Networks and Interethnic Cooperation

Jennifer M. Larson, New York University

Ethnic groups are thought to be particularly good at enforcing cooperative behavior, in part because social networks among coethnics are favorable to peer sanctioning schemes, resulting in observed outcomes like higher public goods provision in ethnically homogeneous areas and infrequent interethnic conflict. This article formalizes this process, accounting for networks that spread news relevant to sanctioning from peer to peer. It shows that impediments to intra- and interethnic cooperation arise from positions in the network that are too peripheral or too controlling: contrary to conventional wisdom, the definitive feature of networks is not density but "integration." Some groups can only support a low volume of civil interethnic interactions due to intra-ethnic networks that are poorly integrated. These results help explain variance across homogeneous areas, identify a barrier to cooperation in heterogeneous areas, generate empirical predictions, reveal sources of improvement masked by nonnetwork models, and offer guidance for future network elicitation.

Groups can enforce cooperative behavior among their members by threatening to sanction misbehavior. By this mechanism, even absent any official rules or formal enforcement power, groups can successfully attain cooperative outcomes like sharing common pool resources (Ostrom 1990), trading in perilous environments (Greif 1993; Landa 1981), and extending credit in migrant communities (Laszlo and Santor 2009).

While, in principle, any group can threaten peer sanctions, an ethnic group is thought to be particularly well equipped to do so. Due to the combination of a common language, shared cultural understanding, an ability to transmit gossip rapidly, and a means of locating coethnics quickly, ethnic groups are in a privileged position to implement peer sanctioning effectively. This privileged position has been cited as an explanation for high contributions to public goods in ethnically homogeneous areas, as well as for the low incidence of interethnic conflict across the globe: low contributors and conflict inciters would be sanctioned by fellow coethnics.

Scholars of ethnicity predominantly take this privileged ability to sanction as a first principle;[1] consequently, the precise relationship between ethnicity and an ability to sanction is black-boxed, which precludes explaining variance across ethnic groups. On the other hand, scholars of the theory of cooperation make the means of sanctioning within an arbitrary group precise and explore potential variance across groups, but the results in this area are largely focused on extending folk theorems and characterizing sets of equilibria at the highest level of generality possible.[2] While these results have undisputed value, theory has progressed largely divorced from empirical application. The theoretical approach in this article is narrower, sacrificing some generality to inform studies of ethnicity.

This article aims to unpack the black box of peer sanctioning within ethnic groups. It presents a generalization of the model of intra- and intergroup interactions in Fearon and Laitin (1996), which accounts for the precise networks that spread gossip relevant to sanctioning within ethnic groups. The model considers individuals who can interact with anyone—coethnics or non-coethnics—but only share gossip about these interactions with coethnics with whom they have a relationship in a social network.

This approach offers a number of new insights. First, prevailing wisdom holds that ethnic networks facilitate sanctioning due to their density—the large number of links thought to connect coethnics to one another. However, I show that the relationship between networks and cooperation depends on more than a mere count of links. Impediments to en-

Jennifer M. Larson (jenn.larson@nyu.edu) is an assistant professor of politics at New York University, New York, NY 10012.

Data and supporting materials necessary to reproduce the numerical results in the article are available in the *JOP* Dataverse (https://dataverse.harvard.edu/dataverse/jop). An online appendix with supplementary material is available at http://dx.doi.org/10.1086/690066.

1. See, e.g., Chandra (2004), Fearon and Laitin (1996), Gubler and Selway (2012), and Miguel and Gugerty (2005).
2. See, e.g., Ali and Miller (2013), Cho (2011), Laclau (2014), Nava and Piccione (2014), and Renault and Tomala (1998).

The Journal of Politics, volume 79, number 2. Published online January 27, 2017. http://dx.doi.org/10.1086/690066

forcing cooperation stem from individuals who are especially peripheral or controlling in the networks that transmit news, limiting the reach of information in the ethnic group. Some individuals, because of their specific network position, can have a greater incentive to misbehave. Networks can be denser and yet have more of these problematic positions. The model suggests that if ethnic networks facilitate sanctioning, it is due to a more subtle property than simple density: the absence of positions with low reach—the level of "network integration."

Second, this approach identifies a limit on cooperative interethnic interactions. When intergroup cooperation is supported by coethnic sanctioning, the networks within each ethnic group determine an upper bound on the maximum proportion of interactions that can be between non-coethnics and still be cooperative. Some ethnic groups can only support low volumes of cooperative interethnic dealings; interactions at a higher volume would be conflictual, not because of any greater tension or animosity but because news would spread too slowly among coethnics for sanctions to be effective.

Third, this article presents potential improvements to cooperation that are masked by nonnetworks models. Improved communications technology that speeds the spread of information, threats of longer-lasting sanctions, and civil society interventions all have the potential to make interethnic cooperation strictly more likely.

Finally, this approach identifies an explanation for why ethnically diverse areas may experience less cooperation than ethnically homogeneous ones. As others have found, time spent interacting with non-coethnics who are not tasked with sanctioning reduces the efficacy of coethnic sanctions. However, this article shows that even if non-coethnics were tasked with administering sanctions, communication barriers between ethnic groups would still undermine cooperation. Diversity plus communication barriers can reduce even intraethnic cooperation.

INTERETHNIC COOPERATION AND PEER SANCTIONS

Ethnicity and cooperation

Mounting empirical evidence points to the importance of ethnicity for a wide range of outcomes pertaining to political and economic development. The extent of ethnic diversity and the geographic concentration of ethnic groups have been linked to voting behavior (Chandra 2004; Ichino and Nathan 2013), public goods provision (Alesina, Baqir, and Easterly 1999; Kimenyi 2006; Miguel and Gugerty 2005), access to information (Larson and Lewis 2016a), economic outcomes (La Ferrara 2002), and the onset and duration of civil conflict (Cederman, Weidmann, and Gleditsch 2011; Kasara 2015; Larson and Lewis 2016b; Toft 2003; Weidmann 2009).

Findings from these literatures generally support two broad conclusions: coethnics are particularly successful at engaging in collective action, and areas with greater ethnic diversity experience less success with collective action.[3]

While a variety of mechanisms have been posited to explain collective action success among coethnics, a leading explanation points to ethnic groups' privileged ability to threaten sanctions in response to uncooperative behavior. For example, if individuals explicitly or implicitly threaten to sanction coethnics who under-contribute to a public good, this threat can incentivize high contributions (see Miguel and Gugerty 2005).

Experimental evidence corroborates this explanation, suggesting the presence of a "technology mechanism" by which coethnics possess a greater ability to sanction each other relative to non-coethnics (Habyarimana et al. 2007, 2009). Based on shared language and cultural understanding, and favorable features of networks within ethnic groups, ethnic groups are well suited to enforce behavior among their members.

Enforcing behavior within an ethnic group can also affect behavior toward non-coethnics. If ethnic groups threaten to sanction coethnics for misbehaving against non-coethnics, then in-group sanctioning can support cross-group cooperation. A political official in Uganda describes this logic at play in his own village: "If a Mufumbira causes a problem or starts a fight with a Mutoro, he is punished right away within his own community by the elders/opinion leaders within his tribe. The punishments vary according to the crime—[they] are often fines. Punishment [is] kept within the zone—no police or other outside authorities [are] involved" (Habyarimana et al. 2009, 172).

Fearon and Laitin (1996) offer other examples of groups using peer sanctions to punish intergroup misbehavior in contexts ranging from the Ottoman Empire to colonial Nigeria and formalize the process in a model of intergroup interactions. The model in Fearon and Laitin (1996) relies on the stylized fact that "Ethnic groups are frequently marked by highly developed systems of social networks that allow for cheap and rapid transmission of information about individuals and their past histories," which explains why for small groups in a small geographic space, "it is often the case that everyone knows everything about everybody, more or less" (1996, 718, 719). In the model, to approximate this process, all individuals learn about the actions of all coethnics immediately.

