A Failure to Communicate: Networks and Interethnic Conflict*

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Abstract How do the social structures of ethnic groups affect their ability to cooperate with each other? How does the character of civil society influence the risk of civil conflict? Many explanations of the peaceful coexistence of ethnic groups hinge on communication: groups that are able to share information easily from member to member can coordinate punishment strategies and can spread knowledge which counteracts potentially incendiary rumors. Widespread communication can help to sustain cooperation, but realistically, in large, diffuse, busy, segmented, or technology-poor societies, some pairs of group members may not communicate directly, and indirect communication may transmit tainted information. How widespread is widespread enough? Is volume of communication the only relevant variable, or does the structure of communication in civil society matter? Building on Fearon and Laitin (1996), I present a game-theoretic model of interethnic relations to examine the relationship between civil society and ethnic conflict. I model civil society as a social network representing the flow of information between individuals. In contrast with the conventional approach that assumes all members of an ethnic group are perfectly informed about all other members, I allow for the possibility that some members of an ethnic group do not directly observe or receive first-hand information about all others. I show that cooperation depends on subtle properties of the social network, such as its shape and the distribution of links. Finally, I discuss the correspondence between these network properties and observable features of ethnic groups, such as centralization, inequality and segregation.

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N ot e t o R eader s

This is a wo r k ing pa p e r a t a ve r y e a r ly s ta g e . I have tr ie d to g et e no ug h down o n pa p e r to c o nve y a s e ns e o f whe r e I s e e the pr o je c t g o ing a nd to e lic it use ful fe e dba ck . I wo uld a ppr e c ia te a ny fe e dba ck tha t o c c ur s to yo u. I wo uld e sp e c ia lly a ppr e c ia te he a r ing wha t yo u think o f the mo de l (a nd how my de s c r iptio n o f it c o uld b e c le a r e r), ide a s fo r r e le va nt c a s e s a nd a pplic a tio ns , a nd wha t yo u think the mo s t inte r e s ting e xte ns io ns wo uld b e . I a p o lo g iz e in a dva nc e fo r the ha s ty a s s e mbly a nd g la r ing o mis s io ns (like the a pp e ndix , o r a c o nc lus io n, o r a ns we r ing the q ue s tio ns p o s e d in the a bs tr a c t...). Tha nk s fo r ta k ing the time to lo o k thr o ug h this fir s t o n- pa p e r dr a ft!

How do the social structures of ethnic groups affect their ability to cooperate with each other? Are segregated societies at greater risk of ethnic conflict than integrated ones? Does the presence of a powerful elite help or hurt prospects for interethnic cooperation? Can egalitarian societies work together more easily than hierarchical ones?

This paper investigates the relationship between civil society and interethnic conflict. That ethnic conflict can be mitigated by civic interactions which cross ethnic lines has been observed by many scholars (e.g. Lipset and Rokkan, 1967; Varshney, 2003). Interethnic ties are thought to build trust between ethnic groups, and to provide a communication channel useful for dispelling rumors and preventing polarization. Civic interactions between members of the same ethnic group can also facilitate cooperation by allowing a group to coordinate punishment strategies that deter violence between groups, and by spreading the information that counteracts rumors (e.g. Fearon and Laitin, 1996).

Given the importance of communication within and between groups for staving off conflict, intuition would suggest that more ties are better than fewer. However, little is known about the particular structure of civil society within ethnic groups most conducive to cooperation. I present a game theoretic model of inter- and intra-ethnic relations that allows me to relate the feasibility and sustainability of cooperation to the particular structure of civil society that ties members of an ethnic group to each other.

[1]Building on Calvert (1995) and Fearon and Laitin (1996), I model interactions between members of two ethnic groups. Players are paired at random to play a prisoner's dilemma, and some proportion of the random pairs match people from different ethnic groups. Players can perfectly identify their coethnics but not members of the other ethnic group; when paired across groups, players simply know they are playing someone from the other group. In the Fearon and Laitin game, everyone within an ethnic group learns all information every coethnic has regarding who played whom and the outcomes of the games. Rather than assume that all members of an ethnic group are perfectly informed about all other members, I allow for the possibility that some members of an ethnic group do not directly observe or receive first-hand information about all others.

