in school attainment, literacy, paved roads and immunizations (Gennaioli and Rainer, 2007). It better predicts nighttime lights today than country-level institutional quality (Michalopoulos and Papaioannou, 2010). The few modern states in Africa that inherited the legitimacy of a pre-colonial predecessor have done better (Englebert, 2000). The parts of French West Africa with more centralized states before colonial rule better resisted French settlement, but these same areas received less investment during the colonial period (Huillery, 2008). These recent empirical findings are in line with those of historians and political scientists, who have argued that alien rulers had to take African systems as given and build upon them during the colonial period (Austin, 2008b; Berry, 1992; Mamdani, 1996). In other contexts, economists have similarly found that the long historical roots of modern states are relevant for modern development (Banerjee and Iyer, 2005; Bockstette et al., 2002; Iyer, 2007). Explaining pre-colonial states, then, is necessary for understanding modern Africa.

In this paper, I test a "Ricardian" view of sub-Saharan states presented by Bates (1983), in his *Essays on the political economy of rural Africa*. He builds on earlier arguments made by Oliver and Fage (1962) and Vansina (1966), among others, who argued that

[†]DEPARTMENT OF ECONOMICS, UNIVERSITY OF OXFORD
E-mail address: james.fenske@economics.ox.ac.uk.
Date: February 28, 2011.
I am grateful to Achyuta Adhvaryu, Robert Bates, Prashant Bharadwaj, Timothy Guinnane, Namrata Kala, Elias Papaioannou, Aloysius Siow and Christopher Udry for their comments. I am also thankful for the feedback I have received from seminars at the University of Oxford, Hebrew University, and Tel Aviv University.

TABLE 1. Bates' Evidence

[Table 1 here]

long-distance trade required centralized authorities for administrative purposes, diffused concepts of centralized polities, and stimulated territorial expansion (Bisson, 1982). His model is verbal:

> One of the basic arguments linking political centralization with economic reward rests upon the desire of people to benefit from the gains in welfare which can be reaped from markets. In essence, the argument is Ricardian... the contribution of the state is to provide order and peace and thereby to render production and exchange possible for members of society. The origins of the state, then, lie in the welfare gains that can be reaped through the promotion of markets.

He suggests that gains from trade are greatest where products from one ecological zone can be traded for products from another. It is near ecological divides, then, that we should expect to see states. To support his view, he takes 34 pre-colonial African societies, asks whether they "abut an ecological divide," and classifies them as having a "kinship" political structure, "chiefs," or "central monarchs." I present a condensed version of his results in Table 1. The proportion of societies with central monarchs is greater on an ecological divide.

In this paper, I argue that Bates (1983) is ultimately correct. His argument has been overlooked because his sample size prevents him making a credible econometric argument that this correlation is causal. In this paper, I use ethnographic and geographic data to overcome this limitation. I take data on state centralization for 440 societies in pre-colonial sub-Saharan Africa from Murdock's (1967) *Ethnographic Atlas*. Merging the map of African ethnic groups from Murdock (1959) with information on African ecological zones from White (1983), I am able to compute for each society an index of its "ecological diversity," which I take as a proxy for the gains from trade that existed before colonial rule. I show that this index is strongly related to the presence of pre-colonial states. I use spatial variation in rainfall to control for possible reverse causation, and show that the OLS estimates of the impact of ecological diversity are not overstated. I also use exogenous geographic features to predict raster-level ecological regions, and find that the diversity measured by these predicted points is also related to pre-colonial African states. The relationship between trade and states is robust to several additional controls, removing influential observations, alternative measures of states and trade, and a variety of estimation strategies.

I show that the "Ricardian" view better explains the relationship between states and diverse ecology than six alternative stories. First, while larger territories may require more levels of administration and may be more diverse, area does not explain away the relationship between ecological diversity and states. Second, because panel data are not available for these ethnic groups, I am not able to conclusively show that societies that independently developed state centralization did not migrate to capture the regions in which the gains from trade were high. In order to argue that this does not explain my results, I construct artificial societies and present narrative evidence on the histories of the most influential observations in the data. By adding similar controls, I am able to show that two other stories – dense population in diverse regions and defense of "islands" of land quality – do not explain away the relationship between trade and states. Fifth, I show that the diversity of grains available for cultivation do not explain away the main results. Sixth, while diverse areas are more ethnically fractionalized, ecology directly impacts states even when this is included in the sample of artificial countries. I test for several mechanisms by which trade may have facilitated state centralization, and find that class stratification is the channel best supported by the data. No one type of trade is shown to be more important than others.

The Ricardian view is only one of many theories of the long-run geographic origins of strong states. It is not my aim, however, to test the Ricardian view against these except insofar as they may also explain the observed link between states and ecological diversity. Diamond (1997) argues that Eurasian endowments of domesticable plants and animals, combined with an East-West orientation that facilitated their diffusion, gave that landmass an early advantage over the Americas and Africa. Jones (2003) makes an argument for Europe that is remarkably similar to the Ricardian view, stating that:

> In Europe's case, the most relevant aspect of the resource endowment was probably the way it was dispersed across a geologically and climatically varied continent, since this provided an inducement to trade (p. xxxii).

Specifically, he suggests that the gains from bulk, low value trade encouraged rulers to gain their revenues through taxation of protected trade, rather than the arbitrary confiscations that would be possible with trade in luxuries (p. 89). Olson (1993), by contrast, suggests that above the level of hunter-gatherers, most societies have some vestige of a state because it is in the interests of "roving" bandits to establish themselves as ruling "stationary" bandits and encourage economic activity that they can tax. In this light, my study highlights a geographic condition that makes this possible through trade. States are only one of many imperfect ways to govern the market (Dixit, 2004), and this study then draws attention to one condition under which they emerge. There are also reasons why we might expect ecological *homogeneity* to facilitate trade and states. Societies that can only produce a narrow range of goods may be compelled to trade. Moav and Mayshar (2011) suggest that the homogeneity of ancient Egypt benefitted that state's centralization, compared with Israel and Babylon. Because all farmers depended on the Nile flood, which could be easily monitored, the state was uniquely able to tax them effectively.

Similarly, this Ricardian view of the origins of pre-colonial African states contrasts with other, though not necessarily rival, theories of African political centralization. Again, it is not the purpose of this paper to test between these hypotheses unless they are alternative explanations of the relationship between ecological diversity and states. First, the "land-abundance" view (Austin, 2008a; Herbst, 2000) of Africa argues that the relative absence of large states in pre-colonial Africa was the result of sparse population. Unable to tax land, which had little value, African states had to rely on trade taxes for revenue. This is to be understood in contrast with the view of Tilly and Ardant (1975), who argue that it was the need to secure and defend territory that gave rise to modern nation states in Europe. I show in this paper that, even controlling for population density, gains from trade allowed states to exist in Africa. Second, contributions by Nunn (2008) and Robinson (2002) have built on older views, such as those of Rodney (1972), and argued that the slave trade and colonial rule undermined institutional development in Africa, including state centralization. I show that the relationship between states and ecology is robust to measures of access to the transatlantic slave trade.

In the remainder of this paper, I proceed as follows. In section 2, I describe my sources of data, how I measure state centralization, and how I compute ecological diversity for each society. In section 3, I outline the principal econometric specification and the baseline results. In section 4, I demonstrate the robustness of these results to endogeneity, unobserved heterogeneity, influential observations, and alternative measures of trade and states. In section 5, I give evidence that five alternative stories – area necessitates centralization, states migrate to capture gains from trade, states emerge to protect "islands" of land quality in otherwise barren regions, ecological diversity proxies for population density, and ecological diversity produces ethnic diversity – do not explain the results. In section 6, I present suggestive evidence that centralized states emerged from trade because it supported class differentiation, and that no one type of trade mattered most. In section 7, I conclude.

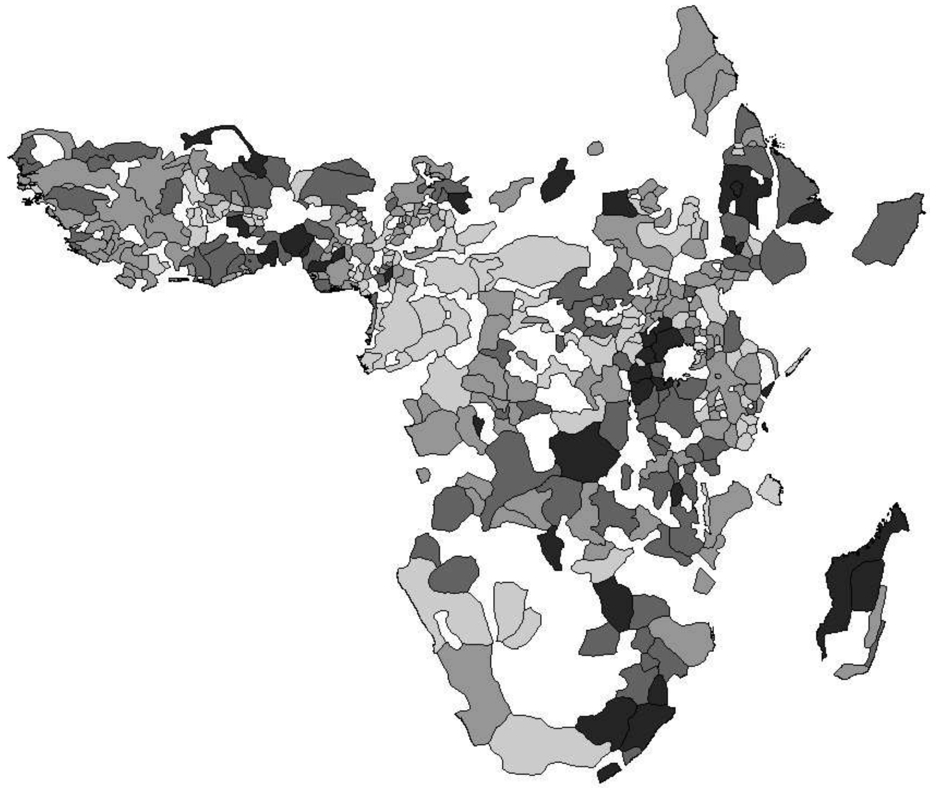
2. DATA

In order to test the Ricardian theory of African states empirically, I need data on three things – African states, the gains from trade, and other variables whose omission could potentially bias the results. In this section I describe my sources of for each.

To measure African states, I take data from Murdock's (1967) *Ethnographic Atlas*. This was originally published in 29 issues of *Ethnology* between 1962 and 1980. It contains data on 1267 societies from around the world.[1] From this source, I use variable 33, "Jurisdictional Hierarchy Beyond Local Community" to measure state centralization. This gives a discrete categorization between "No Levels" and "Four Levels." This is the same

[1]In particular, I use the revised Atlas posted online by J. Patrick Gray at http://eclectic.ss.uci.edu/~drwhite/worldcul/EthnographicAtlasWCRevisedByWorldCultures.sav.

FIGURE 1. State centralization



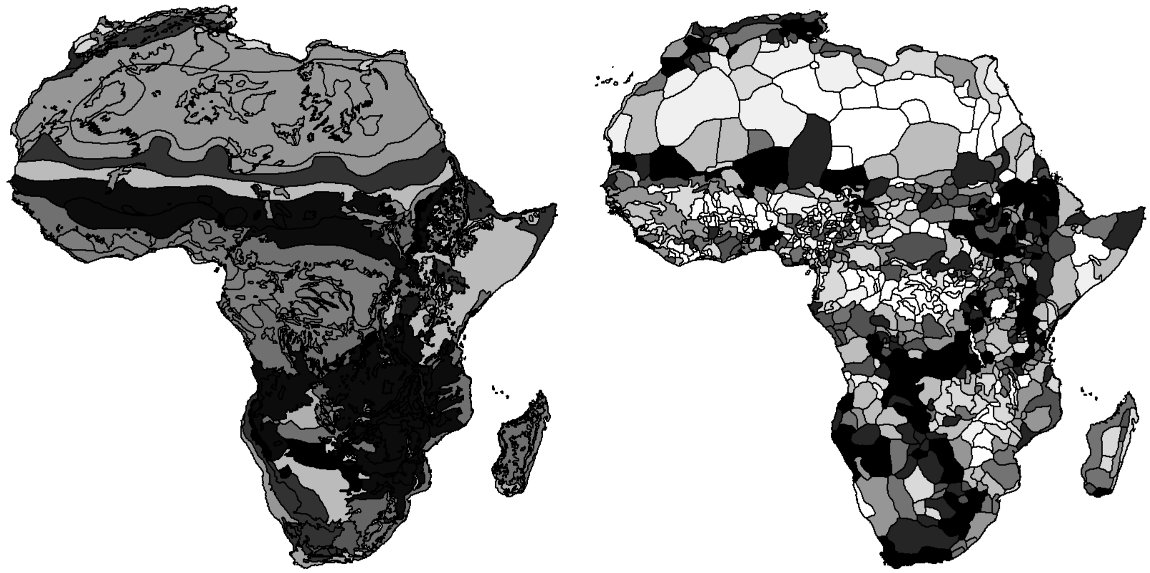
Source: (Murdock, 1967). Darker regions have more centralized states.

variable that was used by Michalopoulos and Papaioannou (2010), and originally converted by Gennaioli and Rainer (2007) into a discrete variable to capture the same concept.[2] The sample used for the analysis consists of the 440 sub-Saharan societies, including Madagascar, for which this variable is not missing. I map this measure of state centralization on Murdock's (1959) ethnic map of Africa in Figure 1.[3]

To measure the gains from trade, I follow Bates (1983) in assuming that the ability to trade across ecological zones will be particularly beneficial. To get information on ecology, I use White's (1983) vegetation map of Africa.[4] This classifies African vegetation into 17 major types, which I plot in Figure 2.[5]

[2]In particular, they took a society as "centralized" if it had at least one level of jurisdiction above the local, and weighted this by each society's share in the national population in 1960 to construct a country-level measure of pre-colonial state centralization in Africa.
[3]This map is available on Nathan Nunn's website.
[4]This is available at http://www.grid.unep.ch/data/download/gnv031.zip.
[5]Altimontaine, anthropic, azonal, bushland and thicket, bushland and thicket mosaic, cape shrubland, desert, edaphic grassland mosaic, forest, forest transition and mosaic, grassland, grassy shrubland, secondary wooded grassland, semi-desert, traditional scrubland, woodland, woodland mosaics and transitions.