Here I relax this assumption and directly model the process by which coethnics pass news to each other in their

3. See Habyarimana et al. (2009, chap. 2) for an overview.

social networks. While this process may result in everyone in an ethnic group eventually knowing everything about everybody, more realistically, as news passes from person to person there is a period of time in which some people are out of the loop.[4] This approach can be seen as formalizing the "technology" by which coethnics can potentially sanction each other well. Being out of the loop matters because the fewer coethnics who know about misbehavior, the fewer can sanction it. Sanctions by fewer peers are less painful and so are less of a deterrent to misbehavior. Networks that fail to spread news widely and quickly are less conducive to enforcing intra- or interethnic cooperation.

Scholars of ethnicity acknowledge that some networks should be better than others for implementing peer sanctions and frequently cite the "density" of ethnic groups' networks as the theoretical source of their advantage (Chandra 2004, 71; Colson 1974, 54; Fearon and Laitin 1996, 719; Gubler and Selway 2012, 210; Miguel and Gugerty 2005, 2330). By formalizing both the process by which news spreads through a network and the use of sanctions to enforce cooperative behavior, the model below allows a precise characterization of advantageous networks. It turns out that density is not the definitive metric; networks can be denser and yet be strictly worse for enforcing cooperation. A more subtle property of networks, their level of "integration,"[5] determines the extent to which coethnics can successfully enforce behavior.[6]

This article zeroes in on the sanctioning mechanism by which ethnicity facilitates cooperation. Doing so identifies sources of potential pitfalls to intra- and interethnic cooperation, which, unusually, allows comparison across ethnic groups and across areas with the same level of diversity. These network features are measurable, though estimating integration requires measuring a network more precisely than estimating density would require, discussed below.

Cooperation and networks

This article joins a small but growing theoretical literature that accounts for networks in the enforcement of within-group cooperation. Others build on the community enforcement tradition (Kandori 1992) and either take the network as a description of who encounters whom (see, e.g., Ali and Miller 2013; Cho 2011; Lippert and Spagnolo 2011) and/or (like the present approach) of how information about encounters spreads (see, e.g., Dixit 2003; Nava and Piccione 2014; Wolitzky 2013).

The work most similar to the present approach is Wolitzky (2013) (as well as the extension in Acemoglu and Wolitzky [2015]), which also considers pairwise interactions and information that spreads along a network. The present article differs in three key respects. First, it considers both an in- and an out-group. This allows results about the interaction between intra- and interethnic cooperation. Moreover, it offers a rare look at subcommunities within a broader network, showing how communication barriers that impede the spread of information between communities impact overall within-network cooperation. Second, it considers the consequences of punishment, not contagion strategies. While in Wolitzky (2013) information spreads in the sense that the behavior of some agents tip others off that something has changed, here information spreads via word of mouth communication and is used to implement peer sanctions.

Finally, the present approach focuses on different equilibria. In Wolitzky (2013), to cooperate is to make a potentially unboundedly large contribution, which means the harshest possible punishments that can eke out the largest possible contributions are optimal. Here, to cooperate is to select the cooperative action from a binary action set. The cooperation of interest is not taking an unboundedly large action; it is refraining from taking the uncooperative action. Consequently, the equilibria of interest are those that incentivize cooperation with finite length punishment.[7]

The first set of results presented here are similar in character to those under infinite punishment in Wolitzky (2013) and Ali and Miller (2013) and find that cooperation depends on how widely and quickly information can spread through a

4. As Larson and Lewis (2016a) demonstrate through a field experiment, even after six days, a substantial part of an ethnically homogeneous village in Uganda still had not heard salient information the researchers seeded. Colson (1974, 54) describes how individuals pool information about each other in Kenyan villages via a series of meetings, often over beer, to discuss goings-on: the process is gradual, even if it ultimately results in everyone forming a consensus.

5. Network integration is defined below. Loosely speaking, a network is well integrated if no nodes have neighborhoods substantially smaller than the average neighborhood size and if no nodes are bottlenecks that could block the reach of information.

6. This result is in keeping with a large interdisciplinary literature that studies the consequences of the arrangement of a network's links for the spread of something. Different arrangements are optimal for different outcomes like group performance (Balkundi and Harrison 2006), learning solutions to complex problems (Lazer and Friedman 2007; Mason and Watts 2012), solving coordination tasks (Judd, Kearns, and Vorobeychik 2010), adopting new technology (Rogers 2010), surviving errors and outages (Albert, Jeong, and Barabási 2000), and diffusing information widely (Jackson and Rogers 2007; Pastor-Satorras and Vespignani 2001). In general, when outcomes hinge on individual access to something spreading through the network, it is not overall density but node-specific features that matter.

7. With a binary action set, punishment must be sufficiently large to encourage players to avoid the uncooperative act; larger is overkill and less efficient off the equilibrium path, which may be of particular concern in weak-state contexts.

network. Simple statistics capture this ability, which are functions of how reachable a node is in the network and how bridge-like any of its links are. The second set uses these statistics to derive an upper bound on the volume of cooperative intergroup interactions that two groups could sustain. The third set generates potential improvements to cooperation. The article concludes with empirical implications for the study of ethnicity.

A NETWORK THEORY OF INTERETHNIC COOPERATION

The model

The model is a generalization of the models in Calvert (1995) and Fearon and Laitin (1996) in which actors interact with coethnics and non-coethnics at random. In the generalization, actors have relationships with some set of other individuals, all in their own ethnic group. The aggregate of all relationships in an ethnic group is that group's social network. This network is used to disseminate information about behavior in interactions. Interactions are strategic; sharing information is not. Individuals encounter others at random and gossip about who did what in the random encounters with their contacts in the social network, who spread the news to their contacts, who spread the news to theirs, and so on.

Gossip about interactions makes sanctioning possible. In the model, individuals who learn that a coethnic behaved badly can punish that person at the next opportunity. The structure of the network determines how many coethnics have learned about an offense by any point in time. The more people who know, the more painful the sanction, and so the more effective it is. Hence, the structure of the network determines how successfully an ethnic group can enforce cooperation.

Specifically, let there be two groups, A and B, with sets of players $\{1, \ldots, n\}$ and $\{n+1, \ldots, 2n\}$.[8] Define an infinitely repeated game G in which in every round, all players are matched to play one round of prisoner's dilemma with a random opponent who, with probability p, is a non-coethnic, and with probability $1-p$ is a coethnic.

Nature reveals to each player only his own pairing. Payoffs each round are:

$$\begin{array}{c} \\ C \\ D \end{array}\begin{array}{cc} C & D \\ \left(\begin{array}{c} 1,\ 1 \\ \alpha,\ -\beta \end{array}\right. & \left.\begin{array}{c} -\beta,\ \alpha \\ 0,\ 0 \end{array}\right) \end{array},$$

where $\alpha > 1$, $\beta > 0$ and $((\alpha-\beta)/2) < 1$. Players have common discount factor $\delta < 1$.

Each ethnic group has a "communication network" defined by the pair (g^A, A) with $n \times n$ adjacency matrix g^A where $g^A_{i,j} = g^A_{j,i} = 1$ indicates the presence of a link between $i \neq j \in A$, and likewise (g^B, B) for group B. I refer to the networks as "g^A" and "g^B" or simply as "g" when the group identity is unimportant. Links in the networks are undirected and unweighted, no links span the two groups, and no nodes are isolates. Networks are common knowledge within but not across groups. While players know their own network, they know merely the topology (but not node labeling) of the other group.[9]

Assume that coethnics can perfectly identify each other, describe each other, and would recognize each other if rematched. Individuals cannot recognize or describe non-coethnics; they simply know they are playing "someone" in the other group when matched.[10] Individuals can observe the actions taken in their network neighbors' interactions with non-coethnics. Actions in coethnic interactions are unobservable.[11]

The communication network g transmits relevant information about rounds (clarified below). Information is passed as a message, which spreads truthfully and deterministically through the network at a rate $r = \textit{Degrees Spread}/\textit{Rounds Played}$. When $r = 1$, messages about rounds spread one degree, to the immediate neighbors of the source(s), before players are rematched and play again. When $r = 2$, news spreads two degrees, from person to person to person before the next round, and so on.