Specifically, I model civil society as a social network representing the flow of gossip and information between individuals. Links in the network represent who directly interacts with or

[1]The assumption that all players observe or receive first-hand information from all others may be especially suspect among groups that are large, diffuse, segregated, busy or technology-poor.

receives information from whom. Networks provide a tractable way of formalizing civil society in this setting. Even if the exact social network underlying civil society were unobservable, classes of networks could still be observable. This approach allows the comparison of types of civil society: decentralized types in which people are tied to many others but not everyone, types in which some people are tied to many others and some are tied to few others, types in which a hierarchy of ties exists, types in which a well connected group of elites is relatively disconnected from everyone else, types in which individuals cluster into smaller groups of close ties, and so on.

[2]I explore the way civil society affects ethnic groups' ability to coordinate punishment strategies that deter conflict when no interethnic ties are present. By varying civil society type, I am able to determine which types are most amenable to the cooperative equilibria that Fearon and Laitin identify. I also compare civil society types with respect to how fragile cooperation is expected to be, and I identify other sorts of institutions that could sustain cooperation in different settings.

Cooperation when communication is perfect

Building on Calvert (1995), Fearon and Laitin (1996) present a model of interactions between members of two ethnic groups. In each period, players are randomly paired to play a single round of prisoners' dilemma; with some probability an individual is assigned to play with a member of the other group. Players are assumed to be able to identify and remember individuals within their own group, but can only identify the group and not the individual identity of players belonging to the other group. So long as everyone within a group learns who plays whom and the outcome of all the play in every period, two efficient subgame perfect equilibria are possible. In the in-group policing equilibrium, all players cooperate with each other in equilibrium because fellow group members will punish their own members when they defect against their own and when they defect against a member of the other group. In the spiral equilibrium, all players cooperate with each other in equilibrium because if any member of a group is defected against by a member of the other group, the aggrieved group will indiscriminately punish the offending

[2]Fearon and Laitin (1996) identify two equilibria that result in full cooperation: an in-group punishment regime in which coethnics punish their own who defect against members of the other group, and a spiral punishment regime in which single defections by one ethnic group are punished by every member of the other. Threats of these punishments are sufficient to deter defections and ensure cooperation in equilibrium under some set of conditions. The possibility of sustaining these equilibria depends on the structure of the social network representing civil society, as does the fragility of these equilibria and the presence of other cooperative equilibria.

group. The ability of a group to coordinate punishment strategies sustains cooperation.

Arguing that ethnic groups provide informational benefits to their members, Fearon and Laitin (1996) note 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." The authors are careful to point out that while it may be implausible in some cases to assume that all group members observe and learn about every interaction pertaining to every member of their own group, this assumption is a useful first approximation and captures the more plausible information asymmetry case in which members of an ethnic group know relatively more about their coethnics than about members of the other ethnic group.

[3]In what follows, I relax the assumption of perfect information within an ethnic group and take a closer look at possible structures of 'rumor, gossip and inquiry' which transmit information within an ethnic group. Even if it were the case that everyone learned all relevant information about all coethnics, the speed by which people learned this information, the robustness of the spread of information to noise, and the susceptibility of the information network to missing links and gossips taking a sick day vary depending on how dense the information network is, how many paths through the network connect two coethnics, how grid-like or wagon wheel-like the communication network is, and so on. Moreover, it may be that not all people directly observe the play of all coethnics or receive information of perfect quality about all coethnics.

Intuition suggests that cooperation will be easier to sustain, and the spiral and in-group equilibria proposed in Fearon and Laitin (1996) will be more likely to obtain the more connected the communication network is. However, what counts as 'more connected' for our purposes is not obvious: does more connected mean more paths through the network that could transmit

[3] The amount, credibility and verifiability of information shared when people communicate can vary, as can the speed with which information spreads between people. If one person knows that another person is about to trade with a notorious cheater today but will not see the person until tomorrow, communication is technically present, but is hardly valuable. If the person in the know often cries wolf, communicating today may not be very effective. If the person can deliver a warning today, but can only do so by telling a third party, who will tell a fourth party, who will tell a fifth party, who will finally convey the warning, that warning may be taken less seriously than a warning personally and directly delivered. If the person in the know sends the warning by letter through a mail service that loses mail with non-zero probability, communication is attempted, but is less effective. If the person who knows about the reputation of the cheater tells everyone she knows, who tell everyone they know, and so on, this communication will only affect the soon-to-be victim if someone in this chain knows her. The structure of communication –the way people interact and the pattern of who interacts with whom– matters for its effectiveness at thwarting interethnic violence.

