Ecology, trade and states in pre-colonial Africa

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ECOLOGY, TRADE AND STATES IN PRE-COLONIAL AFRICA

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ABSTRACT. State capacity matters for growth. I test Bates' explanation of pre-colonial African states. He argues that trade across ecological boundaries promoted states. I find that African societies in ecologically diverse environments had more centralized states. This is robust to reverse causation, omitted heterogeneity, and alternative interpretations of the link between diversity and states. The result survives including non-African societies. I test mechanisms connecting trade to states, and find that trade supported class stratification between rulers and ruled. I underscore the importance of ethnic institutions and inform our knowledge of the effects of trade on institutions.

1. INTRODUCTION

States that can collect taxes, protect property, and sustain markets matter for development. It is not only modern states that matter; state antiquity predicts growth and stability in the present (Bockstette et al., 2002). Understanding state capacity, then, improves our knowledge of the causes of growth. The origins of state capacity have, however, received comparatively little attention in the literature (Besley and Persson, 2010). Explaining why strong states existed in the past in some regions but not others adds to our knowledge of state capacity in the present and helps explain present-day income differences (Gennaioli and Voth, 2012; Moav et al., 2011). If the historical variables that predict past states are not well understood, their lingering effects in the present may be mis-attributed to other intermediate channels.

In this paper, I test a "Ricardian" theory of states in sub-Saharan Africa originally presented by Bates (1983). Building on earlier views,[1] he argues that long-distance trade gave rise to states in Africa. His model is verbal:

> [T]he contribution of the state is to provide order and peace and thereby to render production and exchange possible for members of society. The

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[1]See Bisson (1982), Oliver and Fage (1962), and Vansina (1966), for example.

> 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 boundaries, then, that we should expect to see states. To support his view, he takes 34 pre-colonial African societies, and shows that the proportion of societies with central monarchs is greater on an ecological boundary.[2]

Bates' view has been overlooked because his small sample and lack of controls prevent him from making a credible econometric argument that this correlation is causal. In this paper, I use ethnographic and geographic data to overcome this limitation. I merge data on state centralization for 440 ethnic groups in pre-colonial sub-Saharan Africa with a map of African ecological zones. I use ethnic-level ecological diversity to proxy for the gains from trade. I show that ecological diversity is strongly related to the presence of pre-colonial states. For example, within the societies classified as "Equatorial Bantu," the Luba score .69 on the diversity index and 3 out of 4 on the centralization index. The Kela and Ndonko, by contrast, have no diversity and no centralization. On the "Guinea Coast," the Yoruba score 3 on centralization and .58 on diversity, while the Yako score zero on both.

I show that this result is robust. I use spatial variation in rainfall as an instrumental variable, in order to control for possible reverse causation. The result survives additional controls, checks for unobserved heterogeneity, alternative estimation strategies, removing influential observations, and alternative measures of trade and states. I show that the "Ricardian" view better explains the relationship between states and diverse ecology than six alternative interpretations. These are: first, larger territories are more diverse and require more levels of administration; second, societies that independently develop states conquer trading regions; third, dense population in diverse regions explains statehood; fourth, defense of "islands" of land quality accounts for states; fifth, the diversity of available economic activities creates states, and; sixth, competition between ethnic groups in more diverse areas leads to state formation. I rule out these alternative explanations by controlling for these mechanisms directly, by re-estimating the results using artificial countries of a uniform shape and size as the unit of observation, and by presenting narrative evidence from the most influential observations in the data.

Unlike Bates, I am agnostic about whether it is long-distance or local trade that matters most to state formation, and about whether trade gives rise to states by increasing the returns to investment in public goods, by cheapening the cost of extending authority over space, or by making rulers more effective in public goods provision. The public goods provided by states can lower the costs of both inter-state and intra-state trade. In the web appendix, I present a simple model of the mechanisms by which trade may

[2] I present a condensed version of his results in the web appendix.

lead to state centralization. I find that class stratification is the channel best supported by the data, though trade is associated with a wide range of state functions.

Although I focus on Africa, I show that the relationship between diversity and states holds even when non-African societies are included in the analysis. While many historians of Europe link states to the growth of markets (e.g. Jones (1981)), historians of Africa put particular emphasis on trade (Bates, 1983). The importance of ecologically-driven trade in Africa is well documented in the historical literature (e.g. Lovejoy and Baier (1975)). There is also particular institutional continuity in Africa. Traditional authorities were often coopted by colonial states, and their successors possess significant powers today (Acemoglu et al., 2012; Mamdani, 1996). The historical territories of ethnic groups can be measured with more precision in Africa than in many other areas. It is in Africa that empirical studies have established the importance of these "ethnic" types of institutions.

1.1. **Related literature.** My results contribute to our understanding of the origins of state capacity and of the relationship between trade and institutional quality.

1.1.1. *State capacity.* A wealth of theories exist on the origins of the state, stressing factors such as the relative benefits of "stationary" versus "roving" bandits (Olson, 1993), the relative benefits of different mechanisms for governing markets (Dixit, 2004) conflict (Besley and Persson, 2010; Gennaioli and Voth, 2012), ease of taxation (Moav et al., 2011), and past investments (Besley and Persson, 2009). This literature has, however, focused overwhelmingly on institutions that exist in the present day or those that were created in the circum-Mediterranean or in European colonies. Less is known about the origins of states that have not been built by Europeans. Pre-colonial states do, however, matter for contemporary African development (Michalopoulos and Papaioannou, 2012). I provide evidence on the causes of institutions indigenous to Africa, linking them specifically to trade.

In addition, testing specific theories of state centralization informs policy. Each of the theories just mentioned suggests different mechanisms for improving state capacity. These need not be mutually exclusive: it is possible that both past investments and access to trade bolster the strength of contemporary states. Knowing which causes matter most, however, helps identify those that are the most urgent targets for policy.

Because my results distinguish this theory of state formation from several alternatives, they help establish that the relationship between ethnic institutions and present-day outcomes is causal. Bockstette et al. (2002), for example, suggest that historical states matter for reasons such as learning-by-doing and bureaucratic discipline that outlast the original motivation for state creation. If instead the determinants of historical states continue to have direct effects in the present, these conclusions will be unwarranted. Because African trade patterns have changed dramatically under colonial rule and again since independence, historical gains from trade can be used to instrument for

ethnic institutions. I show that the main result from Michalopoulos and Papaioannou (2012), in which historical states predict historical luminosity, continues to hold when ecological diversity is used as an instrument for historical states.

1.1.2. *Trade and institutions.* Historically, trade and institutions have co-evolved, with better rulers encouraging trade, and trade accentuating initial differences in institutional quality (Acemoglu et al., 2005; De Long and Shleifer, 1993). A substantial literature exists testing whether causation works in either direction, with a particular emphasis on the possible relationship between trade and democracy. Empirical results, however, are conflicting. The effects of trade on democracy may be positive (López-Córdova and Meissner, 2005), negative (Rigobon and Rodrik, 2005), or negligible (Ahlquist and Wibbels, 2012; Papaioannou and Siourounis, 2008). The impact may depend on the timing of trade reforms (Giavazzi and Tabellini, 2005) or on the distribution of the gains from trade (Brückner et al., 2012).