Consider an example communication network for a nine-member ethnic group shown twice in each row of figure 1 in which players 8, 7, 6, and 5 all communicate with each other,

8. Considering groups of different sizes is more cumbersome since it requires considering pairs of matching probabilities with bounds determined by the group sizes.

9. Network topology is the arrangement of links independent of which node sits where. In fact, in-group policing strategies do not require any information about the other group's network; this stronger assumption makes it more plausible that groups would coordinate on this set of strategies in the first place. Each group would know the other is capable of successful enforcement.

10. This scenario potentially exaggerates the differences between in- and out-group recognizability in order to analyze the hard case for interethnic cooperation (Fearon and Laitin 1996, 727).

11. This information environment comports with the recognizability assumptions. Interactions among coethnics may occur in a private setting, say, in a home. Non-coethnic interactions are by assumption between strangers and are more likely to occur visibly, as in public marketplaces, festivals, encounters on the street, etc. A different information environment in which both coethnic and non-coethnic interactions are observable is presented in the appendix. The results are similar, but the issue of bottlenecks below ceases to be a problem.

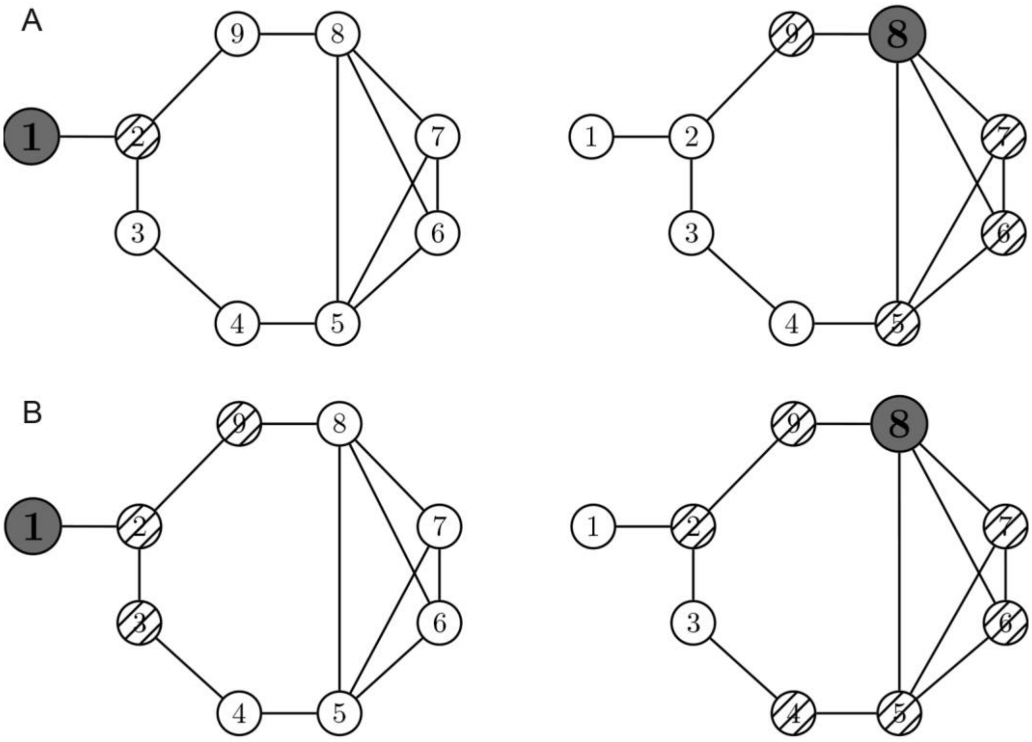

Figure 1. The reach of news in $t + 1$ (*top*) and $t + 2$ (*bottom*) when it originates with player 1 (*left*) in t and when it originates with player 8 (*right*) in t for $r = 1$

some players communicate with few others, and player 1 only communicates with one other. For illustration, fix $r = 1$. Messages that begin with player 1 reach only one other player immediately, player 2 (top left). In contrast, messages that begin with player 8 reach four other players immediately: players 9, 7, 6, and 5 (top right). The first row in figure 1 shows the reach of messages starting from both sources in t by $t + 1$, and the second row shows the reach by $t + 2$. The network determines the reach of news at any point in time, and the reach of news will determine who will be informed enough to punish particular defections.

The infinitely repeated game G proceeds as follows: at the beginning of each round, nature creates a roster of pairings for both groups. Players observe only their own pairing on the roster, which contains the most specific opponent identifier possible. Pairs play one round of the prisoner's dilemma. Messages are spread at rate r, ending the round, and the next round begins.

Strategies for enforcing intra- and interethnic cooperation

The infinitely repeated prisoner's dilemma admits many equilibria, even in this case with random matching, two groups, and a network that transmits information. Here I restrict attention to a network analog of the in-group policing equilibria of Fearon and Laitin (1996) and derive conditions for full intra- and interethnic cooperation.[12]

The strategy profile of interest, σ^{NWIGP}, requires players to keep track of whether and for how long coethnics deserve punishment. Punishment begins immediately after an offense in time t and lasts through round $t + T$. Relevant information then includes who deviated from the strategy profile and when. Players pass relevant information along to their neighbors until it becomes irrelevant (after T periods).

Formally, messages are constructed and passed as follows: when i deviates from σ^{NWIGP} in a round with coethnic j, j sends a message $m_{j,i,t} = \{i, t\}$ to himself and his neighbors that spreads through the network $g \setminus i$ at rate r.[13] When

12. This set of strategies threatens finite punishment of the offender for the T rounds after an offense committed against anyone, coethnic or not. Players use the messages sent through the network and punish those whom they have heard deserve punishment. These strategies have the property of limited inefficiency off the equilibrium path, which is beneficial in the presence of errors and also have an egalitarian property such that like offenses warrant the same punishment from anyone. Finally, the strategies have a built-in presumption of innocence: players who have heard nothing about another player treat the other as if he were cooperative. Real groups appear to use strategies of this form, as discussed in the previous section.

13. Network $g \setminus i$ is the network obtained by removing node i. This captures the logic that an offender i does not help spread information about his own offense.

i deviates in a round with a non-coethnic, neighbors of i ($j \in N_i(g)$) send themselves a message $m_{j,i,t} = \{i, t\}$ which spreads through the network $g \setminus i$ at rate r. Call $M_{i,t}$ the set of individuals about whom i has received messages by the start of time t about rounds that have occurred since $t - T$. The strategy profile depends on received messages:

Definition 1. (Network in-group policing σ^{NWIGP}). All players play C in the first round. Subsequently, all players i matched with coethnics in round t play C if matched with $j \notin M_{i,t}$ and D if matched with $j \in M_{i,t}$. All players matched with non-coethnics play C.

In other words, to follow network in-group policing, players plan to cooperate with everyone. If they encounter someone whom they have heard has defected against either a coethnic or a non-coethnic in the last T rounds, they punish that person. Any time a player is the victim of a coethnic defection, he tells his neighbors. Any time a player observes an out-group defection, he tells his neighbors.