info r ma tio n fr o m p e r s o n i to p e r s o n j , o r a g r e a te r pr o p o r tio n o f to ta l p o s s ible link s pr e s e nt in the ne two r k , o r a g r e a te r numb e r o f indiv idua ls r e a cha ble in the ne two r k , o r the g r e a te s t ave r a g e numb e r o f p e o ple r e a cha ble fr o m a r a ndo mly cho s e n p er s o n, o r s o me thing e ls e ? The ne x t s e c tio n fo r ma liz e s the no tio n o f a c o mmunic a tio n ne twor k a nd pr e s e nts a mo difie d ve r s io n o f the g a me in Fe a r o n a nd L a itin (1 9 9 6).

T he Mo del

B e g in with two e thnic g r o ups , A a nd B , e a ch c o nta ining n a g e nts with n e ve n. Ag e nts in the mo de l p e r fo r m two a c tio ns : the y play g a me s , a nd the y g o s s ip ab o ut g a me s . Ag e nts play g a me s with o ne o the r a g e nt a t a time , a nd the ir o pp o ne nts a r e r a ndo mly de te r mine d e a ch p e r io d. With pr o ba bility p a n a g e nt is pa ir e d with a me mb e r r a ndo mly s e le c te d (with pr o ba bility 1 / (n - 1)) fr o m the o the r e thnic g r o up; with pr o ba bility 1 - p a n a g e nt is pa ir e d with a r a ndo mly s e le c te d (with pr o ba bility 1/ (n - 1)) me mb e r o f he r own e thnic g r o up. E a ch pa ir play s a s ing le r ound o f the pr is o ne r 's dile mma with c o mmo n payo ff ma tr ix

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< 1 . P laye r s have c o mmo n dis c o unt fa c to r d < 1. E a ch g a me b e twe e n playe r s r e pr e s e nts a r a ndo m me e ting a nd inte r a c tio n with the p o s s ibility o f de fe c ting . Inte r a c tio ns o f r o ug hly this s o r t o c c ur in ma ny ar e na s : b e twe e n buye r s a nd s e lle r s in a ma r ke t who may tr a de fa ir ly o r che a t, b e twe e n pa s s e r s - by o n a s tr e e t who may o ffe r ple a s a ntr ie s o r s ling ins ults , b e twe e n p e o ple s ha r ing a ba r o r c o nc e r t o r fe s tiva l who may to le r a te e a ch o the r 's pr e s e nc e o r thr ow a punch. In e a ch ins ta nc e , the de fe c tio n is like ly to b e g o s s ip- wo r thy : the che a te d tr a de r may wa r n fe llow tr a de r s . The v ic tim o f a fig ht at a fe s tiva l will s ha r e his a ng e r with fr ie nds . In a dditio n, ins ults a nd v io le nc e may b e public , s o de fe c tio ns will have wtine s s e s . If the de fe c tio n is s ig nific a nt e no ug h o r o c c ur s with e no ug h witne s s e s a nd the me a ns o f s pr e a ding g o s s ip a r e s u ffic ie ntly che a p a nd fa r - r e a ching , the n e ve r yo ne in a g r o up may have witne s s e d the de fe c tio n o r have r e c e ive d fir s t- ha nd g o s s ip. Howe ve r , it is e a s y to ima g ine s c e na r io s in which no t e ve r yo ne s e e s o r r e c e ive

s fir s t- ha nd info r ma tio n a b o ut de fe c tio ns . In la r g e , di ffus e , bus y, segmented or technology-poor societies, some may neither witness a particular defection nor hear about it from the victim.

