DOI:
10.1016/j.jdeveco.2020.102475

Document Version
Peer reviewed version

Citation for published version (APA):
Hodler, R., Srisuma, S., Vesperoni, A., & Zurlinden, N. (2020). Measuring Ethnic Stratification and its Effect on Trust in Africa. *JOURNAL OF DEVELOPMENT ECONOMICS*, *146*(0), Article 102475. https://doi.org/10.1016/j.jdeveco.2020.102475

Measuring Ethnic Stratification and its Effect on Trust in Africa☆

Roland Hodler[a,b,c], Sorawoot Srisuma[d], Alberto Vesperoni[e], Noémie Zurlinden[a]

[a] *Department of Economics, University of St.Gallen*
[b] *CEPR, London*
[c] *CESifo, Munich*
[d] *School of Economics, University of Surrey*
[e] *Department of Political Economy, King's College London*

Abstract

We conjecture that mistrust and social conflict in a society may depend on ethnic stratification, i.e., the extent to which the hierarchy in socio-economic positions across individuals follows ethnolinguistic lines. We define and axiomatically characterize an index of ethnic stratification that generalizes the idea of between-group inequality to situations where data on economic and ethnolinguistic distances between pairs of individuals is available. We use Afrobarometer survey data to measure ethnic stratification at the level of towns and villages in 26 ethnically diverse African countries. We find that ethnic stratification is negatively related to trust in relatives, neighbors and other acquaintances, and positively related to nearby conflicts. These findings shed new light on the debate about the merits of conflict and contact theory.

JEL classification: D31; D63; Z13.

Keywords: Measurement; ethnic diversity; between-group inequality; trust; social conflict.

☆We acknowledge helpful comments by three anonymous referees as well as participants at the World Congress of the Econometric Society, the Conference of the Development Economics Network Switzerland, the CSAE Conference on Economic Development in Africa, and the Development Economics and Policy Conference in Berlin.

*Corresponding author
Email address: `roland.hodler@unisg.ch` (Roland Hodler)

1. Introduction

A main goal of the social sciences is to understand and predict cooperation and social conflict, whereby the latter is a broad concept ranging from mistrust to outbreaks of organized violence. Ethnic diversity and economic inequality are prominent candidates for predicting trust and conflict. The effects of diversity and inequality, however, may be intertwined. Conflict and contact theory, for instance, shed light on this interrelation. Conflict theory predicts that diversity and interactions among members of distant ethnolinguistic groups often lead to perceived threats, greater antagonism, mistrust and conflict. In contrast, contact theory, which goes back to Allport (1954), states that intergroup contact can reduce prejudice towards other groups and, thereby, increase trust and reduce conflict. However, Allport (1954) did not expect intergroup contact to have such desirable effects in all circumstances. Among others, he emphasized that the members of the different ethnic groups require "equal status" for interactions to reduce prejudice. This condition makes clear that conflict and contact theory are – from a theoretical perspective – not mutually exclusive.

The empirical literature on the effects of ethnic diversity on social conflict typically employs indices of ethnic fractionalization and polarization. There is considerable evidence that these indices are related to mistrust and a low sense of community (e.g., Alesina and La Ferrara, 2000, 2002; Algan et al., 2016) as well as civil conflict (e.g., Montalvo and Reynal-Querol, 2005; Esteban et al., 2012). These results are consistent with conflict theory, but it is unclear how they relate to contact theory, as these indices are silent on the status of the members of the different ethnic groups. Partly aimed at addressing this shortcoming, some recent studies show that high levels of between-group inequality (sometimes called ethnic or horizontal inequality) are related to low trust (Tesei, 2017) and civil conflict (e.g., Østby, 2008; Cederman et al., 2011; Gubler and Selway, 2012; Guariso and Rogall, 2017).[1]

In this paper, we propose a new predictor of social conflict that builds on the idea of between-group inequality, but offers a more sophisticated account of the interaction between ethnic diversity and economic inequality, and allows us to shed new light on the debate about the merits of conflict and contact theory. We call this predictor an index of *ethnic stratification*. Social stratification

[1] See Kanbur (2006) for an early contribution highlighting the importance of between-group inequality in social conflict.

refers to the hierarchy of socio-economic positions in a population, and ethnic stratification, therefore, to the extent to which the hierarchy in socio-economic positions follows ethnolinguistic lines. Our index is based on interactions between pairs of individuals. A key assumption is that the degree of alienation (or mistrust) between each pair depends on their economic and ethnolinguistic distances, i.e., the difference in their economic resources and the dissimilarity of the languages they speak. Our index of ethnic stratification extends the index of ethnic fractionalization by weighting ethnolinguistic differences between pairs of individuals by their economic distances. Symmetrically, it extends the Gini coefficient of economic inequality by weighting economic inequalities between pairs of individuals by their ethnolinguistic distance. In this sense, our index generalizes the idea of between-group inequality.

Our reliance on ethnolinguistic distances rather than purely categorical data on group affiliation is a major difference to measures of between-group inequality. We thereby follow earlier contributions to the literature on ethnic diversity that proxy for the degree of "alienation" between two members of different ethnolinguistic groups using the dissimilarity of their languages (e.g., Fearon, 2003; Desmet et al., 2009). As an example, consider the three most common languages in Nigeria: Hausa, Igbo and Yoruba. The latter two are closer to one another than to Hausa, as they both belong to the Niger-Congo language family, while Hausa is an Afroasiatic language. To us, it seems desirable to take this information into account when measuring how economic resources are distributed across "alienated" individuals with the aim of predicting social tensions.[2]

The experience of the Igbos in Nigeria illustrates this point. During and after colonization, the Igbos were – in the terminology of Horowitz (1985) – an advanced group in a backward region. Many Igbos were well-educated thanks to Christian mission schools, but there were few economic opportunities in their native Eastern Region. As a consequence, Igbos migrated to other regions of Nigeria "to get jobs in the civil service, trading companies, utilities. Nigeria

[2]There is a second advantage of relying on ethnolinguistic distance. The arbitrary decision of whether to treat two closely related ethnicities as a single group or as two distinct groups may have a large effect on between-group inequality when using ethnicity as a categorical variable. In contrast, ethnolinguistic distances allow for "smoothing" this problem by giving a small, but non-zero, weight to economic differences between members of closely related ethnicities. In this sense, our approach can be interpreted as measuring between-group inequality based on a "fuzzy partition" of the population into (unobserved) groups, where the probability that two individuals belong to the same group depends on their (observed) ethnolinguistic distance.

became, in effect, an Igbo diaspora" (Diamond, 1967, p. 43). The resulting ethnic stratification was higher in towns in the Hausa-dominated Northern Region than in towns in the Yoruba-dominated Western Region for two reasons: First, the ethnolinguistic distance between Igbo and Hausa is larger than that between Igbo and Yoruba. Second, the economic distance, in particular the educational distance, also tended to be greater between Igbo migrants and natives in the Northern Region, where the local Muslim elite opposed Christian missions, than between Igbo migrants and natives in the Western Region. While mistrust and intergroup violence were common in Nigeria in the years after independence, they increased dramatically after two military coups in 1966. "All the envy, resentment and mistrust that Northerners felt for the minority Eastern community living in their midst burst out with explosive force into a pogrom. [...] In the savage onslaught that followed thousands of Easterners died or were maimed, and as others sought to escape the violence, a mass exodus to the East began" (Meredith, 2005, p. 202). While far from peaceful, violence against Igbos was less extreme in the Western Region, where Igbo in-migration had not raised ethnic stratification to the same extent as in the Northern Region.

This paper is divided into a theoretical and an empirical part. As mentioned above, in our theoretical framework we assume that the degree of alienation (or mistrust) between each pair of individuals is determined by the distances between their economic and ethnolinguistic (or social) traits, and we restrict our attention to a class of bivariate measures that are expressions of the *expected alienation* between a randomly selected pair. Having introduced this general class of measures, we focus on a particular index from this class where the alienation of each pair is defined by the product of their economic and ethnolinguistic distances. This strong degree of complementarity across dimensions ensures that economic and ethnolinguistic distances between two individuals are counted only if these individuals are diverse in both dimensions, which is an essential feature of ethnic stratification as a generalization of between-group inequality.

Ethnic stratification, as we define it, depends on two crucial properties of economic and ethnolinguistic distances: their overall magnitude and their co-directionality, i.e., the extent to which these distances correlate across pairs of individuals. To better understand these forces, we show that our index simplifies to the product of the index of generalized ethnic fractionalization, the Gini coefficient of the wealth distribution and the average wealth in the population if we abstract from the co-directionality of economic and ethnolinguistic distances. Hence, ethnic stratification depends on these three components plus co-directionality. To further clarify the properties of our index, we present an axiomatic characterization that uniquely identifies our index from the class of measures of expected alienation via a set of axioms that we motivate as desirable properties of a measure that generalizes between-group inequality. We consider three axioms: *co-directionality by wealth creation or transfer*, *bi-polarization by wealth transfer*, and *co-directionality by linguistic change*. Each of these axioms focuses on a particular trade-off between increasing (decreasing) the magnitude of economic or ethnolinguistic distances and decreasing (increasing) their co-directionality to maintain or increase a given level of ethnic stratification.

Our index can be readily applied to data. There are at least two ways in which it can be used. First, as a summary statistic for directly comparing ethnic stratification across populations. We show that it is easy to perform inference with our index. Second, our index can be used as a key variable to explain and predict social conflict in regression analyses. We illustrate the use of our index in both cases. The main application focuses on the latter.

We use data from geocoded Afrobarometer surveys (BenYishay et al., 2017) for 26 ethnically diverse African countries. We match the respondents' ethnic groups and native languages to the languages listed in the Ethnologue (Gordon Jr., 2005), which allows us to use language trees to calculate ethnolinguistic distances between pairs of individuals. We further construct a wealth index, which allows us to calculate economic distances between pairs of individuals. These distances enable us to compute our index of ethnic stratification and its components at the level of, e.g., countries, or towns and villages. To investigate whether ethnic stratification is a predictor of social conflict at the level of towns and villages, we focus on its relation to *trust* in relatives, neighbors and other people the respondent knows, who are likely to live close by. We thereby focus on the Afrobarometer surveys of round 5 (conducted in 2011–2013), because much less information about the respondents' wealth is available in earlier rounds, and because round 6 does not include the relevant trust questions.

Our main specifications include interacted country-ethnolinguistic group fixed effects and many individual and geographical control variables. We find that respondents are less trusting when local ethnic stratification is high. As one may expect, this negative association is stronger for trust in neighbors and other acquaintances than for trust in relatives. Importantly, it is robust to controlling for ethnic fractionalization and the Gini coefficient. We further document that local ethnic stratification is positively related to the respondents' fear of crime (but not necessarily crime itself) and nearby violent conflict events.

Focusing on ethnic fractionalization, we find a negative relation to trust in neighbors and other acquaintances in specifications that omit ethnic stratification, but not in specifications that include ethnic stratification. These results have important implications for the debate about the merits of conflict and contact theory. The finding that high local ethnic fractionalization tends to go hand-in-hand with low trust towards neighbors and other acquaintances supports conflict theory. The finding that this negative association is strong when the ethnolinguistic distances are complemented by differences in economic resources but disappears when the members of the different groups that interact at the local level have similar socio-economic status supports contact theory.

Our paper develops as follows: Section 2 reviews the related theoretical and empirical literature. Section 3 introduces our index and presents its decomposition and an axiomatic characterization. Section 4 shows how to compute our index using Afrobarometer survey data and illustrates a cross-country comparison with African countries. Section 5 presents our main empirical application studying the effect of local ethnic stratification on trust in African towns and villages. Section 6 concludes.

2. Related literature

2.1. Theoretical literature on inequality and diversity measurement

The theoretical literature related to our contribution is vast, partly because we stand at the intersection between inequality and diversity measurement. Chakravarty (2015) presents a comprehensive review of both fields. In this section we focus on contributions that are particularly close to our framework and methodology. To start with, we see ethnic stratification as an extension of the concept of between-group inequality and our measure is evidently related to the group decomposition of the Gini coefficient. The axiomatic approach to between-group inequality started with a series of seminal contributions characterizing indices decomposable into between-group and within-group components (e.g., Bourguignon, 1979; Cowell, 1980; Shorrocks, 1980). In particular, Shorrocks (1980) shows that, to be decomposable in such a fashion, an index must belong to the class of Generalized Entropy measures. As the Gini coefficient does not belong to this class, its decomposition presents a residual term which has been the subject of various studies and interpretations.[3] Roughly speaking, our index of ethnic stratification can be seen as a generalization of the complement of the within-group component of the Gini coefficient, i.e., the sum of the between-group component and the residual. We choose to build on the Gini coefficient rather than a measure of Generalized Entropy as the latter does not lend itself naturally to the introduction of ethnolinguistic distances, which we believe are crucial for the measurement of ethnic stratification.

In a broader perspective, our index can be seen as a special type of multivariate inequality measure with two dimensions: economic and social traits. All multivariate inequality measures present a certain degree of complementarity across dimensions, which is typically moderate. In this work we deliberately focus on a particularly high degree of complementarity to capture the essential feature of ethnic stratification as a generalization of between-group inequality, i.e., that economic and social distances between individuals are counted only if they differ in both dimensions. Within the context of multivariate inequality, our index can be seen as a bivariate extension of the Gini coefficient.[4]

Our index can also be interpreted as a diversity measure in the form of a bivariate extension of the generalized fractionalization index formulated in Greenberg (1956), which extends the well-known ethnolinguistic fractionalization (ELF) index by introducing continuous distances between languages. Among other diversity measures, the univariate polarization indices in Esteban and Ray (1994), Duclos et al. (2004), and Reynal-Querol and Montalvo (2005) are related to our model but contain a crucial difference: while we assume that

[3] Gini himself denoted it as the "transvariation" coefficient. Within the literature, Ebert (1988) interprets the residual as a measure of the overlap of groups' distributions, while Lambert and Aronson (1993) explore its geometrical properties and link it to the Lorenz curve. There are many ways of decomposing the Gini coefficient, which lead to alternative formulations of the residual. See Deutsch and Silber (1999) for a review.

[4] Other multivariate Gini indices are defined in Koshevoy and Mosler (1997), Gajdos and Weymark (2005) and Banerjee (2010). In particular, the distance-Gini mean difference of Koshevoy and Mosler (1997) and symmetric indices of the class of measures characterized in Theorem 4 of Gajdos and Weymark (2005) belong to our class of measures of expected alienation for the bivariate case. However, as the economic distances between socially identical individuals are counted in the measurement of inequality in their models, their indices do not satisfy the aforementioned essential feature of ethnic stratification as a generalization of between-group inequality. Other multivariate inequality measures with a high level of complementarity belong to the Generalized Entropy family and are characterized in Tsui (1995, 1999). The Entropy indices are not measures of expected alienation and, more generally, are not based on distances between individuals but on individual traits that should be meaningfully ordered from high to low (e.g., income or years of education). As already mentioned, this is a crucial limitation in the context of diversity measurement as it precludes taking ethnolinguistic distances into account.

the alienation between two individuals is only determined by the distance of their attributes, they additionally consider how many individuals share an attribute with them (i.e., the group effect).[5] To the best of our knowledge there are no multivariate fractionalization measures in the literature, while there are some multivariate polarization indices that use categorical attributes to define groups.[6] Permanyer (2012) and Permanyer and D'Ambrosio (2015) axiomatically characterize bivariate measures where groups are defined via a categorical attribute and the polarization between groups is quantified via a cardinal or ordinal attribute. Other non-axiomatic contributions present similar features (e.g., Gigliarano and Mosler, 2009).

2.2. Empirical literature on inequality, diversity, and trust

Going back to Putnam (2000) and Uslaner (2002), the literature on trust typically distinguishes between particularized and generalized (or social) trust. Particularized trust refers to trust towards people within a small radius, whom the trusting individual knows well and who typically (but not necessarily) belong to the same socio-economic or ethnolinguistic group. Generalized trust refers to trust towards socially distant people about whom the trusting individual has little or no information and who typically belong to different groups. The importance of this distinction is supported by evidence that the two types of trust can even be negatively correlated (e.g., Alesina and Giuliano, 2011).