Punishment takes the form of capitulation here (the punished player plays C against a punishing player who plays D) as it does in Fearon and Laitin (1996) and Calvert (1995). That defectors may be required to atone for their offense by capitulating for a certain number of rounds has the property that players gain from punishing defectors (they receive α), and corresponds to observed punishment regimes (Harbord 2006). The above strategy profile is really a set of strategy profiles, each with a particular length of punishment phase T. Just as a group is assumed to coordinate on the strategy σ^{NWIGP}, the group is assumed to coordinate on a particular length of punishment phase to use. Effective punishment lengths are discussed below.

NETWORK DENSITY VERSUS INTEGRATION

Comparing networks

Successfully enforcing cooperation depends on the structure of the networks within each ethnic group. The online appendix contains conditions under which σ^{NWIGP} is sequentially rational and beliefs that extend the behavior to sequential equilibrium, resulting in full intra- and interethnic cooperation. Here I use these conditions to compare individuals and to compare networks, which requires two intermediate definitions. First, the comparisons will establish individuals and networks that make cooperation easier in the following sense:

Definition 2. (When full cooperation is "easier"). A set of conditions is "easier to satisfy" when it can be satisfied for a lower value of the discount factor δ. That is, call δ^{min} the lowest value of δ that would satisfy a condition, given the full set of other model parameters Θ. Let $\delta^{min}(\theta = \theta_i)$ be the lowest value of δ that would satisfy a set of conditions given the set of model parameters $\Theta \setminus \theta$ and parameter θ set to a particular value θ_i. Then we can say that a set of conditions is "easier to satisfy" when $\theta = \theta_i$ than when $\theta = \theta_j$ if $\delta^{min}(\theta = \theta_i) < \delta^{min}(\theta = \theta_j)$.

Second, the comparisons depend on a feature of the network that is a generalization of network neighborhood:

Definition 3. (k-neighborhood). Let $\ell(i, j)$ be the length of the shortest path from i to j. Define i's k-neighborhood in network g^A, $N_i^k(g^A)$ to be the set of all j such that the shortest path from i to j is less than or equal to k. That is,

$$N_i^k(g^A) = \{j \in A : \ell(i, j) \leq k, \ i \neq j\}.$$

Now, the following lemma establishes when the conditions for intra- and interethnic cooperation are more easily satisfied for an individual, and for a network as a whole:

Lemma 1. (Network effects). Given α, β, p, r, and T, we can make the following comparisons:

1. In group A with network g^A, person i can be more easily enticed to cooperate in pairings with non-coethnics than person j when
$$\# N_i^{rT} > \# N_j^{rT}.$$
2. In group A with network g^A, person i can be more easily enticed to cooperate in coethnic pairings than person j when
$$\min_k \{\# N_k^{rT}(g^A \setminus i)\} > \min_l \{\# N_l^{rT}(g^A \setminus j)\}$$
for $k, \ l \in A$.
3. For group A, network g^A satisfies the conditions for cooperation with an out-group B more easily than network $g^{A'}$ when
$$\min_i \{\# N_i^{rT}\} > \min_{i'} \{\# N_{i'}^{rT}\}$$
for $i \in A$ with network g^A, $i' \in A$ with network $g^{A'}$.
4. For group A, network g^A satisfies the conditions for cooperation among coethnics more easily than a network $g^{A'}$ when
$$\min_{i,k} \{\# N_k^{rT}(g^A \setminus i)\} > \min_{i',k'} \{\# N_{k'}^{rT}(g^{A'} \setminus i')\}$$
for $i, k \in A$ with network g^A, $i', k' \in A$ with network $g^{A'}$.

The conditions in lemma 1 are precise statements of the intuition that individuals in network positions from which many others can be reached quickly are easier to entice to behave cooperatively.[14] Individuals whose neighbors could tell many others quickly are easier to entice to cooperate in interethnic interactions. Individuals whose potential coethnic victims could tell many others quickly and who could not themselves block that news from spreading widely are easier to entice to cooperate in coethnic interactions. Networks in which everyone is easier to entice to cooperate in coethnic and interethnic interactions are more cooperative.

More concretely, consider two example networks in figure 2. Take the case in which groups plan to punish deviators for a single round ($T = 1$), and messages spread 2 steps ($r = 2$), to someone's network neighbors and then to their network neighbors, between each round. Condition 1 then says that people with larger 2-neighborhoods—people who are only two steps away from lots of other people in the network—have a greater incentive to cooperate with non-coethnics. Neighbors observe interethnic offenses and then tell their neighbors. Everyone in the 2-neighborhood will know about the offense in time to punish the offender if they encounter him. Those with fewer people who will know in two steps face less likely punishment (it is more likely that they encounter someone who does not know about their offense), and so have a greater incentive to defect against the other ethnic group. In the network on the left, the size of player 1's 2-neighborhood is 5 (composed of {2, 3, 4, 5, 7}), whereas the size of player 6's 2-neighborhood is 2 (composed of {3, 7}). Consequently, 1 is more easily enticed to cooperate in pairings with a non-coethnic than 6 is.

Relatedly, condition 3 says that enforcing full interethnic cooperation on networks with a larger minimum 2-neighborhood is easier than on networks with a smaller minimum 2-neighborhood. The condition is in terms of minima because it accounts for the person most tempted to behave uncooperatively. In the network on the left of figure 2, player 6 has the smallest 2-neighborhood (is most tempted), of size 2; in the network on the right, all are equally tempted, with 2-neighborhoods of size 4. Enforcing full interethnic cooperation is therefore easier in the network on the right.

Condition 2 pertains to deviations against coethnics and is similar, but accounts for the fact that coethnic interactions are unobservable and knowledge about uncooperative behavior comes from messages sent by the victims of offenses. Messages sent by a victim could reach the perpetrator; however, by assumption, perpetrators do not help pass these messages along further. Hence, the relevant network feature is not simply the 2-neighborhood of a potential victim, but the 2-neighborhood of a potential victim in the network omitting the perpetrator. Consider player 3 in the left network of figure 2. His most tempting coethnic victims are players 7 and 6. If he defects against player 7, the message will reach only one other, player 6, because 3 will not help spread 7's message. In other words, the size of 7's 2-neighborhood omitting player 3 is 1. Player 2 is easier to entice to be cooperative in coethnic interactions since his most tempting victim is player 6, whose message could reach two others—the size of 6's 2-neighborhood omitting player 2 is 2.

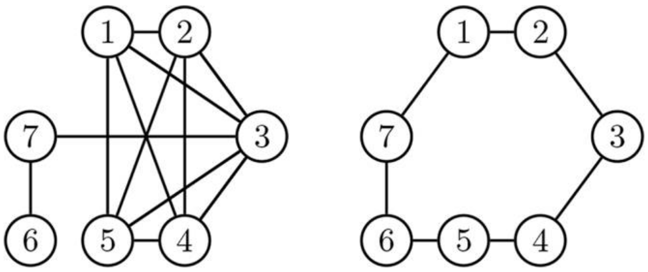

Figure 2. Two example networks. *Left*: 7 people and 12 links. *Right*: 7 people and 7 links.

Because the number of punishers depends on the victim's network position, a person's incentive to defect against a coethnic varies by prospective victim. For any potential offender i, his greatest temptation to defect against a coethnic arises when he plays someone who could reach the fewest other coethnics in rT steps, which in this example is 2, given that i will not help spread the news along. Person i faces a greater incentive to cooperate with all other coethnics than person j if i's most tempting coethnic victim could reach more coethnics in paths of length 2 omitting i than j's most tempting coethnic victim could in the network omitting j.

