

# Geographic axes and the persistence of cultural diversity

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Jared Diamond's *Guns, Germs, and Steel* [Diamond J, (1997) *Guns, Germs, and Steel* (WW Norton, NY)] has provided a scientific foundation for answering basic questions, such as why Eurasians colonized the global South and not the other way around, and why there is so much variance in economic development across the globe. Diamond's explanatory variables are: (i) the susceptibility of local wild plants to be developed for self-sufficient agriculture; (ii) the domesticability of large wild animals for food, transport, and agricultural production; and (iii) the relative lengths of the axes of continents with implications for the spread of human populations and technologies. This third "continental axis" thesis is the most difficult of Diamond's several explanatory factors to test, given that the number of continents are too few for statistical analysis. This article provides a test of one observable implication of this thesis, namely that linguistic diversity should be more persistent to the degree that a geographic area is oriented more north-south than east-west. Using both modern states and artificial geographic entities as the units of analysis, the results provide significant confirmation of the relationship between geographic orientation and cultural homogenization. Beyond providing empirical support for one observable implication of the continental axis theory, these results have important implications for understanding the roots of cultural diversity, which is an important determinant of economic growth, public goods provision, local violence, and social trust.

geography | nation-state | culture | languages

In "Spacious Skies and Tilted Axes," a chapter of *Guns, Germs, and Steel*, Jared Diamond begins with a simple observation from which he draws world historical implications (1). Asking his reader to glance at a world map, he assures us that "You'll be struck by an obvious difference. The Americas span a much greater distance north-south (9,000 miles) than east-west; only 3,000 miles at the widest, narrowing to a mere 40 miles at the Isthmus of Panama . . . In contrast, the major axis of Eurasia is east-west." Diamond explores what effect this difference had on human history.

Diamond's biogeographical insight relies on the well-established notion that plant and animal populations have evolved to survive within specific seasonal regimes that, importantly, vary greatly with latitude. Agricultural innovations in domesticating grains and animals can therefore spread more easily in the east-west direction than to the north or south. Because these innovations diffuse in either an easterly or westerly direction, motivated by the population explosions that are facilitated by technological advance, the technologies of production and sophisticated cultural tools, such as writing, follow suit. Although the exact mechanisms of cultural spread remain controversial (2–4), here we will assume that conquest of, or mass migration to, new areas entails the cultural domination of those bringing the innovations, and the disappearance from history of those peoples who are displaced.

This simple observation facilitates an understanding of broad historical patterns. The rapid spread of grains, animals, technologies, and empires across Eurasia is attributed to the low level of variation in latitude along the lines of settlement. Meanwhile, agricultural innovations in the Americas (treated as a single continent) and Africa were slower and less successful. These continents' north-south orientations made technological diffusion inappropriate and counter-productive. Diamond also illustrates the dynamics at the subcontinental level, highlighting the spread of agricultural innovation in south China and across the Sahel as

supporting evidence. Continental axes, therefore, are for Diamond one of the four important factors explaining Eurasian world domination. "Around those axes," Diamond concludes, "turned the fortunes of history."

However, the continental axis theory has even broader contemporary relevance. One implication of the theory, as we shall elaborate herein, is that east-west expansion of states delimits cultural diversity but north-south expansion sustains it. Research in the social sciences reveals that cultural diversity is associated with poorer provision of public goods (5, 6), lower levels of interpersonal trust (7), higher probabilities of local violence (8), and lower rates of economic growth (9–12). Indeed, if Diamond's axis theory holds, the identified historical patterns continue to impact society, economy, and polity.

However, Diamond's evidence in support of the axis thesis is only suggestive. Unlike the two other major claims in *Guns, Germs, and Steel*, purporting to account for the variation in economic development across the globe—that is, the susceptibility of local wild plants to be developed for self-sufficient agriculture and the domesticability of large wild animals for food, transport, and agricultural production—the continental axis thesis is not put to rigorous test. First, Diamond's evidentiary base consists of only three continents (Eurasia, Africa, and the Americas) and two non-continental supplements (the Sahel and south China), making it impossible to assess statistically the implications of continental axes for the spread of human populations and technologies. Second, obvious anomalies are ignored. For example, we are told that potentially efficient diffusions from South to Central America, or from Mexico to the Andes, were halted because of either "hot intervening lowlands" or "intervening tropical climates." However, in a discussion of Bantu expansion (at first west to east, but then inexplicably north to south) we learn that they "leapfrogged over drier areas" (1). Why Bantus but not Amerindians could leapfrog is not investigated.