Many cross-country studies focus on generalized trust and provide evidence for a negative relation between economic inequality and ethnic diversity, on the one hand, and generalized trust, on the other (e.g., Knack and Keefer, 1997; Delhey and Newton, 2005; Bjørnskov, 2007; Nannestad, 2008). These findings are often (implicitly) interpreted as evidence for a causal effect of inequality and

[5]When comparing the performance of various diversity measures in predicting outcomes related to social conflict, Desmet et al. (2012) rarely find significant differences between polarization and fractionalization measures, indicating that omitting the group effect may be of secondary importance. Indeed, there can be ambiguity on the degree (and even direction) of the effect of group size on the ability of a group to mobilize for collective action due to the opposing forces of economies of scale and free-riding (e.g., Olson, 1965; Isaac and Walker, 1988; Feddersen and Pesendorfer, 1998; Guarnaschelli et al., 2000; Esteban and Ray, 2001).

[6]In their axiomatic analysis of the Greenberg (1956) index, Bossert et al. (2011) interpret it as multivariate and postulate that the average fractionalization across attributes should be equal to the fractionalization of the average attributes, implying that it is additively separable in each dimension. Hodler et al. (2017) propose a framework analogous to ours for the measurement of ethnic segregation based on spatial and ethnolinguistic distances. Their axiomatic characterization treats the spatial and ethnolinguistic dimensions symmetrically, while in this paper we consider specific axioms for the economic dimension based on progressive/regressive transfers of wealth in the tradition of inequality measurement.

diversity on trust, but the direction of causality is difficult to disentangle. Bergh and Bjørnskov (2014) indeed provide evidence for reverse causality running from generalized trust to economic inequality. In line with the aforementioned cross-country evidence, several studies find that within a single (Western) country, individuals living in ethnically mixed or economically unequal localities have lower generalized trust (e.g., Alesina and La Ferrara, 2002; Leigh, 2006; Gustavsson and Jordahl, 2008).

Tesei (2017) is the first to investigate the effect of economic inequality between ethnic groups on trust. He finds that higher between-group inequality lowers generalized trust across US municipalities. Moreover, he documents that the negative effects of economic inequality and ethnic fractionalization on generalized trust turn insignificant once he accounts for between-group inequality. His contribution is probably the closest to our empirical part. There are, however, three important differences: First, we focus on towns and villages in Africa, while Tesei (2017) focuses on US municipalities, making these papers complementary. Second, we apply our index of ethnic stratification, which is based on ethnolinguistic distances between pairs of individuals, while he uses a measure of between-group inequality that treats ethnicity as a categorical variable. Third, our dependent variables measure trust in relatives, neighbors and other acquaintances, while he focuses on generalized trust.

Other contributions study how trust in specific groups of people is related to economic inequality and ethnic diversity. These trust measures are sometimes difficult to classify into generalized and particularized trust.[7] Putnam (2007) shows that individuals in ethnically heterogeneous neighborhoods in the United States have lower levels of trust in neighbors as well as in members of their own and other ethnic groups. Koopmans and Veit (2014) find that ethnic diversity in German neighborhoods made salient by experimental stimuli reduces trust in neighbors. Robinson (2017) focuses on the relation between ethnic diversity and trust in African countries. She finds that the gap between trust in co-ethnics and trust in members of other ethnic groups is greater in more diverse countries, but lower in more diverse regions within countries.

At a more general level, our empirical part contributes to the growing litera-

[7] In our case, for example, trust in relatives is clearly particularized trust. The same holds true for trust in neighbors whom a respondent knows well and who belong to the same socio-economic and ethnolinguistic group. However, it is less obvious how to categorize trust in neighbors or other acquaintances who belong to different socio-economic and ethnolinguistic groups.

ture on the determinants of trust in Africa. Like Robinson (2017) and ourselves, most contributions to this literature rely on trust questions asked in Afrobarometer surveys. One strand documents the importance of the traditional structure of society and historical experiences for current trust. Nunn and Wantchekon (2011) study the effect of the trans-Atlantic slave trade on trust in neighbors and others. Gershman (2016) focuses on the effect of witchcraft on generalized trust and trust in members of other religions. Moscona et al. (2017) investigate the effect of an ethnic group's traditional reliance on segmentary lineage organization on the difference in trust towards relatives and non-family members. Another strand of the literature studies how current events shape trust. For example, Rohner et al. (2013) find that generalized trust deteriorates with conflict intensity in Uganda; and Sangnier and Zylberberg (2017) provide evidence that trust in political institutions decreases after protests.

2.3. Literature on contact and conflict theory

Various scholars have postulated that diversity can lead to prejudice towards out-group members; a view that is often referred to as conflict theory. An often assumed mechanism is that with increasing diversity, individuals perceive out-groups as a greater threat to their own interests and as competitors over limited resources (e.g., Blumer, 1958; Blalock, 1967; Putnam, 2007). While earlier works mostly focus on the negative effects of diversity on prejudice towards out-groups, Putnam (2007) emphasizes that diversity can also lead to mistrust towards in-group members: He expects diversity to lead to a general decrease in trust (and even "social isolation"). In contrast, contact theory, founded by Allport (1954), states that intergroup contact can reduce prejudice towards other groups. Allport (1954) did not expect all intergroup contact to reduce prejduce, but only in situations in which certain conditions are met: namely, if the groups are of equal status, have common goals and cooperate, and their contact is supported by an authority, law or customs. Pettigrew and Tropp (2006), Pettigrew et al. (2011) and Paluck et al. (2019) review the literature in social psychology and social sciences that provides ample evidence in support of this hypothesis. However, as Pettigrew and Tropp (2006) and Pettigrew (2008) point out, most of this literature has focused on positive contact between groups, thereby ignoring the potential effects of negative encounters, such as reduced trust and increased conflict. Paolini et al. (2010) and Barlow et al. (2012) show that negative contact indeed makes the in-group/out-group distinction more salient and can increase intergroup conflict more than positive contact can reduce it, thereby providing evidence for conflict theory. Importantly, contact and conflict theory are not mutually exclusive: Given that Allport (1954) predicts a positive outcome from intergroup contact only if certain conditions are met, negative outcomes of intergroup contact are consistent with contact theory. As discussed in the introduction, our empirical findings indeed suggest that both theories have their merits.

3. Model

In this section, we first introduce our index of ethnic stratification. We then present a decomposition and an axiomatic characterization.

3.1. Definition of ethnic stratification

Consider a population constituted by a large set of individuals $P \subseteq \mathbb{R}_+$. Each individual in this population is associated with an ethnicity and a wealth level. We denote by $f(e, w)$ the density of individuals in the population that are associated with ethnicity $e \in E \subseteq \mathbb{R}_+$ and wealth level $w \in W \subseteq \mathbb{R}_+$, referring to $f : E \times W \to \mathbb{R}_+$ as the density function of the joint distribution of ethnicity and wealth.[8] We measure the distance between each pair of wealth levels $w, w' \in W$ by the absolute value of their difference, $|w - w'|$. Unlike wealth levels, ethnicities are not necessarily ordered in a meaningful way in E. To measure the distance between ethnicities, we assume that each ethnicity is associated with a language and denote by $\lambda(e, e') \in \mathbb{R}_+$ the distance between the languages of each pair of ethnicities $e, e' \in E$. We refer to $\lambda : E^2 \to \mathbb{R}_+$ as the linguistic function. In line with the idea of distance, we assume $\lambda(e, e) = 0$ and $\lambda(e, e') = \lambda(e', e)$ for each $e, e' \in E$.[9] In what follows, we assume that the relevant characteristics of the population are summarized by a pair of density and linguistic functions. Hence, each pair (f, λ) can be interpreted as a different population (or society).

Denoting by $e_i \in E$ and $w_i \in W$ the ethnicity and wealth level of each individual $i \in P$ and by $m > 0$ the size (or mass) of the population, our starting

[8] For a finite population, $f(e, w)$ represents the fraction of individuals associated with ethnicity $e \in E$ and wealth level $w \in W$.

[9] Another standard property of a distance is the triangle inequality, i.e., $\lambda(e, e') \leq \lambda(e, e'') + \lambda(e'', e')$ for each $e, e', e'' \in E$. We do not impose this property on λ as it is not necessarily satisfied by linguistic or, more generally, social distances. However, as the triangle inequality can be desirable in many contexts, our characterization is based on axioms in which the linguistic function satisfies the triangle inequality.

point is the general class of measures

$$\mathcal{M}(f,\lambda) := \frac{1}{m^2}\int_{i\in P}\int_{j\in P}\pi\left(\lambda(e_i,e_j),|w_i-w_j|\right)djdi$$
$$= \int_{e\in E}\int_{e'\in E}\int_{w\in W}\int_{w'\in W} f(e,w)f(e',w')\pi\left(\lambda(e,e'),|w-w'|\right)dw'dwde'de, \tag{1}$$

where $\pi:\mathbb{R}_+^2\to\mathbb{R}_+$ can be any function that is continuous and non-decreasing in each dimension satisfying $\pi(0,0)=0$ and $\pi(a,b)\neq 0$ for some $a,b>0$. We interpret π as a quantification of the degree of alienation (e.g., mistrust or lack of common interest) between two individuals as a function of their distances. Hence, any measure from class (1) can be interpreted as the *expected alienation* between a randomly selected pair of individuals. We refer to Rao (1982) and Bossert et al. (2011) for axiomatic characterizations of this broad class of measures where the alienation between two individuals is interpreted as a generic aggregation of their distances in multiple dimensions.

We are now ready to define our index of ethnic stratification. For each pair (f,λ), we measure the degree of *ethnic stratification* in the population by the index

$$S(f,\lambda) := \frac{1}{m^2}\int_{i\in P}\int_{j\in P}\lambda(e_i,e_j)|w_i-w_j|djdi$$
$$= \int_{e\in E}\int_{e'\in E}\int_{w\in W}\int_{w'\in W} f(e,w)f(e',w')\lambda(e,e')|w-w'|dw'dwde'de. \tag{2}$$

This index belongs to class (1) and coincides with the multiplicative form $\pi(a,b)=ab$ for each $a,b\geq 0$. If the wealth and ethnolinguistic distances between any two individuals take values in the unit interval,[10] then they can be interpreted as the probabilities that the poorer individual feels economically deprived vis-a-vis the richer one and that the two individuals do not share a common ethno-cultural background, respectively. Then, the index (2) can be interpreted as the probability that, for a randomly selected pair of individuals, *both* these events occur so that the poorer individual may feel unjustly deprived due to different economic opportunities across ethno-cultural backgrounds. Note that the interpretation of this joint event as a proxy of alienation is in line with conflict and contact theory at the same time.

[10]This can be readily achieved by dividing these distances by the maximal distances within a superset of the population, e.g., the population of a single country as in our regression analysis.

3.2. Decomposition of ethnic stratification

We next show that our index of ethnic stratification depends on four different components. The first three components are common measures of average wealth, wealth inequality and ethnic diversity. These components capture the overall magnitude (or scale) of the wealth and ethnolinguistic distances across pairs of individuals. The fourth component instead captures the role played by the co-directionality of these distances.

We start by showing that our index of ethnic stratification nests common measures of wealth level, inequality and ethnic diversity. Letting f be any density function, the densities of the marginal distributions of ethnicity and wealth are $\varphi_f(e) := \int_{w\in W} f(e,w)dw$ and $\gamma_f(w) := \int_{e\in E} f(e,w)de$, respectively.[11] We consider three indices that summarize properties of the marginal distributions that are relevant for the decomposition of ethnic stratification: the *average wealth*

$$\mu(\gamma_f) := \frac{1}{m}\int_{i\in P} w_i di = \int_{w\in W} \gamma_f(w)wdw,$$

the *Gini coefficient* of inequality (in relative form) of the marginal distribution of wealth

$$\begin{aligned} G(\gamma_f) :=& \frac{1}{2\mu(\gamma_f)m^2}\int_{i\in P}\int_{j\in P} |w_i - w_j| dj di \\ =& \frac{1}{2\mu(\gamma_f)}\int_{w\in W}\int_{w'\in W} \gamma_f(w)\gamma_f(w')|w-w'|dw'dw, \end{aligned}$$

and the coefficient of *fractionalization* of the marginal distribution of ethnicity[12]

$$F(\varphi_f,\lambda) := \frac{1}{m^2}\int_{i\in P}\int_{j\in P} \lambda(e_i,e_j)djdi = \int_{e\in}\int_{e'\in E} \varphi_f(e)\varphi_f(e')\lambda(e,e')de'de.$$

To see that these indices are nested in our model, note that if ethnolinguistic distances "didn't matter" in the sense that $\lambda(e,e') = 1$ for all $e, e' \in E$ (including $e = e'$), then the ethnic stratification of (f,λ) would be equal to (twice) the Gini coefficient in absolute form, i.e., $S(f,\lambda) = 2\mu(\gamma_f)G(\gamma_f)$. This identifies two

[11]For a finite population, $\varphi_f(e)$ represents the fraction of individuals associated with ethnicity $e \in E$ independently of their wealth level, while $\gamma_f(w)$ represents the fraction of individuals associated with wealth level $w \in W$ independently of their ethnicity.

[12]This coefficient is the generalized fractionalization index proposed by Greenberg (1956) and axiomatically characterized by Bossert et al. (2011).

scale effects related to the marginal distribution of wealth, as $\mu(\gamma_f)$ measures the average scale of wealth and $G(\gamma_f)$ the average scale of the wealth distances between all pairs of individuals relative to the average scale of wealth. Similarly, if wealth "didn't matter" in an analogous way, the ethnic stratification of (f, λ) would be equal to $F(\varphi_f, \lambda)$, which represents the average scale of the ethnolinguistic distances between all pairs of individuals, identifying the scale effect related to the marginal distribution of ethnicity.

In what follows, we show that ethnic stratification would be equal to (twice) the product of the three indices above, $2\mu(f)G(f)F(f, \lambda)$, if wealth and ethnicities were independently distributed across all individuals of society (f, λ). We then argue that the deviation of the "true" ethnic stratification $S(f, \lambda)$ from $2\mu(f)G(f)F(f, \lambda)$ captures the role played by the co-directionality of ethnolinguistic and wealth distances in shaping ethnic stratification in a society. To develop the argument formally, define the *benchmark* of density f as the density function $b_f : E \times W \to \mathbb{R}_+$ such that the marginal densities are identical to those of f and that ethnicity and wealth are independently distributed across individuals, i.e., $\varphi_{b_f}(e) = \varphi_f(e)$, $\gamma_{b_f}(w) = \gamma_f(w)$ and $b_f(e, w) = \varphi_{b_f}(e)\gamma_{b_f}(w)$. By extension, the benchmark of a pair (f, λ) is the pair (b_f, λ) constituted by the benchmark density of f and the same linguistic function λ. Figure 1 provides an example: The population (f, λ) is partitioned into three equally sized wealth classes that also correspond to three different ethnicities, while each ethnicity is proportionally represented within each wealth class in the corresponding benchmark (b_f, λ).

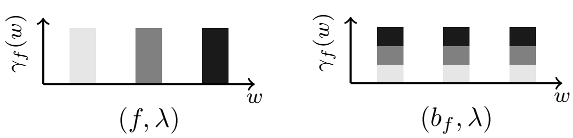


Figure 1: Illustration of a pair of density and linguistic functions and the corresponding benchmark. Notes: Each tone of gray indicates a different ethnicity, and ethnolinguistic distances between ethnicities are given by differences in tones of gray.