[4]To model the spread of information about games, construct a "gossip network" g for ethnic group A. Let the nodes represent agents in $A = \{1, \ldots, n\}$, with links $ij \in g$ between agents $i = j \in A$ denoting channels of gossip. Information may flow through the gossip network g via the two linked nodes talking and revealing information, or via each linked node observing the other. If everyone in A gossiped with everyone else in A, the gossip network would contain every possible link and hence would be complete. If instead person i only hears about person k through person j and not directly from person k, the network would contain the link ij and the link jk but not the link ik. A gossip network can be constructed for ethnic group B as well. The gossip network is taken as an exogenous characteristic of the population and hence is fixed ex ante. I also assume the gossip network (that is, who gossips with whom) is common knowledge.

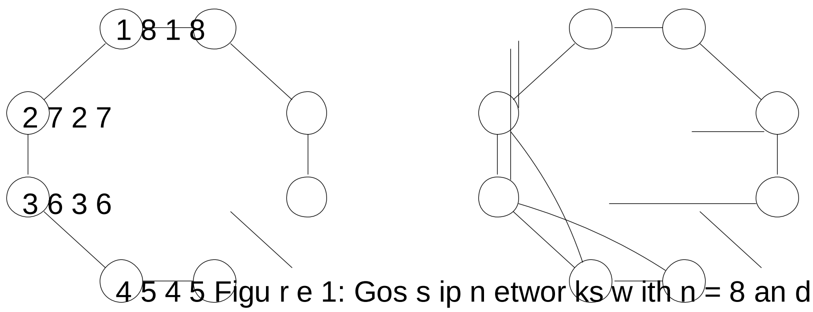
Following Fearon and Laitin (1996), members of one ethnic group can identify members of their own ethnic group but not members of the other ethnic group. When random assignment forms cross-group pairs to play prisoners' dilemma, the players simply know they are playing a member of the other group; they do not know which member. In keeping with this assumption, I will assume that players do not gossip with members of the other group. If sharing information connotes an act of intimacy or trust, it is reasonable that players would only be willing to share information with someone they can recognize, which rules out members of the other group. Hence, both A and B have gossip networks that are distinct. No links span the two groups.

[5]The gossip network for an ethnic group is complete if it contains every possible link: $ij \in g \; \forall i = j \in N$. Consider a simple class of incomplete gossip structures in which everyone gossips with the same number of people. Call that number r. Let the structure be such that agents in A can be arranged in a circle so that half of their gossip partners are the $r/2$ closest clockwise nodes and half of their gossip neighbors are the $r/2$ closest counter-clockwise nodes. Two such networks with $n = 8$, one with $r = 2$ and one with $r = 4$, are shown in Figure 1. When $r = 2$,

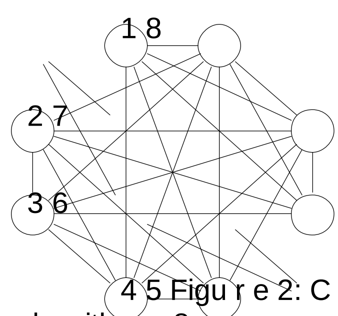
[4]For now, assume g is undirected and contains no loops.

[5]That is, the graphs are r-regular

6p e r s o n 1 g o s s ips with 2 p e o ple , p e r s o n 2 a nd p e r s o n 8 . Whe n r = 4 , p e r s o n 1 g o s s ips with 4 p e o ple , p e r s o n 2 , 3 , 8 a nd 7 .Fo r r e fe r e nc e , a c o mple te ne two r k in which e ve r yo ne g o s s ips with e ve r yo ne e ls e (which may a c c ur a te ly r e pr e s e nt the flow o f g o ss ip in s ma ll c o mmunitie s with a de ve lo p e d me cha nis m fo r s pr e a ding ne ws o r ve r y public a c tions) is s hown fo r n = 8 in Fig ur e 2 .



Figu r e 1: Gos s ip n etwor ks w ith n = 8 an d r = 2 (lef t), an d n = 8 an d r = 4 (r ight).



Figu r e 2: C om p lete gos s ip n etwor k w ith n = 8.