Condition 4 extends this logic to the whole network and says that if more people would hear about an offense committed by the most tempted perpetrator of a coethnic offense in network g^A than would hear about an offense committed by the most tempted perpetrator of a coethnic offense in network $g^{A'}$, then enforcing intra-ethnic cooperation in network g^A is easier. In the left network of figure 2, the most tempting coethnic offense would be perpetrated by 7 against 6, resulting in no one but 6 being able to punish. In the right network, the most tempting offense would be committed by anyone against a neighbor, say, 1 against 2, resulting in 7 and 6 joining 1 in punishing. Hence, enforcing full intra-ethnic cooperation is easier in the network on the right.

14. These conditions are in terms of T because the binding case is an individual contemplating defecting a second time, which would only extend the punishment an additional marginal round, in which everyone in that individual's rT-neighborhood would be informed and so could punish. The details are in the appendix.

In short, the temptation to defect against coethnics and non-coethnics depends on the number of others who will hear about the defection in the coethnic network. This number depends on the network position of potential offenders in the case of interethnic defections and on the relative positions of potential offender-victim pairs in the case of intra-ethnic defections. Positions from which few others can be reached, and positions that can block the wider reach of messages, are the source of problems for intra- and interethnic cooperation.

Implication for density

The key implication of lemma 1 is that full intra- and interethnic cooperation hinges on two network features. First, the presence of peripheral players—those with small rT-neighborhoods—generates incentives to defect against both coethnics and non-coethnics. Second, the presence of players who can block information about themselves from reaching many others in the network generates incentives to defect against coethnics by restricting the reach of rT-neighborhoods.

The density of a network does not perfectly capture whether that network contains peripheral or controlling positions. Hence, network density is not the definitive metric for full intra- or interethnic cooperation.

Proposition 1. (Greater density does not imply greater cooperation). If network $g^{A'}$ contains a larger number of links than g^{A}, this does *not* imply that for α, β, r, T, δ, $\min_{i'}\{\#N_{i'}^{rT}\} > \min_{i}\{\#N_{i}^{rT}\}$ for $i' \in g^{A'}, i \in g^{A}$, or that $\min_{i',k'}\{\#N_{k'}^{rT}(g^{A'} \setminus i')\} > \min_{i,k}\{\#N_{k}^{rT}(g^{A} \setminus i)\}$ for $i', k' \in g^{A'}$ and $i, k \in g^{A}$.

The proof can be found in the appendix, available online. Ethnic groups with networks with a greater number of links can be strictly worse at enforcing full cooperation in equilibrium than ethnic groups with networks with fewer links. The example networks in figure 2 above are a case in point: the left network, despite being denser, is strictly worse at enforcing both intra- and interethnic cooperation, as discussed in the previous section.

To understand why, note that density is a property of the network overall—the proportion of possible links present among the group. Incentives to cooperate or defect are individual—properties of an individual's position within the network. A network can be denser overall and yet have positions that incentivize some people to misbehave.

Lemma 1 establishes that two networks can be compared in terms of their networks. The relevant metric accounts for the position from which the fewest others can be reached. The sufficient comparison, even for networks of different sizes, follows from lemma 1 and the conditions in the appendix. The definitive feature is not density but a feature we can call "reach":

Definition 4. (Network reach). A network's reach is the smallest proportion of its nodes that can be reached in paths of length rT or shorter in any subnetwork induced by omitting one node. Specifically, the reach of network g^{A} with set of nodes A of size n is

$$\frac{1}{n-1} \min_{i,k \in A} \{\#N_{k}^{rT}(g^{A} \setminus i)\}.$$

This network property serves as a sufficient comparison of two groups' networks:

Proposition 2. (Greater reach does imply greater cooperation). If network g^{A} with n_A nodes has greater reach than network g^{B} with n_B nodes, then intra- and interethnic cooperation is easier to enforce in group A. That is, full cooperation can be enforced for a strictly (weakly) lower minimum value of δ in group A than group B if

$$\frac{1}{n_A - 1} \min_{i,k \in A} \{\#N_{k}^{rT}(g^{A} \setminus i)\} > (\geq) \frac{1}{n_B - 1} \min_{i,k \in B} \{\#N_{k}^{rT}(g^{B} \setminus i)\}.$$

The reach of a network is a measure of the worst case scenario for information spread, and captures the greatest incentives to misbehave against a coethnic or non-coethnic. In the example networks above in figure 2 with $T = 1$ and $r = 2$, the reach of the network on the left is 0 while the reach of the network on the right is 2. Therefore, cooperation can be enforced more easily in the network on the right.[15]

A consequence of this logic is that observing two networks with the same number of nodes and noting that one is denser is not sufficient to conclude that cooperation is easier to enforce among individuals in the denser network. Simply counting links in the networks would generate a misleading comparison.

The above also reveals the optimal arrangement of any number of links for enforcing intra- and interethnic cooperation. Call a network "integrated" if it has the largest possible reach for a given number of links:

15. For the left network, the minimum value obtains for $k = 6$, $i = 7$; for the right, it obtains for any neighboring pair, such as $k = 1$, $i = 2$. The fact that 7 sits at a bottleneck position in the network is what severely constrains reach in this case; section 3 of the appendix classifies these positions and explores their consequences further.

Definition 5. (Integrated networks). A network is perfectly *integrated* if, for a given number of links, the links are arranged to maximize the minimum rT-neighborhood in the network omitting any one player. Specifically, a network g^A is integrated if there exists no alternate network $g^{A'}$ for the same set of links A such that

$$\min_{i,k \in A} \{\# N_k^{rT}(g^A \setminus i)\} < \min_{i',k' \in A} \{\# N_{k'}^{rT}(g^{A'} \setminus i')\}.$$

In figure 2, the network on the right is integrated: no other arrangement of those seven links among those seven nodes would improve the reach of the network. The network on the left is not integrated: other arrangements of those 12 links could improve the reach (e.g., by removing the link between 1 and 3 and adding it between 1 and 6).

For a given number of links, the arrangement that is optimal for enforcing inter- and intraethnic cooperation is the integrated arrangement.

Corollary 1. (Integrated networks are optimal). If network g with L links is Integrated, there is no other network g' with L links on which enforcing cooperation is easier.

An integrated network is the optimal network of a certain size. In an integrated network, no one is too peripheral, even accounting for the fact that perpetrators will not help pass messages along.[16] The appendix elaborates further on the consequences of rearranging links, adding links, and adding nodes; it also shows that these results are robust to a matching process that is not uniformly random but weighted to preferentially match individuals with their network neighbors.

Taking stock, lemma 1 allows the comparison of any individuals within a network or of any networks as a whole and suggests the following insights about the relationship between density and intra- and interethnic cooperation:

1. Density is not a necessary or sufficient metric for comparing the ease of enforcing intra- and interethnic cooperation—denser networks can be strictly worse at enforcing cooperation.
2. The reach of a network, which is a measure of how widely messages could spread from the most peripheral network position given that perpetrators will not help spread messages, is the appropriate metric for comparing the ease of enforcing intra- and interethnic cooperation. Networks with greater reach can better enforce cooperation.
3. The reason reach is more informative than density is that incentives to behave uncooperatively arise at the individual level, and reach captures network features at the individual level.
4. Integrated networks—those with maximum reach—are optimal for the enforcement of cooperation given a certain number of social ties.
5. Perfectly dense networks—networks with every link present—can best enforce cooperation, but this is due to their maximal reach and not their density per se.

Imperfectly dense networks cannot be compared simply in terms of their density. These findings help explain variance across ethnically homogeneous groups: differences in ethnic groups' networks generate differences in intra- and interethnic cooperation.

CONSTRAINTS ON COOPERATIVE INTERETHNIC INTERACTIONS

An implication of the results in the previous section is that the arrangement of links bears on how well groups can enforce interethnic cooperation. Note that no group could support 100% of interactions being between non-coethnics with an in-group policing strategy since there would never be an in-group interaction in which punishment could be administered. Some groups, however, are capable of maintaining cooperation in a greater volume of interethnic interactions than others due to more a conducive arrangement of links in their coethnic networks.