Proposition 1. *For each pair (f, λ), the ethnic stratification of the benchmark (b_f, λ) is*

$$S(b_f, \lambda) = 2\mu(\gamma_f)G(\gamma_f)F(\varphi_f, \lambda). \tag{3}$$

Proposition 1 offers several insights for the decomposition of ethnic stratification in terms of scale and co-directionality effects. First, it shows that the ethnic stratification of the benchmark can be written as a function of the marginal densities γ_f and φ_f instead of f, providing a formal link between ethnic stratification and the three scale effects corresponding to the indices $\mu(\gamma_f)$, $G(\gamma_f)$ and $F(\varphi_f, \lambda)$. Second, in comparison to the ethnic stratification of the benchmark, the "true" ethnic stratification of (f, λ) additionally depends on a fourth component that captures the co-directionality of ethnolinguistic and wealth distances across pairs of individuals. Roughly speaking, we should expect

$$S(f, \lambda) > S(b_f, \lambda),$$

i.e., a positive residual indicating co-directionality, whenever high (low) wealth distances tend to go hand in hand with high (low) ethnolinguistic distances across pairs of individuals, but $S(f, \lambda) < S(b_f, \lambda)$, i.e., a negative residual indicating "reverse" co-directionality, whenever high (low) wealth distances tend to be associated with low (high) ethnolinguistic distances. To conclude, it follows from Proposition 1 that each of the three components $\mu(\gamma_f)$, $G(\gamma_f)$ and $F(\varphi_f, \lambda)$ captures a different scale effect, while the co-directionality effect is quantified by the deviation of the ethnic stratification of (f, λ) from the ethnic stratification of the benchmark (b_f, λ).[13]

Remark 1. *For each pair (f, λ), the three components of*

$$S(b_f, \lambda) = 2\mu(\gamma_f)G(\gamma_f)F(\varphi_f, \lambda)$$

indicate different scale effects, while the comparison $S(f, \lambda) \lesseqgtr S(b_f, \lambda)$ indicates the co-directionality effect.

3.3. Axiomatic characterization of ethnic stratification

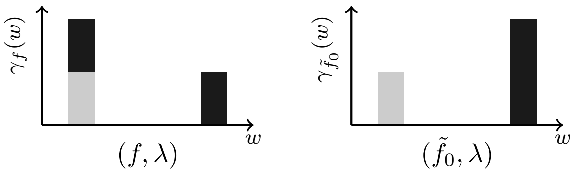
In what follows we show that a measure $M \in \mathcal{M}$ from class (1) satisfies a set of desirable properties (or axioms) if and only if it coincides with our index of ethnic stratification (2) up to positive scalar multiplication, i.e., $M = kS$ for some constant $k > 0$. We motivate our axioms as natural properties of an index of ethnic stratification that generalizes the idea of between-group inequality

[13] This deviation could be formalized in many alternative ways, e.g., the subtractive form $S(f, \lambda) - S(b_f, \lambda) \lesseqgtr 0$, the ratio form $S(f, \lambda)/S(b_f, \lambda) \lesseqgtr 1$, the logarithmic form $\ln[S(f, \lambda)/S(b_f, \lambda)] \lesseqgtr 0$, or the exponential form $\exp[S(f, \lambda) - S(b_f, \lambda)] \lesseqgtr 1$. Each of these formalizations would lead to a different decomposition of ethnic stratification into the three parts $\mu(\gamma_f)$, $G(\gamma_f)$ and $F(\varphi_f, \lambda)$ plus the corresponding version of co-directionality.

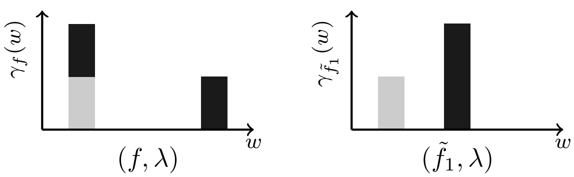
to situations where additional data on ethnolinguistic differences is available. Moreover, we believe these to be appealing properties of an index that aims to predict social tensions in line with the intuitions of conflict and contact theory. For simplicity, we state our axioms by means of examples based on degenerate joint distributions consisting of two or three mass points. These examples consist of comparative static exercises (or shifts) in the functions f and λ, and our axioms impose ethnic stratification to increase (or at least not to decrease) as a consequence of these shifts, all else equal. We consider three axioms in total, each focusing on a different trade-off between increasing (decreasing) the overall magnitude of wealth or ethnolinguistic distances and decreasing (increasing) their co-directionality.

Our first axiom, *co-directionality by wealth creation or transfer (CDbW)*, considers shifts in the density function induced by wealth creation or progressive (i.e., inequality-decreasing) wealth transfers within ethnicities such that the population becomes clustered into two groups whose members are perfectly homogeneous both in terms of ethnicity and wealth level. The intuition can be immediately grasped from Figures 2(a) and 2(b). In each of them the distribution on the right is obtained from the distribution on the left by a shift in the density function. In Figure 2(a) the poor of the dark group become rich by wealth creation, while in Figure 2(b) they become wealthier by a transfer of wealth from their rich co-ethnics. In both cases the population becomes partitioned into two perfectly homogeneous groups so that ethnic and economic divisions perfectly coincide. The axiom, which we are about to state formally, requires ethnic stratification to weakly increase as a consequence of such shifts due to the perfect ethnic homogeneity of the new economic classes. The idea that the population should become more conflictual as individuals of different ethnicities no longer share the same socio-economic status is supported by contact theory (and consistent with conflict theory).

Axiom CDbW (co-directionality by wealth creation or transfer). *Data:* Let the pair (f, λ) be such that the population is partitioned into three equally sized sets $P_1, P_2, P_3 \subset P$. Suppose that all individuals in P_2 hold wealth level w_1 while all individuals in $P_1 \cup P_3$ hold wealth level w_2, where $w_1 > w_2$ so that $P_1 \cup P_3$ are the poor and P_2 are the rich. Moreover, assume that the population is partitioned into two ethnicities, labelled 1 and 2, speaking different languages, and that all individuals in P_1 belong to ethnicity 1 while all individuals in $P_2 \cup P_3$ belong to ethnicity 2. This description implies $f(1, w_2) = f(2, w_1) =$



(a) Axiom CDbW with $\epsilon = 0$.



(b) Axiom CDbW with $\epsilon = 1$.

Figure 2: Illustration of Axiom CDbW. Notes: The two graphs of each sub-figure illustrate examples of the two pairs of density and linguistic functions corresponding to this axiom. Each tone of gray indicates a different ethnicity.

$f(2, w_2) = 1/3$ and $\lambda(1, 2) > 0$. *Statement:* For any $\epsilon \in [0, 1]$, we require $M(\tilde{f}_\epsilon, \lambda) \geq M(f, \lambda)$ for the density function $\tilde{f}_\epsilon$ that satisfies $\tilde{f}_\epsilon(1, w_2) = 1/3$ and $\tilde{f}_\epsilon(2, (1-\epsilon)w_1 + \epsilon(w_1 + w_2)/2) = 2/3$.

Let us discuss the shift from density f to density $\tilde{f}_\epsilon$ in more detail. Axiom CDbW requires that ethnic stratification should not decrease when wealth is created by P_3 (i.e., the poor of ethnicity 2) or transferred from P_2 to P_3 (i.e., from the rich to the poor of ethnicity 2) to the point that all individuals in $P_2 \cup P_3$ (i.e., all members of ethnicity 2) come to hold the new wealth level $(1-\epsilon)w_1 + \epsilon(w_1 + w_2)/2$, which is above w_1 (i.e., the wealth level of all members of ethnicity 1), where $\epsilon \in [0, 1]$ denotes the fraction of wealth that is transferred from P_2 to P_3 while the remaining fraction $(1-\epsilon)$ is created by P_3.[14] As a result,

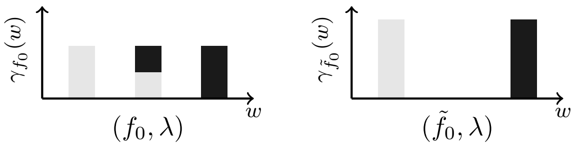
[14]Let us discuss Axiom CDbW in relation to standard principles in inequality measurement (see, e.g., Cowell, 2011 for a review). Let us start with the Principle of Transfers (stating that inequality should decrease when wealth is transferred from the rich to the poor). Axiom CDbW relaxes this principle when such transfers occur within an ethnic group. This violation of the Anonymity Axiom (stating that the identity of individuals should not affect the measurement of inequality) is standard in between-group inequality measurement as only wealth differentials between members of different groups should be taken into account. Notice further that the kind of wealth creation considered in Axiom CDbW (which weakly increases ethnic stratification) can lead to decreases in standard inequality measures. For instance, note that average wealth appears in the denominator of the Gini coefficient in relative form, as shown in

for each ϵ the population becomes clustered in two ethnically homogeneous economic classes, P_1 and $P_2 \cup P_3$, leading to a weakly higher average wealth differential between the two groups. Axiom CDbW implicitly assumes that these changes fuel ethnic tensions and requires that they weakly increase ethnic stratification.

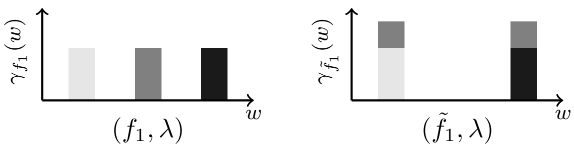
Our second axiom, *bi-polarization by wealth transfer (BPbW)*, considers shifts in the density function induced by regressive (i.e., inequality-increasing) transfers of wealth such that the wealth distribution becomes polarized into two opposite economic classes while (possibly) altering the co-directionality of wealth and ethnolinguistic distances. The message can be easily discerned from Figures 3(a) and 3(b), where in each of them the distribution on the right is obtained from the distribution on the left by a shift in the density function. In both, the disappearance of the middle class follows from the same regressive transfer within itself but has different consequences on within-group homogeneity. In Figure 3(a), the half of the middle class that gets richer belongs to the dark gray group (which is already richer on average) while the half that gets poorer belongs to the light gray group (which is already poorer on average), so that the rise in inequality strengthens economic homogeneity within ethnic groups. In Figure 3(b) on the other hand, the middle class is constituted by a third ethnic group in mid gray (thus linguistically in between the other two), so that the rise in inequality partially blurs the ethnic homogeneity within economic classes. In both cases, the average wealth differential between ethnically diverse individuals is weakly higher than before. We think of ethnic stratification as closely related to such wealth differentials, and contact theory also suggests that such wealth differentials are a core determinant of ethnic tensions. Therefore, the axiom requires ethnic stratification to weakly increase as a consequence of such shifts in the density function.

Axiom BPbW (bi-polarization by wealth transfer). *Data:* Let the pair (f_ϵ, λ) be such that the population is partitioned into three equally sized sets

Section 3.2. For this reason we believe that ethnic stratification should be seen as an inequality measure in absolute form, as substantiated by our decomposition in Section 3.2, which accounts both for the Gini coefficient in relative form and the average wealth level as separate components (which jointly account for the Gini coefficient in absolute form). Moreover, note that our index increases linearly in the scale of wealth (i.e., by multiplying all wealth levels by the same positive constant). It is therefore scale invariant only in the sense of not altering the ranking of populations and not altering their ethnic stratification levels up to a common positive scalar multiplication, as standard inequality measures in absolute form.



(a) Axiom BPbW with $\epsilon = 0$.



(b) Axiom BPbW with $\epsilon = 1$.

Figure 3: Illustration of Axiom BPbW. Notes: The two graphs of each sub-figure illustrate examples of the two pairs of density and linguistic functions corresponding to this axiom. Each tone of gray indicates a different ethnicity, and ethnolinguistic distances between ethnicities are given by differences in tones of gray.

$P_1, P_2, P_3 \subset P$ divided into three ethnicities, labelled 1, 2 and 3, such that all individuals in P_1 belong to ethnicity 1, all individuals in P_3 belong to ethnicity 3, and a fraction $\epsilon \in [0, 1]$ of the individuals in P_2 belong to ethnicity 2 while the remaining fraction $(1 - \epsilon)$ is equally split between ethnicity 1 and ethnicity 3. Assume that the wealth level is homogeneous within each set P_1, P_2, P_3, and denote by $w_1 > w_2 > w_3$ the respective wealth levels. Hence, we can refer to P_1, P_2 and P_3 as the rich, the middle class and the poor. This description implies $f_\epsilon(1, w_1) = f_\epsilon(3, w_3) = 1/3$, $f_\epsilon(2, w_2) = \epsilon/3$ and $f_\epsilon(1, w_2) = f_\epsilon(3, w_2) = (1 - \epsilon)/6$ for each $\epsilon \in [0, 1]$. In addition, suppose that the wealth of the middle class is the average of those of the rich and the poor and that the language of ethnicity 2 is a balanced mixture of the languages of ethnicities 1 and 3, implying $w_2 = (w_1 + w_3)/2$ and $\lambda(1, 2) = \lambda(2, 3) = \lambda(1, 3)/2 > 0$. *Statement:* For any $\epsilon \in [0, 1]$, we require $M(\tilde{f}_\epsilon, \lambda) \geq M(f_\epsilon, \lambda)$ for the density function $\tilde{f}_\epsilon$ that satisfies $\tilde{f}_\epsilon(1, w_1) = \tilde{f}_\epsilon(3, w_3) = (3 - \epsilon)/6$ and $\tilde{f}_\epsilon(2, w_1) = \tilde{f}_\epsilon(2, w_3) = \epsilon/6$.

Let us discuss the shift from density f_ϵ to density $\tilde{f}_\epsilon$ in more detail. Axiom BPbW requires that ethnic stratification should not decrease when half of the middle class becomes poor (with their wealth level going from w_2 down to w_3) while the other half becomes rich (with their wealth level going from w_2 up to w_1) due to regressive transfers of wealth from the former to the latter. As a result, the middle class disappears and economic inequality unquestionably surges, leading to economic bi-polarization. However, for each ϵ this surge in inequality weakly blurs the pattern of ethno-economic clustering, as there is now a mass $(3-\epsilon)/6$ of members of ethnicity 2 within the poor and the rich economic classes (which were originally constituted only by members of ethnicity 1 and ethnicity 3, respectively). Despite this, note that for each ϵ the average wealth differential between ethnic groups weakly rises due to the growth in wealth distances between the ex-middle class members of ethnicities 1 and 3. Axiom BPbW requires that ethnic stratification weakly increases in response to this weak increase in the average wealth differential. This requirement can be interpreted as a counter-force to Axiom CDbW, which considers the same trade-off in the opposite direction, guaranteeing that our framework is sensitive to within-group homogeneity but still (and mainly) about the measurement of economic inequality.

Our third axiom, *co-directionality by linguistic change (CDbL)*, considers shifts in the linguistic function that increase the co-directionality of wealth and ethnolinguistic distances by altering the relative ethnolinguistic distances between ethnic groups while leaving their overall magnitude unchanged. Figure 4, where the distribution on the right is obtained from the distribution on the left by a shift in the linguistic function, easily conveys the intuition. There are three economic classes that coincide with three different ethnic groups. The middle class (in mid gray) speaks a language exactly in between those of the rich (in dark gray) and the poor (in light gray) and holds a wealth level that is closer to that of the rich than to that of the poor. The axiom, which we are about to state formally, requires ethnic stratification to weakly increase when the language of the middle class shifts closer to that of the rich and farther from that of the poor, thus strengthening the co-directionality of economic and linguistic distances. In line with the insights of contact theory, this should weakly increase ethnic tensions, as individuals with higher wealth differentials diverge further along the ethnolinguistic dimension.