In this paper, I trace out the importance of trade for one specific institutional outcome – the centralization of African states – and find that trade increases state capacity. Although I do not have data on the degree to which the central state was democratic in my sample, I am able to show that gains from trade predict greater levels of local democracy. Ethnic groups whose territories were more ecologically diverse were more likely to appoint local headmen through election or another form of formal consensus.

In section 2, I describe my econometric specification and sources of data. In section 3, I present the baseline results. In section 4, I demonstrate the robustness of these results. In section 5, I give evidence that the six alternative stories mentioned above do not explain the results. In section 6, I present evidence that centralized states emerged from trade because it supported class differentiation, that no one type of trade mattered most, and that ecological diversity can be used as an instrument for ethnic institutions today. In section 7, I conclude.

2. DATA

To test whether the gains from trade due to ecological diversity predict the existence of centralized states, I estimate the following equation on a sample of pre-colonial African societies, using an ordered probit:

$$\textit{State centralization}_i = \alpha + \beta \textit{Gains from trade}_i + x_i'\gamma + \epsilon_i. \tag{1}$$

In this section, I explain my sources of data on state centralization, my ecological proxies for the gains from trade, and the controls that I include in x_i. I cluster standard errors by the ethnographic regions recorded in the sample.[3]

[3]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.

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.[4] 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." The sample used for the analysis consists of the 440 sub-Saharan societies for which this variable is not missing.[5] For comparison with Europe and Asia, the Chekiang and Japanese score a 4 on this index, the Czechs and the Dutch score a 3, while the Lolo and Lapps each have no centralization. I do not have data on possible substitutes for states, such as multi-ethnic federations that coordinate tax collection or tributary relationships across ethnic groups.

As far as I am aware, no data exist on pre-colonial African trade that could allow comparison of a large number of societies. My approach is to use geographic proxies for the capacity to trade. I follow Bates (1983) in assuming that the ability to trade across ecological zones creates gains from trade. I use White's (1983) vegetation map of Africa to identify these regions.[6] This classifies African vegetation into 18 major types, which I plot in the web appendix.[7] I use three measures of the ecologically-driven gains from trade: ecological diversity, distance from an ecological boundary, and ecological polarization. I merge these measures with the *Ethnographic Atlas* using Murdock's (1959) map of African ethnic groups.[8] This has also been used by Michalopoulos and Papaioannou (2011, 2012) and in several papers by Nathan Nunn. A similar approach for North America has been employed by Dippel (2011).

In section 4, I supplement this with historical and anthropological evidence from six African societies.[9] In each, the exchange of products across ecological zones was significant. My only other measure of pre-colonial trade is a map of trade routes from Brice

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

[5]It is probable that stateless societies are more likely to be missing from these data. This will only bias the results if they are more likely to be missing in ecologically diverse regions.

[6]This is available at http://www.grid.unep.ch/data/download/gnv031.zip.

[7]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, transitional scrubland, water, woodland, woodland mosaics and transitions.

[8]This is available on Nathan Nunn's website. While most groups are matched directly by name, some require an alternative spelling, an alternative name, linkage to a supergroup or subgroup, or joining to an ethnic group in roughly the same location. A table of these matches is in the web appendix.

[9]It is possible that gains from trade could arise from other forms of geographic heterogeneity. Empirically, ecological diversity performs best. I have found no positive effect of other indices, such as ruggedness or a Theil index of land quality on states. Area under water in White (1983) indicates rivers and lakes: this has a negative impact on statehood if included with the baseline set of controls. Mangroves and coastal areas are classified as "azonal," and have no effect. The difference in land quality between the most fertile and least fertile points in an ethnic group's territory does predict states, but this is given a different interpretation in section 4.

and Kennedy (2001). I show in Section 6 that these predict states. I do not make them a focus of this paper, as their placement is potentially endogenous.[10]

Though Bates (1983) focuses on long distance trade, internal trade may also facilitate states. A state may protect intra-ethnic trade, but it may also facilitate trade between polities occupying two separate, internally homogenous regions. In section 6, I show that the data cannot ultimately disentangle whether it is local trade or long distance trade that matters most. Thus, I construct indices of the gains from both local and long-distance trade.

The principal measure that I use of gains from trade is ecological diversity. I calculate the share s_i^t of each society i's area that is occupied by each ecological type t. Ecological diversity is a Herfindahl index constructed from these shares:

$$\text{Ecological diversity}_i = 1 - \sum_{t=1}^{t=18} (s_i^t)^2. \tag{2}$$

This is captures the opportunities for trade that exist within an ethnic group's territory – the gains from internal trade.

The second index that I use measures ecological polarization. This is also constructed from the vegetation shares:

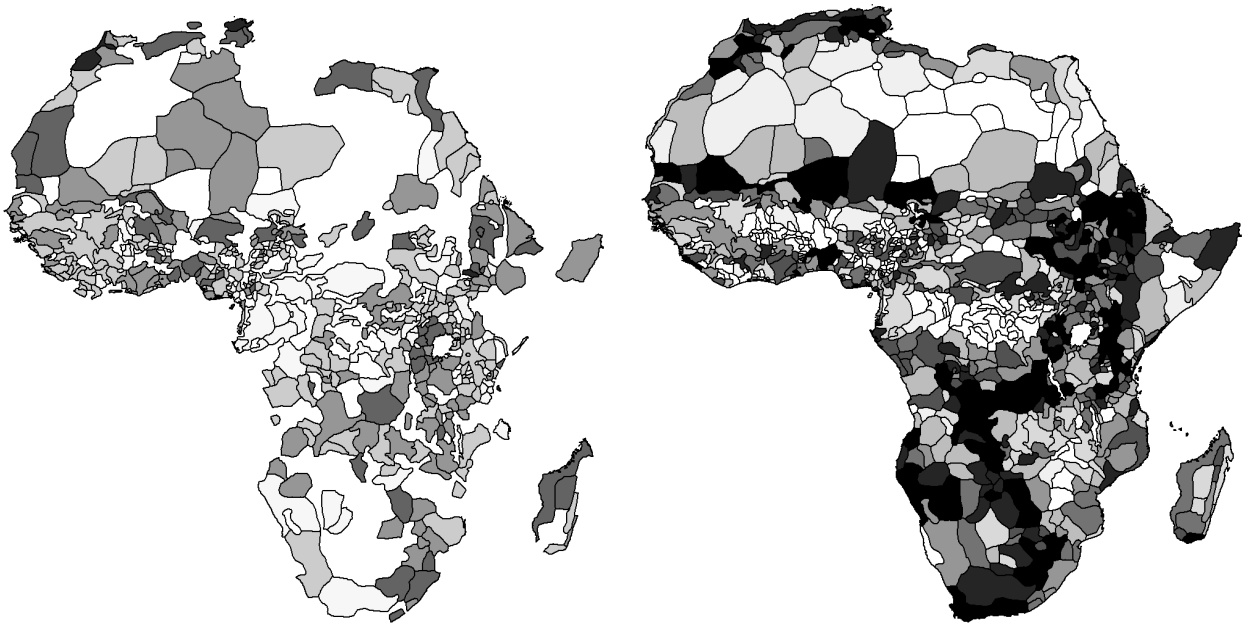
$$\text{Ecological polarization}_i = 1 - \sum_{t=1}^{t=18} \left(\frac{0.5 - s_i^t}{0.5} \right)^2 s_i^t. \tag{3}$$

This measures the degree to which a society approximates a territory in which two vegetation types each occupy half its area. Similar measures have been used for ethnicity (Montalvo and Reynal-Querol, 2005). This also captures gains from internal trade. If increasing returns to scale exist in production or trade, trade may be most profitable if a society is evenly divided into two ecological zones. This would maximize the polarization index.