FIGURE 2. Vegetation types and ecological diversity



Source: White (1983). In the left-hand map of vegetation types, each shade of grey represents a different one of each of the sixteen major types. In the right-hand side map of ecological diversity, darker regions are more ecologically diverse

To construct a measure of how location relative to these regions could give rise to gains from trade, I calculate the share s_i^t of each society i's area that is occupied by each ecological type t. Then, I use a Herfindahl index to construct a measure of each society's ecological diversity:

$$\text{Ecological diversity}_i = 1 - \sum_{t=1}^{t=17} (s_i^t)^2. \quad (1)$$

The economic analogy for this measure is that, if ethnic groups were markets, vegetation types were firms and these area shares were market shares, this would be an index of the competitiveness of the market. As more ecological zones intersect a society's area, the natural ability to trade increases, and the index rises. I show a map of this variable in Figure 2. Visually comparing Figures 1 and 2, it is apparent that the most centralized African states are clustered along an East-West line between the Sahara desert and West African forest zone, in the diverse microclimates of the Ethiopian highlands, along the barrier between the equatorial rainforest and the East and Central African woodland mosaics, and on the divide between grassland and woodland in the continent's south-eastern corner. In section 4, I show that distance from an ecological divide performs as well as this index at predicting states, as does an alternative index created from FAO data. Summary statistics for the main measures of states and trade, as well as alternatives that will be explained later in the paper, are included in Table 2.

TABLE 2. Summary statistics

[Table 2 here]

It is possible that, even if there is a strong correlation between ecological diversity and state centralization, this is due to omitted variables correlated with the diversity index. I am able to join several other geographic variables to the data on ecology and states using the Murdock (1959) map of Africa. Except where I note otherwise, I take data stored in raster format, and for each society I compute the average value of the points within its territory.[6] In particular, I control for:

Major river: This is a dummy that equals one if the Benue, Blue Nile, Chire, Congo, Lualaba, Lukaga, Niger, Nile, Orange, Ubangi, White Nile, or Zambezi Rivers intersect the ethnic group's territory.

Ag. constraints: This is an index of combined climate, soil and terrain slope constrains on rain-fed agriculture, taken from the FAO-GAEZ project (see Fischer et al. (2001)). I interpret it as an inverse measure of land quality.

Dist. coast: This is average distance from each point in the ethnic group territory to the nearest point on the coast, in decimal degrees, calculated in ArcMap.

Elevation: This is average elevation in meters.

Malaria: This is average climatic suitability for malaria transmission, computed by Adjuik et al. (1998).

Precipitation: This is average annual precipitation (mm). Because some societies are too small for a raster point to fall within their territory, I impute missing data using the nearest raster point.

Ruggedness: This is a measure of terrain ruggedness used by Nunn and Puga (2009). It computes the average absolute difference between an elevation grid cell and its neighbors.

Temperature: This is the accumulated temperature on days with mean daily temperature above 0°C, computed using monthly data from 1961 to 2000 collected by the Climate Research Unit (CRU) of the University of East Anglia. I treat 55537 is as an error code and drop these points. I impute missing values using the nearest raster point.

Dist. L. Victoria: I compute the distance between each ethnic group's centroid and Lake Victoria using the globdist function in Stata.

[6]Raster data taken from the following sources: Ag. Constraints, `http://www.iiasa.ac.at/Research/LUC/SAEZ/index.html`, plate 28; Elevation, `http://epp.eurostat.ec.europa.eu/`; Malaria, `http://www.mara.org.za/lite/download.htm`; Precipitation, `http://www.iiasa.ac.at/Research/LUC/SAEZ/index.html`, plate 1; Temperature, `http://www.iiasa.ac.at/Research/LUC/SAEZ/index.html`, plate 6; Ruggedness, `http://diegopuga.org/data/rugged/`.

TABLE 3. Summary statistics

[Table 3 here]

Date observed: This is the rough date at which the information on the society was recorded, according to the *Ethnographic Atlas*. Dates of observation are missing for the Bomvana and Betsileo. I recode the Bomvana to 1850, to match the date of observation for the other Xhosa. I recode the Betsileo to 1900, the modal date for the other Malagasy societies in the data.

Dist. Atlantic ST: This is the minimum distance between the ethnic group's centroid and the nearest major source of new world demand for slaves (Virginia, Havana, Haiti, Kingston, Dominica, Martinique, Guyana, Salvador, or Rio), computed using the globdist function in Stata. The choice of ports here follows Nunn (2008).

Dist. Indian ST: This is, similarly, the distance to the nearest of Mauritius and Muscat.

Dist Saharan ST: This is the minimum distance to Algiers, Tunis, Tripoli, Benghazi, or Cairo.

Dist Red ST: This is the minimum distance to Mussawa, Suakin, or Djibouti.

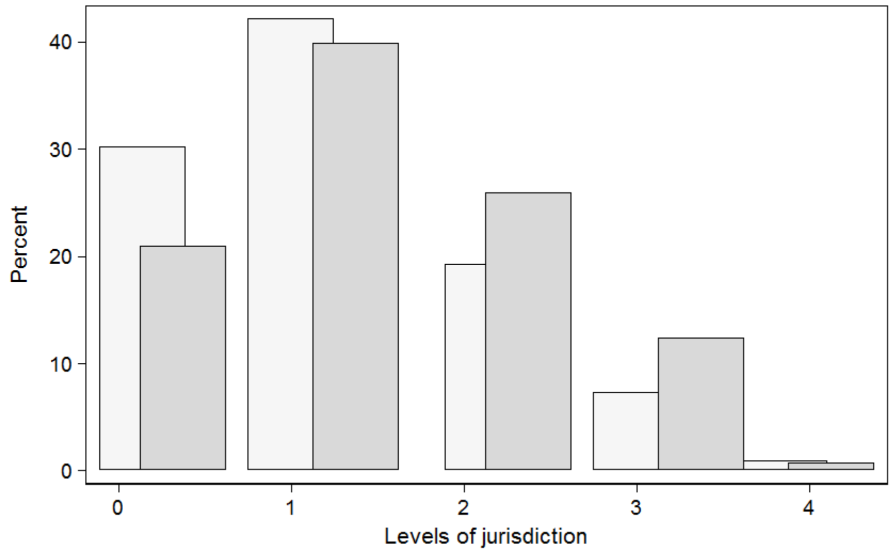
Crop type: I construct dummy variables out of the major crop types recorded in the *Ethnographic Atlas*. I treat these as exogenous characteristics of the natural environment, not as choices.

Summary statistics for these controls and any other variables used in the later analysis are given in Table 3. It is clear that the greatest difficulty with these data are that they are anachronistic – the institutional variables are recorded at an earlier date than the geographic controls and the measure of ecological diversity. Insofar as broad differences across regions in their capacities for rainfed agriculture, terrain ruggedness, ecological regions and similar variables do not change much, this should only add measurement error to the analysis. It is possible, however, that states transform their environments in ways that non-state societies cannot. I use both instrumental variables and non-anthropogenic predictors of ecological types in Section 4 to address this concern.

3. RESULTS

Before undertaking more sophisticated econometric tests, it is worth investigating whether there is a visible unconditional relationship between the ecological measure of gains from trade and state centralization. Because centralization is a discrete variable, a scatter plot will not present the data clearly. Instead, in Figure 3, I cut the sample into two – societies above and below the median in terms of ecological diversity. For each, I show a histogram of the relative frequencies of states of each level of centralization. It is clear that, below the median (the lighter bars), it is more common for societies to have no levels jurisdiction above the local, or one level. Above the median, there is a greater concentration of societies with two or three levels of jurisdiction. Both above and below

FIGURE 3. State centralization when ecological diversity is above and below the median



The dark bars are for ecological diversity above the median, the light bars for ecological diversity below it. Percentage is on the y axis and levels of jurisdiction on the x axis.

the median, it is quite uncommon for societies to have four such levels. The general pattern is clear; as ecological variation rises, the distribution of state centralization skews to the right.

To test econometrically whether there the gains from trade due to ecological diversity predict the existence of centralized states in pre-colonial Africa, I estimate the following using an ordered probit:

$$\textit{State centralization}_i = \alpha + \beta \textit{Ecological diversity}_i + X_i'\gamma + \epsilon_i. \quad (2)$$

In (2), state centralization is the number of levels of jurisdiction recorded by the *Ethnographic Atlas*. Ecological diversity is the index defined above. The matrix X_i includes the other controls reported listed in section 2, as well as (in some specifications) dummy variables for the thirteen ethnographic regions recorded in the sample.[7] Standard errors are clustered by region.

Table 4 presents the resulting estimates of β. I report the full set of coefficient estimates in Table 19 in the appendix, omitting them in the text for space. In column 1, only the measure of ecological diversity is included. Ecological diversity has a significant

[7]These are: African Hunters, South African Bantu, Central Bantu, Northeast Bantu, Equatorial Bantu, Guinea Coast, Western Sudan, Nigerian Plateau, Eastern Sudan, Upper Nile, Ethiopia/Horn, Moslem Sudan, and Indian Ocean.

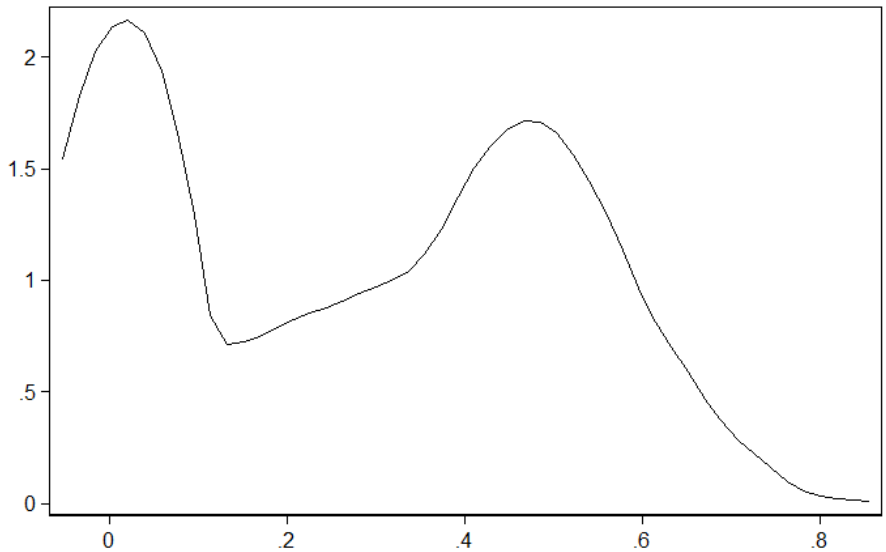
TABLE 4. Main results

[Table 4 here]

and positive correlation with state centralization. This is robust to the inclusion of additional controls in column 2, and the coefficient does not fall by much. While regional dummies do knock away some of the magnitude of the coefficient estimate, it remains significant at the 10% level. Surprisingly, few of the additional controls are statistically significant. The exceptions are elevation (positive in column 3), date of observation (negative in both columns), no major crop (negative in column 2), roots and tubers (positive in columns 2 and 3), major river (positive in columns 2 and 3), and ruggedness (positive in both columns). The positive effect of elevation is likely capturing benefits associated with mountainous regions, such as defensibility, less susceptibility to disease, and soil fertility. The negative effect of the date of observation likely suggests that colonial-era anthropologists chose to first study the least remote and most centralized African societies – the low hanging academic fruit. The negative effect of no major crop suggests that it is difficult to form a state without an agrarian base of any sort. The positive effect of roots and tubers is a surprise, and is likely proxying for unobservable features of forest-zone Bantu societies that better enabled them to create states. Major rivers are associated with trade, and further suggest that the Ricardian view of African states is largely correct. Ruggedness will be related to defensibility. Following Nunn and Puga (2009), it also predicts the ability of African societies to have escaped the worst effects of the slave trades.