Axiom CDbL (co-directionality by linguistic change). *Data:* Let the pair (f, λ) be such that the population is partitioned into three equally sized sets $P_1, P_2, P_3 \subset P$ with homogeneous wealth level and ethnicity within each set. Denote by $w_1 > w_2 > w_3$ the respective wealth levels, so that we can again refer to P_1, P_2 and P_3 as the rich, the middle class, and the poor. Then, letting 1, 2 and 3 indicate the ethnicities of the sets P_1, P_2 and P_3, we can write $f(1, w_1) = f(2, w_2) = f(3, w_3) = 1/3$. In addition, suppose that the language of

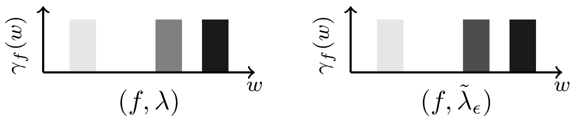


Figure 4: Illustration of Axiom CDbL with generic $\epsilon \in (0, \lambda(1,2)]$. Notes: The two graphs illustrate examples of the two pairs of density and linguistic functions corresponding to this axiom. Each tone of gray indicates a different ethnicity, and ethnolinguistic distances between ethnicities are given by differences in tones of gray.

ethnicity 2 is a mix of the languages of ethnicities 1 and 3, implying $\lambda(1,3) = \lambda(1,2) + \lambda(2,3) > 0$. Importantly, let the wealth level of the middle class be closer to that of the rich than to that of the poor, so that $w_2 > (w_1 + w_3)/2$. *Statement:* For each $\epsilon \in (0, \lambda(1,2)]$, we require $M(f, \tilde{\lambda}_\epsilon) \geq M(f, \lambda)$ for the linguistic function $\tilde{\lambda}_\epsilon$, which is identical to λ except that $\tilde{\lambda}_\epsilon(1,2) = \lambda(1,2) - \epsilon$ and $\tilde{\lambda}_\epsilon(2,3) = \lambda(2,3) + \epsilon$.

Let us discuss the shift in the linguistic function from λ to $\tilde{\lambda}_\epsilon$ in more detail. Axiom CDbL requires that a change in the language of the middle class (ethnicity 2) which brings it ϵ-closer to that of the rich (ethnicity 1) and ϵ-farther from that of the poor (ethnicity 3), should not lead to a decrease in ethnic stratification. This should hold for any ϵ such that the language of the middle class remains in between the other two languages, i.e., any $\epsilon \in (0, \lambda(1,2)]$. As by assumption the wealth level of the middle class (w_2) is closer to that of the rich (w_1) than to that of the poor (w_3), this linguistic change increases the co-directionality between the wealth distances $|w_i - w_j|$ and the ethnolinguistic distances $\lambda(e_i, e_j)$ across all pairs of individuals i, j on average. Then, while the overall magnitude of such distances is unchanged (as wealth distances are fixed, while for each ϵ-increase there is a corresponding ϵ-decrease in linguistic distances), the "effective" wealth differential between ethnic groups increases due to the higher alignment of distances across the economic and ethnolinguistic dimensions. As previously mentioned, we believe such a wealth differential to be at the core of the idea of ethnic stratification and a significant predictor of ethnic tensions.

We are now ready to state our characterization result:

Theorem 1. *A measure $M \in \mathcal{M}$ satisfies axioms CDbW, BPbW, CDbL if and only if it coincides with (2) up to positive scalar multiplication.*

To further clarify the role of each axiom, we now sketch the "only if" part of the proof of Theorem 1.[15] As our premise is any measure from class $\mathcal{M}$, the proof focuses on showing that the three axioms jointly imply $\pi(a, b) = kab$ for some $k > 0$. To start with, we show that the combination of CDbW and BPbW implies $\pi(a, 0) = \pi(0, b) = 0$ for each $a, b > 0$, meaning that the wealth and ethnolinguistic distances between two individuals are counted only if the individuals differ in both dimensions. As argued earlier, we believe this high degree of complementarity is a defining feature of ethnic stratification as a generalization of between-group inequality, and a core insight of conflict and contact theory to predict ethnic tensions. Given this, we proceed by showing that CDbW additionally requires $\pi(a, b)$ to be weakly concave in b, while BPbW additionally demands it to be weakly convex in b, so that $\pi(a, b)$ must be linear in b by the combination of these two axioms.[16] Together with our finding $\pi(a, 0) = \pi(0, b) = 0$ for each $a, b > 0$, this implies that $\pi(a, b) = \rho(a)b$ for some non-decreasing function $\rho : \mathbb{R}_+ \to \mathbb{R}_+$ that satisfies $\rho(0) = 0$ and $\rho(a) > 0$ for some $a > 0$. Finally, our proof concludes by showing that by CDbL the function ρ is linear, so that $\rho(a) = ka$ for some $k > 0$.

4. Computing ethnic stratification

In this section, we first describe how to construct the economic and ethnolinguistic distances between pairs of individuals using data from Afrobarometer surveys. We then show that our index of ethnic stratification can be interpreted as a parameter that can be estimated from data, which we illustrate with a cross-country comparison.

4.1. Constructing economic and ethnolinguistic distances

The main data we use comes from Afrobarometer surveys. These surveys aim to be representative of all citizens of voting age in a given country and year. For that purpose, the samples are stratified according to the main subnational administrative units and by urban or rural locations. Importantly, the samples within the primary sampling units, which we later call towns and villages, are randomly drawn from the local population (Afrobarometer, 2018).

[15]The "if" part is trivial as it is straightforward that $M = kS$ satisfies the axioms for each $k > 0$.

[16]These conclusions are drawn by considering the implications of CDbW and BPbW at the extreme cases with $\epsilon = 1$, as depicted in Figure 2(b) and Figure 3(b).

The use of Afrobarometer data has several advantages. First, these surveys contain information on the respondents' wealth. This information, which is considerably richer from survey round 5 onward, allows us to create measures of individual economic wealth and, consequently, economic distances between pairs of respondents. Second, the Afrobarometer surveys contain information on the respondents' native language and their ethnic affiliation. After matching this information to the languages in the Ethnologue (Gordon Jr., 2005), we can use the Ethnologue's language trees to compute ethnolinguistic distances between pairs of individuals. Third, the Afrobarometer data has recently been geocoded by AidData (BenYishay et al., 2017). Given the geo-coordinates of the survey locations, plus the economic and ethnolinguistic distances between pairs of individuals, we can compute ethnic stratification at the level of various spatial units, including countries or towns and villages. Fourth, the Afrobarometer surveys, in particular round 5, include questions on trust in relatives, neighbors and other acquaintances, which allows us to study the relation between local ethnic stratification and the respondents' trust in people they know.

To compute economic distances, we first construct a wealth index similar to the one constructed in the Demographic and Health Surveys (DHS). We thereby use the information on the assets that the respondents and their families possess and the quality of the house in which they live. Afrobarometer surveys of round 5 contain information on the possession of a radio, television, mobile phone, and a motorcycle or car, and on the types of water source, toilet, house and roof (see Online Appendix A.1 for details). We then follow DHS in creating a wealth index consisting of the first principal component of the asset and housing variables, and we construct the wealth index for each country separately and later normalize them to take a value between zero and one.[17] We use the resulting wealth indices as a measure of individual economic wealth and the absolute difference between the index values of a pair of individuals as their economic distance.

[17] The first principal component is calculated by conducting a principal component analysis. This method is used to reduce the large number of asset and housing variables to linear combinations, which can be interpreted more easily. The first principal component has the largest variance of all linear combinations and thus accounts for the largest part of the variation in the data (Jolliffe, 2002). For robustness tests that include multiple survey rounds, we construct the wealth index separately for each survey, i.e., each country and survey round. We do not construct separate wealth indices for urban and rural areas, because the asset and housing variables on which our index is based appear relevant in both urban and rural settings.

In addition, Afrobarometer surveys provide information on the respondents' native language and their ethnic affiliation.[18] To compute the ethnolinguistic distances between respondents, we match the language and ethnicity information from the Afrobarometer to the languages in the Ethnologue. The Ethnologue provides the most complete classification of world languages. It lists 7,097 known living languages, of which 2,143 are in Africa. The Ethnologue's data are modelled as trees that show the historical relation between all languages.

Many languages and ethnic groups used in the Afrobarometer surveys do not match the names of the languages in the Ethnologue. We match them manually using information from the Ethnologue website,[19] which contains information on alternative names and dialects, and sometimes also on the ethnic groups that speak a certain language. In cases in which a language or ethnic group from Afrobarometer was not found on the Ethnologue website, we use the following sources to match the information from Afrobarometer to the Ethnologue: Eldredge (2015), Falola and Jean-Jacques (2015), Futhwa (2012), Hall (1999), Olson (1996), Otlogetswe (2011), and the Joshua Project.[20] For Afrobarometer surveys of round 5, we successfully match 727 Afrobarometer languages to 560 Ethnologue languages, and 677 Afrobarometer ethnicities to 502 Ethnologue languages. We are unable to match 14 (19) languages (ethnicities) of the possible answer categories in the Afrobarometer surveys of round 5 to any Ethnologue language. For some respondents, we cannot match the language or ethnicity information from Afrobarometer to the Ethnologue because the corresponding question was not asked or not answered.[21] In addition, we treat European languages (i.e., English, French, German and Portuguese) as missing. For all these reasons and in order to base our indices on as many respondents as possible, we combine the respondents' information on language and ethnicity, and compute two different measures of ethnolinguistic distance between pairs of individuals: one based primarily on the Afrobarometer language (with the

[18]The specific questions are: "Which language is your home language?" and "What is your ethnic community, cultural group or tribe?"

[19]`https://www.ethnologue.com`

[20]`https://www.joshuaproject.net`

[21]The Afrobarometer data also contain responses that do not fit to any of the Afrobarometer's answer categories. Of these additional responses, we successfully match 296 (213) languages (ethnicities), which contribute to the total of 727 (677) languages (ethnicities) matched. We cannot match 86 (226) languages (ethnicities) of these additional responses to any Ethnologue language listed in the respondent's country. We additionally use Afrobarometer surveys of rounds 3, 4 and 6 in robustness tests. Aggregated over rounds 3–6, we are able to match 1,211 (1,167) Afrobarometer languages (ethnicities) to 714 (661) Ethnologue languages.

Afrobarometer ethnicity used only if the Afrobarometer language could not be matched to any Ethnologue language), and one based primarily on the Afrobarometer ethnicity (with the Afrobarometer language used only if the Afrobarometer ethnicity could not be matched to any Ethnologue language). We get 578 distinct ethnolinguistic groups according to the Ethnologue's classification when relying primarily on Afrobarometer languages, and 545 groups when relying primarily on Afrobarometer ethnicities.[22] For our main analysis, we use the coding that relies primarily on Afrobarometer languages, as all surveys ask about the respondents' native language whereas some do not ask about their ethnic affiliation.

Language trees depict the historical relations between languages, as languages that share more branches have a longer common history. Therefore, many scholars have used language trees to calculate the distance between any two ethnolinguistic groups (e.g., Fearon, 2003; Desmet et al., 2009). Here, we use the formula proposed by Putterman and Weil (2010) to compute ethnolinguistic distances:

$$\lambda(e_i, e_j) = 1 - \sqrt{\frac{2t_{ij}}{T_i + T_j}},$$

where T_i and T_j are the number of nodes in the branch of the languages of the ethnolinguistic groups e_i and e_j, respectively, and t_{ij} the number of common nodes.

4.2. Ethnic stratification as a parameter

Suppose our dataset consists of an i.i.d. sample of size $n \geq 2$, $\{(E_i, W_i)\}_{i=1}^n$, where (E_i, W_i) are ethnicity and wealth levels of individual i that have the same distribution as (E, W). For a given λ, we can equivalently re-write ethnic stratification from equation (2) as a population parameter:

$$\theta := \mathbb{E}\left[\lambda\left(E, E'\right)|W - W'|\right].$$

where (E, W) and (E', W') denote two generic independent pairs of random variables that are drawn from some density underlying f.

The most natural way to estimate θ is to use its sample counterpart, where

[22] Aggregated over rounds 3–6, the number of distinct ethnolinguistic groups is even 731 (702) when relying primarily on Afrobarometer languages (ethnicities).

an expectation is replaced by a sample average. In particular, using the Law of Iterated Expectation, we see that $\theta = \mathbb{E}\left[\mathbb{E}\left[\lambda\left(E, E'\right)|W - W'||\, E, W\right]\right]$. We thus propose the following estimator for θ:

$$\theta_n := \frac{1}{n^2}\sum_{i=1}^{n}\sum_{j=1}^{n}\lambda\left(E_i, E_j\right)|W_i - W_j|\,. \tag{4}$$

A measure of ethnic stratification can therefore be computed in a similar way to other related indices in the literature (e.g., Gini, fractionalization, polarization).

One use of the above index is to compare ethnic stratification across samples. We show in Appendix B that θ_n is a consistent estimator of θ and has an asymptotic normal distribution. Furthermore, the asymptotic variance of θ_n can be easily estimated so that one can construct confidence intervals and perform inference. As an illustration, we plot the ethnic stratification estimates for African countries and their corresponding confidence intervals in Figure 5.

To generate Figure 5, we use all respondents from Afrobarometer surveys of round 5 who answered the questions used to construct the wealth index and whom we could assign to an Ethnologue language group. We exclude countries where more than 95 percent of the respondents belong to the largest ethnolinguistic group.[23] We are left with 26 ethnolinguistically diverse African countries. We present the estimates of these countries' ethnic stratification, arranged from highest to lowest.

5. Estimating the effect of ethnic stratification on trust

In this section, we compute ethnic stratification at the level of African towns and villages according to (4) and use it as an explanatory variable and estimate its relation to trust in relatives, neighbors and other people the respondent knows. We first discuss the construction of the dataset and our empirical specification. We then present our main results, many robustness tests, a comparison of our index with other indices of diversity and inequality, as well as results for crime and violent conflict.

[23] We discuss our sample selection in more detail in Section 5. Note that the respondents that we exclude here are a subset of the respondents that we exclude in Section 5, where we focus on the local level and need the respondents' answers on the trust questions of interest.

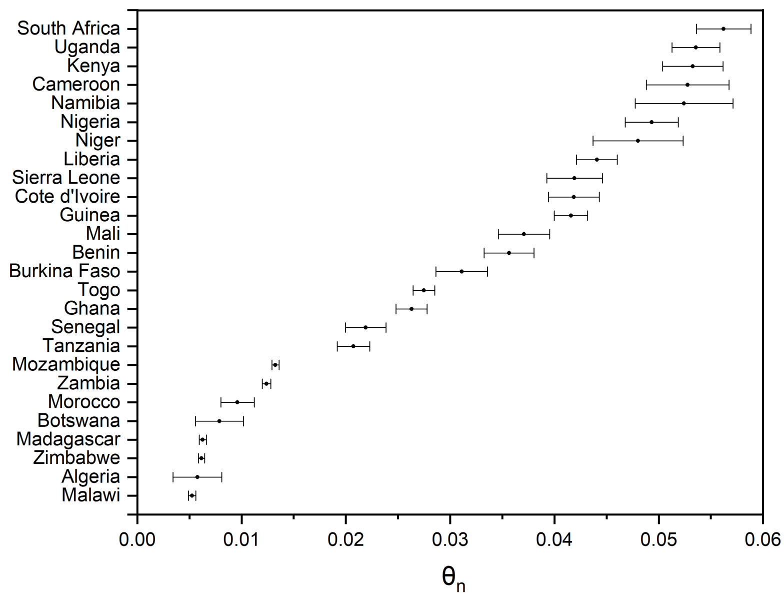


Figure 5: Country-level inference. Notes: Dots indicate point estimates of the countries' ethnic stratification index and lines the 95% confidence intervals based on equations (4) and (10). Data are from Afrobarometer surveys of round 5. Economic distances are based on our wealth index. Ethnolinguistic groups are primarily based on the respondents' language, and ethnolinguistic distances are computed using the Putternam and Weil (2010) formula.

5.1. Our dataset

We base our main analysis on Afrobarometer surveys of round 5. There are two main reasons for this. First, none of the other rounds contains all of the three trust questions we are interested in. Questions on trust in relatives are asked in rounds 3–5, questions on trust in neighbors in rounds 3 and 5, and questions on trust in other people the respondent knows in rounds 4 and 5. Round 6 contains none of these questions. Second, the definition of our index of ethnic stratification in equation (2) makes clear that good proxies for economic/wealth distances between pairs of individuals are crucial for the computation of this index; and round 5 (and round 6) contain considerably richer information on individual wealth, in particular on the quality of housing, than rounds 3 and 4 (see Online Appendix A.1 for details).

For our main analysis, we compute our index of ethnic stratification at the level of survey areas such as town or villages. We focus on ethnic stratification at such a granular level, because we are interested in its relation to trust in people the respondents know. We use the wealth and ethnolinguistic distances between pairs of individuals (see Section 4.1) to compute our index of ethnic stratification S_{vc} at the level of each town or village v of country c. In addition, we can also compute the average wealth (μ_{vc}), the Gini coefficient (G_{vc}) and the index of ethnic fractionalization (F_{vc}). They are all nested in the ethnic stratification index (see Section 3.2), such that their computation requires no additional information.