Proposition 3. (Upper bound on cooperative cross-group interactions). The largest proportion of cross-group interactions, p^{max}, that group A with network g^A can sustain in a fully cooperative equilibrium is:

$$p^{max} = \min \left\{1 - \frac{(n-1)(\alpha-1)}{\min_{k,l}\{\# N_k(g^A \setminus l) \cup k\}\delta^T(1+\beta)}, \; 1 - \frac{(n-1)\beta}{\min_{k,l}\{\# N_k(g^A \setminus l) \cup k\}\delta^T(1+\beta)}\right\}$$

for $i, k, l \in A$.

16. A consequence of this fact is that a denser integrated network is necessarily better for cooperation: for two integrated networks g and g' with number of links L and L' such that $L' > L$, enforcing full cooperation in the group with network g' will be easier. So integrated networks with more links are better for cooperation than integrated networks with fewer. But this is a consequence of integrated networks having the largest reach at each size: density does not unconditionally make enforcing cooperation easier. Section 7 of the appendix further elaborates on this comparison.

In other words, the largest proportion of interactions that could be between non-coethnics and still be cooperative is determined by each group's coethnic network. Specifically, the limit to the volume of cross-group cooperation is determined by the reach of each network—the extent to which there are positions in the network from which news would not spread widely. Moreover, the ability of both groups to support interethnic cooperation depends on the minimum p^{max} for the two groups.

Groups that are better able to punish their more tempted members—those about whom news does not spread as widely—can support more interethnic cooperation. For illustration, compare two different networks that an ethnic group could have, shown in figure 3 and fix $r = 2$, $T = 1$, $\alpha = 1.05$, $\beta = .7$, and $\delta = .95$. The maximum proportion of cooperative interethnic interactions that the group on the right can sustain is $p^{max} = .57$, while the value is only $p^{max} = .24$ for the group on the left.[17]

The group on the left can only support 24% of the group's interactions as cross-group; any additional interactions between the groups and the sanctioning will not be strong enough to keep them cooperative. The networks establish an upper bound on peaceful interethnic interactions.

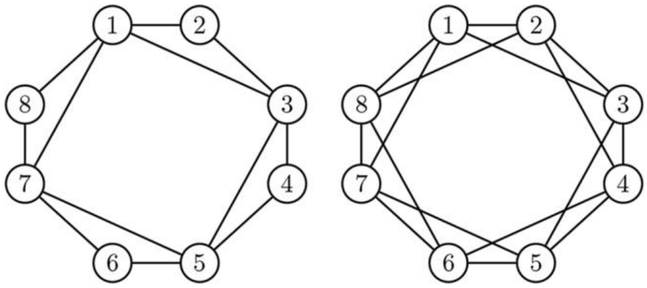

Figure 3. Example group in which everyone has two or four neighbors on the left; everyone has four neighbors on the right.

DISCUSSION

Improving cooperation

By accounting for the role of networks in coethnic enforcement of cooperation, the results uncover important sources of improvement to full intra- and interethnic cooperation. I present the intuition here, with details and proofs in sections 4 and 7 of the appendix. First, and straightforwardly, if news spreads more quickly, cooperation is weakly (and often strictly) easier to enforce. The rate of information transmission affects how well groups can enforce cooperation: a group can enforce cooperation more easily when messages spread more rapidly. Relatedly, groups can support a greater volume of interethnic interactions that are cooperative when messages spread more rapidly. Communities that experience a boon to communications technology should find themselves in a better position to enforce intra- and interethnic cooperation; communities that experience setbacks in their communications technology should find themselves in a worse position to enforce cooperation.[18] This intuitive result is masked by models that presume networks to be complete.

Second, increasing the length of the punishment phase that groups threaten to inflict on offenders can improve cooperation.[19] Interestingly, when networks are assumed to be complete so that everyone learns everything about a coethnic's behavior immediately, if cooperation were possible, punishment lasting a single round would be at least as effective as punishment that lasts any larger number of rounds. In fact, longer punishment would be strictly harmful because it would delay additional punishment that those contemplating defecting a second time in a row would face.

Real world communication networks tend to not be complete; instead, some possible links are absent so that some people receive news secondhand or thirdhand or more.[20] Considering realistic, incomplete networks recovers the potential usefulness of long punishments. In incomplete networks, increasing the length of the punishment phase would increase the time during which messages sent by someone could spread through his group's network, increasing the number of punishers each round.

Long punishment phases increase the amount of expected punishment by both increasing the number of time periods in which a person is eligible for punishment and by increasing the number of people who know that punishment is de-

17. The large difference stems from the least punishable person in an in-group defection. In the group on the right, in $rT = 2$ rounds, all other coethnics would have received any victim's message. In the group on the left, if 1 defects against 2, only three other coethnics would know in $rT = 2$ rounds: 2 tells 3, who tells 4 and 5, while 1, being the perpetrator, does not tell anyone.

18. The appendix also shows that how responsive a network is to this improvement depends in part on its structure and whether or not positions called "controlling" are present.

19. In the simple prisoner's dilemma setup here, punishment in any round is inflicted by playing D against the punished who plays C; in any round, then, the amount of punishment inflicted is $-\alpha$. The magnitude of punishment can be altered by changing T, the number of rounds in which $-\alpha$ is inflicted. Hence, these results are stated in terms of the length of punishment.

20. See, e.g, Larson and Lewis (2016a). Some have argued that humans have an innate upper limit on the number of meaningful relationships they can maintain (Dunbar 1992); groups with more members than this upper bound naturally have incomplete networks.

served. This second coordinating role is masked when communication is assumed to be instantaneous.[21]

A final source of improvement would be more difficult, but not impossible, to implement: changes to the network structure itself. The appendix considers the most beneficial changes. In the model, each ethnic group is endowed with a fixed network that transmits information from person to person. In practice, networks that transmit news may be the product of multiple forces and may serve multiple roles. Links among coethnics may form due to close kinship or shared membership in clans and subclans or be the product of interactions at religious ceremonies, or working together, or sharing interests, and so on. Some cultural practices of ethnic groups may serve to make or keep a network integrated. For instance, rules of exogamy forge social ties between individuals of different clans. This could result in bottleneck network positions that could block the wide reach of information, but accompanying customs in which both families participate would ensure that the married couple's network positions do not remain bottleneck-like. Norms and customs can have implications for ultimate communication networks, drawing in peripheral individuals, and facilitating enough mixing to improve a network's reach.[22]

Because the links that transmit information are the product of meaningful relationships and may require trust, these social ties are not necessarily forged quickly or altered easily. However, there are instances of changes in customs which resulted in eventual changes in the arrangement of social ties. A case in point is discussed in Ensminger (2001). When the Orma of northwestern Kenya shifted from a system of family herding to hired cattle herders, a principal-agent problem incentivized herders, often strangers, to cheat the owners through theft or deceit. In response to this potential for uncooperative behavior by peripheral members of the group's communication network, the Orma found a way to add links: cattle owners married their daughters to the herders. Such additional links were certainly among the most efficient additions since they connected the most peripheral members, the herders, to the center of families. While the fathers may not have thought about their daughters' marriages in terms of links in a communication network, the motivation to draw in otherwise peripheral group members reflects the intuition presented here.

Changes in customs from the "inside" raise an intriguing possibility of change from the "outside." Interventions that have a civil society component and seek to regenerate or reorganize social life have the potential to forge new links in a social network over time. The model here suggests that changes that make a network more integrated have the potential to improve prospects for intra- as well as interethnic cooperation.

Why is ethnic diversity a problem?

The results above help unpack the role of coethnic networks in enforcing cooperative behavior. If ethnic groups threaten sanctions for misbehavior and use communication networks to spread news about misbehavior, then intra- and interethnic cooperation can be enforced if networks are favorable enough.