We seek to provide a more rigorous test of Diamond's intuition by moving beyond his comparison of three continents. To increase the number of observations and allow for a statistical test of the impact of geographic axes, we take the nation-state as the unit of analysis. For each country, we measure the degree to which its axes run across ecological biomes relative to within them. This measure takes the form of the ratio of the average length of the north-south axis relative to the average length of the east-west axis. To the extent that the ratio is greater, we ask whether there has been greater persistence of cultural diversity within the boundaries of that state. Diamond's theory would expect linguistic diversity to erode naturally with east-west migrations. The combining of societies relying on similar technologies would amalgamate those societies into wider speech communities. The theory would then predict the concomitant loss in viability of either the languages of the migrants or those of societies indigenous to the lands that had been populated by those migrants. Meanwhile, the theory would not expect such erosion with north-south migrations, as in this case even small speech communities would survive culturally intact, relying on their special skills related to conditions in climate zones different from where the migrants left.

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This study builds on others that have attempted to provide evidence of the continental axis theory. For example, Turchin, Adams, and Hall find that historical empires were significantly more likely to have expanded farther in the east-west direction than in the north-south direction, but that modern states do not exhibit the same inclination (13). Thus, although they provide evidence that the processes described by Diamond are apparent in historical empires, they make no claims about the implications such expansion had for the populations in its wake. Currie and Mace (14) find that political complexity correlates with the area covered by ethnolinguistic groups, and use Diamond's thesis to argue that the east-west orientation of Eurasia, in conjunction with the highly complex Russian state system, facilitated the rapid expansion of the Russian language zone. Similarly, Cashdan (15) argues that the capacity for state expansion is the determining factor for linguistic expansion.

The present study moves beyond these contributions in two important ways. First, our dataset has the largest coverage to date. While Turchin, Adams, and Hall (13) measure geographic axis ratios for only the 29 largest countries in the world, our analysis includes most modern states, allowing us to control for the size of the country rather than excluding smaller countries. Second, our measure of cultural diversity moves beyond what Cashdan (15) calls the "ethnographic present." We capture the persistence of cultural diversity by measuring the percentage of historically indigenous language groups in all countries' histories that are still represented by a self-sustaining language community today. Thus, although our measure of historically spoken languages has a presentism bias (see *Materials and Methods*), the inclusion of recently extinct and moribund languages allows us to better capture linguistic persistence as a historical process. The result is a systematic dataset on linguistic persistence to complement the important narratives provided by classic studies of language death (16, 17).

The observable implication of Diamond's axis thesis that we test in this article is that if the thesis is correct, the length of a country's north-south axis, relative to its east-west axis, should be positively related to the persistence of cultural diversity. To perform this test, we compiled a dataset that includes data on the geographic axis ratio, degree of linguistic persistence, and several control variables for 147 modern countries. We then use a multivariate linear regression to estimate the effect of geographic axes on cultural persistence while controlling for other factors likely to impact the persistence of cultural diversity.

To calculate the axis ratios, we use Mathematica software to plot the geographic coordinates of a state and measure the lengths of both the north-south and the east-west axes of the main land mass of each country. To capture the relative length of the axes, we calculate the axis ratio by dividing the average length of the north-south axis by the average length of the east-west axis. Thus, an axis ratio equal to one corresponds to a roughly square country; axis ratios above one signify countries with greater north-south orientations; and ratios below one represent more east-west oriented countries. Fig. 1 shows the coordinates and resulting ratio for one country, China. Because of the nature of ratios (i.e., ratios below 1

range from 0 to 1, but ratios above one can theoretically range from 1 to infinity), the measure of relative lengths of axes is positively skewed. Thus, we log-transform the measure of axis ratio, resulting in a normal distribution across countries, and all analyses presented use the natural log of axis ratio.

Our measure of linguistic persistence is conceptualized as the proportion of historically spoken languages within a country that have maintained a self-perpetuating language community. We use Ethnologue (18), the most comprehensive list of human languages, both living and defunct, to construct this variable. After coding all languages for indigeneity and viability (see *Materials and Methods*), we calculate linguistic persistence for each country as the proportion of historically spoken languages persisting in a self-sustaining way today.