7In the mo de l, playe r s g o s s ip a b o ut the r e s ults o f the ir g a me s. In pa r tic ula r , the y s ha r e ne ws o f de fe c tio n. The g o s s ip ne two r k s p e c ifie s who le a r ns the r e s ults o f which g a me s ; if the g o s s ip ne two r k is inc o mple te , no t e ve r yo ne le a r ns a b o ut a ll g a me s in a g ive n p e r io d.In e a ch dis c r e te time p e r io d, playe r s play o ne r o und o f pr is o ne r s ' dile mma with the ir r a ndo mly - a s s ig ne d o pp o ne nt. At the e nd o f the p e r io d, playe r s te ll the ir ne ig hbo r s who playe d which a c tio n. Mo r e pr e c is e ly, in e a ch p e r io d:

1 . A r o s te r o f r a ndo m pa ir ing s is public ly a nno unc e d.

2 . Pa ir s play o ne r o und o f pr is o ne r s ' dile mma .

3 . P laye r s le a r n a b o ut the ir g o s s ip ne ig hb o r s ' g a me s .

6A lin k can b e u n d erst o o d as word - of- mou t h gossip or as ob servat ion . For ex amp le, t h e lin k b etween 1 an d 2 can mean t h at 1 t ells 2 in format ion an d t h at 2 t ells 1 in format ion, or it can mean t h at 1 ob serves 2 an d 2 ob serves 1.

7A gain , t o reint erp ret gossip in t erms of ob serv in g n eighb ors, t h e gossip n etwork sp ecifi es wh o ob serves wh ich games' act ion s an d ou t comes.

In step 3, players learn who played which action, and they also learn what information the two players knew about the punishment status of each other. More on this below.

Note that the gossip structure is fixed ex ante - who tells who about their games is fixed. However, players are randomly assigned opponents and part of their gossip pertains to their opponents. Therefore, even though in n = 8, r = 2 person 1 always learns about the games of players 2 and 8, 1 is also receiving information about other players at random since other players are randomly assigned to be the opponent in the games of players 2 and 8.

Sustaining Cooperation

When the gossip network is complete, everyone learns the results of every game in every period. Fearon and Laitin (1996) show that the efficient subgame perfect nash equilibria of this case rely on the threat of coordinated punishment. Either ethnic groups punish their own members who defect against the other ethnic group (the so-called "In-Group Policing equilibrium") or ethnic groups indiscriminately punish all members of the other ethnic group in the event of a single defection (the so-called "Spiral equilibrium"). Crucial to the sustainability of cooperation in these equilibria is the magnitude of expected punishment that a defector faces.

[8]When the gossip network is incomplete, punishment is less certain. Consider the in-group policing equilibrium. In-group members can only punish defectors among them if they know about the defection. If players are playing a strategy which punishes a defector for a single period, a player who defects in period t will only be punished if he happens to be assigned in t + 1 to the same player he played in t (his victim), or to one of his neighbors (who witnessed the defection) or to a neighbor of his victim (who witnessed or was told first-hand about the defection). If he is assigned to play anyone else in t + 1, he will not be punished because his opponent will not know he deserves to be punished. The total number of players eligible to punish him in t + 1 (victim + victim's neighbors + his neighbors) depends on the structure of the gossip network. With probability 1 - p, the defector will be assigned an in-group opponent at random in t + 1; the more neighbors he or his victim had, the greater the probability he will play someone in t + 1 who knows he deserves punishment.

[8]It follows that defections against in-group members are more likely to be punished than defections against out group members since an out-group victim does not gossip with other in-group members.