Returning to the empirical literature on ethnic interactions, a key, consistent finding is that the presence of multiple ethnic groups in the same area—ethnic diversity—is negatively related to cooperative outcomes like the provision of public goods.

If the source of ethnicity's positive effect on cooperation is its facilitation of coethnic sanctioning, then the presence of multiple ethnic groups in an area need not undermine cooperation in principle. If each ethnic group can threaten sanctions of its own members and all ethnic groups do so, these threats could result in cooperation, even in a diverse area. So why the inverse relationship between diversity and cooperation empirically?

The model does point to one source of cooperation breakdown that could stem from the existence of multiple ethnic groups in the same area. If individuals in areas with higher diversity necessarily must interact more frequently with non-coethnics, then cooperation, even intra-ethnic cooperation, becomes more difficult. The formal reason is that this increases p; the informal reason is that any time spent with non-coethnics is time that could not be devoted to punishment.[23] The more time spent with non-coethnics, the less time spent with coethnics who are tasked with implementing punish-

21. Real world punishment does vary in duration. Some blood feuds demand single instances of homicide as punishment; some demand more (Boehm 1984). Some groups of traders punish cheaters with a one-time fee; some sentence cheaters to long-term exile (Greif 1993).

22. Others have speculated that social structures and customs within ethnic groups shape social networks. For instance, Colson (1974, 29) notes that the structure of clans can be thought of as a social design which facilitates certain kinds of interaction. Larson and Lewis (2016b) argue that the migration patterns and cultural rules have shaped the social networks in ethnically homogeneous areas to have short paths and low fragmentation.

23. This trade-off assumes that everyone is participating in as many interactions as they can or prefer, i.e., that they are using their whole interaction budget. Since sanctions are doled out in these interactions and news about who deserves sanctions only reaches coethics, time with non-coethnics is time when one cannot be sanctioned.

ment, and so the greater the incentive to defect in all interactions.

This result may appear to be an artifact of the assumption that coethnics play strategies that only issue sanctions to coethnics. Perhaps if individuals were also tasked with sanctioning non-coethnics who misbehave, then time spent interacting with other ethnic groups would not undermine cooperation.

However, the fundamental reason out-group interactions are a problem is not that the out-group is not tasked with punishing in-group members. The problem is that information does not reach one group from the other. In fact, if the out-group were tasked with punishing while the communication barrier between the two groups persisted (no links span the two groups), time spent interacting with non-coethnics would still undermine cooperation.

Section 5 of the appendix considers this scenario in detail. Intuitively, any barriers that keep information about a member of one ethnic group from reaching another ethnic group impede the efficacy of a scheme in which non-coethnics can sanction each other. The problem stems from separation between the two groups' communication networks—"communication barriers" between the two ethnic groups—and not the fact that strategies happen to not task ethnic groups with punishing non-coethnics. Given communication barriers across ethnic groups, sanctioning schemes that rely on information spread through communication networks will be less effective at enforcing cooperation, even intra-ethnic cooperation, in the presence of high ethnic diversity.

Implications for the empirical study of ethnic networks

The results above suggest that the efficacy of peer sanctioning depends on features of coethnic networks that vary by individual. Barriers to intra- and interethnic cooperation arise from the presence of network positions from which information cannot spread widely, whether due to small neighborhoods or the presence of network positions that could block it from spreading further.

These results have consequences for network elicitation measures used in the field. Lemma 1 generates specific statistics that can be computed for any empirically measured network. The network measurement technique must be sensitive enough to detect the presence of positions from which information cannot spread widely, and consistent enough to compare nodes within networks. These conditions would be satisfied if every possible individual were included in the network study as a respondent, but obtaining full coverage of a population is unrealistic in practice. Given incomplete coverage, data analysis that combines nodes measured in different ways could be misleading.[24]

Because eliciting full networks is onerous, an important agenda for future research will be to explore simplified measurement techniques. Research suggests that estimating network neighborhood size and identifying those least peripheral in a network can be done without eliciting network ties (Banerjee et al. 2014; Killworth et al. 1990). Whether similar measures can identify the most peripheral people or network reach awaits future research.

Likewise, there may be empirical correlates of low-reach positions in networks. Measurable features like immigration status, geographic location, or terrain surrounding one's homestead may bear on network formation and correlate with the network positions that affect cooperative behavior. Pinning down the correlates will also have to await future work, but the better the measures of network reach, the better our empirical understanding of intra- and interethnic cooperation will be.

CONCLUSION

> By formalizing the set of "technology mechanisms" that facilitate sanctioning among coethnics, this article offers new insights into ethnicity's role in enforcing cooperative behavior. Despite conventional wisdom, denser networks are not necessarily more conducive to enforcing cooperation. In fact, denser networks can be strictly worse at enforcing intra- and interethnic cooperation. The definitive property of networks is a measure of how widely news could spread from any individual through her ethnic group, accounting for the possibility that those whom the news condemns will not help spread it. This property of networks, their "integration," determines both how successfully coethnics can be enticed to cooperate in coethnic and interethnic interactions, and also establishes a limit on the volume of cooperative interethnic interactions that two groups could sustain.

Social networks form for a variety of reasons, are shaped by many forces, and serve multiple functions at once. If forming and maintaining social ties were free and humans had the

24. For instance, pooling individuals surveyed with individuals mentioned by someone in response to a network tie question who were not themselves surveyed could be particularly misleading. Those mentioned but not surveyed will likely appear to be in positions with low reach simply because, unlike the respondents, they had no opportunity to tell the researchers the rest of their ties.

cognitive capacity to relate to an unlimited number of other people, networks would perhaps all contain every possible link. Real social networks are incomplete and are complicated. The results here show that if forces were perfectly aligned to pressure networks to support intra- and interethnic cooperation, and the formation of ties faced no other constraints, then we might expect to observe integrated networks—ones in which no positions feature lower reach than any others. However, in complex reality, networks vary, and the reach of positions within networks varies too.

This article helps make sense of the variance and affirms the utility of collecting data in the field that records network structure precisely enough to detect the variance empirically (see, e.g., Banerjee et al. 2014; Barr, Ensminger, and Johnson 2010; Conley and Udry 2010; Larson and Lewis 2016a). The results here suggest that barriers to interethnic cooperation arise not from the average node but from network outliers. If ethnic networks are favorable to enforcing cooperation, it is because they feature arrangements of links that reduce the difference between outliers and the average and hence are "integrated": no nodes have especially low reach or are susceptible to being blocked by others. Data collection techniques that are sensitive enough to detect network positions with low reach will offer the best chance at meaningful empirical comparisons of whole groups and of individuals within groups in the future study of interethnic cooperation.

ACKNOWLEDGMENTS

Thanks to the many who have taken time to offer feedback on this project, especially Robert Bates, Bruce Bueno de Mesquita, Andrew Coe, Drew Fudenberg, Michael Gilligan, Torben Iversen, David Lazer, Janet Lewis, James Robinson, Kenneth Shepsle, and Arthur Spirling.

REFERENCES

Acemoglu, Daron, and Alexander Wolitzky. 2015. "Sustaining Cooperation: Community Enforcement vs. Specialized Enforcement." National Bureau of Economic Research Working paper no. 21457. http://www.nber.org/papers/w21457.pdf.

Albert, R., H. Jeong, and A. L. Barabási. 2000. "Error and Attack Tolerance of Complex Networks." *Nature* 406 (6794): 378–82.

Alesina, Alberto, Reza Baqir, and William Easterly. 1999. "Public Goods and Ethnic Divisions." *Quarterly Journal of Economics* 114:1243–84.

Ali, S., and D. Miller. 2013. "Cooperation and Collective Enforcement in Networked Societies." Working paper.