The third index that I use is distance from an ecological boundary. 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. This captures gains from external trade, since the boundary may lie outside the ethnic group. Because a society that is intersected by a boundary will also be ecologically diverse, the measures of internal and external trade will be positively correlated. Distance from a boundary does, however, predict states even in the sub-sample of ecologically homogeneous societies.

[10] See Michalopoulos et al. (2010). This map includes mostly routes across the Sahara or connecting Lake Victoria to the coast. These are not correlated with ecological diversity.

FIGURE 1. State centralization and ecological diversity



Notes: States, on the left, are from Murdock (1967). Darker regions have more centralized states. Ecological diversity, on the right, is computed using White (1983). Darker regions are more ecologically diverse.

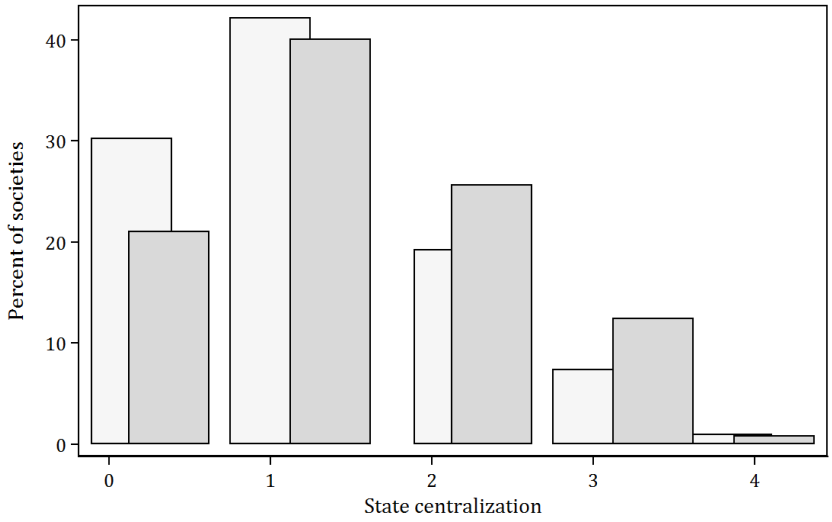
I present maps of state centralization and ecological diversity in Figure 1.[11] The most centralized African states are clustered along an East-West line between the Sahara and West African forest, in the microclimates of the Ethiopian highlands, along the barrier between the equatorial rainforest and the East and Central African woodland mosaics, and on the divide between grassland and woodland in the continent's southeastern corner.

I join several other geographic variables to the data on ecology and states using the Murdock (1959) map of Africa. I include these in x_i as controls. 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.[12] In particular, I control for the presence of a major river, agricultural constraints (an inverse measure of land quality), distance from the coast, elevation, suitability for malaria, precipitation, ruggedness, temperature, distance from Lake Victoria, date of observation, crop type dummies, and distance from the Atlantic and Indian Ocean slave trades. These variables are described in more detail

[11]The base map of ethnic groups is available on Nathan Nunn's website. While most ethnic groups can be matched to this map directly by name, some require an alternative spelling, an alternative name, linkage to a supergroup, or subgroup, or joining to an ethnic group in roughly the same location. A table of these matches is included in the web appendix.

[12]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/`.

FIGURE 2. State centralization above and below median diversity



The dark bars are for ecological diversity above the median, the light bars for ecological diversity below it.

in the web appendix. Summary statistics are given in Table 1. These data are admittedly anachronistic – the institutional variables are recorded at an earlier date than the geographic controls and the measure of ecological diversity. Because these variables are slow to change, this should only add measurement error to the analysis.

3. RESULTS

I begin by showing the unconditional relationship between gains from trade and state centralization. In Figure 2, I cut the sample into societies above and below median ecological diversity. For each, I show the relative frequencies of states of each level of centralization. Below the median (the lighter bars), it is more common for societies to have no levels of centralization, or only one level. Above the median, there is a greater prevalence of societies with two or three levels. As ecological variation rises, the distribution of state centralization shifts to the right.

Table 2 presents estimates of β. I report the full set of coefficient estimates in the web appendix, omitting them here for space. In column 1, only the measure of ecological diversity is included. Ecological diversity has a significant and positive correlation with state centralization. This is robust to the inclusion of additional controls in column 2. In column 3, I add fixed effects for the major regions of Africa by UN classifications. These are intended to account for the role of large differences in culture and geography. This has almost no impact on the results.

Few of the additional controls are significant. Some important exceptions are no major crop (negative) and roots and tubers (positive). The negative effect of no major crop suggests that it is difficult to form a state without an agrarian base. The positive effect of

roots and tubers is likely capturing unobservable features of forest-zone Bantu societies that better enabled them to create states.

Is the effect of ecological diversity large? In Table 2, I report marginal effects. The impact of a one unit change in ecological diversity is to reduce the probability of having no centralization by roughly 14-26 percentage points. The probabilities of having two or three levels increase to match this. Ecological diversity has a bimodal distribution; societies are clustered around peaks of zero diversity and roughly 0.5 (see the web appendix). If an ecologically homogenous society such as the Tallensi or the Yako were to be and placed in a more typically diverse region, such as that of the Fur (0.496) or Wolof (0.506), the probability of any centralization would rise roughly 7 to 13 percentage points. Mirroring this thought experiment, I replace the ecological diversity measure with an indicator for being above median diversity. The marginal effect, in Table 2, is between 6 and 11 percentage points.

The pseudo-R^2 statistics, by contrast, are low. While the effect of diversity is sizable, the controls here cannot explain more than 10% of the variation in African states. The estimation without controls correctly predicts the level of centralization for 42% of the sample, barely an improvement over selecting the mode. Adding controls raises this to only 45%. Although the bulk of pre-colonial state centralization in Africa remains to be explained (Osafo-Kwaako and Robinson, 2012), the impact of ecologically-driven gains from trade is robust and economically significant.

I also use Table 2 to show that the results can be expanded to cover the rest of the world. On a sample of more than 1,000 global societies, ecological diversity continues to predict the existence of states.[13] I conduct as many of the robustness checks as possible in this global sample that I do for the sub-Saharan sample in sections 4, 4, and 6. Results are reported in the Web Appendix.[14] These "whole world" results are less robust than those specific to sub-Saharan Africa. Consistent with the historical literature, this suggests that access to ecologically-driven trade has been of particular importance for African states.