Is the effect of ecological diversity large? In Table 4, I report the marginal effects of ecological diversity for each of the three specifications. Across specifications, the marginal effect of a one unit change in ecological diversity is to reduce the probability of having no levels of jurisdiction above the local by roughly 13-26 percentage points; the probabilities of having two or three levels increase to match this, though the effect is slightly stronger for three levels. A one unit change corresponds with a move of roughly four standard deviations in the ecological diversity measure. At a first glance, this would appear to suggest that the effect, while statistically significant, is small. However, ecological diversity has a very clearly bimodal distribution (see Figure 4). A move from one peak at zero to the other peak, at roughly 0.5, better captures the comparison between "diverse" and homogenous societies. This would suggest, then, that were a society to be taken from an ecologically homogenous region and placed in one that was typically diverse, the probability of having some form of state centralization would rise very roughly between 6 and 13 percentage points.

FIGURE 4. Kernel density of ecological diversity



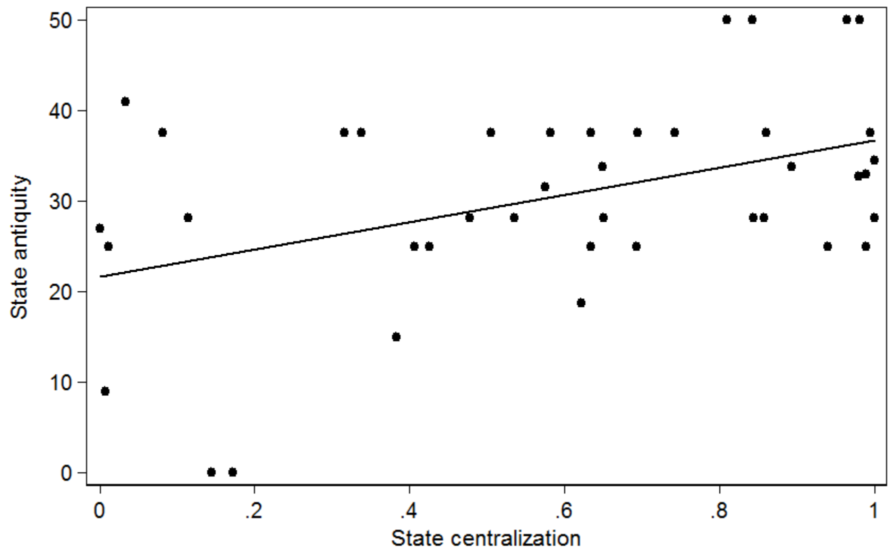
4. ROBUSTNESS

4.1. **Validity of the state centralization measure.** The measure of state centralization I use is far from ideal. One deficiency is that weak but pyramidal states will appear to be centralized in this data. The Bemba, as an example, have two levels of jurisdiction above the local. I would like to replicate these results with alternative measures of state strength. I am not, however, aware of any similar measure available for more than a small sub-sample of the ethnic groups in my data. Instead, I take two other approaches to validate the state centralization measure.

First, I show that it is strongly correlated with other measures of states for which I have data in other samples. Bockstette et al. (2002) and Chanda and Putterman (2007) construct indices of "state antiquity" for modern countries that reflect, in a given fifty year period, a) the existence of a government, b) the proportion of the modern country's territory covered, and c) whether the state was indigenous or externally imposed. I take this measure for the period 1850-1900 as a measure of state strength from roughly the same period as the centralization index. Gennaioli and Rainer (2007) aggregate the state centralization index to the country level using ethnic groups' population shares reported in the *Atlas Narodov Mira.* For 41 countries, I have both of the antiquity and centralization measures. In Figure 5, I show that there is a positive correlation between country-level centralization and state antiquity in the late nineteenth century.

Similarly, the *Standard Cross Cultural Sample* (SCCS) is a sub-sample of 186 societies recorded in the *Ethnographic Atlas* for which much larger number of variables are available. I have not used these in the present study, since only 28 societies in the SCCS

FIGURE 5. State antiquity and state centralization



State centralization is the country-level measure of Gennaioli and Rainer (2007). State antiquity is the variable "aosnew2," covering the period 1851-1900, based on Bockstette et al. (2002), and available on Louis Putterman's website. The regression coefficient is 15.096, and the standard error is 4.970. There are 41 observations.

TABLE 5. Robustness: Regressions of alternative SCCS measures of states on state centralization

[Table 5 here]

TABLE 6. Robustness: Alternative measures of states and diversity

[Table 6 here]

from sub-Saharan Africa. I can, however, show that the centralization measure I use is strongly correlated with the other measures of states coded in the SCCS.[8] For nearly thirty variables from the SCCS that capture ordinal measures of various aspects of state strength, I regress the variable on my measure of state centralization and report the results in Table 5. All of these are significantly related to state centralization, whether they measure the existence of a police force, the presence of taxation, or the capacity of states to enforce their decrees. The measure used in this study, then, is a valid proxy for state strength.

Second, I recode the state centralization measure into a dummy that equals one if the society has any levels of jurisdiction above the local. This may better capture state strength if, for example, it is impossible for a central authority to delegate administrative functions to regional leaders without also losing some control over them. I show in Table 6 that this measure is also positively related to ecological diversity.

[8]The centralization measure is v237 in the SCCS.

TABLE 7. Robustness: Estimation methods

4.2. **Validity of the gains from trade measure.** While ecological variation captures to some degree the presence of gains from trade, it is not clear that it is the best measure available. Bates (1983) divides societies into those that abut a divide, those that are diverse, and those that have no significant variation. As an alternative measure of the gains from trade, I use the White (1983) map to compute the average distance (in decimal degrees) of all points in a group's territory from the nearest boundary between two ecological regions. I present the results in Table 6. The statistical robustness of these results is stronger than the results obtained using ecological diversity. The results are consistent with a one standard deviation increase in the distance from an ecological divide raising the probability of having no levels of jurisdiction above the local by roughly 5 percentage points, with this increase coming from reductions in the probabilities that a society would have two or three levels of jurisdiction. Results using a binary indicator for whether the society is diverse at all (equivalent to whether it is intersected by a divide) are similar. Finally, because some of the ecological types recorded in White's map are similar, potentially leading to over-estimation of ecological diversity, I collapse these classifications into eight "simpler" types.[9] Results are again similar, though the effect of ecological diversity becomes marginally insignificant when regional fixed effects are added. Simplifying the classes in this manner does not do away with the sharply bi-modal distribution of diversity.

In addition, the FAO-GAEZ project created its own separate classification of ecological zones that can be used to construct an alternative diversity measure.[10] This source categorizes raster points in Africa into eleven "dominant ecosystem classes."[11] For each ethnic group in the data, I construct a measure analogous to that in (1) using the share of raster points for each ecosystem class, rather than the share of area. Results using this alternative measure of ecological diversity are presented in Table 6. As with the distance from an ecological divide, the coefficient estimates here are more statistically robust than main results.

4.3. **Validity of the estimation.** There are many possible reasons the approach taken to the estimation may be questioned. First, the "parallel regression" assumption of the standard ordered probit model, that the explanatory variables have the same impact on

[9]Mountain if altimontane, other if anthropic, water or azonal, bushland if bushland and thicket or bushland and thicket mosaics, shrub if cape shrubland, transitional scrubland or grassy shrubland, desert if desert or semi-desert, grassland if grassland, secondary wooded grassland or edaphic grassland mosaics, forest if forest or forest transitions and mosaics, and woodland if woodland or woodland mosaics and transitions.

[10]This is plate 55, downloaded from http://www.iiasa.ac.at/Research/LUC/GAEZ/index.htm.

[11]These are Undefined; Grassland; Woodland; Forest; Mosaics including crops; Cropland; Intensive cropland; Wetlands; Desert, bare land; Water and coastal fringes; Ice, cold desert, tundra; and Urban agglomerates.

TABLE 8. Robustness: Influential observations

[Table 8 here]

the latent index at all points, is often violated in real data. In Table 7, I re-estimate the main results using a generalized ordered probit model (Maddala, 1986), in which the coefficients on the latent variables are allowed to vary with the points where the categories of the dependent variable are separated. Convergence could not be achieved with regional fixed effects, so this specification is not reported. As before, ecological diversity predicts greater state centralization. Here, it is clear that this effect is not confined to any single level of centralization. Excepting at four levels, for which few observations exist, the effect is positive throughout.

Another potential concern is that, with only 440 observations in most specifications and thirteen regions, the clusters used for the standard errors may be too small. I have re-defined alternative clusters corresponding roughly to the United Nations' division of Africa into regions – Southern Africa (African Hunters, South African Bantu), Western Africa (Guinea Coast, Western Sudan, Nigerian Plateau, Moslem Sudan), Central Africa (Central Bantu, Equatorial Bantu, Eastern Sudan) and Eastern Africa (Northeast Bantu, Upper Nile, Ethiopia/Horn, Indian Ocean). Re-estimating the main results, I show in Table 7 that the results are now more statistically robust. The coefficient estimate falls less with the addition of these broader fixed effects than with fixed effects added for the regions as defined in the *Ethnographic Atlas*.

Finally, the inclusion of the major river dummy and distances from the coast, Lake Victoria, and slave trade ports may be capturing elements of trade based on features other than ecological diversity. Similarly, while the inclusion of the date of observation is intended to control for both remoteness and the possible impacts of European influence, it may be endogenous to state centralization. I show in Table 7 that excluding these variables barely affects the results.

It is also possible that the results here are driven by outliers. In Table 8, I control for this possibility by dropping influential observations from the sample. I estimate the main results by OLS with the full set of controls and without fixed effects. I then compute the leverage and dfbeta (for ecological diversity) statistics for each observation. In column 1 of Table 8, I drop all observations with leverage greater than $2(df+2)/N$. In column 2, I remove any observations with absolute dfbeta greater than $2/\sqrt{N}$. The main result survives both of these procedures, though the former is marginally insignificant when fixed effects are included. It is also possible that the results are spuriously identified by variation within a single African region. In columns 3 through 6, I drop each of the "South African bantu," "Ethiopia/horn," 'Moslem sudan" and "Indian Ocean" in turn. These are the regions in which most states are concentrated. The results again are robust to each of these, though some are again marginally insignificant with fixed

TABLE 9. Robustness: Reverse causation

[Table 9 here]

effects. It is not the contrast between a handful of states and their neighbors that is driving the results.

4.4. **Possible reverse causation.** It is also possible that stronger states shape the environment; McCann (1999) describes, for example, the careful regulation of forest resources in Ethiopia before the twentieth century. To control for this possible reverse causation, I employ the standard deviation of temperature within an ethnic group's territory as an instrument for its Ecological diversity. This is intended to capture variation in ecological conditions that are beyond human control, and which give rise to differences in actual vegetation. The disadvantage of this instrument is that it cannot be computed for societies so small that they have only one raster point for temperature, or whose temperature measure was imputed from a nearest neighbor. I present the results in Table 9. In columns 1 through 3, I replicate the main results from Table 4 using OLS, for comparability with the other columns. In columns 4 through 6, I repeat the analysis, but restrict the sample to societies for which the instrument is available. The coefficient estimates are roughly similar, suggesting that selection into non-missing observations of temperature variance will not drive the results. In columns 7 through 9, I present the IV results. I also present the Kleibergen-Paap Lagrange multiplier and F statistics. While these are less statistically robust than the OLS results, the coefficients grow larger. There is no evidence that the ordered probit estimates overstate the effect of ecological diversity on state centralization. This argument is analogous to Frankel and Romer (1999), who instrument for trade openness using using geographical features in a cross-country setting and find that, while their effects are statistically insignificant, there is no evidence that OLS overstates the causal effect of trade on growth.

I am also able to use the FAO classifications to construct an alternative measure of ecological diversity that is not endogenous to human action. For each of the 365,788 raster points in that data, I regress an indicator for each of the eleven ecosystem classes on deciles in latitude, longitude, average precipitation, distance from the coast, accumulated temperatures above five and ten degrees, ruggedness, length of the growing period, and terrain slope, as well as dummies for each type of thermal growing period, frost-free period, and soil class.[12] From each of these linear regressions, I take the linear prediction as the probability that the raster point falls into that ecosystem type. I take the most probable class as the predicted type, and I am able to correctly predict a bit

[12]All of these are downloaded from the FAO-GAEZ website, calculated in ArcMap, or already described above, except for soil type, which is taken from Zobler's grouping of the world's soils into 106 classes such as "Eutric Cambisoils," downloaded from the UNEP website. These often differ from the resolution of the ecosystem raster, and so the nearest raster point in each plate is used.