In our estimation of the impact of geographic ratios on linguistic persistence, we control for other factors likely to impact the persistence of cultural diversity. First, we control for the total number of historical languages—the original language stock—because our measure of persistence will be lower for countries with fewer historic languages, even if the absolute level of language loss were constant across states. For example, the measure of persistence for a country with only two historic languages will be more impacted by the loss of a single language than a country with 10 historical languages, and we need to control for this differential impact. Second, we control for distance from the equator, because linguistic and cultural heterogeneity has consistently been shown to correlate with proximity to the equator (19, 20), even though there is some evidence that the relationship is less clear for language extinction (21). Third, we include a measure of the range in quality of land for agricultural production. Previous work has found that land quality range is positively related to cultural diversity (22), and theoretically should relate to persistence of diversity for the same reason as geographic orientation; variation in land quality should preclude migration and homogenization in the same way that climatic variation induced by a predominately north-south axis should. Fourth, we include the land area and a proxy for degree of mountainousness of a country, with the expectation that both large size and mountainousness will enable cultural persistence. Finally, we control for the age of a country and expect that the time that a country has had to homogenize its population will be negatively related to the persistence of diversity. We provide the resulting data ([Datasets S1](#) and [S2](#)) and summary statistics ([Table S1](#)) in the Supporting Information.

## Results

Consistent with Diamond's continental axis theory, we find that the degree to which a country is more north-south than east-west is positively related to the persistence of cultural diversity. More specifically, our data show a positive bivariate relationship between the geographic axis ratio of a country and the persistence of its linguistic diversity ( $r = 0.13$ ,  $P = 0.11$ ). The relationship remains positive and the estimated effect size is statistically different from zero at the 1% significance level in a multivariate regression that

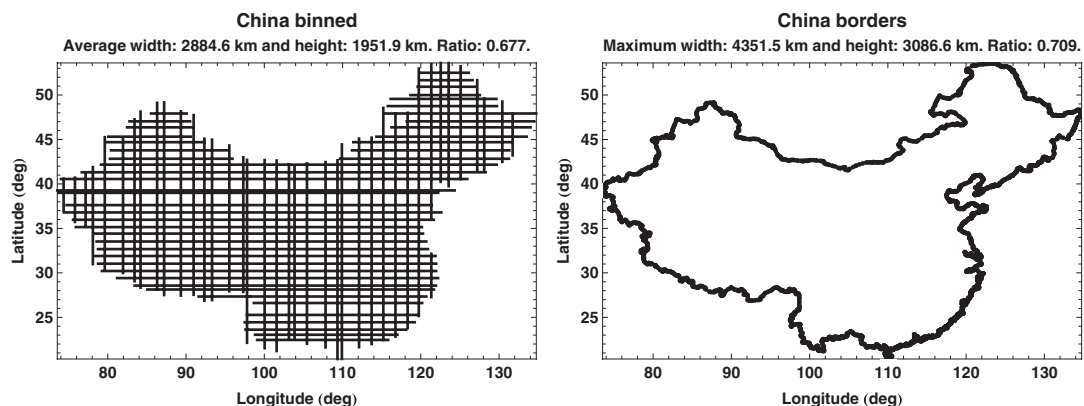


Fig. 1. Visual demonstration of axis ratio calculation for China.





**Table 3. Geographic axes and the persistence of linguistic diversity for artificial paired-neighbor units, ordinary least-squares regression**

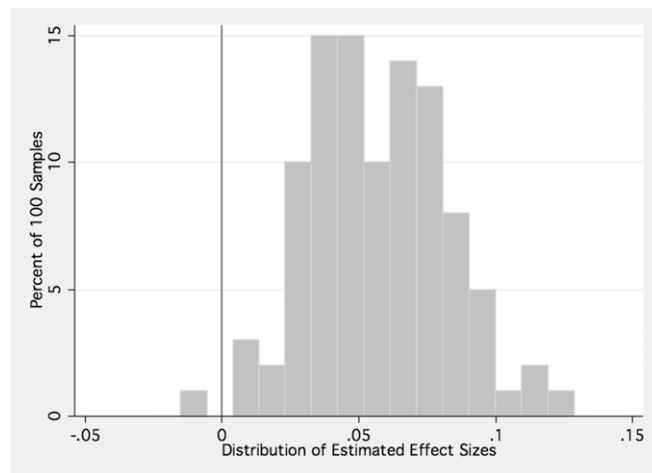
Variable	Model 1
Axis ratio (natural log)	0.08***
Total number of indigenous languages	0.05 (0.02) 0.14***
Average distance from equator	0.03 (0.01) -0.41***
Average land quality range	-0.69 (0.08) -0.08**
Area in 1,000s km <sup>2</sup> (natural log)	-0.11 (0.04) -0.25***
Average elevation difference in 1,000s m	-0.05 (0.01) -0.02
Average age of unit in decades	-0.01 (0.00) -0.16***
Constant	-0.01 (0.00) 1.26 (0.04)
Continent fixed effects?	Yes
Observations	538
Adjusted <i>r</i> <sup>2</sup>	0.69