To construct our main dependent variables, we focus on the following three trust questions in the Afrobarometer surveys: "How much do you trust each of the following types of people: Your relatives? Your neighbors? Other people you know?" Following Rohner et al. (2013), we build indicator variables that equal one if the respondent answers "a lot" or "somewhat," and zero if she answers "just a little" or "not at all."

We also use alternative dependent variables measuring crime and conflict. For crime, we use two binary measures based on questions in the Afrobarometer surveys. The first measure, which we call "fear of crime," indicates whether the respondent (or a family member) had feared crime within their own home during the past year. The second, which we call "actual crime," indicates whether the respondent (or a family member) had been physically attacked or something had been stolen from their home during the past year. For measuring conflict at the local level, we use data from the Armed Conflict Location and Event Dataset (ACLED) introduced by Raleigh et al. (2010). We proxy for conflict with a binary variable that indicates whether there would be at least one violent conflict event within 10 km of the center of the town or village within three years from the date of the interviews.[24] This conflict variable is available at the level of towns and villages rather than individual respondents. (We postpone the discussion of the implications that this change in the units of observation has for our empirical strategy to Section 6.6.)

For our analysis, we restrict the sample along three dimensions. First, as in Section 4, we exclude countries where more than 95 percent of the respondents belong to the same ethnolinguistic group according to our data. These countries are Burundi, Cape Verde, Egypt, Lesotho, Mauritius, Sudan, Swaziland and

[24] ACLED records reported events of political violence across Africa (and other regions of the world). Among other information, ACLED provides the date, the location and the type of each event. We classify the following types as violent events: "battles," "violence against civilians," and "explosions/remote violence."

Tunisia.[25] Second, we restrict our attention to interviews conducted in locations that AidData (BenYishay et al., 2017) classified as "populated places" such as towns or villages (and whose coordinates correspond to an exact location), as we want to be sure that the various respondents from a cluster were living in close proximity.[26] Third, we exclude respondents who answered none of the trust questions we are using, respondents who did not answer some of the questions used to construct the wealth index, respondents to whom we could not assign an Ethnologue language, and respondents for whom information on age, education or religion (which we use as control variables) is missing. In addition, we exclude the few towns and villages where the wealth index and the Ethnologue language are available for fewer than three respondents, because our index of ethnic stratification is not defined in case of a single respondent and would depend on just one pair of individuals in case of two respondents.

Our final sample consists of 21,379 respondents from 2,558 towns and villages across 1,147 districts (ADM2 regions) in 371 provinces (ADM1 regions) of 26 ethnolinguistically diverse African countries. 54% of these towns and villages have exactly eight respondents, and the average town or village has 8.50 respondents. Figure 6 depicts the towns and villages in our final sample. In addition, it provides some information on local ethnic stratification, with darker dots indicating higher values.

Table 1 reports summary statistics. Out of every ten respondents, around eight trust their relatives, around six their neighbors, and around four other acquaintances. Similarly, seven out of every ten respondents were afraid of crime

[25] Respondents in Burundi indicate different ethnicities (Hutu, Tutswi, Twa), which are however not distinct languages in the Ethnologue; and more than 99 percent indicate Rundi as their native language. Respondents in Cape Verde indicate ethnicities that cannot be matched to the Ethnologue (as they are related to, e.g., age or class), and 100 percent indicate Kabuverdianu as their native language. Respondents in Egypt, Sudan and Tunisia were not asked about their ethnicity, and more than 99 percent indicate Arabic as their native language. Most respondents in Mauritius indicate ethnicities that cannot be matched to the Ethnologue (e.g., their religion), and more than 96 percent indicate Creole as their native language. More than 97 percent of the respondents in Lesotho indicate Southern Sotho as both their native language and their ethnicity. Respondents in Swaziland were not asked about their ethnicity, and more than 98 percent indicate Swati as their native language.

[26] There are three other categories: "Administrative regions," "structures" (e.g., schools or health clinics), and "other topographical features" (e.g., mountains, rivers or forests). We exclude clusters coded as "administrative regions" or "other topographical features," because they are less geographically precise, as confirmed by the precision code in the data. We exclude locations coded as "structures," because schools or health clinics might serve as central meeting points to conduct interviews with people from different villages. Results remain qualitatively unchanged and quantitatively very similar if we include the relatively few respondents from "structures."

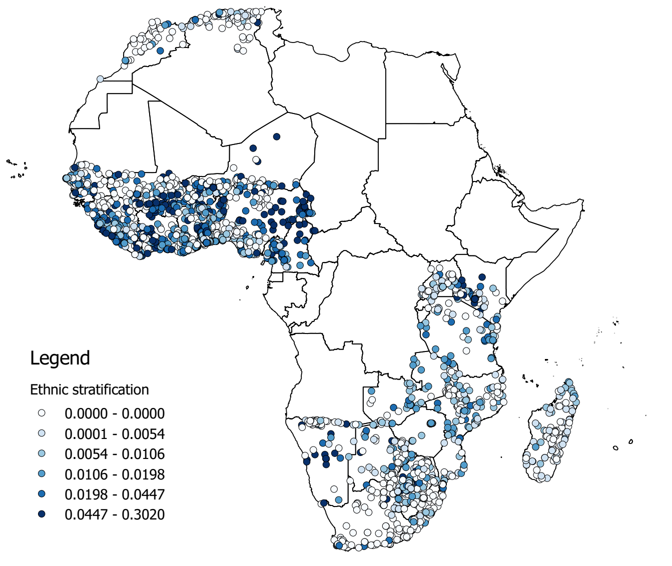


Figure 6: Towns and villages in Afrobarometer round 5. Notes: Dots indicate the towns and villages in the final sample from Afrobarometer round 5. Darker shades indicate higher local ethnic stratification.

Table 1: Summary statistics

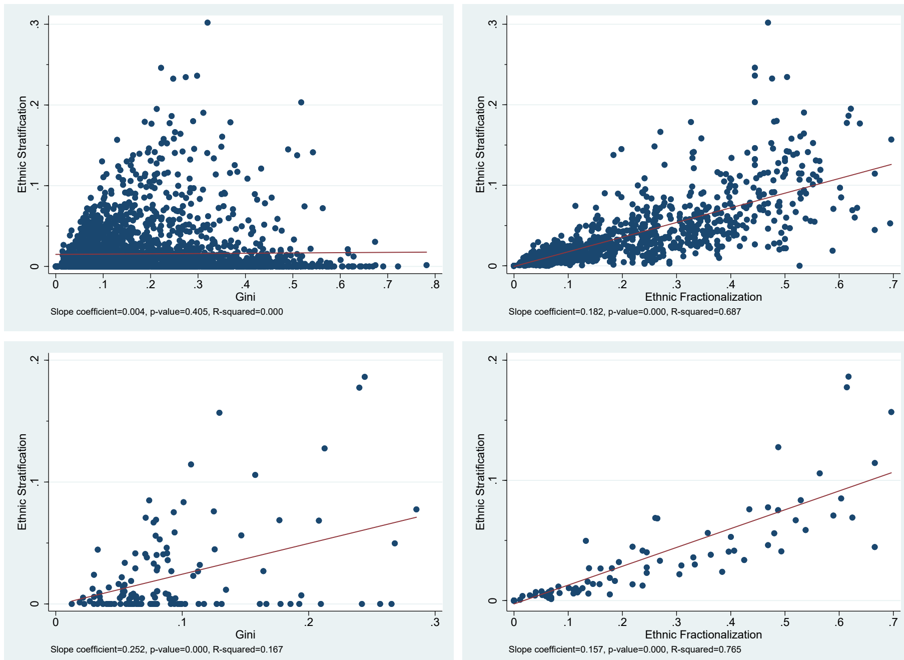
Variable	Obs.	Mean	Std.Dev.	Min.	Max.
Stratification	21,379	0.018	0.033	0	0.302
Fractionalization	21,379	0.103	0.147	0	0.696
Gini	21,379	0.203	0.140	0	0.782
Average wealth	21,379	0.462	0.243	0.012	1
Trust in relatives	21,318	0.826	0.379	0	1
Trust in neighbors	21,295	0.607	0.488	0	1
Trust in others	21,249	0.416	0.493	0	1
Fear of crime	21,330	0.700	1.172	0	1
Actual crime	21,372	0.296	0.457	0	1
Violent conflict	2,558	0.276	0.447	0	1

Notes: All variables are described in the text. They are all based on Afrobarometer surveys of round 5, except that violent conflict events is based on ACLED. The units of observation are individual respondents for all variables based on Afrobarometer, but towns and villages for conflict events. Summary statistics for violent conflict events are weighted by the number of respondents per town or village.

in the previous year, and three experienced crime. The correlation coefficients between any two of the three trust measures range from 0.30 to 0.54, and the correlation coefficient between the two crime measures is 0.28.

Figure 7 presents scatter plots illustrating how ethnic stratification relates

Figure 7: Scatter plots illustrating the index of ethnic stratification and its main components



Notes: The two scatter plots on the left show the association between the index of ethnic stratification and the Gini coefficient; and the two on the right the association between the index of ethnic stratification and ethnic fractionalization. The two scatter plots in the top row include all towns and villages from our sample, and the two in the bottom row only towns and villages from Nigeria.

to the Gini coefficient and ethnic fractionalization at the local level. The top row does so for all the towns and villages in our sample, and the bottom row for the towns and villages in Nigeria only. These scatter plots show that the towns and villages differ considerably in terms of ethnic stratification even after accounting for the Gini coefficient or ethnic fractionalization; and that ethnic stratification is more strongly related to ethnic fractionalization than the Gini coefficient.[27]

[27] These observations are consistent with the results of the Shapley-Owen decomposition in Online Appendix A.2. When we estimate a linear model using ethnic stratification as the dependent variable, this decomposition of our index gives the contribution that each regressor has on the R^2. It shows that the country fixed effects contribute 5.8%, ethnic fractionalization 50.5%, the Gini coefficient 1.5%, average wealth 1.9%, and the co-directionality of economic and ethnolinguistic distances across pairs of individuals the remaining 40.3%. This substantial contribution by the co-directionality lends further support to our index of ethnic stratification, which differs from other measures of diversity and inequality by explicitly taking co-directionality into account.

The Nigerian village with the highest level of ethnic stratification (0.19) in our sample is Tsokundi in Taraba state. Ethnic fractionalization is high (0.62) as the 13 respondents from this village belong to seven different ethnolinguistic groups, with eight respondents speaking languages of the Niger-Congo language family and five respondents languages of the Afroasiatic language family. The Gini coefficient is high (0.24) as five respondents belong to the bottom-10% of the Nigerian wealth distribution (according to our wealth index), while two respondents belong to the top-10%. Ethnic stratification is high mainly because ethnic fractionalization and wealth inequality are high. Moreover, economic and ethnolinguistic distances are relatively co-directional, with the five respondents from the bottom-10% of the wealth distribution belonging to different ethnolinguistic groups than the two respondents from the top-10%. As we would expect, the respondents from Tsokundi are not very trusting: six of the 13 respondents trust their relatives, one trusts their neighbors and not a single one trusts other people they know.

The bottom left scatter plot of Figure 7 shows that there are two villages with zero ethnic stratification despite having a slightly larger Gini coefficient than Tsokundi. These two villages are ethnolinguistically homogenous. Similarly, the bottom right scatter plot shows that there are two villages with much lower ethnic stratification despite having slightly higher ethnic fractionalization. These two villages have considerably lower wealth inequality than Tsokundi. Interestingly, the respondents from each of these four villages are on average more trusting towards relatives, neighbors and others than the respondents from Tsokundi (except one village where again no respondent trusts others). We next investigate more systematically whether such a negative relation between ethnic stratification and trust holds at a more general level.

5.2. Empirical specification

We use the following two specifications to investigate the relation between local ethnic stratification and trust:

$$Trust_{ivce} = \alpha_{ce} + \beta S_{vc} + \theta X_{ivce} + \lambda Q_{vc} + \epsilon_{ivce} \quad (5)$$

$$Trust_{ivce} = \alpha_{ce} + \beta S_{vc} + \gamma F_{vc} + \delta G_{vc} + \psi \mu_{vc} + \theta X_{ivce} + \lambda Q_{vc} + \epsilon_{ivce} \quad (6)$$

where $Trust_{ivce}$ is one of our three trust indicators for respondent i living in town or village v of country c and belonging to ethnolinguistic group e. The interacted country-ethnolinguistic group fixed effects α_{ce} (henceforth simply country-group fixed effects) control for all country-specific determinants and experiences that may affect trust as well as any group-specific characteristics or experiences. In addition, they allow for the fact that some ethnolinguistic groups are present in multiple countries and play different roles in different countries.[28] To address potential omitted variable bias, we further include individual and geographical control variables. The vector of individual control variables X_{ivce} contains respondent i's economic wealth (measured by our wealth index), her age and age squared as well as indicator variables for her gender, her religion (Christian/ Muslim/ other), her education (none/ primary/ secondary/ tertiary) and whether she lives in an urban or rural area. The vector of geographical control variables Q_{vc} includes soil suitability for agriculture, malaria suitability, average precipitation, altitude, terrain ruggedness, distance to the coast, population, and a measure of past conflict events.[29]

The main coefficient of interest is β, which measures the effect of local ethnic stratification (S_{vc}) on the respondents' trust. We expect β to be negative in both specifications. In specification (5), $\beta < 0$ implies a negative relation between ethnic stratification and trust (conditional on all the fixed effects and control variables). This specification, however, provides no information about whether the negative relation is driven by ethnic diversity, economic inequality or, indeed, the interaction of ethnolinguistic and economic distances at the level of pairs of individuals. In specification (6), we therefore control for ethnic fractionalization (F_{vc}), the Gini coefficient (G_{vc}) and average wealth (μ_{vc}). Hence, in this specification, $\beta < 0$ implies that the negative relation between ethnic stratification and trust is driven by the interaction of ethnolinguistic and economic distances (as a negative relation can no longer result from a direct effect of F_{vc}, G_{vc} or μ_{vc}).[30]

Furthermore, specification (6) is helpful to shed light on the merits of conflict and contact theory. In particular, it allows us to investigate whether ethnolinguistic distances between pairs of individuals are predictive for mistrust in general (as captured by F_{vc}) or only if they go hand-in-hand with economic

[28]Country-group fixed effects or, at least, country fixed effects are also important because we calculate our wealth index and the economic distances for each country/survey separately.

[29]The geographical control variables are computed for circles with a radius of 10 km around the locations' geo-coordinates provided by BenYishay et al. (2017). Online Appendix A.3 provides more information.

[30]In support of this interpretation, we further control for benchmark stratification (as defined in Proposition 1) in some robustness tests.

distances (as captured by S_{vc}).

We estimate all specifications using linear probability models. We use multiway clustering and cluster the standard errors ϵ_{ivce} at the level of country-ethnolinguistic group interactions and provinces (ADM1 regions).

5.3. Main results

Table 2 presents our main results. The outcome variables are our indicators for trust in relatives in columns (1)–(2), trust in neighbors in columns (3)–(4), and trust in others in columns (5)–(6). The odd columns of Panels A and B present the results for specifications (5) and (6), respectively. Panel C will be helpful to discuss the merits of conflict and contact theory. The even columns include province fixed effects and therefore serve as the first robustness test.

Starting with panel A, we see that the estimated coefficient on ethnic stratification is negative and statistically significant at the 5%-level in all six regressions. Hence, the general pattern is clear: high local ethnic stratification coincides with low trust in people that a respondent knows. The estimates in the odd columns imply that an increase in ethnic stratification by one standard deviation coincides with a reduction in the probability that a respondent trusts her relatives, neighbors and others by 1.4, 2.5 and to 2.1 percentage points, respectively. It is worth noticing that the reduction in trust in relatives is smaller than the reduction in trust in neighbors and others. Possible reasons are that relatives may be more likely than neighbors and other acquaintances to belong to the same ethnolinguistic group as the respondent; and that respondents may have more private information about relatives, such that trust in relatives depends to a lesser degree on town- and village-level characteristics such as ethnic stratification.