FIGURE 6. Kernel density of predicted ecological diversity (FAO)

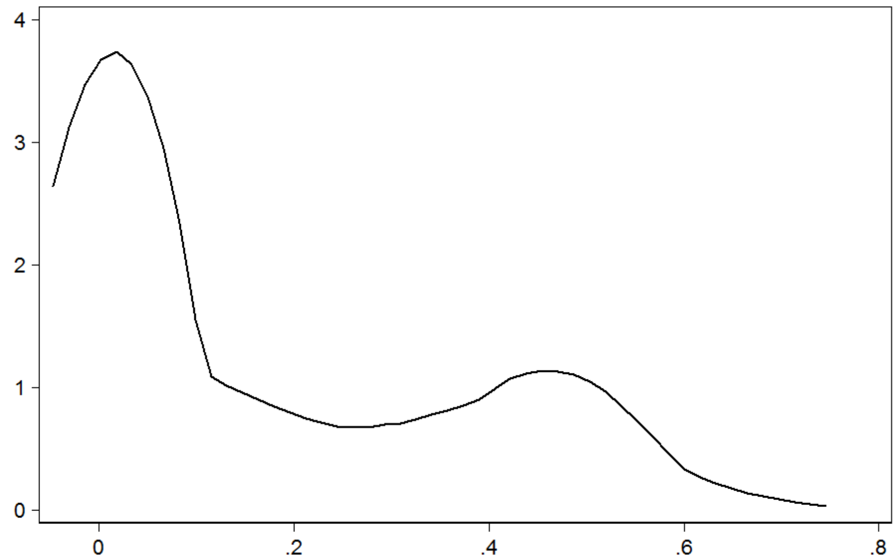


TABLE 10. Robustness: Reverse causation

[Table 10 here]

more than 70% of the raster points by this method. I re-calculate the diversity index using these predicted types. The results using this as a diversity measure are presented in Table 9. I continue to find that this predicts state centralization, except when regional fixed effects are included. This degree of robustness is surprising; because this method is particularly bad at predicting raster points in the less common ecological types, it under-predicts ecological diversity (see the kernel density in Figure 6). This further suggests the results are not due to strong states transforming their landscapes.

4.5. **Possible omitted heterogeneity.** As with any cross-sectional analysis, one of the most pernicious concerns is that the results are driven by unobservables that happen to be correlated with the causal variable of interest – in this case ecological diversity. While I have included an index of ecological diversity constructed from the area shares s_i^t of each ecological type for each ethnic group, I have not generally controlled for these directly. This is primarily for statistical power. These may, however, be significant determinants of states and correlated with ecological diversity. In Table 10 I add these as additional controls. The estimated effect of diversity is now larger, and more statistically robust.

Similarly, the inclusion of regional fixed effects may not fully capture the presence of localized unobservables. In the first panel of Table 10, I include quartics in latitude and longitude, which allow unobservables to vary smoothly across space. The results are robust to including this, though they become insignificant when region fixed effects are also included. This is not surprising, since this leaves little variation in the data to provide identification.

In Table 10, I also account for omitted heterogeneity by re-estimating the main results using a spatial error model. This replaces the vector of errors in (2) with a spatially-weighted vector $\lambda W \epsilon$, and a vector of iid errors, u. W is a row-normalized spatial weights matrix. I select W so that all societies whose centroids are within ten decimal degrees of each other are given a weight inversely proportionate to their distance from each other. I report the results in Table 10.[13] The effect of ecological diversity remains statistically significant before fixed effects are included, though the estimated coefficients are smaller than in Table 9. Once additional controls are added, I find no evidence that λ is statistically significant. This may be because neighbors' observables fully explain correlations in states across space. In Table 10 I add the observable X of each society's neighbors, weighted by the matrix W. While these are strongly significant – neighbors' characteristics matter – a Moran's I test conducted on the residuals suggests that there is no spatial correlation conditional on these.

In Section 5, I attempt to deal with specific unobservables that are related to alternative interpretations of the data.

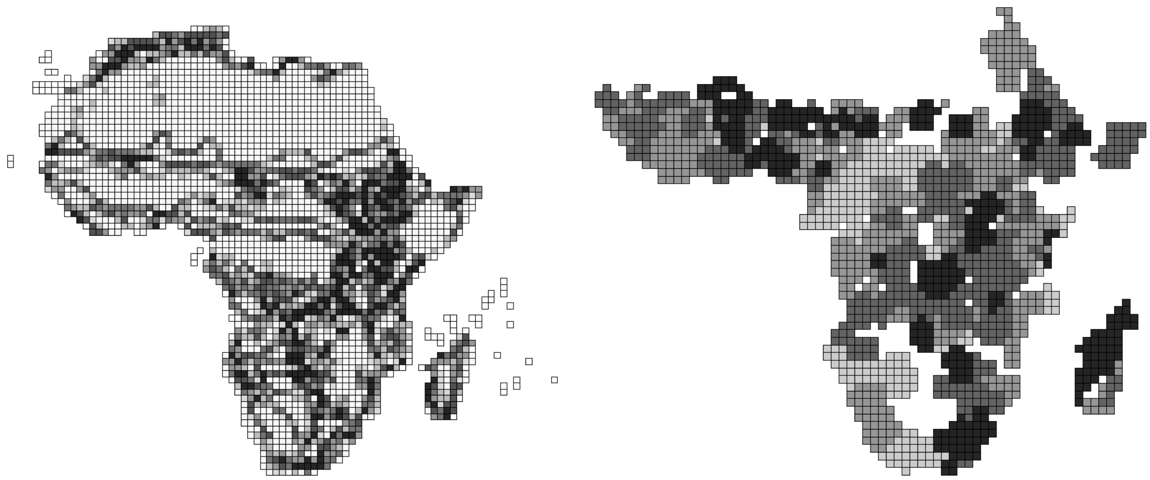
Finally, I take three more general approaches to deal with unobservables. First, I use the strategy suggested by Wooldridge (2002) for testing robustness to unobserved heterogeneity. I de-mean all of the standard controls included in Table 4, and interact them with my ecological diversity measure. A similar approach is used by Bhalotra and Cochrane (2010), for example. Results are reported in Table 10. I find that, while some of these interactions are significant, they do little to diminish the main result, suggesting that it cannot be explained away by heterogeneous treatment effects once controls are added.

Second, I employ a nearest neighbor matching estimator in order to shift the bulk of identifying variation to those observations that are most similar along their observables.[14] Because these estimators consider a binary "treatment," I divide the sample into observations above and below the median in ecological diversity. Results are given in Table 10. The main results look qualitatively similar using this measure of ecological diversity. If observations are matched using their observable controls (column 4), the difference in state centralization between "treated" and "untreated" societies (the average treatment effect) remains statistically significant and is similar in magnitude to the comparable regression in column 2.

Third, I compute Altonji-Elder-Taber statistics. Replicating the main regression using OLS, I obtain the estimated coefficient on ecological diversity $\hat{\beta}_1$ and the estimated variance of the residuals $\hat{V}_1$. Regressing state centralization on the controls, I obtain

[13]In particular, I use the spatwmat and spatreg commands in Stata.
[14]In particular, I use the nnmatch command in Stata.

FIGURE 7. Ecological diversity and state centralization for artificial countries



Source: Murdock (1967) and White (1983). In the left-hand map of ecological diversity, darker regions are more diverse. In the right-hand map of state centralization, darker regions are more centralized.

the predicted values xb and the estimated variance of the residuals $\hat{V}_2$. Regressing ecological diversity on xb, I obtain the coefficient estimate $\hat{\beta}_2$. Altonji et al. (2005) suggest that if $\frac{\hat{\beta}_1 \hat{V}_2}{\hat{\beta}_2 \hat{V}_1} > 1$, it is unlikely that unobservables will explain away the result of interest. The estimates reported, 4.51 if fixed effects are not included and 3.08 if they are, do not support selection on the unobservables.

5. ALTERNATIVE STORIES

The results presented so far are not, however, completely dispositive. They are consistent with at least five alternative stories of the relationship between ecology, trade and states in pre-colonial Africa. In the remainder of this section, I give evidence that the Ricardian view of African states better fits the data.

5.1. **Larger areas are more diverse and require more centralized administration.** It is possible that, if administering a larger area requires more levels of administration, states that happen to cover greater territories for reasons unrelated to their strength will appear more centralized in the data. Further, larger areas may be mechanically more likely to be ecologically diverse. Conversely, there is the "territorial expansion model" of Spencer (1998, 2010), who argues that the delegation of administrative authority to regional units is a ruler's rational response to territorial expansion. Again, this could create a link between diversity and states that operates through the geographic scope of a society, and not through trade.

I have three strategies for dismissing this alternative explanation of my results. The first is to adopt the "virtual countries" approach of Michalopoulos (2008). I divide the

TABLE 11. Alternative stories: Artificial countries and area groups

[Table 11 here]

African continent into squares 1° by 1° (see Figure 7) and repeat the main analysis. Excepting coastal societies, the units of observation now all have the same area. Because several ethnic groups might intersect a single square, I keep the levels of jurisdiction of the most centralized state as that square's measure of state centralization; that society's crop type, date of observation, and ethnographic region are also kept for the analysis. Results are presented in Table 11. These are even more statistically robust than the main results. Similarly, because the unit of observation for the main analysis is the ethnic group, this approach mitigates the concern that multi-ethnic states will be "double-counted" in the data.

Second, I restrict the sample to societies of similar areas. I compute area quintiles for all ethnic groups. In Table 11, I report the results if the smallest quintile (Q1), largest quintile (Q5) or both are dropped. Results are robust to this sample restriction, and the coefficients on ecological diversity are greatest when both the largest and smallest ethnic groups are removed from the sample. Third, I control for area directly in Table 13 and show that the main effect does not disappear. I discuss this in greater detail below.

5.2. **States conquer trading regions.** The second alternative explanation of the results is that states emerge for reasons unrelated to the gains from trade, and then move to occupy prime trading regions through migration or conquest. My first argument against this alternative story is to appeal to the artificial country results above. That similar results can be achieved using units with regular boundaries suggests that diversity does not result from the irregularly-shaped boundaries of ethnic groups that have conquered their surroundings in ways that overlap with ecology. My second strategy for dismissing this alternative story is to give narrative evidence on the most influential (in terms of dfbeta) societies in the data. The top fourteen of these are listed in Table 12. The central argument of this paper is that trade causes states. If the centralized societies in this list are known to have developed states where they are, rather than migrating to capture them, this supports the Ricardian view. Further, if these states derived their wealth and power from their location relative to geographically-shaped trade routes, it is evidence that profitable trade routes were necessary for states to exist in these locations. I choose six of the most influential centralized states for case study evidence.

It is possible that not all societies are able to take advantage of gains from trade in order to become states. Groups that look different from their neighbors early on may expand in response to new trading opportunities not seized by other societies around them. This need not, on its own, imply rejection of the basic argument that this expansion was based on trade. What is critical is whether the society would have had the resources to become a regional power in the absence of revenues and other benefits coming from this trade. Alternative stories: Six influential states

TABLE 12. Alternative stories: Six influential states

[Table 12 here]

There are six centralized states in Table 9 – the Yoruba, Songhai, Toro, Suku, Luba and Lozi. To test the "Ricardian" view, I ask five questions in each case. First, did these societies participate in trade? Second, was trade a source of wealth for the society? Third, was trade a source of state power? Fourth, did these polities rise and fall with the fortunes of external trade? Fifth, did these states move to capture trading regions after they grew strong? I summarize the answers to these questions in Table 12. While the evidence does not in every case support the view that trade promotes states rather than the reverse (especially the answers to the fourth question), it is broadly consistent with this interpretation.

Yoruba. Morton-Williams (1969) argues that Yoruba Oyo and Akan Ashanti "developed under the stimulus of external trade, owing much from their beginnings to their proximity to the Mande trade routes in the north, and later also to their fortunate positions in the hinterlands during the growth of the maritime markets on the coast." Law (1977) is more guarded, suggesting that three factors together explain the rise of Oyo – the strength of its imported cavalry, its participation in long-distance commerce with the north, and its engagement in the Atlantic slave trade, the latter being followed by Oyo's imperial expansion. It is clear that trade was important in the Oyo economy. Oyo cloth was sold to Dahomey and Porto Novo, and the state imported kola nuts from the forest areas of Yorubaland for consumption and re-export. Salt and camwood were imported, and the latter was re-exported to Nupe. The horses on which the Oyo cavalry depended were also imported from the north, albeit in return for slaves. Critically, Law (1977) shows that the *Alafin* (king) relied heavily on trade taxes for his revenues; even direct taxes were collected in cowries and other currencies that were largely acquired through trade. Further, he and other chiefs engaged in trade personally. Trade upheld the authority of the *Alafin* by permitting him to maintain a superior standard of life, and by enabling him to distribute money and trade goods. The story that emerges from the accounts of Morton-Williams (1969) and Law (1977), then, is of a state that depended on trade across ecological zones for its existence, but was spurred to expand by the rise of the coastal slave trade. Neither author mentions conquest of neighboring regions as a pre-condition for trade.