Balkundi, Prasad, and David A Harrison. 2006. "Ties, Leaders, and Time in Teams: Strong Inference about Network Structure's Effects on Team Viability and Performance." *Academy of Management Journal* 49 (1): 49–68.

Banerjee, Abhijit V., Arun Chandrasekhar, Esther Duflo, and Matthew O. Jackson. 2014. "Gossip: Identifying Central Individuals in a Social Network." MIT Working paper no. 14-15. https://ssrn.com/abstract=2425379.

Barr, A., J. Ensminger, and J. C. Johnson. 2010. "Social Networks and Trust in Cross-Cultural Economic Experiments." In Karen S. Cook, Margaret Levi, and Russell Hardin, eds., *Whom Can We Trust?* New York: Russell Sage Foundation, 65–90.

Boehm, C. 1984. *Blood Revenge: The Anthropology of Feuding in Montenegro and Other Tribal Societies*. Lawrence: Kansas University Press.

Calvert, R. L. 1995. "Rational Actors, Equilibrium, and Social Institutions." In J. Knight and I. Sened, eds., *Explaining Social Institutions*. Ann Arbor: University of Michigan Press, 57–94.

Cederman, Lars-Erik, Nils B. Weidmann, and Kristian Skrede Gleditsch. 2011. "Horizontal Inequalities and Ethnonationalist Civil War: A Global Comparison." *American Political Science Review* 105 (3): 478–95.

Chandra, Kanchan. 2004. *Why Ethnic Parties Succeed: Patronage and Ethnic Head Counts in India*. Cambridge: Cambridge University Press.

Cho, Myeonghwan. 2011. "Public Randomization in the Repeated Prisoner's Dilemma Game with Local Interaction." *Economics Letters* 112 (3): 280–82.

Colson, E. 1974. *Tradition and Contract: The Problem of Order*. London: Aldine.

Conley, T. G., and C. R. Udry. 2010. "Learning about a New Technology: Pineapple in Ghana." *American Economic Review* 100 (1): 35–69.

Dixit, A. 2003. "Trade Expansion and Contract Enforcement." *Journal of Political Economy* 111 (6): 1293–317.

Dunbar, Robin I. M. 1992. "Neocortex Size as a Constraint on Group Size in Primates." *Journal of Human Evolution* 22 (6): 469–93.

Ensminger, J. 2001. "Reputations, Trust, and the Principal Agent Problem." In Karen S. Cook, ed., *Trust in Society*. New York: Russell Sage Foundation, 185–201.

Fearon, J. D., and D. D. Laitin. 1996. "Explaining Interethnic Cooperation." *American Political Science Review* 90 (4): 715–35.

Greif, A. 1993. "Contract Enforceability and Economic Institutions in Early Trade: The Maghribi Traders' Coalition." *American Economic Review* 83 (3): 525–48.

Gubler, Joshua R., and Joel Sawat Selway. 2012. "Horizontal Inequality, Crosscutting Cleavages, and Civil War." *Journal of Conflict Resolution* 56 (2): 206–32.

Habyarimana, J., M. Humphreys, D. N. Posner, and J. M. Weinstein. 2007. "Why Does Ethnic Diversity Undermine Public Goods Provision?" *American Political Science Review* 101 (4): 709–25.

Habyarimana, J., M. Humphreys, D. N. Posner, and J. M. Weinstein. 2009. *Coethnicity: Diversity and the Dilemmas of Collective Action*. New York: Russell Sage Foundation.

Harbord, David. 2006. "Enforcing Cooperation among Medieval Merchants: The Maghribi Traders Revisited." https://ssrn.com/abstract=958617.

Ichino, Nahomi, and Noah Nathan. 2013. "Crossing the Line: Local Ethnic Geography and Voting in Ghana." *American Political Science Review* 107 (2): 344–61.

Jackson, M. O., and B. W. Rogers. 2007. "Relating Network Structure to Diffusion Properties through Stochastic Dominance." *BE Journal of Theoretical Economics* 7 (1): 1–13.

Judd, S., M. Kearns, and Y. Vorobeychik. 2010. "Behavioral Dynamics and Influence in Networked Coloring and Consensus." *Proceedings of the National Academy of Sciences* 107 (34): 14978–82.

Kandori, M. 1992. "Social Norms and Community Enforcement." *Review of Economic Studies* 59 (1): 63.

Kasara, Kimuli. 2015. "Does Local Ethnic Segregation Lead to Violence? Evidence from Kenya." *Quarterly Journal of Political Science* (forthcoming). http://www.columbia.edu/~kk2432/segviolence0616.pdf.

Killworth, Peter D., Eugene C. Johnsen, H. Russell Bernard, Gene Ann Shelley, and Christopher McCarty. 1990. "Estimating the Size of Personal Networks." *Social Networks* 12 (4): 289–312.

Kimenyi, Mwangi S. 2006. "Ethnicity, Governance and the Provision of Public Goods." *Journal of African Economies* 15 (S1): 62–99.

Laclau, Marie. 2014. "Communication in Repeated Network Games with Imperfect Monitoring." *Games and Economic Behavior* 87:136–60.

La Ferrara, Eliana. 2002. "Self-Help Groups and Income Generation in the Informal Settlements of Nairobi." *Journal of African Economies* 11 (1): 61–89.

Landa, J. T. 1981. "A Theory of the Ethically Homogeneous Middleman Group: An Institutional Alternative to Contract Law." *Journal of Legal Studies* 10 (2): 349–62.

Larson, Jennifer M., and Janet I. Lewis. 2016a. "Ethnic Networks." Working paper.

Larson, Jennifer M., and Janet I. Lewis. 2016b. "Rumors, Kinship Networks, and Rebel Group Formation." Working paper.

Laszlo, S., and E. Santor. 2009. "Migration, Social Networks, and Credit: Empirical Evidence from Peru." *Developing Economies* 47 (4): 383–409.

Lazer, David, and Allan Friedman. 2007. "The Network Structure of Exploration and Exploitation." *Administrative Science Quarterly* 52 (4): 667–94.

Lippert, S., and G. Spagnolo. 2011. "Networks of Relations and Word-of-Mouth Communication." *Games and Economic Behavior* 72 (1): 202–17.

Mason, Winter, and Duncan J. Watts. 2012. "Collaborative Learning in Networks." *Proceedings of the National Academy of Sciences* 109 (3): 764–69.

Miguel, E., and M. K. Gugerty. 2005. "Ethnic Diversity, Social Sanctions, and Public Goods in Kenya." *Journal of Public Economics* 89 (11–12): 2325–68.

Nava, Francesco, and Michele Piccione. 2014. "Efficiency in Repeated Games with Local Interaction and Uncertain Local Monitoring." *Theoretical Economics* 9 (1): 279–312.

Ostrom, E. 1990. *Governing the Commons: The Evolution of Institutions for Collective Action*. Cambridge: Cambridge University Press.

Pastor-Satorras, Romualdo, and Alessandro Vespignani. 2001. "Epidemic Spreading in Scale-Free Networks." *Physical Review Letters* 86 (14): 3200.

Renault, J., and T. Tomala. 1998. "Repeated Proximity Games." *International Journal of Game Theory* 27 (4): 539–59.

Rogers, Everett M. 2010. *Diffusion of Innovations*. New York: Simon & Schuster.

Toft, Monica Duffy. 2003. *The Geography of Ethnic Violence: Identity, Interests, and the Indivisibility of Territory*. Princeton, NJ: Princeton University Press.

Weidmann, Nils. 2009. "Geography as Motivation and Opportunity: Group Concentration and Ethnic Conflict." *Journal of Conflict Resolution* 53 (4): 526–43.

Wolitzky, Alexander. 2013. "Cooperation with Network Monitoring." *Review of Economic Studies* 80 (1): 395–427.