Standardized coefficients, \*\*\**P* < 0.01, \*\**P* < 0.05, \**P* < 0.1; nonstandardized coefficients (robust SEs).

resulted in a positive estimated coefficient. Combining data from our complete set of paired countries along with the data from 100 randomly paired neighbors suggests endogeneity of modern state borders is not driving our estimate of the biogeographical impact of axis ratio on the persistence of cultural diversity.

### Conclusion

We offer here an improved statistical test of Jared Diamond's claim that the continental axes "turned the fortunes of history." By examining an observable implication of the theory at the country-level (instead of Diamond's continent), and computing an axis ratio for all countries, we are able to get sufficient leverage for a statistical test, with far more observations than previous work as well as going beyond tests that examine the diversity of language in a single area. Furthermore, by computing an index of language persistence by country, we are able to go beyond the ethnographic present and capture cultural dynamics.



**Fig. 4.** Histogram of the estimated effect size of axis ratio on linguistic persistence across 100 random samples of artificial paired-neighbor units. Only 1 of the 100 random samples produced an estimated effect size of less than zero (indicated by a horizontal line), and the estimates are centered around 0.05.

Acknowledging the drawback of using modern states, the borders of which are not always exogenous to the processes of cultural homogenization, we supplement this main analysis using two approaches. First, we use indicators of the degree to which state borders are endogenous and evaluate the impact of geographic axes on cultural persistence as a function of that endogeneity. We find suggestive evidence that the more exogenous a state's borders are, the greater the impact of geographic orientation on the persistence of cultural diversity. Next, we evaluate the impact of axis ratio on the persistence of diversity among artificial geographic units comprised of contiguous neighbors, and again find a positive relationship. All of these results provide consistent evidence that the degree to which a geographic unit is oriented more north-south than east-west is related to the persistence of cultural diversity within that unit.

Support for the continental axis theory contributes to our nascent understanding of the roots of contemporary cultural diversity and its social implications. To be sure, we cannot claim from our study that historically conditioned cultural diversity, with the persistence of linguistic heterogeneity, consigns societies to low economic growth (9–12), high rates of generalized distrust of others (7), high likelihood of local violence spiraling beyond original combatants (8), and failure by governments to provide public goods (5, 6). Nonetheless, Diamond's continental axis theory reveals that these unfortunate outcomes are not a reflection of any particular culture's capacities, but rather the historical patterns fostered by geographical constraints that discouraged the integration of cultures.

### Materials and Methods

**Sample.** We start with the 156 countries with populations above one million included in the Fearon and Laitin (30) dataset. We then drop countries that are archipelagos in which the largest land mass does not constitute a majority of the total land mass; we only calculate axis ratios for single land masses to avoid distances covered by water being included in the ratio. This criterion excludes the following nine countries: Fiji, Indonesia, Japan, Malaysia, Mauritius, New Zealand, Papua New Guinea, The Philippines, and Trinidad and Tobago. Ratios for remaining archipelagos, such as Australia, reflect the axis ratio of the main island only.

**Axis Ratio.** To obtain the north-south vs. east-west axis ratios, we compute the average height divided by the average width of each country and artificial unit. The algorithm is written in Mathematica and uses the CountryData routine sourced by the United States Geological Survey, which provides a list of coordinates defining the country borders. These coordinates are the minimum data required to draw the outlines of each country, but may only have two coordinates defining straight borders, such as the United States–Canada border and the borders of many African countries. In the first step of the computation, additional points are added to borders such that the boundaries are defined by an equal density of points along the borders.