Songhai. The Songhai Empire, with its capital at Gao, took advantage of a weakened Mali to become free from Malinke control in 1340. Levzion (1975) only links this weakness to trade conditions in a roundabout way, noting that Mali power in Timbuktu was dislodged by first Mossi and later Tuareg raids. Gao was captured by Moroccan forces in 1591, after which the empire fractured. Levzion (1975) attributes Songhai weakness at this point to a divisive civil war, and not to trade factors. It is clear that the empire depended for its wealth on the trans-Saharan trade. Neumark (1977) attributes the success, not only of Songhay but of the states that preceded it, to "their strategic commercial position on the fringes of the Sahara." Songhay exported principally gold and slaves, as well as ivory, rhinoceros horns, ostrich feathers, skins, ebony, civet, malaguetta pepper, and semi-precious stones. It re-exported cloth and leather goods from Hausaland and kola from the forest zone. It imported salt, linen, silk, cotton cloth, copper utensils and tools, ironwork, paper, books, weapons, cowries, beads, mirrors, dates, figs, sugar, cattle and horses. Leo Africanus noted the empire's prosperity, as abundant food could be produced in the southern savanna and shipped to Timbuktu via the Niger (Levzion, 1975). Lovejoy (1978), similarly, notes that Timbuktu and Gao, Songhay's most important cities "controlled trans-Saharan trade, desert-side exchange, and river traffic on the Niger. Located in the Sahil but with easy access to western and central savanna, they were at the hub of overland and river routes where staples of desert-side trade such as grain and salt could readily be transferred from river boat to camel, and vice versa." Songhay was the first Sudanic empire whose power reached as far as the salt mines of Taghaza (Levzion, 1975). Shillington (1989) notes taxes on trade as a key source of government revenue.

It is true that, after its establishment, Songhay did expand – Bovill (1995) writes that Songhay moved into the Hausa states to capture their quality land and into Air to drive out Tuareg raiders. Levzion (1975) adds that these conquests were largely along the Niger river, because of Songhay's dependence on its Sorko fleet for its military power. This is not necessarily counter to the Ricardian view. In the case of Air, this was a movement to protect existing trade interests, not to secure new routes. The strength of Songhay, like many of the states that came before it, had already been based on its favorable location for trade before it began its expansion.

Toro. One of Uganda's four traditional kingdoms, Toro broke free of Bunyoro in 1830, was reconquered in 1876, and became independent once again with Lugard's help in 1891. The base of economic production in Toro was hoe-cultivation of finger-millet, plantains, sweet potatoes and beans, though a cattle-keeping class existed (Taylor, 1962). Under Bunyoro control, the territory produced iron goods and salt for sale within the interlacustrine region (Ingham, 1975). This shaped the revenues of subordinate states; the Babito chief of Kisaka introduced agents to collect tax from both salt producers and traders, a portion of which was sent to Bunyoro (Ingham, 1975). Trade was a source of revenue to the state, both through tribute collection and direct control. Taylor (1962) states that the king, chiefs and lords of Toro maintained control over land, cattle, lakes, salt lakes, medicinal springs, canoe services, and "certain commodities having exchange or prestige value," such as tusks and lion skins. They collected many of these same goods as tribute, as well as labor and military service, and reallocated them to relatives, chiefs, officials and others. He further suggests that the "distribution of goods and services" was mainly through kinship and feudal systems, though barter was also present.

Ingham (1975) describes the Toro region as one of relative prosperity. The Toro kings sold slaves, ivory and cows to Arab traders in return for guns and cloth (Taylor, 1962). Independent Toro was also an exporter of salt; Good (1972) notes that, until 1923, the *okukama* or *Mukama* (king) of Toro held personal ownership over the trade in salt from Lake Katwe and other lake deposits near Kasenyi. This was sold for regional consumption in Bunyoro, ocassionally as far east as Lake Victoria, in Rwanda and Tanzania, and into the Congo perhaps fifty miles beyond the present border (Good, 1972). This was, however, an example of a state expanding to take advantage of a tradable resource. Lake Katwe was in Busongora, which had also seceded from Bunyoro, and which was an early conquest by independent Toro (Good, 1972). Bunyoro recaptured the territory during the 1880s.

Suku. The Suku are a petty state in the Congolese savanna, part of the Central African "matrilineal belt." They appear to have become independent from the Lunda empire during the early nineteenth century by moving into vacant land east of the Kwango valley (Kopytoff, 1965). This was precipitated by the collapse of Lunda rule over the region as a whole (Kopytoff, 1964). Kopytoff (1965) writes that Suku participation in the rubber trades of the nineteenth century and Second World War was "marginal," and that these periods were "the only ones when the Suku had any cash crops to sell. At present, the region is both too poor and too far from the centers to export a commercially feasible product of any kind." Similarly, the Suku lacked a developed system of market places and itinerant trade was "not at all developed" (Kopytoff, 1967). The Suku did, however, participate as middlemen in the long-distance trade between the raffia and palm-oil producers north and east of them and southern groups who traded directly with the Portuguese (Kopytoff, 1967). They also purchased raw raffia for weaving into cloth, which was exported to the southeast along with palm oil in return for shell money and European goods, some of which were exported (Kopytoff, 1967). The Suku were known for their wealth in shell money. The Suku *MeniKongo* (king) actively ruled over some twenty or thirty villages around the capital, and administered the remainder of his kingdom through regional chiefs. Kopytoff (1964) tells us that shell money was legal tender in rendering tribute to chiefs, so the same logic as used by Law (1977) implies that direct taxes were, indirectly, taxes on trade.

Given that much of the Suku kingship terminology is Lunda, Kopytoff (1965) supposes that Suku political organization (like that of the neighboring Yaka) is also Lunda in origin. Lunda dominated the upper Kasai basin from c. 1700 (Birmingham, 1976). Within the empire's territory lay both copper mines and salt, which were sources of both trade and tribute (Birmingham, 1976). Slaves for export were collected through both war and the tributary system of tax collection, and this revenue allowed the royal court to judiciously distribute the trade goods over which it held a virtual monopoly (Birmingham, 1976). The Suku inherited state forms from their trading predecessor, and prospered from their position as middlemen.

Luba. The separate Luba states were not unified until the eighteenth century (Birmingham, 1976). Before this period, separate Luba states such as Kikonja or Songye had control of localized dired fish, salt, oil palm, raffia cloth, and copper-working industries (Birmingham, 1976). Trade was largely "vertical," collected by chiefs as tribute, and no class of "horizontal" traders exchanging goods between producers emerged before the growth of the Luba empire. In the late eighteenth century, Luba Lomami responded most vigorously to the new long distance trade in ivory and slaves (Birmingham, 1976). Bisa traders exchanged cloth, beads and cattle for tusks that were sold subject to taxation and supervision by either the royal household or by chiefs (Birmingham, 1976). This trade was preceeded by "pioneering chiefs," who advanced into new lands and arranged for the purchase of ivory while at the same time creating "a more or less permanent Luba political superstructure" behind which the Bisa traders followed (Birmingham, 1976).

After 1780, the Luba expanded, first into the space between the Lualaba and Lake Tanganyika, and later into the fishing and palm oil areas of the Lalaba lakes, the copper production portions of the Samba, and the ivory-producing province of Manyema (Birmingham, 1976). At its peak in the mid-nineteenth century, the empire presided over "a wide-ranging and international trade" in oil, salt, poisons, drums, slaves, copper, palm cloth, baskets, iron, skins and fish. Wilson (1972) argues that long-distance trade was the cause of this expansion. The slave trade pushed Lunda to establish Kazembe as a tributary kingdom. Sub-regional specializations, such as Sanga production of copper crosses, was stimulated by the influx of trade goods. Luba-Lomami itself began as a producer of salt and hoes, sold in neighboring regions. New trades developed in response to trade goods; for example, the traditional trade with the Holoholo was supplemented with beads and ivory. Birmingham (1976) argues that the decline of the Luba kingdom followed that of the ivory trade. Their Yeke-Nyamwezi trading partners began to focus on copper, conquering production centers belonging to Mpande and Katanga. Swahili-Arab traders began to trade directly into the forest, cutting out the Luba. With ivory becoming scarce and the price of slaves declining, the Luba were unable to purchase the guns needed to secure their power without exporting large numbers of internally captured slaves. The kingdom disintegrated into warring factions and became dominated by its neighbors.

Lozi. The pastoral Lozi (or Barotse) have occupied the Barotse floodplain of the Zambezi river since roughly 1600 (Gluckman, 1941), and have had a centralized king since at least as early as the start of the nineteenth century (Birmingham, 1976). There was considerable trade within Lozi territory in the specialized products of each region – bulrush millet and cassava meal, wood products and iron were brought in from the bush areas, and the Zambezi facilitated transport (Gluckman, 1941). He further suggests that Lozi domination of its surroundings was facilitated by the society's internal cohesion, stemming from the inequality made possible by royal control of the most productive farming mounds within the floodplain, as well as a need to protect cattle in outlying areas during the flood season. The result was that the Lozi traded with its neighbors as they did not trade among themselves. Further, the king and princess chief both collected tribute in the form of specialized production of the "tribes" under his command, including canoes, weapons, iron tools, meat, fish, fruit, salt, honey, maize and manioc (Birmingham, 1976).

The Lozi were ruled between 1840 and 1864 by the Sotho-speaking Kololo who invaded from the south. The Lozi spurned Lovale traders before the emergence of the trade in slaves and ivory in southern Kololo around 1850. Before this, they had sent traders to the Lunda areas of the upper Zambezi, trading only indirectly with the Portuguese (Flint, 1970). Flint (1970) suggests that the major change was the rise of the ivory trade relative to the slave trade by 1853. He argues that the Kololo used Livingstone as a 'prestigious outsider,' helping them negotiate with the peoples through whose territory the Lozi traded. By 1860, long distance trade had become of major importance to the Barotse. The Kololo obtained ivory either as tribute from the Barotse or by selling iron hoes to the Tonga, and then sold this ivory either to middlemen or directly to the coast. The Lozi also exported cattle and forest products in return for trade goods during this period (Gluckman, 1941). Trade gave the Kololo king an independent power base, strengthening him against other chiefs who depended on cattle raiding for revenue. He worked to establish a new set of 'caravan chiefs' (Flint, 1970).

Flint (1970) suggests that the more trade-oriented Barotse of the floodplain came into conflict with the southern Kololo, whose raids on their neighbors disrupted trade, and who refused to move the capital into the floodplain where it would be better situated relative to trade routes. Further, the king received profits from ivory and distributed within his court, shutting out the Barotse. Though the details are not clear, Birmingham (1976) ties the restoration of Lozi independence to this trade. He argues that traders operated independently of the state, and the second Kololo king was followed by an interregnum before a Lozi king was restored in the 1870s. He suggests that the western ivory trade "may have facilitated" this restoration. Gluckman (1941) suggests that the restored Lozi king traded cattle, ivory and slaves on his own account for trade goods that he distributed, both among his own people and among subject tribes.

Overall, these are consistent with the Ricardian view that opportunities for trade give rise to states. While Songhai and Oyo expanded to capture more territory, they did so after having arisen in a location favorable to trade across ecological zones. The Luba too expanded after 1780, but did so based on power already acquired through proximity to the Bisa ivory trade. When that trade declined, the kingdom collapsed. The pre-Kololo Lozi dominance over surrounding peoples, while stemming in part from the cohesion deriving from their environment, also depended on the ability to trade and collect tribute in the diverse products of their neighbors. That the Suku participated in long-distance trade while possessing only limited internal markets further supports that

TABLE 13. Alternative stories: Additional controls and ethnic competition

[Table 13 here]

it is the ability to trade the products of different macro-ecological regions that matters most. In every case, rulers relied heavily on taxing trade. The exception is Toro, which emerged in a region with an existing trade in salt and iron, but conquered Busongora in part to capture the most important source of salt in the region. Toro, however, inherited its political structure from Bunyoro, which had previously grown strong in part due to its sale of metal goods and control of the Kibiro salt industry.

My third strategy for dismissing this alternative explanation is to control directly for area. This is not done in the main analysis, because it is potentially endogenous. States that independently develop strong states might have larger areas, biasing the coefficient on both area and potentially on the other coefficients. With that caveat in mind, if it is only through expansion that states become correlated with ecological diversity, there should be no correlation conditional on area. I include it, then, as an additional regressor in Table 13. The impact of area is negligible, and the coefficient remains significant, positive, and of a similar magnitude.