4. ROBUSTNESS

4.1. **Validity of the state centralization measure.** I take two approaches to validate the state centralization measure. First, it is strongly correlated with alternative measures of states. Bockstette et al. (2002) and Chanda and Putterman (2007) report a country-level index of historical state strength for the period 1850-1900, which just precedes colonial

[13]This sample has been created for Fenske (2012). Details on these are given in the web appendix for that paper.

[14]Some tests cannot be carried out on the global sample due to data availability. I do not have historical trade routes, pre-colonial cities, or salt production outside of Africa. Because the global diversity measure is constructed using raster data that uses different classifications than White (1983), I cannot compute distance from an ecological boundary, construct simpler ecological classes, or measure diversity within artificial ethnic groups in the global sample.

rule for most African societies. The state centralization index has been aggregated to the country level by Gennaioli and Rainer (2007). For 41 countries, I have both measures. Their correlation is positive and significant at the 1% level. Similarly, the *Standard Cross Cultural Sample* (SCCS) gives additional variables for 186 societies. It only includes 28 sub-Saharan observations, so I cannot use it in the baseline. I show in the web appendix that several SCCS measures of state strength are positively correlated with centralization, whether they measure the existence of a police force, the presence of taxation, or the capacity of states to enforce their decrees.[15]

Second, the main result holds if I use an indicator for any levels of jurisdiction above the local as an outcome (see the web appendix). This might better capture state strength if, for example, a central authority cannot delegate functions to regional leaders without losing some control over them.

4.2. **Validity of the gains from trade measure.** Results are robust to using alternative measures of the gains from trade are presented in the web appendix. Distance from an ecological boundary and ecological polarization both predict states. Distance from a divide also predicts states in the sub-sample of ethnic groups not intersected by a boundary (not reported). Results using an indicator for any diversity (equivalent to intersection by a boundary) are similar. I collapse ecological classifications from White's map into eight "simpler" types.[16] This does not change the bi-modal distribution of diversity. I re-build the data-set discarding slices of map in which historical population density is less than 15% of the density of the entire ethnic group.[17] These potentially irrelevant regions do not determine the results. Finally, an alternative diversity index using the Food and Agriculture Organization's (FAO) division of Africa into "dominant ecosystem classes" also predicts states.[18]

4.3. **Validity of the estimation.** I use a generalized ordered probit model in the web appendix (Maddala, 1986). Results are similar to the baseline. Because multi-ethnic polities might be double-counted in the data, I down-weight all centralized societies by one half, and the results are virtually unchanged (not reported). Major rivers and distances from the coast, Lake Victoria, and slave trade ports may capture trade. I show in the appendix that excluding each of these controls barely affects the results. Nor does excluding the date of observation or including country-level timing of the neolithic revolution (not reported).[19] In the web appendix, I discard influential observations. I also

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

[16]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.

[17]I use density in 1960.

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

[19]Data are from Louis Putterman's website.

drop each of the "South African bantu," "Ethiopia/horn," "Moslem sudan" and "Indian Ocean" in turn, as these are the regions in which most states are concentrated. I also exclude non-agricultural societies, societies with animal husbandry, and the desert fringe. These do not drive the results. The main sample includes only sub-Saharan Africa; results are similar using the whole continent (not reported).

4.4. **Possible reverse causation.** To control for the possibility that states may shape their environment, I use variation over space (not time) in rainfall to instrument for ecological diversity.[20] I use the log of the rainfall range as an instrument, where:

$$\text{Log rainfall range}_i = \ln(1 + (rain_i^{max} - rain_i^{min})). \tag{4}$$

Here, $rain_i^{max}$ and $rain_i^{min}$ are the values of the raster points with the most and least precipitation for society i. The natural log improves fit. This cannot be computed for societies too small to have at least two raster points. Results are robust to assigning these societies a log rainfall range of zero. In addition to controlling for reverse causation, these estimates will correct measurement error in ecological diversity – error that may be both physical (if the underlying data on vegetation types is coarse or imprecise) and conceptual (if a Herfindahl index is an imperfect measure of the ecologically-driven gains from trade).

Results (including the reduced-form and first stage) are in Table 3. The IV estimates are larger than the ordinary least squares (OLS) estimates. Measurement error in ecological diversity is a plausible explanation, since vegetation classes are subjective and have imprecise boundaries. Further, ecological diversity may be correlated with unobservable variables that hinder states. Where ecological boundaries abut agriculturally marginal areas such as deserts and mangrove swamps, states may have less agricultural surplus to tax.

4.5. **Possible omitted heterogeneity.** I show that results are robust to six general approaches towards omitted heterogeneity in the web appendix. First, I add area shares s_i^t of each ecological type as additional controls. Second, I include a cubic in latitude and longitude with full interactions, allowing unobservables to vary smoothly across space. Third, I adjust for spatial autocorrelation by including the spatially-weighted observable characteristics of a society's neighbors as controls, and estimating Conley's OLS with standard errors corrected for spatial dependence with cutoffs of 5 decimal degrees.[21] I do not use Conley's estimator in the baseline because the dependent variable is ordinal. I instead cluster standard errors by ethnographic region in the baseline.

[20]Variation over time is unlikely to predict ecological diversity, which is variation across space in vegetation. Further, fluctuations in rainfall over time may lead to conflict (Miguel et al., 2004), which could directly affect state formation.

[21]I select the spatial adjacency matrix 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.

Fourth, I interact de-meaned controls with ecological diversity (Wooldridge, 2002). Fifth, I compute Altonji-Elder-Taber statistics.[22] Finally, I use fixed effects in lieu of controls. In successive columns, I control for ethnographic region, United Nations region,[23] country,[24] and language family.[25] I do not use these in the baseline because they will exacerbate measurement error. In an OLS regression, ethnographic region dummies explain 19% of the variance in state centralization and 25% of the variance in ecological diversity.

5. Alternative interpretations

The Ricardian view of African states better fits the data than six alternative interpretations of the link between ecological diversity and states. Some of these are complements, rather than rivals, to the Ricardian view. Still, they do not fully account for the relationship between ecology and states.

5.1. **Larger areas are more diverse and require centralized administration.** States that cover wider territories for reasons unrelated to their strength may have more levels of jurisdiction (Spencer, 1998, 2010). These areas may be more diverse by construction. I have three strategies for dismissing this alternative. First, I restrict the sample to societies of similar area. In Table 4, I show that results are robust if the smallest quintile (Q1), largest quintile (Q5) or both are dropped. Second, I control for the log of area directly in the main analysis.

Third, I adopt the "virtual countries" approach of Michalopoulos (2011). I divide the African continent into 1° by 1° squares and repeat the main analysis. I map these virtual countries in the web appendix. Excepting coastal societies, these units have a uniform shape and area.[26] This exercise shows that, even conditioning on size and shape, diverse areas are more likely to host states. Further, this mitigates the concern that multi-ethnic states are "double-counted." Some readers may prefer these "exogenous" units. I use centralization of the strongest state in a square as its measure of centralization. Results, in Table 4, are robust to this approach.

[22]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 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.

[23]I make the following assignments. 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. Eastern Africa: Northeast Bantu, Upper Nile, Ethiopia and Horn, Indian Ocean.