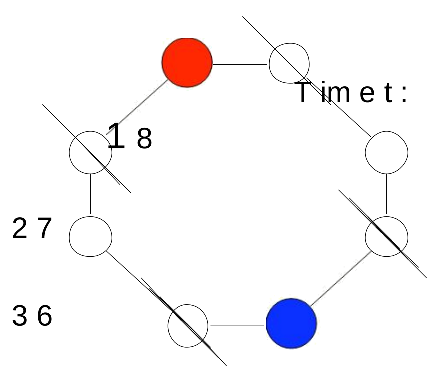
pB e fo r e de lv ing into the s ubtle tie s intr o duc e d by a n inc o mple te g o s s ip ne two r k , fir s t c o ns ide r the info r ma tio n tr a ns mitte d a lo ng the g o s s ip ne two r k in Fe ar o n a nd L a itin’s g a me , i.e . the c a s e in which the ne two r k is c o mple te . L e t T_pb e the numb e r o f r o unds in the punis hme nt pha s e o f the g a me . E a ch playe r le a r ns the r e s ults o f e ve r y g a me in e ve ry p e r io d a nd c a n r e me mb e r e ve r y r e s ult fo r the la s t T[9]r o unds s o tha t the y c a n a lway s punis h a r a ndo mly a s s ig ne d o ppo ne nt who de s e r ve s punis hme nt. O ne way to think a b o ut the info r ma tio n tha t playe r s r e c e ive a b o ut o the r playe r s is to think in te r ms o f a s e t o f “ de s e r ve d punis hme nt co unte r s .” Ima g ine tha t e a ch playe r ke e ps a s e t o f n - 1 de v ic e s tha t s to r e the numb e r o f r o unds le ft in a ny o the r playe r ’s punis hme nt pha s e which mus t b e ke pt by the ke e p e r o f the de v ic e s .pAs s ume the de v ic e s a r e g e ne r o us : the de fa ult dis play s a r e 0 . Tha t is , in the a bs e nc e o f e v ide nc e o f de fe c tio n, playe r s a s s ume o the r s a r e c o o p e r a to r s a nd do no t de s e r ve punis hme nt. E a ch playe r is r es p o ns ible fo r s e tting a nd r e s e tting his s e t o f c o unte r s , which he do e s whe n he le a r ns tha t s o me o ne ha s de fe c te d. Think o f this like a s e t o f wo r ld c lo ck s tha t mus t b e s e t by the c lo ck s ’ owne r in a wo r ld with e r r a tic day lig ht s av ing s r ule s tha t mus t b e le a r ne d by tr ave le r s o r tr ave le r s’ fr ie nds . Co unte r s s ho uld dis play 0 fo r a ll playe r s who have no t de fe c te d. Co unte r s s ho uld dis play $T_p$fo r a ny playe r s who de fe c te d la s t p e r io d. P laye r s who de fe c te d thr e e p e r io ds a g o s ho uld have c o unt T_p- 2 . E a ch playe r s e ts the ir c o unte r s a c c o r ding to info r ma tio n the y le a r n thro ug h the g o s s ip ne two r k , a nd in e a ch p e r io d the c o unts a uto ma tic a lly de c r e a s e by o ne . P laye r s who e x p e r ie nc e o r o bs e r ve de fe c tio ns s e t the ir dis play s a c c o r ding ly. If playe r i de fe c ts in t , his v ic tim, his ne ig hb o r s a nd his v ic tim’s ne ig hb o r s o bs e r ve / he a r a b o ut the de fe c tio n a nd s e t the ir punis hme nt c o unte r s fo r playe r i . Whe n the ne two r k is c o mple te , e ve r yo ne is b o th a ne ig hb o r o f the de fe c to r a nd a ne ig hb o r o f the v ic tim, s o e ve r yo ne (a nd he nc e the ne x t o pp o ne nt) will a lway s have a c c ur a te ly - s e t c o unte r s . P laye r s c o nditio n the ir punis hme nt o n the r e a ding s o f the ir s e t o f c o unte r s , s o s o me o ne de s e r v ing punis hme nt will b e punis he d in e ve r y r o und o f Twhe n the g o s s ip ne two r k is c o mple te .

pNow c o ns ide r a g o s s ip ne two r k which is inc o mple te . Whe n i de fe c ts , no t e ve r yo ne will s e t the ir c o unte r fo r i to T: s o me will le ave the c o unte r fo r i a t its pr e v io us va lue , p o s s ibly 0 . To ta ke a n e x a mple , c o ns ide r the g o s s ip ne two r k o n the le ft in Fig ur e 1 , the r e g ula r ne two r k with n = 8 a nd r = 2 . Supp o s e in time t , playe r 1 is r a ndo mly a s s ig ne d to play playe r 5 , a nd 1 de fe c ts fo r the fir s t time . Now his v ic tim (playe r 5), his ne ig hb o r s (playe r s 2 a nd 8) a nd his v ic tim’s

[9]O r, less imagin at ively, a p layer rememb ers a vect or of cou nts t h at corresp on d t o t h e nu mb er of rou n d s let in a p u n ish ment p h ase.

ne ig hb o r s (playe r s 4 a nd 6) a ll have a c c ur a te e p
ntr ie s o f T

Co ntinue the e x a mple to time t + 2 . If Tp



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in the ir playe r 1 c o unte r s . If playe r 1 is a s s ig ne d to a ny o f the s e five playe r s in p e r io d t + 1 , the y will c o ns ult the ir c o unte r a nd will k now e no ug h to punis h 1 . If ins te a d 1 is a s s ig ne d to play 3 o r 7 in t + 1 , the s e o pp o ne nts will no t have up da te d the c o unte r fo r playe r 1 , will s e e c o unt 0 , a nd he nc e will no t k now e no ug h to punis h 1 in t + 1 .