5.3. **Islands of quality.** The third alternative story is that states emerge to protect "islands" of particular quality. This competition is fiercest when these islands are very different from neighboring areas, and areas with diverse land qualities will similarly have diverse ecologies. Jones (2003, p. 105-106), similarly, argues that the European patchwork of nation states (as opposed to China's unifying empire) was based on the prevalence of fertile islands separated by natural boundaries. This is also similar to Allen's (1997) view that the Egyptian state benefitted from the fact that its citizens were confined to a fertile valley surrounded by desert. Carneiro (1970), likewise, has noted that the Nile, Tigrus-Euphrates, and Indus valleys as well as the Valley of Mexico and the mountain and coastal valleys of Peru were all areas of circumscribed agricultural land. In columns 3 and 4 I control for the range of agricultural constraints – the difference in land quality between the best and worst points in a society's territory. This does diminish the effect of ecological diversity, though it remains significant when regional fixed effects are not included. That the range of agricultural constraints is not significant, however, suggests it should not be included in the best specification. Results are also robust to including the presence of bovines as a control (not reported).

5.4. **Population density.** Fourth, it is possible that ecological diversity is correlated with population density, which alone explains the centralization of pre-colonial African states. I add population density in 1960, published by the United Nations Environment Programme, as a proxy for historical population density.[15] This is reported in columns 5 and 6 of Table 13, and the effect of ecological diversity remains intact.

[15]Raster data taken from `http://na.unep.net/datasets/datalist.php`.

TABLE 14. Mechanisms: Other institutional outcomes

[Table 14 here]

5.5. **Ethnic competition.** Fifth, it is possible, combining the stories of Michalopoulos (2008) and Tilly and Ardant (1975), that ecology-specific human capital gives rise to a greater number of ethnic groups in regions of diverse ecology, and that competition between these groups leads to greater state centralization. To show that this is not driving my results, I return to my sample of artificial countries. For each square, I count the number of ethnic groups that intersect it in Murdock's map, and include this as an additional control in Table 13. In column 1, there is a positive but insignificant correlation between diversity and the number of ethnic groups in an "artificial country." This is an artefact of the specification chosen – if I take the full sample of artificial countries (rather than only those for which information on states are available) the correlation is strong and positive, confirming the Michalopoulos (2008) result with a different measure of geographic heterogeneity. If I include the number of ethnic groups as an additional control, this does not diminish the direct effect of ecological diversity on states, suggesting that this and the gains-from-trade explanation of states are not mutually exclusive.

6. MECHANISMS

6.1. **How does trade cause states?** There are many reasons centralized states might arise due to gains from trade. In Table 14, I test whether the *Ethnographic Atlas* supports any of these. The first possible mechanism is to take over the authority of other smaller states in its vicinity. The atlas contains a variable (V32) that records the number of "levels of local jurisdiction." Following Bolt and Smits (2010), I take this as a crude measure of the strength of local states, and use it as an outcome in place of state centralization in (2). While there is a suggestive negative correlation between ecological diversity and local states when no other controls are added, this is not robust to the inclusion of other variables or to region fixed effects. Similarly, V72 records the rules for succession to the office of the local headman. I construct a "headman is appointed" dummy if this rule is "appointment by higher authority." There appears to be no correlation in the data. I am not able to conclusively test for the spread of Islam as a mechanism. The data only state whether high gods are "supportive of human morality", which is only positive for a handful of societies outside of the Moslem Sudan, Western Sudan and Ethiopia. This is only for a sample roughly half the size of the main sample, and does not appear to be related to ecological diversity, though its collinearity with the region fixed effects make it impossible to test whether it this is the case within regions.

Another possible mechanism for the rise of states is the ability of kings to amass wealth through taxation, letting them gain prestige and control the flow of tribute. To

TABLE 15. Mechanisms: Other sources of trade

[Table 15 here]

test for this mechanism, I use V66, "class stratification among freemen," which is divided into five levels. In order, these are "absence among freemen," "wealth distinctions," "elite," "dual," and "complex." Here there is a strong relationship between gains from trade and inequality. Results (not reported) are similar if a binary class stratification measure is used. Similarly, I test whether there is a relationship between gains from trade and one particular form of inequality – slavery. V70 codes slavery into four levels. These are "absence or near absence," "incipient or nonhereditary," "reported but type not identified," and "hereditary and socially significant." While there is a positive correlation of ecological diversity and slavery conditional on other controls, this is not apparent in the unconditional correlation, nor when regional fixed effects are added. Many of these results are statistically weak, but they do suggest strong links between trade and class stratification.

It is also interesting to note that the ecological diversity variable does predict modern economic activity, though not robustly. I use the same $\ln(1 + \text{Avg. light density})$ normalization of 2009 nighttime lights as Michalopoulos and Papaioannou (2010) to test this. The ecological diversity measure predicts conditional, though not unconditional, differences in modern light densities. This effect disappears, however, when standard errors are clustered by ethnographic regions.

6.2. **What sort of trade matters?** While the ecological diversity measure serves as a proxy for the capacity to trade products from different ecological zones, it will not capture other forms of trade. In Table 15, I test whether three other sources of trade – fishing, iron, and gold – give similar rise to states. A society's percentage dependance on fishing is V3 in the *Ethnographic Atlas*. I find no correlation between this and states. While it is possible that the impact of fishing is being hidden by the impacts of other controls (notably coastal distance and major rivers), regressing states on the fishing variable similarly does not yield a significant result (not reported). To test the importance of minerals, I take data from the US Geological Service's Mineral Resources Program.[16] These records contain data on both metallic and nonmetallic mineral resources at specific sites, with their latitudes and longitudes. "Iron" is the number of deposits of iron found within an ethnic group's territory, and "gold" is analogously defined. If there is likely to be any endogeneity bias from using modern data, it will be positive, since states that have inherited the strength of their pre-colonial predecessors will likely be better able to exploit their countries' resources. Despite this, I find no evidence that iron matters. Gold enters significantly having either mineral within an ethnic group's

[16]The data are available at `http://mrdata.usgs.gov/`

TABLE 16. Mechanisms: Regressions of SCCS measures of trade on state centralization

[Table 16 here]

TABLE 17. Mechanisms: Local or long distance trade?

[Table 17 here]

TABLE 18. Mechanisms: Is Africa different?

[Table 18 here]

territory when no controls are added, though the effect of gold is marginally insignificant with controls. "Salt" is the number of salt-producing cites listed by Sundstr
"om (1974) within an ethnic group's territory.[17]

While the sample of African societies in the SCCS is too small to use for comparing that source's data on trade with the main sample here, I can test whether state centralization is correlated with any particular form of trade in the SCCS's global sample of ethnic groups. In Table 16, I present the results of regressing several of these indicators on the state centralization measure and a constant. The presentation here is similar to Table 5. I find that societies with states are more likely to trade for food, through more levels of intermediation, and that this trade is more important to their subsistence. Political power is more likely to depend on commerce in more centralized states, trade and markets are more likely to exist, and exchange is more important both within and beyond the community, though this latter correlation is not significant at conventional levels.

Interestingly, Tables 16 and 15 suggest that it is more mundane, intra-community trade in products such as food, rather than long distance trade in products such as gold and ivory, that matters for the formation of states. The main data sources here do not allow for these two types of trade to be conclusively tested against each other. However, the "ecological diversity" measure is more intuitively related to trade that is possible within an ethnic group's borders, while the "distance from an ecological divide" variable is more suggestive of long distance trade. In Table 17, I test whether the estimated effect of either one disappears when both are included as regressors. They are, however, strongly correlated (see column 1), which limits the power of this test. With controls, both coefficients fall relatively 40% relative to their values in Tables 4 and Table 6. The distance from a divide remains more statistically robust, especially once regional fixed effects are added. It is not, then, possible to rule out the importance of either long distance or local trade.

[17]Of 271 sites he lists, I match 84 to ethnic groups in the data and 157 to specific geographic locations, such as Cape Lopez. For 30 I could not find a match.

6.3. **Is Africa different?** In other work, I have assembled an analogous data-set for all 1,267 societies of the *Ethnographic Atlas*.[18] While some of the controls used here are either not available or computed somewhat differently in that data, I am able to expand the present analysis to the whole world. Results in Table 18 suggest that Africa is not different: in a sample of more than 1,000 societies from around the world, ecological diversity continues to predict the existence of states.

7. Conclusion

I have used this paper to provide empirical support for Bates's (1983) Ricardian view of pre-colonial African states. The gains from trade stemming from ecological diversity predict the presence of state centralization across sub-Saharan societies recorded in the *Ethnographic Atlas*. Moving from a homogenous zone to one that is ecologically diverse predicts that the chance a society is centralized rises between 6 and 13 percentage points. Distance from an ecological divide serves as well in predicting states. There is no evidence this is overstated due to endogeneity or the influence of outliers or specific ethnographic regions. The histories of African societies are consistent with this interpretation of the data, rather than one in which states emerge and then migrate. Similarly, area, defense of fertile islands, correlation with dense population, and ethnic competition do not explain the results. Michalopoulos and Papaioannou (2010) show that the strength of pre-colonial African states does more to predict modern development, using night-time lights as a measure, than country-level institutions. These states are rooted in the intersection of ecology and trade.

References

Adjuik, M., Bagayoko, M., Binka, F., Coetzee, M., Cox, J., Craig, M., Deichman, U., Don deSavigny, F., Fraser, C., Gouws, E., et al. (1998). Towards an atlas of malaria risk in Africa. *First technical report of the Mapping Malaria Risk in Africa/Atlas du Risque de la Malaria en Afrique (MARA/ARMA) collaboration. Durban, MARA/ARMA*.

Allen, R. (1997). Agriculture and the Origins of the State in Ancient Egypt. *Explorations in Economic History*, 34(2):135–154.

Altonji, J., Elder, T., and Taber, C. (2005). Selection on observable and unobservable variables: Assessing the effectiveness of Catholic schools. *Journal of Political Economy*, 113(1):151–184.

Austin, G. (2008a). Resources, Techniques, and Strategies South of the Sahara: Revising the Factor Endowments Perspective on African Economic Development, 1500-2000. *Economic history review*, 61(3):587–624.

Austin, G. (2008b). The reversal of fortunethesis and the compression of history: perspectives from African and comparative economic history. *Journal of international development*, 20(8):996–1027.

[18] For more details, see Fenske (2011).

Banerjee, A. and Iyer, L. (2005). History, institutions, and economic performance: the legacy of colonial land tenure systems in India. *The American economic review*, 95(4):1190–1213.

Bates, R. (1983). *Essays on the political economy of rural Africa*. University of California Press.

Berry, S. (1992). Hegemony on a shoestring: indirect rule and access to agricultural land. *Africa*, pages 327–355.

Bhalotra, S. and Cochrane, T. (2010). Where have all the young girls gone? On the rising trend in sex selection in India. *Working Paper*.

Birmingham, D. (1976). The Forest and Savanna of Central Africa.

Bisson, M. (1982). Trade and Tribute. Archaeological Evidence for the Origin of States in South Central Africa (Commerce et tribut. Documents archéologiques sur l'origine des États du sud de l'Afrique centrale). *Cahiers d'études africaines*, 22(87):343–361.

Bockstette, V., Chanda, A., and Putterman, L. (2002). States and markets: The advantage of an early start. *Journal of Economic Growth*, 7(4):347–369.

Bolt, J. and Smits, J. P. (2010). Can the nature of pre-colonial institutions explain governance quality in Africa? *Working Paper*.

Bovill, E. (1995). *The golden trade of the Moors: West African kingdoms in the fourteenth century*. Markus Wiener Pub.

Carneiro, R. (1970). A theory of the origin of the state. *Science*, 169(3947):733.

Chanda, A. and Putterman, L. (2007). Early Starts, Reversals and Catch-up in the Process of Economic Development. *Scandinavian Journal of Economics*, 109(2):387–413.

Diamond, J. (1997). *Guns, germs, and steel*. 1997.

Dixit, A. (2004). *Lawlessness and economics: alternative modes of governance*. Princeton Univ Pr.

Englebert, P. (2000). Solving the Mystery of the AFRICA Dummy. *World development*, 28(10):1821–1835.

Fenske, J. (2011). Does land abundance explain african institutions? *Working paper: To be posted soon*.

Fischer, G., Shah, M., van Velthuizen, H., and Nachtergaele, F. (2001). *Global agro-ecological assessment for agriculture in the 21st century*. IIASA.

Flint, E. (1970). Trade and politics in Barotseland during the Kololo period. *Journal of African History*, 11(1):71–86.

Frankel, J. and Romer, D. (1999). Does trade cause growth? *American Economic Review*, 89(3):379–399.

Gennaioli, N. and Rainer, I. (2007). The modern impact of precolonial centralization in Africa. *Journal of Economic Growth*, 12(3):185–234.

Gluckman, M. (1941). *Economy of the central Barotse plain*. Rhodes-Livingstone Institute.

Good, C. (1972). Salt, trade, and disease: Aspects of development in Africa's northern Great Lakes Region. *International Journal of African Historical Studies*, 5(4):543–586.

Herbst, J. (2000). *States and power in Africa: comparative lessons in authority and control*. Princeton Univ Pr.

Huillery, E. (2008). The Impact of European Settlement within French West Africa. Did pre-colonial prosperous areas fall behind? *Mimeogr., Paris Sch. Econ.*

Ingham, K. (1975). *The kingdom of Toro in Uganda*. Methuen; New York: distributed by Harper & Row, Barnes & Noble Import Division.