[24]I assign each ethnic group to the country into which the largest slice of its territory falls.

[25]This is constructed from variables 98 and 99 in the *Ethnographic Atlas*.

[26]Because the length of a degree of longitude varies by distance from the equator, I have also replicated the results in Table 4 down-weighting observations by the degree of this distortion. The results (not reported) are nearly identical.

5.2. **States conquer trading regions.** States might emerge for reasons unrelated to the gains from trade, and then occupy trading regions through migration or conquest. This could only be conclusively ruled out using panel data – data that do not exist. I use the cross section to make three arguments. First, the artificial country results above suggest that diversity does not result from the irregularly-shaped boundaries of ethnic groups that have conquered their surroundings. Second, if conquest requires that states expand, I have shown above that controlling for area does not eliminate the main result.

Third, I give narrative evidence on some of the most statistically influential societies in the data. This is effectively a very small panel taken from the larger cross section. The eighteen most influential societies (by dfbeta) are listed in the web appendix. If the centralized societies in this list developed states where they are or derived their wealth and power from their proximity to trade routes, rather than migrating to capture trade, this supports the Ricardian view. I choose six centralized states for case study evidence.[27] Because these are narrative examples, they cannot be subjected to systematic measurement and testing. The results of this exercise must be interpreted with caution; the evidence that can be provided by this approach is inherently suggestive, rather than dispositive.

To test the "Ricardian" view, I ask four questions about the Yoruba, Songhai, Toro, Suku, Luba and Lozi. 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 states move to capture trading regions after they grew strong? I summarize the answers as a table in the web appendix. Though two of these did conquer areas with tradable resources, they relied on trade-related income to become powerful before expanding.

Yoruba. Morton-Williams (1969) argues that Yoruba Oyo "developed under the stimulus of external trade," benefiting initially from its proximity to northern trade routes, and later from coastal markets. Law (1977), similarly, links the rise of Oyo to its imported cavalry, participation in long-distance northern commerce, and engagement in the Atlantic slave trade.

Trade was important. Oyo cloth was sold to Dahomey and Porto Novo, and the state imported kola nuts from forested areas of Yorubaland for consumption and re-export. Salt and camwood were imported, and the latter was re-exported to Nupe. Cavalry horses were imported from the north. The *Alafin* (king) relied on trade taxes for revenue (Law, 1977). Even direct taxes were collected in currencies acquired through trade. Trade upheld the *Alafin's* authority by enabling him to distribute money and trade goods while maintaining a superior lifestyle. He and other chiefs engaged in trade personally.

[27] I choose these, rather than non-centralized societies, because the alternative story being discussed is specific to centralized ethnic groups and because the secondary historical literature is richer for these groups. These were the six most influential states when a different baseline specification was used in earlier versions of this paper.

Neither Morton-Williams (1969) nor Law (1977) mention conquest of neighboring regions as a pre-condition for trade.

Songhai. The Songhai Empire depended on trans-Saharan trade. Neumark (1977) explains the success of Songhay and the states that preceded it using "their strategic commercial position on the fringes of the Sahara." Songhay exported 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 forests. It imported salt, linen, silk, cotton cloth, copper goods, ironwork, paper, books, weapons, cowries, beads, mirrors, dates, figs, sugar, cattle and horses. This trade brought wealth; Leo Africanus noted the empire's prosperity (Levzion, 1975).

Taxes on trade provided government revenue (Shillington, 1989). Lovejoy (1978) notes that Songhay's 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 did expand into the Hausa states to capture their fertile land and into Air to drive out Tuareg raiders (Bovill, 1995). The latter was a movement to protect existing trade interests, not to secure new routes. Songhay's strength, like the states that came before it, was based on its favorable location before it expanded.

Toro. The Toro region was one of relative prosperity, producing iron goods and salt for sale within the interlacustrine region (Ingham, 1975). Trade was a source of state revenue, through both tribute and direct control. 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 (Taylor, 1962). They collected goods as tribute, reallocating them to relatives, chiefs, officials and others. Subordinate states introduced agents to collect tax from both salt producers and traders, a portion of which was sent to Bunyoro (Ingham, 1975). The Toro kings sold slaves, ivory and cows to Arab traders in return for guns and cloth (Taylor, 1962). Toro was also an exporter of salt; 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 (Good, 1972). Toro did expand to take advantage of a tradable resource. Lake Katwe, in Busongora, was an early conquest (Good, 1972). Salt was, however, only one of many tradable goods that enhanced the power of the Toro state.

Suku. The Suku of the Congolese savanna lacked a developed system of market places, sold no cash crops and only limited rubber, and itinerant trade was "not at all developed" in the colonial era (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 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 (Kopytoff, 1967). Though relatively poor, the Suku were known for their wealth in shell money (Kopytoff, 1964).

The Suku *MeniKongo* (king) directly ruled villages around the capital and administered the remainder through regional chiefs. Shell money was used to render tribute (Kopytoff, 1964), and so direct taxes were indirectly taxes on trade. The effect of trade on the Suku state was inherited in part from the Lunda, from whom Suku seceded (Kopytoff, 1965). Within the Lunda's territory lay both copper mines and salt, which were sources of trade and tribute (Birmingham, 1976). Slaves for export were collected through war and tributary tax collection, and this revenue allowed the royal court to distribute the trade goods over which it held a near monopoly (Birmingham, 1976). The Suku inherited state forms from their trading predecessor, and prospered from their position as middlemen.

Luba. Before they were unified, the separate Luba states controlled local dried fish, salt, oil palm, raffia cloth, and copper-working industries (Birmingham, 1976). In the late eighteenth century, Luba Lomami responded to the new long distance trade in ivory and slaves, unifying the Luba (Birmingham, 1976). 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 preceded 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 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-producing 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 the Luba to establish Kazembe as a tributary kingdom. Birmingham (1976) argues that Luba decline followed that of the ivory trade. Their trading partners turned to focus on copper. Swahili-Arab traders began to trade directly into the forest, cutting out the Luba. The Luba became unable to purchase the guns needed to secure their power without exporting internally captured slaves.

Lozi. The pastoral Lozi occupy the Zambezi floodplain (Gluckman, 1941). Within Lozi territory, trade was in the specialized products of each region, including bulrush millet and cassava meal, wood products and iron (Gluckman, 1941). Before 1850, the Lozi sent traders to the Lunda areas of the upper Zambezi, trading indirectly with the Portuguese (Flint, 1970). By 1860, long distance trade, especially in ivory, became important (Flint, 1970). The Lozi exported cattle and forest products (Gluckman, 1941).

The king and princess chief collected tribute in kind from "tribes" under their command, including canoes, weapons, iron tools, meat, fish, fruit, salt, honey, maize and manioc (Birmingham, 1976). The Kololo, who ruled the Lozi between 1840 and 1864, obtained ivory as tribute and sold iron hoes to the Tonga. The Kololo king established 'caravan chiefs' and kept profits from ivory within his court (Flint, 1970). On re-gaining independence, the Lozi king traded cattle, ivory and slaves for goods that he distributed (Gluckman, 1941).