Panel B shows that ethnic stratification remains negatively related to trust after we control for ethnic fractionalization, the Gini coefficient, and average wealth. The estimated coefficients become even larger in absolute values for all trust variables and specifications. The relative statistical significance of ethnic stratification compared to ethnic fractionalization and the Gini coefficient highlights the prominent role that ethnic stratification plays in explaining mistrust at the local level.

In order to understand the role of ethnic stratification better, we re-estimate the regressions used to generate Panel B after removing ethnic stratification. These results are reported in Panel C. We still find almost no relation between the Gini coefficient and trust. The estimated coefficient on average wealth is

Table 2: Main results for trust

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. variable:	Trust in relatives		Trust in neighbors		Trust in others	
Panel A:						
Stratification	-0.43**	-0.36**	-0.77***	-0.59***	-0.63***	-0.38**
	(0.17)	(0.15)	(0.18)	(0.20)	(0.13)	(0.16)
R^2	0.16	0.21	0.19	0.23	0.12	0.17
Panel B:						
Stratification	-0.63**	-0.42*	-0.88***	-0.63**	-0.83***	-0.73***
	(0.29)	(0.22)	(0.30)	(0.29)	(0.30)	(0.28)
Fractionalization	0.08	0.04	0.06	0.04	0.07	0.12*
	(0.06)	(0.05)	(0.07)	(0.06)	(0.07)	(0.07)
Gini	-0.02	-0.06	-0.04	-0.08	0.02	0.01
	(0.05)	(0.06)	(0.06)	(0.07)	(0.05)	(0.05)
Average wealth	-0.08**	-0.10**	-0.16**	-0.14**	-0.13**	-0.11**
	(0.04)	(0.05)	(0.06)	(0.07)	(0.06)	(0.05)
R^2	0.16	0.21	0.19	0.23	0.13	0.17
Panel C:						
Fractionalization	-0.04	-0.04	-0.10**	-0.08*	-0.08***	-0.02
	(0.03)	(0.03)	(0.04)	(0.05)	(0.03)	(0.04)
Gini	-0.06	-0.09	-0.10	-0.11*	-0.04	-0.04
	(0.06)	(0.06)	(0.06)	(0.06)	(0.05)	(0.05)
Average wealth	-0.10**	-0.11**	-0.18***	-0.15**	-0.15***	-0.13**
	(0.04)	(0.04)	(0.07)	(0.07)	(0.06)	(0.05)
R^2	0.16	0.21	0.19	0.23	0.12	0.17
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Country-group FE	Yes	Yes	Yes	Yes	Yes	Yes
Province FE	No	Yes	No	Yes	No	Yes
Observations	21,318	21,318	21,295	21,295	21,249	21,249

Notes: Linear probability estimates. Units of observation are respondents to Afrobarometer surveys of round 5. Dependent variables indicate whether respondents trust the respective group/institution “a lot” or “somewhat” as opposed to “not at all” or “just a little”. The index of ethnic stratification, the index of ethnic fractionalization, the Gini coefficient and average wealth are introduced in Section 3. These indices are computed relying on (i) economic wealth and economic distances that are based on the wealth index, and (ii) ethnolinguistic distances that are primarily based on the respondents’ language and the Putternam and Weil (2010) formula. All regressions include individual and geographical control variables. The individual control variables are the respondents’ economic wealth, age and age squared, and indicator variables for gender, religion, education and urban. The geographical control variables are malaria suitability, soil suitability for agriculture, distance to coast, altitude, terrain ruggedness, average precipitation, population and past conflict events. All columns include interacted country-ethnolinguistic group fixed effects. Even columns further include province (ADM1 region) fixed effects. All data (except the geographical controls) are based on Afrobarometer surveys of round 5. Standard errors are adjusted for two-way clustering at the level of provinces and country-ethnolinguistic group interactions. ***, **, * indicate significance at the 1, 5 and 10%-level, respectively.

again negative and statistically significant. This negative relation suggests that individuals are more trusting in poorer towns or villages.[31] More interestingly, the estimated coefficients on ethnic fractionalization have all turned negative compared to the all positive estimates found in Panel B. Even though these effects tend to be weak in terms of statistical significance, the emerging pattern lends itself to the following interpretation: The negative coefficients on ethnic fractionalization in Panel C show that ethnic diversity does typically coincide with low trust. The results in Panel B however show that ethnolinguistic distances between individuals are only predictive of mistrust if the ethnolinguistic distances go hand-in-hand with economic distances. These results have important implications for the debate on the merits of conflict and contact theory. They confirm the prediction of conflict theory that ethnic diversity is on average related to mistrust, and the prediction of contact theory that intergroup interactions contribute to mistrust only if the ethnically diverse individuals also differ in their socio-economic status.

5.4. Robustness tests

Online Appendix B presents many robustness checks. Tables B.1–B.6 test the internal validity of our main results. In Table B.1, we base our indices primarily on the Afrobarometer's ethnicity information rather than its language information. In Table B.2, we base our indices on ethnolinguistic distances computed by the formula of Fearon (2003) rather than Putterman and Weil (2010). In Table B.3, we base our indices on economic distances measured by absolute differences in the lived poverty index, which is an experiential measure of poverty.[32] In Table B.4, we drop towns and villages where the computation of our indices is based on fewer than eight individuals, as our indices may be biased when computed with a very small number of observations (Deltas, 2003). In Table B.5, we follow Nunn and Wantchekon (2011) and use the respondents'

[31] One possible reason for this negative relation could be that there are more resources available to be seized in richer communities, providing incentives for conflict and appropriation (Garfinkel and Skaperdas, 2007) and thereby deteriorating trust (Uslaner, 2002; Rohner et al., 2013). Table 4 (columns 5 and 6) indeed shows that average wealth is positively related to violent conflict. Another possible reason for this negative relation is that richer communities tend to be more populous and more likely to be located in urban areas. As a result, social interactions in richer communities may be more anonymous, which could deteriorate trust.

[32] The lived poverty index is based on questions about how often respondents and their family members had gone without food, water, medical care, cooking fuel, and cash income over the past year. It corresponds to the average of the ordinal answers to these five questions. We reverse its scale as higher values of the original index imply that people had to go without basic necessities more often.

categorical answers to the trust questions of interest to build variables that can take integer values from 0–3. In Table B.6, we follow Rohner et al. (2013) in estimating Probit maximum likelihood models instead of linear probability models. These robustness tests support the general pattern of a negative relation between local ethnic stratification and trust in relatives, neighbors and others. The only exception is that the negative coefficients on ethnic stratification become statistically insignificant in at least half of the regressions when using the lived poverty index to compute economic distances.

In Table B.7, we provide results for regressions including benchmark stratification, which is defined in Proposition 1 as $2\mu_{vc}G_{vc}F_{vc}$, as an additional regressor. By construction, benchmark stratification corresponds to our index of ethnic stratification if and only if ethnolinguistic and economic distances are unrelated to one another. This exercise therefore allows us to take a closer look at the role that the co-directionality of ethnolinguistic and economic distances plays in predicting mistrust. We find that the estimated coefficients on our index remain negative in all twelve regressions. While only four of these are statistically significant, most have similar magnitude as those in Table 2. The differences are in the standard errors, as they have increased by more than three-folds in the non-significant cases. This is due to the multicollinearity issues arising from the high correlation between our index and benchmark stratification. On the other hand, the estimated coefficients on benchmark stratification vary in sign across columns. They also tend to generate low t-ratios when compared to ethnic stratification (lower by at least an order of magnitude in all but two cases), and they are never statistically significant. These findings suggest that our index, which captures the interaction of ethnolinguistic and economic differences at the level of pairs of individuals, is a better predictor of mistrust than alternatives like benchmark stratification, which simply capture the interaction of ethnic diversity and economic inequality at the level of towns and villages. Hence, trust is low in ethnically stratified towns and villages, not just because they are ethnically diverse and economically unequal, but also because ethnic and economic differences between pairs of individuals go hand-in-hand.

We next test whether our results carry over to ethnic stratification in alternative geographical units, to alternative Afrobarometer survey rounds, and to alternative trust measures. In Table B.8, we restrict our attention to respondents living within the boundaries of a city with more than 50,000 inhabitants, and compute the index of ethnic stratification and its components at the level of these cities.[33] In Tables B.9 and B.10, we again include the respondents from all our locations, but compute the indices at the level of districts (ADM2 regions) and provinces (ADM1 regions), respectively. The coefficients of interest remain negative and sizeable in most instances, with those in specification (5) typically being statistically significant when the outcome variable is trust in neighbors or others. We conjecture that our trust measures are more closely related to ethnic stratification at the local level than at the district or province level, because most respondents may primarily interact with people at the local level and because the corresponding trust questions in the Afrobarometer surveys explicitly ask about people whom the respondent knows.[34]

We include additional Afrobarometer survey rounds in Tables B.11 and B.12. First, we include round 4 and compute our indices for rounds 4 and 5 based on those wealth variables that are available in both rounds. The inclusion of round 4 implies that we can no longer use information about the type of shelter where the respondent lives and the material of its roof. Table B.11 presents our estimates based on rounds 4 and 5. We again see the same pattern as in Table 2, but the coefficients become smaller in absolute values. A plausible reason is attenuation bias due to a coarsened measure of ethnic stratification resulting from the reduction of wealth information.[35] In Table B.12, we additionally include round 3, which provides less information on assets and no information on the quality of housing. We therefore compute the indices for all rounds using the lived poverty index as the measure of individual wealth (as in Table B.3). Perhaps unsurprisingly, results become weaker, but the coefficient of interest remains negative in all instances and statistically significant in specification (5).

We consider two alternative trust variables in Table B.13: trust in the municipal assembly and generalized trust. The latter is based on the question:

[33] To identify city boundaries, we rely on the city polygons provided by the Africapolis database (OECD/SWAC, 2018), and consider Afrobarometer locations that lie within these polygons. We use the population count in 2010, which is also provided by Africapolis.

[34] To further explore the role of cities, we test whether the relation between ethnic stratification and trust is stronger in cities than in rural areas. In Table B.14, we rely on the Afrobarometer's information on whether a location is urban or rural. In Table B.15, we use information on whether or not a cluster lies within the boundaries of a city with more than 50,000 inhabitants. The relation between ethnic stratification and trust in neighbors and others tends to be stronger in cities, but the differences are typically not statistically significant.

[35] The results for trust in neighbors supports this interpretation. The corresponding question was not asked in Afrobarometer surveys of round 4. Hence, the only difference between columns (3)–(4) of Tables 2 and B.11 is that the indices are based on a noisier measure of the respondents' wealth in Table B.11; and we indeed find that the coefficients are lower in columns (3)–(4) of Table B.11.

"Generally speaking, would you say that most people can be trusted or that you must be very careful in dealing with people?" As expected, local ethnic stratification tends to be negatively related to trust in the municipal assembly. Local ethnic stratification tends to be negatively associated with generalized trust as well, but the corresponding coefficients are relatively small in absolute values and not statistically significant. They become somewhat larger when computing our indices at the level of provinces instead of towns and villages. This pattern is consistent with the idea that economic and ethnolinguistic differences at the local level matter for how respondents answer questions on trust in people they know, but less so for how they answer the generalized trust question.

5.5. Comparison of our index with other indices of diversity and inequality

We next investigate how our index of ethnic stratification compares to some other indices of ethnic diversity and economic inequality when it comes to predicting mistrust at the local level in Africa. We focus on the following well-known indices: The between-group Gini coefficient, the between-group polarization index by Gigliarano and Mosler (2009), the distance-Gini mean difference of Koshevoy and Mosler (1997), the between-group and within-group Theil indices, and the index of ethnolinguistic fractionalization (ELF) for categorical ethnicity data computed at different levels of the Ethnologue's language tree following Desmet et al. (2009). We compute all these indices at the local level using the same data as for the computation of our own index.[36] The estimates in the odd columns of Table 3 are based on regressions analogous to equation (5) where we replace our index of ethnic stratification by these alternative indices. These alternative indices (apart from the within-group Theil index) are negatively related to trust in relatives, neighbors and others, and most of the corresponding coefficients are statistically significant.

The even columns of Table 3 present regressions analogous to the odd columns but include our index of ethnic stratification as an additional regressor. They confirm that these alternative indices (apart from the within-group Theil index and ELF at level 1) and our index of ethnic stratification are negatively related to all three measures of trust. The pattern of statistical significance suggests that ethnic stratification is a more important factor than the other indices for describing trust in neighbors and others, while the between-group Gini and between-group polarization are the leading factors in describing trust

[36] Summary statistics for these indices are presented in Online Appendix A.4.

Table 3: Comparison of our index with other indices of diversity and inequality

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. variable:	Trust in relatives		Trust in neighbors		Trust in others	
Panel A:						
Between-group Gini	-0.34***	-0.30**	-0.44***	-0.16	-0.29***	0.05
	(0.12)	(0.14)	(0.10)	(0.14)	(0.09)	(0.12)
Stratification		-0.08		-0.58**		-0.69***
		(0.19)		(0.26)		(0.19)
R^2	0.16	0.16	0.19	0.19	0.12	0.12
Panel B:						
Between-group Pol.	-0.88***	-0.70*	-1.04***	-0.28	-0.75***	-0.04
	(0.34)	(0.40)	(0.27)	(0.34)	(0.24)	(0.30)
Stratification		-0.16		-0.66***		-0.62***
		(0.18)		(0.24)		(0.17)
R^2	0.16	0.16	0.19	0.19	0.12	0.12
Panel C:						
Distance-Gini	-0.37**	-0.13	-0.63***	-0.15	-0.48***	-0.01
	(0.14)	(0.19)	(0.16)	(0.20)	(0.13)	(0.22)
Stratification		-0.32		-0.64**		-0.63***
		(0.23)		(0.25)		(0.21)
R^2	0.16	0.16	0.19	0.19	0.12	0.12
Panel D:						
Between-group Theil	-0.26	-0.14	-0.46***	-0.24*	-0.30**	-0.11
	(0.18)	(0.17)	(0.14)	(0.14)	(0.12)	(0.13)
Within-group Theil	0.01	0.01	0.03	0.03	0.06	0.06
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
Stratification		-0.35**		-0.65***		-0.58***
		(0.15)		(0.19)		(0.14)
R^2	0.16	0.16	0.19	0.19	0.12	0.12
Panel E:						
ELF (level 1)	-0.07	0.03	-0.15***	-0.01	-0.15***	-0.05
	(0.04)	(0.07)	(0.05)	(0.07)	(0.03)	(0.06)
Stratification		-0.50*		-0.75***		-0.53**
		(0.25)		(0.25)		(0.23)
R^2	0.16	0.16	0.19	0.19	0.12	0.12
Panel F:						
ELF (level 6)	-0.01	0.06**	-0.05	0.07**	-0.05*	0.05
	(0.02)	(0.03)	(0.03)	(0.04)	(0.02)	(0.04)
Stratification		-0.67***		-1.05***		-0.82***
		(0.22)		(0.24)		(0.21)
R^2	0.16	0.16	0.19	0.19	0.12	0.12
Panel G:						
ELF (level 15)	-0.05***	-0.02	-0.09***	-0.04*	-0.05***	-0.00
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Stratification		-0.34		-0.58**		-0.63***
		(0.22)		(0.23)		(0.18)
R^2	0.16	0.16	0.19	0.19	0.12	0.12
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Country-group FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	21,318	21,318	21,295	21,295	21,249	21,249

Notes: See Section 6.5 and Online Appendix A.4 for information on all the other indices of diversity and inequality, and the notes to Table 2 for details on all other aspects of the regressions presented in this table. Standard errors are adjusted for two-way clustering at the level of provinces and country-ethnolinguistic group interactions. ***, **, * indicate significance at the 1, 5 and 10%-level, respectively.

in relatives. We interpret these findings as evidence that our index of ethnic stratification captures characteristics of a community that (i) are important for predicting mistrust (in particular mistrust towards people outside the family) and (ii) are not captured by established indices of ethnic diversity and economic inequality.