In the second step, the coordinates are binned in both the longitudinal and latitudinal directions into 10–100 bins, depending on the length of the border. The width or height of a bin is computed using the geodesic distance between the minimum and maximum longitude/latitude within each bin, and that difference is converted from degrees to kilometers correcting for the spherical nature of the globe. The average width of a country is derived by averaging the widths of all bins, weighted by the latitudinal extent of each bin. The average height is computed similarly from the binned heights weighted by the longitudinal bin-widths. As a test of the accuracy of this approach, the area of each country is computed twice, by integrating both the widths and the heights of all bins over the whole country. The results are compared with the official country areas in the same data set with very high levels of agreement.

In the third and final step, we calculate the axis ratio by dividing the average north-south axis length by the average east-west axis length.

**Cultural Persistence.** The dependent variable—persistence of linguistic diversity—is conceptualized as the proportion of historically spoken languages within a country that have maintained a self-perpetuating language community.

To measure the total number of indigenous languages that were historically spoken by a viable speech community within the boundaries of a country, we use data from Ethnologue (18). Languages that meet any of the following criteria were excluded from our count of historically spoken indigenous languages: listed as an immigrant language; originated from a different continent or only spoken on an island other than the mainland; nonspeaking (sign) language; used only as

a *lingua franca* with no population using it as a first language; or lacking a rural population base. Of the 8,237 languages listed by Ethnologue for the 147 countries in our sample, 6,073 (74%) are indigenous. This list represents a presentism bias, because languages that died out long before Ethnologue began collecting data are not counted. However, language death is a slow phenomenon, and thus many languages that are practically extinct remain coded by Ethnologue as languages spoken only by very few individuals. Thus, even though the editors of Ethnologue warn that they do not include long-extinct languages, we feel that our Ethnologue-based count offers a relatively good proxy for the total number of languages historically spoken within a country.

All languages are then coded as to whether they are presently spoken by a self-perpetuating language community. To code this, we use the UNESCO Atlas of World Languages in Danger (31), which codes languages as “vulnerable,” “definitely endangered,” “severely endangered,” “critically endangered,” or “extinct.” Languages listed in the Atlas are thus coded as nonself-perpetuating. Languages not listed as in danger by UNESCO are considered to be self-perpetuating, because they are spoken by all generations and there is uninterrupted intergenerational transmission. Of the 6,073 indigenous languages in our sample of 147 countries, 67% have self-perpetuating language communities.

We then divide the total number of viable languages by the total number of indigenous languages historically spoken in that country. Thus, for each of the 147 countries in our dataset, we have a number between 0 and 1 that represents the proportion of historical languages persisting in a sustainable way today.

**Control Variables.** Our control measure for “original language stock” is the total number of historically spoken languages, described above. For all analyses, this number is divided by 100 to see effect sizes in models. This transformation only affects the coefficients presented, not the size or significance of the effects. “Distance from the equator” is measured in degrees of

latitude of the central point in a country, and ranges from 0 (Democratic Republic of Congo) to 64 (Finland). Distance from the equator is also divided by 100 to be able to see the effect size, although again the transformation does not affect the substantive size or statistical significance of the effects. “Variation in land quality” comes from Michalopoulos (22), who first measures the quality of land for agricultural production for small-sized parcels of land. By taking the difference between the highest and lowest quality land parcel within each country, this measure captures the range in land quality. Bahrain exhibits the least variation in land quality (0.002); the United States has the most variation (1.00). Each country’s “land area” is measured in square kilometers and logged to normalize the distribution. The “difference in elevation,” a proxy for the mountainousness of a country, is the difference in altitude between the highest and lowest points in a country, measured in 1,000 m. A country’s “age” is measured by the number of decades since a country entered the international system, which in our dataset begins in 1816. The oldest states in our sample include 13 states at 196 y old, and the youngest include Macedonia and Eritrea at 19 y. Our “postcolonial” measure is an indicator for whether or not a state was decolonized since 1945 (but excluding post-Soviet states that entered the international system since 1991) and comes from the year-entry variable in the Correlates of War dataset (28). In our sample of 147 countries, 63 (43%) are coded as postcolonial. “Artificiality” of a state’s borders is coded by Alesina, Easterly, and Matuszeski (29) based on the straightness of borders and the degree to which they partition cultural groups. We use the first principal component of these two variables as our indicator of the degree to which a country’s borders are artificial.

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