Public goods. Subjects and traders received greater peace and protection from these states. The Toro "expected patronage - protection, justice, undisturbed occupation of their land, and rewards especially in stock or chieftainships or honours for good service" (Taylor, 1962, p 60). Lozi political authorities re-distributed tribute, sometimes to those in need, serving as a "clearing house" (Gluckman, 1941, p. 73). Traders gave gifts to the king, "for they traveled by his permission and largely, despite their muskets, under his protection (p. 78)." Lewanika, for example, sent a punitive expedition against subject Ila for having killed a party of traders (p. 79). Oyo caravans, similarly, often traveled under cavalry protection (Law, 1975).

Summary. These cases are consistent with the Ricardian view. Songhai and Oyo expanded, but did so after having arisen in locations favorable to trade. The Luba expanded after 1780 based on power already acquired through the Bisa ivory trade. When that trade declined, the kingdom collapsed. Lozi dominance over surrounding peoples depended trade and tribute from the diverse products of their neighbors. That the Suku participated in long-distance trade while possessing only limited internal markets highlights the importance of trade spanning macro-ecological regions. In every case, rulers taxed trade. Though Toro conquered Busongora to capture the most important source of salt in the region, it inherited its political structure from Bunyoro, which had previously grown strong due to its sale of metal goods and control of the Kibiro salt industry.

5.3. **Islands of quality.** If states emerge to protect "islands" of land quality that differ from neighboring areas, these will also have diverse ecologies. In Table 4, I control for a Theil index of agricultural constrains. This captures the variation in land quality over space within an ethnic group's territory. The effect of diversity remains significant.

5.4. **Population density.** Ecological diversity may be correlated with population density, which itself explains pre-colonial African states (Osafo-Kwaako and Robinson, 2012). I proxy for historic population density by measuring it in 1960.[28] This is reported in Table 4, and the effect of ecological diversity remains intact. This is also true if I include the log of (one plus) population density (not reported).

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

5.5. **Ethnic diversity.** Ecology-specific human capital gives rise to a greater number of ethnic groups in regions of diverse ecology (Michalopoulos, 2011). Competition between these groups may lead them to develop stronger states (Tilly, 1992). Alternatively, more heterogeneous communities might form more sophisticated institutions to reduce conflict (Aghion et al., 2004). To show this is not driving my results, I return to my sample of artificial countries. I count the number of ethnic groups that intersect each square, and include this as an control in Table 4. The main result survives this. It also survives controlling for modern-day heterogeneity, measured as the number of languages reported in the World Language Mapping System (not reported).[29]

This alternative interpretation would also contradict several established findings. Ethnic diversity increases the cost of nation-building (Alesina et al., 2005), inhibits public goods provision (Easterly and Levine, 1997), and predicts the break-up of nations (Desmet et al., 2009).[30] Ecological diversity overcomes both these potential effects of greater ethnic diversity and the possible substitutability between trade openness and nation-building (e.g. Alesina and Spolaore (1997)).

5.6. **Diversity and risk.** Ecological diversity may increase the number of activities a society can use to cope with risk and seasonal variation. It may permit animals to be moved to take advantage of seasonal resources and avoid diseases (Beinart, 2007). I have shown above that the results are not driven by societies dependant on animal husbandry. Results are also robust to controlling for presence of bovines (not reported). In Table 4, I show they are robust to adding subsistence diversity as a control. This is a Herfindahl index computed from the income shares derived from hunting, fishing, gathering, husbandry, and agriculture reported in the *Ethnographic Atlas*.

Cultivating a diverse set of grains may enable a state to better cope with risk (e.g. McCann (1999)). If these grains are exchanged through intra-regional trade, this is not inconsistent with an interpretation linking diversity to states through trade. Controlling for a Herfindahl index constructed from the shares of each society's territory that are most suitable for the grains listed in plate 48 of the FAO-GAEZ data does not change the main result (not reported).

6. MECHANISMS

6.1. **How does trade cause states?** To illustrate the possible mechanisms connecting trade to state centralization, I introduce a simple model in the web appendix. This is based on Gennaioli and Voth (2012). In the model, a ruler extends his authority within his ethnic group's territory in order to tax trade. This trade cannot occur unless he offers

[29]The map can be purchased from `http://www.worldgeodatasets.com/language/`.

[30]Within artificial countries, the centralization of the median ethnic group is negatively related to the number of ethnic groups (not reported). I have found no evidence that this relationship is non-monotonic. The positive coefficient in Table 4 likely comes from selecting the maximum state from a larger number of ethnic groups.

public goods that lower the costs of trade. These public goods could include dispute-resolution services or physical protection. I do not specify whether these public goods are used to facilitate trade with the citizens of neighboring states, or to promote internal trade, since state services could lower trade costs in either case. I show that greater gains from trade will lead the ruler to centrally administer a larger fraction of group's territory. In the model, there are three mechanisms by which trade may lead to states:

(1) Greater gains from trade will directly increase the profitability of state centralization. It raises the tax base, allowing the ruler to extract greater revenues from the territory he controls. Investment in public goods and administration becomes worthwhile. Adding to this direct revenue effect, the ability of rulers to tax exchange and to trade on their own was highlighted by the case studies above.
(2) If greater access to trade makes it cheaper to project authority over space, centralization will increase. Access to trade can lower these costs. The ability to trade for horses and for firearms made it easier for states such as Oyo and Songhai to extend their power over space.
(3) If access to trade makes the ruler more effective at providing public goods, state centralization becomes more profitable. Access to trade may give the ruler access to goods that increase his authority in settling disputes and in demanding that traders not be harassed. The *Alafin* (king) of Oyo gained prestige by maintaining a superior lifestyle, while the Lozi and Toro rulers secured loyalty by redistributing the profits from trade. Cavalry and firearms could be used to extend protection to traders.

It is beyond the scope of this paper to discuss whether trade or centralization are "good" outcomes in all cases, or whether states that depend on tradable resources for revenues are "better" than states that have other sources of revenue (Brunnschweiler and Bulte, 2008; Mehlum et al., 2006; Sachs and Warner, 2001).

6.2. **Trade and intermediate outcomes.** Here, I test whether trade predicts specific outcomes related to state formation. I find that ecological diversity is strongly associated with class stratification and local democracy, but not with diminished local political authority or with religion. Trade in the SCCS is correlated with a wide selection of state functions, rather than a few narrow indicators of state capacity.

Diminished local authority. 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." 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 (1). 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. 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." In Table 5, I show that there is no correlation in the data.

Democracy. Although I do not have the data to test whether trade made central states more democratic, I am able to test whether trade predicts the level of democracy in local government for the ethnic groups in my sample. As above, I use V72, which records the rules for succession to the office of the local headman. Following Whatley (2012), I create a variable, "headman is democratic," which takes the value 1 if $V72$ reports that the succession rule is "election or other formal consensus, nonhereditary." In Table 5, I show that ecological diversity predicts greater local democracy. Although political centralization was not necessarily inclusive in pre-colonial Africa, societies such as the Tswana and the Ganda did have local assemblies and checks on the power of the state (Acemoglu et al., 2003). Within the sample used here, the correlation between state centralization and local democracy is positive and significant at the 10% level.