Iyer, L. (2007). Direct versus indirect colonial rule in India: Long-term consequences. *Mimeogr., Harvard Bus. Sch.*

Jones, E. (2003). *The European miracle: Environments, economies, and geopolitics in the history of Europe and Asia*. Cambridge Univ Pr.

Kopytoff, I. (1964). Family and Lineage among the Suku of the Congo. *The family estate in Africa: studies in the role of property in family structure and lineage continuity*, pages 83–116.

Kopytoff, I. (1965). The Suku of Southwestern Congo. *Peoples of Africa*, pages 441–80.

Kopytoff, I. (1967). Labor allocation among the Suku. *Paper presented at conference on competing demands for the time of labor in traditional African societies.*

Law, R. (1977). *The Oyo empire: c. 1600-c. 1836: a west African imperialism in the era of the Atlantic slave trade*. Clarendon press.

Levzion, N. (1975). The Western Maghrib and Sudan. In Gray, R., editor, *The Cambridge history of Africa: from c. 1600 to c. 1790*, pages 331–462. Cambridge University Press.

Lovejoy, P. (1978). The role of the Wangara in the economic transformation of the central sudan in the fifteenth and sixteenth centuries. *The Journal of African History*, 19(02):173–193.

Maddala, G. (1986). *Limited-dependent and qualitative variables in econometrics*. Cambridge Univ Pr.

Mamdani, M. (1996). *Citizen and subject: Contemporary Africa and the legacy of late colonialism*. Princeton Univ Pr.

McCann, J. (1999). *Green land, brown land, black land: an environmental history of Africa, 1800-1990*. James Currey.

Michalopoulos, S. (2008). The Origins of Ethnic Diversity. *Working Paper*.

Michalopoulos, S. and Papaioannou, E. (2010). 'Divide and Rule' or the Rule of the Divided? Evidence from Africa. *Working Paper*.

Moav, O. and Mayshar, J. (2011). Title not yet listed on programme. *Paper presented at the 2011 Royal Economic Society meetings.*

Morton-Williams, P. (1969). The influence of habitat and trade on the polities of Oyo and Ashanti. In *Man in Africa*, pages 79–98. Tavistock Publications.

Murdock, G. (1959). *Its Peoples and Their Culture History*. Nueva York.

Murdock, G. (1967). *Ethnographic atlas*. University of Pittsburgh Press.

Neumark, S. (1977). Trans-Saharan Trade in the Middle Ages. *The pre-colonial period*, page 127.

Nunn, N. (2008). The Long-Term Effects of Africa's Slave Trades. *Quarterly Journal of Economics*, 123(1):139–176.

Nunn, N. and Puga, D. (2009). Ruggedness: The blessing of bad geography in Africa. *NBER Working Paper*.

Oliver, R. and Fage, J. (1962). *A short History of Africa*. Harmondsworth: Penguin.

Olson, M. (1993). Dictatorship, democracy, and development. *American Political Science Review*, 87(3):567–576.

Robinson, J. (2002). States and Power in Africa by Jeffrey I. Herbst: A review essay. *Journal of Economic Literature*, 40(2):510–519.

Rodney, W. (1972). How Europe Underdeveloped Africa. *Beyond borders: Thinking critically about global issues*, pages 107–125.

Shillington, K. (1989). *History of Africa*. Bedford Books.

Spencer, C. (1998). A mathematical model of primary state formation. *Cultural Dynamics*, 10(1):5.

Spencer, C. (2010). Territorial expansion and primary state formation. *Proceedings of the National Academy of Sciences*, 107(16):7119.

Sundstr
”om, L. (1974). *the exchange economy of pre-colonial tropical Africa*. C. Hurst & Co. Publishers.

Taylor, B. (1962). The western lacustrine Bantu. *London: International African Institute*.

Tilly, C. and Ardant, G. (1975). *The formation of national states in Western Europe*. Princeton Univ Pr.

Vansina, J. (1966). *Kingdoms of the Savanna*. University of Wisconsin Press London.

White, F. (1983). The vegetation of Africa: a descriptive memoir to accompany the UNESCO/AETFAT/UNSO vegetation map of Africa. *Natural resources research*, 20:1–356.

Wilson, A. (1972). Long distance trade and the Luba Lomami Empire. *The Journal of African History*, 13(04):575–589.

Wooldridge, J. (2002). *Econometric analysis of cross section and panel data*. The MIT press.

TABLE 19. Full results

[Table 19 here]

Table 1. Bates' evidence

	Abuts ecological divide	Diversified area	No ecological variation
		Political structure	
Kinship	12%	17%	40%
Chiefs	38%	50%	20%
Central monarch	50%	33%	40%
N	8	6	20
		Central bureaucracy	
Absent	25%	40%	67%
Present	75%	60%	33%
N	8	5	18
		National army	
Absent	38%	40%	50%
Present	62%	60%	50%
N	8	5	20
		Army commanded at	
Local level	62%	40%	50%
Regional level	0%	20%	10%
National level	38%	40%	40%
N	8	5	20

Notes: Adapted from Bates (1983), p. 43.

Table 2. Summary Statistics

	Mean	s.d.	Min	Max	N
			Outcomes		
State centralization	1.15	0.93	0	4	440
Any centralization	0.73	0.44	0	1	440
Local state	2.91	0.68	2	4	439
Class stratification	1.25	1.41	0	4	364
Slavery	1.83	1.03	0	3	383
Headman appointed	0.066	0.25	0	1	320
Light density	1.50	0.18	1.15	3.34	440
			Gains from trade		
Ecological diversity	0.30	0.23	0	0.80	440
Eco. Div. (FAO)	0.47	0.23	0	0.80	440
Predicted Eco. Div. (FAO)	0.20	0.21	0	0.70	440
Dist. ecological divide	0.45	0.53	0.019	2.95	440
Any diversity	0.78	0.42	0	1	440
Salt	0.42	0.88	0	6	440
Gold production	0.34	1.86	0	24	440
Iron production	0.12	0.33	0	1	440
% dep. on fishing	8.32	10.9	0	70	440

Table 3. Summary Statistics

	Mean	s.d.	Min	Max	N
	Controls				
Major river	0.23	0.42	0	1	440
Ag. constraints	5.41	1.06	2.94	8.92	440
Dist. coast	5.54	3.76	0	14.9	440
Elevation	728	520	-7.41	2,308	440
Malaria	0.83	0.27	0	1	440
Precipitation	1,194	528	32.4	2,954	440
Ruggedness	71,792	70,413	0	421,381	440
Temperature	8,882	1,112	5,295	10,699	440
Dist. L. Victoria	2,198	1,438	131	5,708	440
Date observed	1,919	21.6	1,830	1,960	440
Dist. Atlantic ST	6,688	1,515	3,671	9,949	440
Dist. Indian ST	4,546	1,589	1,028	7,953	440
Dist. Saharan ST	3,333	975	806	6,999	440
Dist. Red ST	2,887	1,360	107	5,773	440
Crop: Missing	0	0	0	0	440
Crop: None	0.025	0.16	0	1	440
Crop: Trees	0.084	0.28	0	1	440
Crop: Roots/tubers	0.19	0.39	0	1	440
	Other variables used				
Temperature s.d.	294	292	0	1,635	370
Area	2.43	3.64	8.2e-06	27.0	440
Pop. density	22.2	28.5	0	311	440
Ag. Constraints Range	4.66	1.95	0	9	440
Grain endemicity	0.35	0.25	0	0.76	425

Table 4. Main Results

	(1)	(2)	(3)
	State centralization		
Ecological diversity	0.794***	0.703***	0.437**
	(0.266)	(0.234)	(0.219)
Other controls	No	Yes	Yes
Region F.E.	No	No	Yes
	Marginal effects		
0 levels	-0.259***	-0.220***	-0.132**
	(0.087)	(0.069)	(0.064)
1 level	-0.022	-0.024	-0.016*
	(0.038)	(0.029)	(0.009)
2 levels	0.152***	0.149***	0.098**
	(0.052)	(0.050)	(0.048)
3 levels	0.118***	0.091***	0.048**
	(0.044)	(0.034)	(0.024)
4 levels	0.010	0.004	0.001
	(0.008)	(0.004)	(0.002)
Observations	440	440	440

*** p<0.01, ** p<0.05, * p<0.1. Regressions estimated by ordered probit. Standard errors in parentheses clustered by region. Other controls are those listed as "controls" in the table of summary statistics.

Table 5. Regressions of alternative SCCS measures of states on state centralization

Dependent variable	Coef	s.e.	N
v81: Political autonomy	0.485	0.082	182
v82: Trend in political autonomy	0.395	0.069	182
v84: Higher political organization	0.400	0.071	181
v85: Executive	0.801	0.086	181
v89: Judiciary	0.261	0.022	181
v90: Police	0.889	0.080	178
v91: Administrative hierarchy	0.943	0.071	181
v700: State punishes crimes against persons	0.185	0.033	91
v701: Full-time bureaucrats	0.242	0.026	91
v702: Part of kingdom	0.136	0.029	86
v756: Political role specialization	1.220	0.167	89
v759: Leaders' perceived power	0.432	0.069	89
v760: Leaders' perceived capriciousness	0.240	0.097	66
v761: Leaders' unchecked power	0.385	0.076	85
v762: Inability to remove leaders	0.420	0.100	77
v763: Leaders' independence	0.426	0.070	86
v764: Leaders' control of decisions	0.584	0.136	87
v776: Formal sanctions and enforcement	0.412	0.068	89
v777: Enforcement specialists	0.461	0.076	88
v779: Loyalty to the wider society	0.228	0.104	83
v784: Taxation	0.536	0.069	84
v785: Rareness of political fission	0.154	0.102	64
v1132: Political integration	1.185	0.070	118
v1134: Despotism in dispute resolution	0.132	0.023	104
v1135: Jurisdictional perquisites	0.172	0.067	34
v1736: Tribute, Taxation, Expropriation	0.961	0.152	77
v1740: Levels of political hierarchy	1.600	0.196	100
v1741: Overarching jurisdiction	0.331	0.070	94
v1742: Selection of lower officials	0.524	0.061	95

Each row reports the estimated coefficient and standard error when the listed variable in the SCCS is regressed on state centralization and a constant (not reported). All results are significant at conventional levels. I have reversed the signs for variables 756, 759, 760, 761, 762, 763, 764, 765, 776, 777, 779, and 784, so that higher values correspond to greater state strength. I have re-labeled these variables to capture the positive re-coding, and have re-labeled some other variables so that their meaning is clearer. I have removed the missing values 0 and 8 from variable 1132, and converted variable 89 into a binary ``judiciary present'' measure, since the categories of judiciary were not clearly ordered.

Table 6. Robustness: Alternative measures of states and diversity

	(1)	(2)	(3)
		Any centralization	
Ecological diversity	0.252**	0.280**	0.207*
	(0.128)	(0.128)	(0.118)
		State centralization	
Dist. ecological divide	-0.326***	-0.301***	-0.267***
	(0.078)	(0.071)	(0.073)
		State centralization	
Any diversity	0.480***	0.359**	0.225*
	(0.155)	(0.142)	(0.126)
		State centralization	
Ecological diversity (Simpler classes)	0.907***	0.793**	0.557
	(0.335)	(0.311)	(0.356)
		State centralization	
Eco. Div. (FAO)	0.967***	0.999***	0.540**
	(0.198)	(0.282)	(0.275)
Other controls	No	Yes	Yes
Region F.E.	No	No	Yes
Observations	440	440	440

*** p<0.01, ** p<0.05, * p<0.1. Robust standard errors in parentheses. Regressions estimated by ordered probit with coefficients reported, except with "any centralization" as the outcome, in which case probit is used with marginal effects reported. Standard errors in parentheses clustered by region. Other controls are those listed as "controls" in the table of summary statistics.

Table 7. Robustness: Estimation methods

	(1)	(2)	(3)
	State centralization: Generalized ordered probit		
Equation 1	0.778*	0.976**	
	(0.408)	(0.455)	
Equation 2	0.916***	0.848***	
	(0.282)	(0.268)	
Equation 3	0.777**	0.865**	
	(0.359)	(0.420)	
Equation 4	-1.249*	-19.310***	
	(0.691)	(1.282)	
	State centralization: Alternative regions		
Ecological diversity	0.794***	0.703**	0.661*
	(0.212)	(0.343)	(0.373)
	State centralization: No "trade" controls		
Ecological diversity	0.794***	0.506**	0.415*
	(0.266)	(0.257)	(0.222)
	State centralization: No date control		
Ecological diversity	0.794***	0.693***	0.423*
	(0.266)	(0.238)	(0.221)
Other controls	No	Yes	Yes
Region F.E.	No	No	Yes
Observations	440	440	440

*** p<0.01, ** p<0.05, * p<0.1. Robust standard errors in parentheses. Regressions estimated by ordered probit. Standard errors in parentheses clustered by region. Other controls are those listed as "controls" in the table of summary statistics.