5.6. Results for crime and conflict

In this section, we look at alternative measures of social conflict, namely crime and violent conflict. We use the two Afrobarometer-based binary variables indicating fear of crime and actual crime as dependent variables in columns (1)–(4) of Table 4. We see that local ethnic stratification is positively related to fear of crime.[37] The relation to actual crime is ambiguous, with different signs across specifications.

For conflict we use our binary variable indicating whether there would be a violent conflict event within 10 km of the center of the town or village within three years from the date of the interviews. The fact that this information is available only at the level of towns and villages (rather than individual respondents) has several implications for our empirical specifications. First, the sample size decreases from the number of respondents to the number of towns and villages. To keep the results as comparable as possible to previous results, we run weighted linear regressions with weights equal to the number of respondents per town or village. Second, we average the individual control variables at the level of towns and villages. Third, we can no longer include country-group fixed effects. We replace them with simple country fixed effects. Columns (5) and (6) of Table 4 show that local ethnic stratification is a strong predictor of future violent conflict events, in particular in specifications without province fixed effects.

Unlike the questions on trust in relatives, neighbors and others, the questions on crime were asked in Afrobarometer surveys of round 6 as well. In addition, this round also includes all the relevant questions on assets and the quality of housing used to construct an informative wealth index. The conflict data, too, is available for the three years following the interviews of round 6. We present results using the index of ethnic stratification based on Afrobarometer surveys of rounds 5 and 6 in Table B.16. The pattern remains similar as in Table

[37] The positive relation between ethnic stratification and (fear of) crime could be indirect, as lower trust may increase (fear of) crime (Buonanno et al., 2009).

Table 4: Crime and conflict

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. variable:	Fear of crime		Actual crime		Violent conflict	
Units of obs.:	Ind. respondents		Ind. respondents		Towns/villages	
Stratification	0.45***	0.27*	0.27*	0.11	1.38***	0.49
	(0.16)	(0.15)	(0.14)	(0.17)	(0.48)	(0.32)
R^2	0.11	0.15	0.09	0.12	0.52	0.69
Stratification	0.46*	0.41*	-0.35	-0.46*	1.67**	0.34
	(0.25)	(0.25)	(0.24)	(0.24)	(0.77)	(0.50)
Fractionalization	0.01	-0.04	0.19***	0.17***	-0.07	0.02
	(0.07)	(0.07)	(0.06)	(0.05)	(0.14)	(0.10)
Gini	-0.03	-0.03	0.03	0.05	-0.07	0.09
	(0.07)	(0.08)	(0.07)	(0.06)	(0.09)	(0.07)
Average wealth	-0.02	-0.03	-0.03	-0.06	0.15*	0.17***
	(0.05)	(0.06)	(0.05)	(0.05)	(0.08)	(0.06)
R^2	0.11	0.15	0.09	0.12	0.52	0.69
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	No	No	No	No	Yes	Yes
Country-group FE	Yes	Yes	Yes	Yes	No	No
Province FE	No	Yes	No	Yes	No	Yes
Observations	21,330	21,330	21,372	21,372	2,558	2,558

Notes: Dependent variables are an indicator of whether the respondent (or a family member) had feared crime within their home over the past year in columns (1)–(2); an indicator of whether the respondent (or a family member) had been physically attacked or something had been stolen from their home over the past year in columns (3)–(4), and an indicator of whether a violent conflict event would occur nearby within three years after the interviews in columns (5)–(6). See the notes to Table 2 for further details relevant for columns (1)–(4). Columns (5)–(6) use towns and villages rather than individual respondents as units of observation and present weighted least squares using the number of respondents per town or village as weights. Individual controls are averaged at the level of towns and villages in columns (5)–(6). Standard errors are adjusted for two-way clustering at the level of provinces and country-ethnolinguistic group interactions in columns (1)–(4), and for clustering at the level of provinces in columns (5)–(6). ***, **, * indicate significance at the 1, 5 and 10%-level, respectively.

4. The positive relation between local ethnic stratification and future violent conflict events even extends to specifications that include province fixed effects. These results suggest that the patterns presented throughout our paper should generalize beyond the respondents of Afrobarometer surveys of round 5.

6. Conclusions

In this paper, we have defined an index of ethnic stratification that generalizes the idea of between-group inequality and measures the extent to which the hierarchy in socio-economic positions follows ethnolinguistic lines. A defining feature of this index is a strong complementarity between economic and ethnolinguistic distances, which is essential to the notion of ethnic stratification as a generalization of between-group inequality. We have provided an axiomatic characterization of our index and discussed how it depends on average wealth, the Gini coefficient of wealth inequality, the index of generalized ethnic fractionalization, and the co-directionality of economic and ethnolinguistic distances across pairs of individuals.

We have computed our index at the level of towns and villages in 26 diverse African countries, and documented a robust negative relation between local ethnic stratification and trust in relatives, neighbors and other acquaintances. Future violent conflict events are more likely around ethnically stratified towns and villages too. These findings suggest that our proposed index is indeed a good predictor of social conflict, and we have shown that it tends to be more successful in predicting mistrust towards neighbors and others than many established measures of diversity and inequality.

We have further employed the index of generalized ethnic fractionalization and our index of ethnic stratification, which would reduce to the former in the absence of any economic inequality, to shed new light on the debate about the merits of conflict and contact theory. Our findings suggest that, on average, ethnic diversity tends to be associated with mistrust, as predicted by conflict theory; but that this negative relation is driven by towns and villages where ethnolinguistic distances between individuals are complemented by differences in economic resources, as predicted by contact theory.

We are hopeful that our index will prove useful in studying many more interesting and relevant questions on potential determinants and consequences of ethnic stratification. Furthermore, a casual glance at the world today reveals that there are socio-economic hierarchies along many social dimensions other than ethnicity. Prominent examples include caste and religion, the skill-level of occupations, and even cultural values. We are confident that our index can be fruitfully applied to studying stratification along such alternative social dimensions.

Appendix A: Proofs of results in Section 3

Proof of Proposition 1. Let (f, λ) be any pair of density and linguistic functions. The ethnic stratification of the corresponding benchmark (b_f, λ) is

$$S(b_f, \lambda) = \int_{e \in E} \int_{e' \in E} \int_{w \in W} \int_{w' \in W} b_f(e, w) b_f(e', w') \lambda(e, e') |w - w'| dw' dw de' de,$$

where by definition of the benchmark

$$b_f(e, w) = \gamma_{b_f}(w) \varphi_{b_f}(e) = \gamma_f(w) \varphi_f(e) \text{ for each } e \in E \text{ and } w \in W.$$

Then, combining these equations we obtain that $S(b_f, \lambda)$ is equal to

$$\left(\int_{w \in W} \int_{w' \in W} \gamma_f(w) \gamma_f(w') |w - w'| dw' dw \right) \left(\int_{e \in E} \int_{e' \in E} \varphi_f(e) \varphi_f(e') \lambda(e, e') de' de \right),$$

which leads to $S(b_f, \lambda) = 2\mu(\gamma_f) G(\gamma_f) F(\varphi_f, \lambda)$ and concludes our proof. □

Proof of Theorem 1. It is straightforward that any positive scalar multiplication of index (2) fulfills axioms CDbW, BPbW, CDbL. Then, it remains to be shown that an index from class (1) satisfies these axioms only if it takes the form (2) up to positive scalar multiplication, i.e., only if $\pi(a, b) = kab$ for some constant $k > 0$. By axiom CDbW, focusing on the extreme case $\epsilon = 1$,

$$\begin{aligned} M(\tilde{f}_1, \lambda) &= (4/9) \pi \left(\lambda(1, 2), |w_1 - w_2|/2 \right) \\ &\geq M(f, \lambda) = (2/9) \left[\pi \left(\lambda(1, 2), |w_1 - w_2| \right) + \pi(0, |w_1 - w_2|) + \pi(\lambda(1, 2), 0) \right], \end{aligned}$$

which can be rewritten as

$$2\pi \left(\lambda(1, 2), |w_1 - w_2|/2 \right) - \pi \left(\lambda(1, 2), |w_1 - w_2| \right) \geq \pi(0, |w_1 - w_2|) + \pi(\lambda(1, 2), 0). \quad (7)$$

By axiom BPbW, focusing on the extreme case $\epsilon = 1$,

$$\begin{aligned} M(\tilde{f}_1, \lambda) = (2/9) &\left[\pi \left(\lambda(1, 3)/2, |w_1 - w_3| \right) \right. \\ &+ \pi \left(\lambda(1, 3)/2, 0 \right) + \pi \left(0, |w_1 - w_3| \right)/4 + \pi \left(\lambda(1, 3), |w_1 - w_3| \right) \left. \right] \\ &\geq M(f_1, \lambda) = (2/9) \left[2\pi \left(\lambda(1, 3)/2, |w_1 - w_3|/2 \right) + \pi \left(\lambda(1, 3), |w_1 - w_3| \right) \right], \end{aligned}$$

which implies

$$\pi\left(0,|w_1-w_3|\right)/4 \geq 2\pi\left(\lambda(1,3)/2,|w_1-w_3|/2\right)-\pi\left(\lambda(1,3)/2,|w_1-w_3|\right). \quad (8)$$

Combining (8) with (7) and letting $a, b \geq 0$ denote a generic pair of wealth and ethnolinguistic distances, we obtain

$$\pi(0,b)/4 \geq 2\pi(a,b/2)-\pi(a,b) \geq \pi(0,b)+\pi(a,0).$$

By the non-negativity of π this implies $\pi(0,b)=\pi(a,0)=0$ and $2\pi(a,b/2)=\pi(a,b)$, so that there is a non-decreasing function $\rho:\mathbb{R}_+\to\mathbb{R}_+$ such that $\pi(a,b)=\rho(a)b$ and $\rho(0)=0$. By axiom CDbL, for each $\epsilon\in(0,\lambda(1,2)]$,

$$\begin{aligned} M(f,\tilde{\lambda}_\epsilon) = (2/9)\left[\pi\left(\lambda(1,2)-\epsilon,|w_1-w_2|\right)+\pi\left(\lambda(2,3)+\epsilon,|w_2-w_3|\right)\right. \\ \left.+\pi\left(\lambda(1,2)+\lambda(2,3),|w_1-w_2|+|w_2-w_3|\right)\right] \\ \geq M(f,\lambda)=(2/9)\left[\pi\left(\lambda(1,2),|w_1-w_2|\right)+\pi\left(\lambda(2,3),|w_2-w_3|\right)\right. \\ \left.+\pi\left(\lambda(1,2)+\lambda(2,3),|w_1-w_2|+|w_2-w_3|\right)\right], \end{aligned}$$

which by our previous finding $\pi(a,b)=\rho(a)b$ can be rewritten as

$$\rho(\lambda(1,2)-\epsilon)|w_1-w_2|+\rho(\lambda(2,3)+\epsilon)|w_2-w_3| \geq \rho(\lambda(1,2))|w_1-w_2|+\rho(\lambda(2,3))|w_2-w_3|. \quad (9)$$

Note that the axiom's restrictions $w_1>w_2>w_3$ and $w_2>(w_1+w_3)/2$ imply $|w_1-w_2|<|w_2-w_3|$. Then, by (9) the function ρ is linear and, given our previous findings, we must have $\rho(a)=ka$ for some constant $k\geq 0$. As $\pi(a,b)>0$ for some $a,b>0$ by assumption, it follows that $k\neq 0$ which concludes our proof. □

Appendix B: Statistical properties of the ethnic stratification index

Here we provide the statistical properties of θ_n, as defined in (4), and explain how they can be used to perform inference on θ. We list them in Propositions 2 to 4. Their proofs are collected at the end of the appendix.

Proposition 2. *Suppose* $\mathbb{E}[|\lambda(E,E')|W-W'||]<\infty$, *then* $\theta_n\xrightarrow{p}\theta$ *as* $n\to\infty$.

Proposition 3. *Suppose* $\mathbb{E}[|\lambda(E,E')|W-W'||^2]<\infty$, *then* $\sqrt{n}(\theta_n-\theta)\xrightarrow{d}\mathcal{N}\left(0,\sigma^2\right)$ *as* $n\to\infty$, *where* $\sigma^2=4Var\left(\mathbb{E}\left[\lambda(E,E')|W-W'||E,W\right]\right)$.

Propositions 2 and 3 respectively assume that $\lambda(E,E')|W-W'|$ has finite first and second moments. These conditions are expected to be satisfied in most applications. For instance, a sufficient condition for $\mathbb{E}[|\lambda(E,E')|W-W'||^k] < \infty$ is when λ is a bounded function and $\mathbb{E}|W|^k < \infty$ for $k = 1,2$. Then, Proposition 2 says that θ_n is a consistent estimator for θ, and Proposition 3 says that θ_n has a limiting normal distribution. Furthermore, the asymptotic variance of θ_n has a simple form that can be estimated by using its sample counterpart. This can be seen from re-writing σ^2 as

$$\sigma^2 = 4\mathbb{E}[\mathbb{E}[\lambda(E,E')|W-W'||E,W]^2] - 4(\mathbb{E}[\lambda(E,E')|W-W'|])^2.$$

One natural candidate for an estimator of σ^2 is σ_n^2, where we again replace expectations in the display above by sample averages:

$$\sigma_n^2 := \frac{4}{n}\sum_{i=1}^{n}\left(\frac{1}{n}\sum_{j=1}^{n}\lambda(E_i,E_j)|W_i-W_j|\right)^2 - 4\theta_n^2. \tag{10}$$

Proposition 4 says that σ_n^2 is a consistent estimator for σ^2.

Proposition 4. *Suppose* $\mathbb{E}[|\lambda(E,E')|W-W'||^2] < \infty$*, then* $\sigma_n^2 \xrightarrow{p} \sigma^2$ *as* $n \to \infty$*.*

Propositions 2 to 4 ensure that we can construct valid confidence intervals and perform hypothesis tests on ethnic stratification based on normal approximation under weak conditions. Alternatively, inference can also be performed using a standard bootstrap (i.e. random resampling with replacement). We will show below that θ_n is essentially a U-statistic that can be consistently bootstrapped (see Arcones and Giné (1992)). Subsequently, we can easily perform inference on differences between ethnic stratifications across independent samples.

Proofs of Propositions 2 and 3. Our Propositions can be easily proven once we recognize that θ_n is asymptotically equivalent to the following object:

$$\theta_n' = \frac{2}{n(n-1)}\sum_{i=1}^{n-1}\sum_{j=i+1}^{n}\lambda(E_i,E_j)|W_i-W_j|.$$

First note that we can re-write θ_n as:

$$\theta_n = \frac{2}{n^2}\sum_{i=1}^{n-1}\sum_{j=i+1}^{n}\lambda(E_i,E_j)|W_i-W_j|.$$

This follows from the fact that $\lambda(E_i, E_j) = \lambda(E_j, E_i)$ for all i, j. Since $\theta_n = \frac{n-1}{n}\theta_n'$ it is clear that θ_n' and θ_n are asymptotically equivalent.