Islam. Islam diffused in Africa through trade networks that encouraged both tribal unification and the adoption of Arabic (Insoll, 2003). This is one of the possible mechanisms linking trade to states. The data do not directly record Islam. They only state whether high gods are "supportive of human morality." This is only positive for a handful of societies outside of the Moslem Sudan, Western Sudan and Ethiopia, and so it is effectively a dummy variable for either Christianity or Islam. This is only available for a sample roughly half the size of the main sample, and does not appear to be related to ecological diversity in Table 5. Similarly, if I include it as a control, the coefficient on ecological diversity falls, but remains significant (not reported). Islam, then, does not drive the correlation between trade and states in the data.

Class stratification. Trade allowed kings to amass wealth through taxation, letting them gain prestige and control the flow of tribute. To 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." Ecological diversity positively predicts this in Table 5. Results (not reported) are similar if a binary class stratification measure is used. Though recent trade models argue that trade increases inequality by raising incomes of abundant factors, increasing skill premia, and through search frictions in import-competing sectors (Harrison et al., 2011), these are of limited relevance to pre-industrial societies. Instead, rulers' access to prestige goods, trade goods, and tax revenues are more likely mechanisms.

Specific state functions. I test whether the various measures of state centralization in the SCCS's global sample are correlated with any of the forms of trade mentioned in that source in the web appendix. Trade in food and the importance of trade in subsistence are related with the greatest number of state functions. The degree of police specialization and the level of the highest political office are correlated with all the trade measures. The degree to which the executive is concentrated in a single person, the presence of a judiciary and the level of highest overarching jurisdiction are correlated with all but one.

Many types of trade, then, are related to several state-related outcomes in the SCCS – no one type of trade operates through one specific mechanism.[31]

6.3. **What sort of trade matters?** *Endowments of tradable products.* The ecological diversity measure cannot capture all forms of trade. In Table 5, I test whether other sources of trade – fishing, iron, gold, and salt – give similar rise to states. These data do not measure trade in these products, only the capacity to trade. Coefficients can be thought of as intent-to-treat effects.

A society's percentage dependance on fishing is V3 in the *Ethnographic Atlas*. I find no correlation between this and states. To test the importance of minerals, I take data from the US Geological Service's Mineral Resources Program.[32] These records contain data on both metallic and nonmetallic mineral resources at specific sites. "Iron" is the number of sites of iron production found within an ethnic group's territory, and "gold" is the number of sites of gold production. If there is any bias from using modern data, it will be positive, since modern states that have inherited the strength of their pre-colonial predecessors should be better able to exploit their countries' resources. Despite this, I find no evidence that iron matters.[33] Gold enters significantly when no controls are added, though the effect of gold is insignificant with controls. "Salt" is the number of salt-producing cites listed by Sundström (1974) within an ethnic group's territory.[34] This too appears irrelevant.

Types of trade. I also test whether state centralization is correlated with any particular form of trade in the SCCS's global sample. In the web appendix, I present the correlations between these indicators and state centralization. Societies with states are more likely to trade for food, through more levels of intermediation, and 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 the community. Interestingly, this suggests that it is more mundane, intra-community trade in products such as food that matters.

[31]Other outcomes may be of interest to the reader. Ecological diversity does predict area in an OLS regression, and this is robust to both the standard controls and regional fixed effects (not reported). I have found no relationship between ecological diversity and urbanization measured by cities in 1850 reported by Chandler and Fox (1974) (not reported).
Similarly, some readers may be interested in how ecological diversity and pre-colonial states relate to colonial outcomes. I show in the web appendix that ethnic groups whose largest slice of territory was conquered by Britain were generally more diverse and more centralized than those captured by France, but less than those not colonized. Within the British empire, Frankema and van Waijenburg (2012) have found early twentieth century real wages were much higher in West Africa than East Africa. If there is any pattern apparent, it is that ethnic groups in Britain's East African conquests were more diverse and centralized than those in Ghana and Nigeria, though Sierra Leone is an exception.

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

[33]I similarly find no result if I use the number of iron-producing sites within a group's territory listed by Sundström (1974) as a measure of iron.

[34]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. The full table of matches is given in the Web Appendix.

Local and long distance trade. Despite this suggestive finding, the data sources here also provide evidence that favors long distance trade. I show in Table 5 that the presence of historical trade routes is correlated with state centralization. This does not, however, rule out the importance of local trade. Similarly, "ecological diversity" is intended as a proxy for intra-ethnic trade and "distance from an ecological boundary" is meant to capture long distance trade. I show in the web appendix that if both are included in the same regression, only distance from an ecological divide remains significant.

6.4. **Does historical trade matter today?** It is not the case today that all African countries have strong states. Even today, a one standard deviation increase in the Gennaioli and Rainer (2007) index of State Centralization predicts a 0.3 standard deviation drop in The Fund for Peace's Failed States Index for 2012.[35] Michalopoulos and Papaioannou (2012) have shown that pre-colonial states predict greater levels of contemporary development, as measured by the intensity of night-time lights. In Table 6, I show that historical trade can be used to instrument for these ethnic institutions. Column (1) replicates the main result from Table 3A in their paper: conditional on controls and country fixed effects, "ethnic" institutions predict present-day luminosity. Column (2) uses ecological diversity as an instrument for these pre-colonial states. The IV estimate is positive and significant. This supports a causal interpretation of the results in Michalopoulos and Papaioannou (2012); ecological conditions that no longer directly influence trade predict institutions that continue to matter in the present.

I present the reduced form estimate in column (3). In column (4), I perform a rough test of the over-identification restriction, and report least squares estimates including both pre-colonial states and ecological diversity on the right hand side. Once states are included, the effect of ecological diversity on luminosity loses magnitude and is no longer significant.

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 by more than 10 percentage points. There is no evidence that the effect is overstated due to endogeneity, or is due to 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, risk mitigation, and ethnic competition do not explain away the

[35] In this bivariate regression, n=47, p=0.041.

results. Ecological diversity continues to matter in the present through the legacy of pre-colonial states.

What does this result add to our understanding of the link between institutions and development in the present? First, it suggests that other findings that have been interpreted as effects of culture may operate through institutions. For example, the result in Durante (2009) that historical experience with mutual insurance leads to greater levels of trust may arise through the institutional consequences of mutually-insuring trade. Second, institutions have heterogeneous effects on development, and part of this heterogeneity is both path-dependent and context-specific. The mechanisms that shaped pre-colonial states in Africa continue to shape development in the present.