Table 8. Robustness Influential observations

Dropped	*High leverage*	*High dfbeta*	*South African Bantu*	*Ethiopia and Horn*	*Moslem Sudan*	*Indian Ocean*
	State centralization					
Ecological diversity	0.642**	0.958***	0.735***	0.752***	0.611**	0.768***
	(0.286)	(0.289)	(0.228)	(0.233)	(0.238)	(0.226)
Other controls	Yes	Yes	Yes	Yes	Yes	Yes
Region F.E.	No	No	No	No	No	No
Observations	406	411	421	400	417	435
	State centralization					
Ecological diversity	0.236	0.682**	0.484**	0.412*	0.369	0.496**
	(0.334)	(0.285)	(0.205)	(0.234)	(0.229)	(0.215)
Other controls	Yes	Yes	Yes	Yes	Yes	Yes
Region F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Observations	406	411	421	400	417	435

*** p<0.01, ** p<0.05, * p<0.1. Robust standard errors in parentheses. Regressions estimated by ordered probit. Standard errors in parentheses clustered by region. Other controls are those listed as "controls" in the table of summary statistics.

Table 9. Robustness: Reverse causation

	(1)	(2)	(3)	(4)	(5)	(6)
	State centralization					
	OLS			*OLS: Temp. s.d. nonmissing*		
Ecological diversity	0.678***	0.542***	0.327**	0.699**	0.612***	0.387**
	(0.219)	(0.163)	(0.150)	(0.275)	(0.190)	(0.191)
Other controls	No	Yes	Yes	No	Yes	Yes
Region F.E.	No	No	Yes	No	No	Yes
Observations	440	440	440	370	370	370
	State centralization					
	IV			*Ordered probit*		
Ecological diversity	1.597**	1.023	1.335			
	(0.716)	(2.711)	(2.366)			
Predicted Eco. Div. (FAO)				0.494***	0.284*	0.037
				(0.181)	(0.151)	(0.179)
Other controls	No	Yes	Yes	No	Yes	Yes
Region F.E.	No	No	Yes	No	No	Yes
Observations	370	370	370	440	440	440

*** p<0.01, ** p<0.05, * p<0.1. Robust standard errors in parentheses. Standard errors in parentheses clustered by region. Other controls are those listed as "controls" in the table of summary statistics.

Table 10. Robustness: Heterogeneity

	(1)	(2)	(3)
	State centralization: Including area shares		
Ecological diversity	1.080***	0.943***	0.479**
	(0.291)	(0.262)	(0.229)
	State centralization: Latitude/longitude quartic		
Ecological diversity	0.676***	0.597***	0.304
	(0.233)	(0.211)	(0.214)
	State centralization: Spatially correlated errors		
Ecological diversity	0.492**	0.491**	0.326
	(0.228)	(0.244)	(0.228)
Wald test (λ=0)	33.71	1.187	7.22e-06
	State centralization: Including neighbors' X		
Ecological diversity	0.697***	0.512***	0.304
	(0.201)	(0.192)	(0.196)
WX p	0	0.000	0.000
Moran p	0.278	0.426	0.186
	State centralization: Interactions with de-meaned controls		
Ecological diversity	0.583	0.730***	0.449*
	(0.420)	(0.259)	(0.244)
	Nearest Neighbor Matching		
Above Median Diversity SATE		0.202**	
		(0.096)	
	Altonji-Elder-Taber Statistics		
		4.51	3.08
Other controls	No	Yes	Yes
Region F.E.	No	No	Yes
Observations	440	440	440

*** p<0.01, ** p<0.05, * p<0.1. Robust standard errors in parentheses. Regressions estimated by ordered probit with coefficients reported, except with spatially correlated errors, described in the text. Standard errors in parentheses clustered by region, except with spatially correlated errors. Other controls are those listed as "controls" in the table of summary statistics.

Table 11. Alternative stories: Artificial countries and area groups

	(1)	(2)	(3)
	State centralization: Artificial countries		
Ecological diversity	0.842***	0.806***	0.804***
	-0.275	-0.107	-0.179
	State centralization: Drop Area Q1		
Ecological diversity	0.957***	0.914***	0.554*
	(0.327)	(0.269)	(0.326)
	State centralization: Drop Area Q5		
Ecological diversity	0.729**	0.665***	0.366
	(0.284)	(0.255)	(0.231)
	State centralization: Drop Area Q1 and Q5		
Ecological diversity	0.987***	1.017***	0.606**
	(0.281)	(0.268)	(0.299)
Other controls	No	Yes	Yes
Region F.E.	No	No	Yes
Observations	440	440	440

*** p<0.01, ** p<0.05, * p<0.1. Regressions estimated by ordered probit with coefficients reported. Standard errors in parentheses clustered by region. Other controls are those listed as "controls" in the table of summary statistics.

Table 12. Alternative stories: Additional controls and ethnic competition

	(1)	(2)	(3)	(4)	(5)	(6)
	State centralization: Additional controls					
Ecological diversity	0.718***	0.673***	0.392*	0.587*	0.535**	0.291
	(0.248)	(0.228)	(0.217)	(0.315)	(0.259)	(0.247)
Area	0.034*	0.021	0.026			
	(0.020)	(0.022)	(0.025)			
Ag. Constraints Range				0.082**	0.065*	0.055
				(0.038)	(0.035)	(0.035)
	State centralization: Additional controls					
Ecological diversity	0.762***	0.682***	0.430**	0.753***	0.703***	0.390*
	(0.260)	(0.230)	(0.208)	(0.273)	(0.230)	(0.211)
Pop. density	0.002	0.001	0.000			
	(0.002)	(0.001)	(0.001)			
Grain endemism				0.442	0.287	0.904**
				(0.310)	(0.403)	(0.395)
Other controls	No	Yes	Yes	No	Yes	Yes
Region F.E.	No	No	Yes	No	No	Yes
Observations	440	440	440	440	440	440
	State centralization: Artificial countries and ethnic competition					
Ecological Diversity	0.369	0.814***	0.749***	0.703***		
	-0.285	-0.27	-0.104	-0.19		
No. of Ethnic Groups		0.073	0.123**	0.145***		
		-0.047	-0.048	-0.048		
Other controls	No	No	Yes	Yes		
Region F.E.	No	No	No	Yes		
Observations	1524	1524	1524	1524		

*** p<0.01, ** p<0.05, * p<0.1. Regressions estimated by ordered probit with coefficients reported. Standard errors in parentheses clustered by region. Other controls are those listed as "controls" in the table of summary statistics.

Table 13. Alternative stories: Six influential states

Name	Cent.	dfbeta	Name	Cent.	dfbeta
Songhai	3	0.1821782	Barea	0	0.122194
Yoruba	3	0.1704813	Shuwa	2	0.1131304
Chiga	0	0.1550042	Luba	3	0.1105842
Lozi	3	0.1492606	Kunama	0	0.1068234
Bagirmi	3	0.1482568	Rundi	3	0.0934491
Toro	3	0.145315	Fur	3	0.0893164
Laketonga	0	0.1378572	Suku	3	0.0849554

	Yoruba	Songhai	Toro	Suku	Luba	Lozi
Participated in trade?	Yes	Yes	Yes	Yes	Yes	Yes
Trade a source of wealth?	Yes	Yes	Yes	Arguable	Yes	Yes
Trade a source of state power?	Yes	Yes	Yes	Yes	Yes	Yes
Rose and fall with trade?	Arguable	No	No	No	Yes	Arguable
No capture of trading regions?	Yes	Yes	No	Yes	No	Yes

Table 14. Mechanisms: Other institutional outcomes

	(1)	(2)	(3)
		Local state	
Ecological diversity	-1.108***	-0.207	0.014
	(0.311)	(0.238)	(0.210)
Observations	439	439	439
		Class Stratification	
Ecological diversity	1.226***	1.474***	1.333***
	(0.346)	(0.230)	(0.241)
Observations	364	364	364
		Slavery	
Ecological diversity	-0.139	0.554***	0.012
	(0.355)	(0.137)	(0.014)
Observations	383	383	383
		Headman is appointed	
Ecological diversity	0.105	-0.085	0.000
	(0.419)	(0.633)	(0.045)
Observations	320	320	320
		High gods	
Ecological diversity	-0.029	-0.267	
	(0.454)	(0.910)	
Observations	242	242	
		Light density	
Ecological diversity	-0.013	0.088*	0.106**
(robust se)	(0.034)	(0.045)	(0.044)
(clustered se)	(0.072)	(0.086)	(0.093)
Observations	440	440	440
Other controls	No	Yes	Yes
Region F.E.	No	No	Yes

*** p<0.01, ** p<0.05, * p<0.1. Regressions estimated by ordered probit with coefficients reported. Standard errors in parentheses clustered by region. Other controls are those listed as "controls" in the table of summary statistics.

Table 15. Mechanisms: Other sources of trade

	(1)	(2)	(3)	(4)
	State centralization			
% dep. on fishing	0.003			
	(0.004)			
Iron production		0.047		
		(0.165)		
Gold production			0.020	
			(0.016)	
Salt				0.040
				(0.051)
Other controls	Yes	Yes	Yes	Yes
Region F.E.	No	No	No	No
Observations	440	440	440	440

*** p<0.01, ** p<0.05, * p<0.1. Regressions estimated by ordered probit with coefficients reported. Standard errors in parentheses clustered by region. Other controls are those listed as "controls" in the table of summary statistics.

Table 16. Mechanisms: Regressions of SCCS measures of trade on state centralization

Dependent variable	Coef	s.e.	N
v1: Trade for food	0.324	0.071	181
v2: Food trade intermediation	0.289	0.087	123
v93: Political power via commerce	0.064	0.018	181
v732: Importance of trade in subsistence	0.154	0.056	92
v1007: Trade and markets	0.382	0.104	52
v1733: Exchange within community	0.200	0.096	95
v1734: Exchange beyond community	0.098	0.079	98

Each row reports the estimated coefficient and standard error when the listed variable in the SCCS is regressed on state centralization and a constant (not reported). I have reversed the sign for variable 732 so that higher values correspond to greater trade. I have converted variable 93 into a binary ``power depends on commerce'' measure if v93 (the most important source of political power) is either 2 (tribute or taxes), 7 (foreign commerce), or 8 (capitalistic enterprises).

Table 17. Mechanisms: Local or long distance trade?

	(1)	(2)	(3)	(4)
	Ecological diversity	*State centralization*		
Ecological diversity		0.549	0.462	0.182
		(0.355)	(0.341)	(0.325)
Dist. ecological divide	-0.284***	-0.168	-0.179	-0.217*
	(0.016)	(0.126)	(0.113)	(0.130)
Other controls		No	Yes	Yes
Region F.E.		No	No	Yes
Observations	440	440	440	440
R-squared	0.424			

*** p<0.01, ** p<0.05, * p<0.1. Regressions estimated by ordered probit. Standard errors in parentheses clustered by region. Other controls are those listed as "controls" in the table of summary statistics.

Table 18. Mechanisms: Is Africa different?

	(1)	(2)	(3)
		State centralization	
Ecological diversity	0.892***	0.892***	0.604***
	(0.196)	(0.198)	(0.223)
Other controls	No	Yes	Yes
Region F.E.	No	No	Yes
Observations	1129	1076	1076

*** p<0.01, ** p<0.05, * p<0.1. Regressions estimated by ordered probit. Standard errors in parentheses clustered by region. Other controls are those listed as "controls" in the table of summary statistics.

Table 19. Full results

	(1)		(2)		(3)	
	State centralization					
Ecological diversity	0.794***	(0.266)	0.703***	(0.234)	0.437**	(0.219)
Ag. constraints			-0.018	(0.059)	-0.020	(0.056)
Dist. coast			0.024	(0.026)	0.036	(0.031)
Elevation			0.000	(0.000)	0.001**	(0.000)
Malaria			-0.501	(0.306)	-0.248	(0.302)
Precipitation			0.000	(0.000)	0.000	(0.000)
Temperature			-0.000	(0.000)	0.000	(0.000)
Dist. L. Victoria			0.000	(0.000)	-0.000	(0.000)
Date observed			-0.003**	(0.002)	-0.005**	(0.002)
Crop: None			-1.558**	(0.772)	-0.481	(0.818)
Crop: Trees			0.136	(0.325)	-0.020	(0.338)
Crop: Roots/tubers			0.456**	(0.203)	0.304	(0.205)
Major river			0.268*	(0.155)	0.283**	(0.138)
Ruggedness			0.000	(0.000)	0.000*	(0.000)
Dist. Atlantic ST			0.000	(0.000)	0.000	(0.001)
Dist. Indian ST			-0.001	(0.000)	-0.000	(0.000)
Dist. Saharan ST			-0.001	(0.001)	-0.001	(0.001)
Dist. Red ST			0.001	(0.001)	0.001*	(0.001)
Region F.E.	No		Yes		Yes	
Observations	440		440		440	

*** p<0.01, ** p<0.05, * p<0.1. Regressions estimated by ordered probit. Standard errors in parentheses clustered by region.