In what follows we shall focus on the asymptotic properties of θ_n' which takes the form of a standard second order U-statistic. We refer the reader to Chapter 5.3 in Serfling (1980) for background materials on this subject. A crucial element in deriving statistical properties of a U-statistic is its *projection*. In particular, for $i \neq j$, let

$$r(E_i, W_i) = \mathbb{E}\left[\lambda(E_i, E_j)|W_i - W_j|\middle| E_i, W_i\right],$$

then we can denote the projection of θ_n' by:

$$\begin{aligned}\widehat{\theta}_n' &= \sum_{i=1}^{n} \mathbb{E}\left[\theta_n' | E_i, W_i\right] - (n-1)\,\mathbb{E}\left[r(E_i, W_i)\right] \\ &= \mathbb{E}\left[r(E_i, W_i)\right] + \frac{2}{n}\sum_{i=1}^{n}\left(r(E_i, W_i) - \mathbb{E}\left[r(E_i, W_i)\right]\right).\end{aligned}$$

The projection is well-defined since $\mathbb{E}[|\lambda(E, E')|W - W'||] < \infty$. By the Law of Iterated Expectation we have $\theta = \mathbb{E}\left[r(E_i, W_i)\right]$. Then we can write,

$$\widehat{\theta}_n' - \theta = \frac{2}{n}\sum_{i=1}^{n}\left(r(E_i, W_i) - \mathbb{E}\left[r(E_i, W_i)\right]\right).$$

Furthermore, it can be shown that $\theta_n' - \theta$ and $\widehat{\theta}_n' - \theta$ have the same asymptotic distribution when $\mathbb{E}[|\lambda(E, E')|W - W'||^2] < \infty$. The square integrability condition holds by assumption. Therefore $\theta_n' = \widehat{\theta}_n' + o_p\left(n^{-1/2}\right)$. Thus $\theta_n - \theta$ can be approximated by a sum of i.i.d. zero mean variables as shown in the display above. Propositions 2 and 3 then follow immediately from a standard Law of Large Numbers and Central Limit Theorem for i.i.d. variables respectively. □

Proof of Proposition 4. Let r_n denote the sample counterpart of r, which is defined in the previous proof, so that

$$r_n(E_i, W_i) = \frac{1}{n-1}\sum_{j \neq i}^{n} \lambda(E_i, E_j)|W_i - W_j|.$$

We can then write (10) as,

$$\sigma_n^2 = \frac{4}{n}\left(\frac{n-1}{n}\right)^2 \sum_{i=1}^{n} r_n\left(E_i, W_i\right)^2 - 4\theta_n^2,$$

and σ^2, defined in Proposition 3, can be written as

$$\sigma^2 = 4\mathbb{E}[r\left(E_i, W_i\right)^2] - 4\theta^2.$$

Since θ_n is consistent, it suffices to show

$$\frac{1}{n}\sum_{i=1}^{n} r_n\left(E_i, W_i\right)^2 = \mathbb{E}[r\left(E_i, W_i\right)^2] + o_p\left(1\right).$$

To this end,

$$\begin{aligned}
\mathbb{E}[\left|r_n\left(E_i, W_i\right) - r\left(E_i, W_i\right)\right|^2] &= \mathbb{E}\left[Var\left(r_n\left(E_i, W_i\right)|E_i, W_i\right)\right] \\
&= \frac{1}{n-1}\mathbb{E}\left[Var\left(\lambda\left(E_i, E_j\right)|W_i - W_j||\, X_i\right)\right] \\
&\leq \frac{1}{n-1}\mathbb{E}[\left|\lambda\left(E_i, E_j\right)|W_i - W_j|\right|^2] \\
&= O\left(n^{-1}\right).
\end{aligned}$$

Therefore $\mathbb{E}[\left|r_n\left(E_i, W_i\right) - r\left(E_i, W_i\right)\right|^2] = o\left(1\right)$, which implies $\mathbb{E}[\left|r_n\left(E_i, W_i\right)^2 - r\left(E_i, W_i\right)^2\right|] = o\left(1\right)$, and the required result follows from Markov's inequality. The proof then follows from applications of the Continuous Mapping Theorem. □

References

Afrobarometer, 2018. Sampling principles and weighting. Retrieved July 03, 2018, from `http://www.afrobarometer.org/surveys-and-methods/sampling-principles`.

Alesina, A., Giuliano, P., 2011. Family ties and political participation. Journal of the European Economic Association 9, 817–839.

Alesina, A., La Ferrara, E., 2000. Participation in heterogeneous communities. Quarterly Journal of Economics 115, 847–904.

Alesina, A., La Ferrara, E., 2002. Who trusts others? Journal of public economics 85, 207–234.

Algan, Y., Hémet, C., Laitin, D.D., 2016. The social effects of ethnic diversity at the local level: A natural experiment with exogenous residential allocation. Journal of Political Economy 124, 696–733.

Allport, G.W., 1954. The Nature of Prejudice. Addison-Wesley Publishing Company, Reading, MA.

Arcones, M., Giné, E., 1992. On the bootstrap of U and V statistics. Annals of Statistics 20, 655–674.

Banerjee, A., 2010. A multidimensional Gini index. Mathematical Social Sciences 60, 87–93.

Barlow, F.K., Paolini, S., Pedersen, A., Hornsey, M.J., Radke, H.R., Harwood, J., Rubin, M., Sibley, C.G., 2012. The contact caveat: Negative contact predicts increased prejudice more than positive contact predicts reduced prejudice. Personality and Social Psychology Bulletin 38, 1629–1643.

BenYishay, A., Rotberg, R., Wells, J., Lv, Z., Goodman, S., Kovacevic, L., Runfola, D., 2017. Geocoding Afrobarometer rounds 1 - 6: Methodology & data quality. Williamsburg, VA: AidData at William & Mary. Retrieved November 20, 2018, from `https://www.aiddata.org/publications/geocoding-afrobarometer-rounds-1-6-methodology-data-quality`.

Bergh, A., Bjørnskov, C., 2014. Trust, welfare states and income equality: Sorting out the causality. European Journal of Political Economy 35, 183–199.

Bjørnskov, C., 2007. Determinants of generalized trust: A cross-country comparison. Public Choice 130, 1–21.

Blalock, Jr., H.M., 1967. Toward a Theory of Minority-Group Relations. John Wiley Sons., New York, NY.

Blumer, H., 1958. Race prejudice as a sense of group position. Pacific Sociological Review 1, 3–7.

Bossert, W., D'Ambrosio, C., La Ferrara, E., 2011. A generalized index of fractionalization. Economica 78, 723–750.

Bourguignon, F., 1979. Decomposable income inequality measures. Econometrica 47, 901–920.

Buonanno, P., Montolio, D., Vanin, P., 2009. Does social capital reduce crime? Journal of Law and Economics 52, 145–170.

Cederman, L.E., Weidmann, N.B., Gleditsch, K.S., 2011. Horizontal inequalities and ethnonationalist civil war: A global comparison. American Political Science Review 105, 478–495.

Chakravarty, S., 2015. Inequality, polarization and conflict: An analytical study. Springer, New Delhi.

Cowell, F., 1980. On the structure of additive inequality measures. Review of Economic Studies 47, 521–531.

Cowell, F., 2011. Measuring Inequality. Oxford University Press, Oxford, UK.

Delhey, J., Newton, K., 2005. Predicting cross-national levels of social trust: Global pattern or Nordic exceptionalism? European Sociological Review 21, 311–327.

Deltas, G., 2003. The small-sample bias of the gini coefficient: results and implications for empirical research. Review of Economics and Statistics 85, 226–234.

Desmet, K., Ortuño-Ortín, I., Wacziarg, R., 2012. The political economy of linguistic cleavages. Journal of Development Economics 97, 322–338.

Desmet, K., Weber, S., Ortuño-Ortín, I., 2009. Linguistic diversity and redistribution. Journal of the European Economic Association 7, 1291–1318.

Deutsch, J., Silber, J., 1999. Inequality decomposition by population subgroups and the analysis of interdistributional inequality, in: Silber, J. (Ed.), Handbook of Income Inequality Measurement. Springer, New York, NY, pp. 363–403.

Diamond, S., 1967. Nigeria: Model of a Colonial Failure. American Committee on Africa, New York, NY.

Duclos, J., Esteban, J., Ray, D., 2004. Polarization: Concepts, measurement, estimation. Econometrica 72, 1737–1772.

Ebert, U., 1988. Measurement of inequality: An attempt at unification and generalization. Social Choice and Welfare 5, 147–169.

Eldredge, E.A., 2015. Kingdoms and Chiefdoms of Southeastern Africa: Oral Traditions and History, 1400-1830. University of Rochester Press, Rochester, NY.

Esteban, J., Mayoral, L., Ray, D., 2012. Ethnicity and conflict: An empirical study. American Economic Review 102, 1310–1342.

Esteban, J., Ray, D., 1994. On the measurement of polarization. Econometrica 62, 819–851.

Esteban, J., Ray, D., 2001. Collective action and the group size paradox. American Political Science Review 95, 663–672.

Falola, T., Jean-Jacques, D. (Eds.), 2015. Africa: An Encyclopedia of Culture and Society. ABC-CLIO, Santa Barbara, CA.

Fearon, J.D., 2003. Ethnic and cultural diversity by country. Journal of Economic Growth 8, 195–222.

Feddersen, T., Pesendorfer, W., 1998. Convicting the innocent: The inferiority of unanimous jury verdicts under strategic voting. American Political Science Review 92, 23–35.

Futhwa, F., 2012. Setho: Afrikan Thought and Belief System. Createspace Independent Publishing Platform, Scotts Valley, CA.

Gajdos, T., Weymark, J., 2005. Multidimensional generalized Gini indices. Economic Theory 26, 471–496.

Garfinkel, M.R., Skaperdas, S., 2007. Economics of conflict: An overview. Handbook of Defense Economics 2, 649–709.

Gershman, B., 2016. Witchcraft beliefs and the erosion of social capital: Evidence from Sub-Saharan Africa and beyond. Journal of Development Economics 120, 182–208.

Gigliarano, C., Mosler, K., 2009. Constructing indices of multivariate polarization. Journal of Economic Inequality 7, 435–460.

Gordon Jr., R.G. (Ed.), 2005. Ethnologue: Languages of the World, Fifteenth edition. SIL International, Dallas, TX.

Greenberg, J., 1956. The measurement of linguistic diversity. Language 32, 109–115.

Guariso, A., Rogall, T., 2017. Rainfall inequality, political power, and ethnic conflict in Africa. LICOS Discussion Paper Series No. 391/2017.

Guarnaschelli, S., McKelvey, R., Palfrey, T., 2000. An experimental study of jury decision rules. American Political Science Review 94, 407–423.

Gubler, J., Selway, J., 2012. Horizontal inequality, crosscutting cleavages, and civil war. Journal of Conflict Resolution 56, 206–232.

Gustavsson, M., Jordahl, H., 2008. Inequality and trust in Sweden: Some inequalities are more harmful than others. Journal of Public Economics 92, 348–365.

Hall, D., 1999. Cumulative bibliography of African studies: A guide. Africa Bibliography 1997, vii–cvii. doi:10.1017/S0266673100006395.

Hodler, R., Valsecchi, M., Vesperoni, A., 2017. Ethnic geography: Measurement and evidence. CEPR Discussion Paper No. 12378.

Horowitz, D., 1985. Ethnic Groups in Conflict. University of California Press, Berkeley, CA.

Isaac, R., Walker, J., 1988. Group size effects in public goods provision: The voluntary contributions mechanism. Quarterly Journal of Economics 103, 179–199.

Jolliffe, I., 2002. Principal Component Analysis. Springer, New York, NY.

Kanbur, R., 2006. The policy significance of inequality decompositions. Journal of Economic Inequality 4, 367–374.

Knack, S., Keefer, P., 1997. Does social capital have an economic payoff? A cross-country investigation. Quarterly Journal of Economics 112, 1251–1288.

Koopmans, R., Veit, S., 2014. Ethnic diversity, trust, and the mediating role of positive and negative interethnic contact: A priming experiment. Social Science Research 47, 91–107.

Koshevoy, G., Mosler, K., 1997. Multivariate Gini indices. Journal of Multivariate Analysis 60, 252–276.

Lambert, P., Aronson, J., 1993. Inequality decomposition analysis and the Gini coefficient revisited. Economic Journal 103, 1221–1227.

Leigh, A., 2006. Trust, inequality and ethnic heterogeneity. Economic Record 82, 268–280.

Meredith, M., 2005. The State of Africa. Free Press, London.

Montalvo, J.G., Reynal-Querol, M., 2005. Ethnic polarization, potential conflict, and civil wars. American Economic Review 95, 796–816.

Moscona, J., Nunn, N., Robinson, J.A., 2017. Keeping it in the family: Lineage organization and the scope of trust in Sub-Saharan Africa. American Economic Review 107, 565–571.

Nannestad, P., 2008. What have we learned about generalized trust, if anything? Annual Review of Political Science 11, 413–436.

Nunn, N., Wantchekon, L., 2011. The slave trade and the origins of mistrust in Africa. American Economic Review 101, 3221–3252.

OECD/SWAC, 2018. Africapolis (database). `www.africapolis.org`.

Olson, J.S., 1996. The Peoples of Africa: An Ethnohistorical Dictionary. Greenwood Publishing Group, Westport, CT.

Olson, M., 1965. The Logic of Collective Action: Public Goods and the Theory of Groups. Harvard University Press, Cambridge, MA.

Østby, G., 2008. Polarization, horizontal inequalities and violent civil conflict. Journal of Peace Research 45, 143–162.

Otlogetswe, T.J., 2011. Text Variability Measures in Corpus Design for Setswana Lexicography. Cambridge Scholars Publishing, Newcastle upon Tyne, UK.

Paluck, E.L., Green, S.A., Green, D.P., 2019. The contact hypothesis re-evaluated. Behavioural Public Policy 3, 129–158.

Paolini, S., Harwood, J., Rubin, M., 2010. Negative intergroup contact makes group memberships salient: Explaining why intergroup conflict endures. Personality and Social Psychology Bulletin 36, 1723–1738.

Permanyer, I., 2012. The conceptualization and measurement of social polarization. Journal of Economic Inequality 10, 45–74.

Permanyer, I., D'Ambrosio, C., 2015. Measuring social polarization with ordinal and categorical data. Journal of Public Economic Theory 17, 311–327.

Pettigrew, T.F., 2008. Future directions for intergroup contact theory and research. International Journal of Intercultural Relations 32, 187–199.

Pettigrew, T.F., Tropp, L.R., 2006. A meta-analytic test of intergroup contact theory. Journal of Personality and Social Psychology 90, 751.

Pettigrew, T.F., Tropp, L.R., Wagner, U., Christ, O., 2011. Recent advances in intergroup contact theory. International Journal of Intercultural Relations 35, 271–280.

Putnam, R.D., 2000. Bowling Alone: The Collapse and Revival of American Community. Simon & Schuster, New York, NY.

Putnam, R.D., 2007. E pluribus unum: Diversity and community in the twenty-first century. The 2006 Johan Skytte Prize Lecture. Scandinavian Political Studies 30, 137–174.

Putterman, L., Weil, D.N., 2010. Post-1500 population flows and the long-run determinants of economic growth and inequality. Quarterly Journal of Economics 125, 1627–1682.

Raleigh, C., Linke, A., Hegre, H., Karlsen, J., 2010. Introducing ACLED: An armed conflict location and event dataset: Special data feature. Journal of Peace Research 47, 651–660.

Rao, C., 1982. Diversity and dissimilarity coefficients: A unified approach. Theoretical Population Biology 21, 24–43.

Reynal-Querol, M., Montalvo, J., 2005. Ethnic polarization, potential conflict and civil war. American Economic Review 95, 796–816.

Robinson, A.L., 2017. Ethnic diversity, segregation and ethnocentric trust in Africa. British Journal of Political Science. Forthcoming.

Rohner, D., Thoenig, M., Zilibotti, F., 2013. Seeds of distrust: Conflict in Uganda. Journal of Economic Growth 18, 217–252.

Sangnier, M., Zylberberg, Y., 2017. Protests and trust in the state: Evidence from African countries. Journal of Public Economics 152, 55–67.

Serfling, R., 1980. Asymptotic Theorems of Mathematical Statistics. Wiley, New York, NY.

Shorrocks, A., 1980. The class of additively decomposable inequality measures. Econometrica 48, 613–625.

Tesei, A., 2017. Trust and racial income inequality: Evidence from the US. Working paper.

Tsui, K., 1995. Multidimensional generalizations of the relative and absolute inequality indices: The Atkinson-Kolm-Sen approach. Journal of Economic Theory 67, 251–265.

Tsui, K., 1999. Multidimensional inequality and multidimensional generalized entropy measures: An axiomatic derivation. Social Choice and Welfare 16, 145–157.

Uslaner, E.M., 2002. The Moral Foundations of Trust. Cambridge University Press, Cambridge, UK.