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Table 1. Summary Statistics

	(1) Mean	(2) s.d.	(3) Min	(4) Max	(5) 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
Headman appointed	0.066	0.25	0	1	320
Light density	1.50	0.18	1.15	3.34	440
Local authority: Democratic	0.081	0.27	0	1	320
			Gains from trade		
Ecological diversity	0.30	0.23	0	0.80	440
Eco. Div. (FAO)	0.47	0.23	0	0.80	440
Ecological polarization	0.51	0.38	0	1.00	440
Dist. ecological boundary	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
			Controls		
Log area	0.16	1.29	-11.7	3.29	440
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	846	468	0	2,474	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: 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		
Log rainfall range	5.18	1.01	1.39	7.42	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
Subsistence diversity	0.52	0.12	0.13	0.74	440

Table 2. Ecological diversity predicts states

	(1)	(2)	(3)	(4)				
	State centralization							
	Sub-Saharan Africa						*Whole world*	
Ecological diversity	0.794***		0.484**		0.442**			
	(0.266)		(0.207)		(0.192)			
Eco. Div. (FAO)							0.446**	
							(0.184)	
Other controls	No		Yes		Yes		Yes	
UN Region FE	No		No		Yes			
Observations	440		440		440		1,077	
Pseudo R-squared	0.0111		0.0724		0.0809		0.171	
	Marginal effects							
	Continuous	*> median*	*Continuous*	*> median*	*Continuous*	*> median*	*Continuous*	*> median*
0 levels	-0.259***	-0.108***	-0.151**	-0.065***	-0.137**	-0.060***	-0.177**	-0.050
	(0.087)	(0.033)	(0.065)	(0.024)	(0.058)	(0.022)	(0.073)	(0.035)
1 level	-0.022	-0.009	-0.016	-0.007	-0.015	-0.007	0.065**	0.018
	(0.038)	(0.016)	(0.019)	(0.008)	(0.016)	(0.007)	(0.029)	(0.013)
2 levels	0.152***	0.063***	0.103**	0.045***	0.095**	0.042***	0.071**	0.020
	(0.052)	(0.019)	(0.045)	(0.016)	(0.041)	(0.015)	(0.030)	(0.014)
3 levels	0.118***	0.050***	0.062**	0.027**	0.054**	0.024***	0.035**	0.010
	(0.044)	(0.018)	(0.027)	(0.011)	(0.024)	(0.009)	(0.015)	(0.007)
4 levels	0.010	0.004	0.003	0.001	0.002	0.001	0.006**	0.002
	(0.008)	(0.003)	(0.003)	(0.001)	(0.002)	(0.001)	(0.003)	(0.001)

*** p<0.01, ** p<0.05, * p<0.1. Regressions estimated by ordered probit. Standard errors in parentheses clustered by region. Coefficient estimates where ecological diversity is replaced with an "above median" indicator are not reported. Other controls in columns (1), (2) and (3) are log area, major river, agricultural constraints, distance to coast, elevation, malaria, precipitation, ruggedness, temperature, distance to Lake Victoria, distance from the Atlantic and Indian Ocean slave trades, and dummies for crop type, unless otherwise specified. Other controls in column (4) are log area, land quality, distance from coast, elevation, malaria, rainfall, temperature, date, crop dummies, major river, ruggedness and absolute latitude.

Table 3. The main result is robust to reverse causation

	(1)	(2)	(3)	(4)
	OLS: Baseline		*IV*	
	State centralization			
Ecological diversity	0.358**	0.440**	1.998*	2.875*
	(0.147)	(0.203)	(1.124)	(1.689)
Other controls	Yes	Yes	Yes	Yes
Observations	440	370	440	370
F-statistic			48.98	7.979
	(5)	(6)	(7)	(8)
	OLS: Reduced form		*OLS: First Stage*	
	State centralization		*Ecological diversity*	
Log rainfall range	0.058**	0.136*	0.029***	0.047***
	(0.027)	(0.079)	(0.004)	(0.016)
Other controls	Yes	Yes	Yes	Yes
Observations	440	370	440	370

*** p<0.01, ** p<0.05, * p<0.1. Standard errors in parentheses clustered by region. Other controls are log area, major river, agricultural constraints, distance to coast, elevation, malaria, precipitation, ruggedness, temperature, distance to Lake Victoria, distance from the Atlantic and Indian Ocean slave trades, and dummies for crop type, unless otherwise specified. The excluded instrument is the log rainfall range. In columns 3, 5, and 7, missing values of the log rainfall range are recoded to zero. In columns 2, 4, 6, and 8, these observations are excluded.

Table 4. The Ricardian interpretation better explains the main result than six alternatives

	(1) *Artificial countries*	(2) *Artificial countries*	(3) *Drop Area Q1*	(4) *Drop Area Q5*	(5) *Drop Area Q1 and Q5*
			State centralization		
Ecological diversity	0.560***	0.536***	0.730***	0.489**	0.845***
	(0.118)	(0.119)	(0.273)	(0.203)	(0.242)
No. of Ethnic Groups		0.118***			
		(0.044)			
Other controls	Yes	Yes	Yes	Yes	Yes
Observations	1523	1523	352	352	264
	(6)	(7)	(8)		
			State centralization		
Ecological diversity	0.488**	0.431**	0.494**		
	(0.204)	(0.191)	(0.206)		
Ag. Constraints Theil	2.564				
	(5.390)				
Pop. density		0.003			
		(0.002)			
Subsistence diversity			-0.175		
			(0.497)		
Other controls	Yes	Yes	Yes		
Observations					

*** 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 log area, major river, agricultural constraints, distance to coast, elevation, malaria, precipitation, ruggedness, temperature, distance to Lake Victoria, distance from the Atlantic and Indian Ocean slave trades, and dummies for crop type, unless otherwise specified. Columns (1) and (2) exclude area, since squares are all 1° X 1°.

Table 5. Trade supports class stratification and local democracy, and no one type of trade matters most

	(1)	(2)	(3)	(4)	(5)
	Local state	*Class Stratification*	*Headman is appointed*	*High gods*	*Headman is democratic*
Ecological diversity	-0.344	1.186***	-0.454	-0.316	1.069***
	(0.247)	(0.230)	(0.620)	(0.931)	(0.373)
Other controls	Yes	Yes	Yes	Yes	Yes
Observations	439	364	320	242	320
	(6)	(7)	(8)	(9)	(10)
			State centralization		
% dep. on fishing	0.006				
	(0.004)				
Iron production		-0.071			
		(0.145)			
Gold production			0.006		
			(0.014)		
Salt				-0.004	
				(0.046)	
Hist. trade route					0.453***
					(0.131)
Other controls	Yes	Yes	Yes	Yes	Yes
Observations	440	440	440	440	440

*** p<0.01, ** p<0.05, * p<0.1. Regressions estimated by ordered probit with coefficients reported, except column (5), which is OLS. Standard errors in parentheses clustered by region. Other controls are log area, major river, agricultural constraints, distance to coast, elevation, malaria, precipitation, ruggedness, temperature, distance to Lake Victoria, distance from the Atlantic and Indian Ocean slave trades, and dummies for crop type, unless otherwise specified.

Table 6. Ecological diversity is an instrument for state centralization

	(1)	(2)	(3)	(4)
	OLS	*IV*	*OLS*	*OLS*
	Light Density			
State centralization	0.279***	0.810**		0.263***
	(0.066)	(0.361)		(0.067)
Ecological diversity			0.618**	0.417
			(0.259)	(0.256)
Other controls	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes
Kleibergen-Paap F		12.09		
Observations	683	683	683	683

*** p<0.01, ** p<0.05, * p<0.1. Standard errors in parentheses clustered by region. Other controls are distance to capital, distance to coast, distance to border, log water area, log land area, elevation, suitability for agriculture, malaria ecology, petroleum and diamonds.