= 2 , the n 1 will b e r a ndo mly a s s ig ne d to a n o pp o ne nt who k nows e no ug h to punis h him if he is a s s ig ne d to play a nyo ne in the fir s t g r o up, playe r s 2 ,4 ,5 ,6 a nd 8 . Additio na l playe r s may k now e no ug h to punis h playe r 1 in t + 2 if the y witne s s e d o ne o f the playe r s in the k now punis hing playe r 1 in t + 1 . Fo r e x a mple , if in t , playe r 1 de fe c te d a g a ins t playe r 5 (s hown in Fig ur e 3), a nd if in t + 1 playe r 1 wa s a s s ig ne d to play 4 a nd 4 punis he d 1 (s hown in Fig ur e 4), the n 4 's ne ig hb or s witne s s e d the punis hme nt a nd up da te d the ir c o unte r s fo r playe r 1 a c c o r ding ly. If in t + 2 a ne ig hb o r o f playe r 4 , playe r 3 , is a s s ig ne d to play 1 , 3 now k nows e no ug h to punis h playe r 1 , e ve n if 3 didn't k now e no ug h to punis h playe r 1 in t + 1 . Sinc e playe r 7 wa s no t a ne ig hb o r to a pa r tic ipa nt in the g ame in which the o r ig ina l de fe c tio n o c c ur r e d no r a ne ig hb o r to a pa rtic ipa nt in a g a me in which punis hme nt o c c ur r e d, 7 s till do e s no t k now e no ug h to punis h 1 by the e nd o f t + 2 (s hown in Fig ur e 5).

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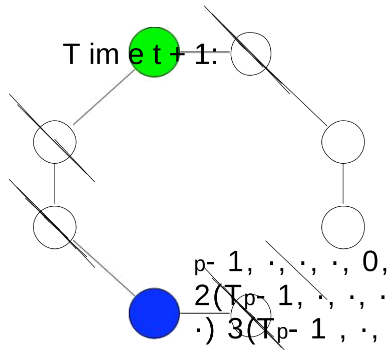
Figu r e 3: I n tim e t , 1 (w h o h as n ever p r eviou s ly d ef ected) is r an d om ly as s ign ed to p lay 5 (w h o h as n ever p r eviou s ly d ef ected); s u p p os e 1 d ef ects (r ed) an d 5 co op er ates (b lu e). 2,8,4 an d 6 als o lear n th is an d u p d ate th e p layer 1 s lot of th eir cou nter s to s h ow Tr ou n d s lef t in p layer 1's p u n is h m ent p h as e.

T im e t + 1:



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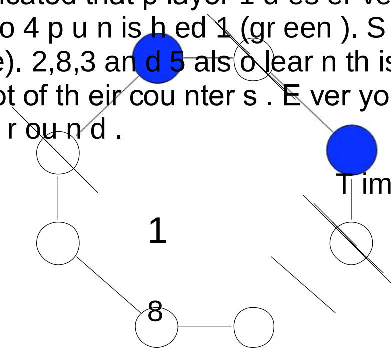
2 7
1 (T p

3 6
4 5

p- 1, ·, ·, ·, 0, ·, ·, ·) 2(Tp- 1, ·, ·, ·, 0, ·, ·, ·) 3(Tp- 1 , ·, ·, ·, 0, ·, ·, ·) 4(Tp- 1, ·, ·, ·, 0, ·, ·, ·) 5(Tp- 1, ·, ·, ·, 0, ·, ·, ·) 6(Tp- 1, ·, ·, ·, 0, ·, ·, ·) 7 (0, ·, ·, ·, 0, ·, ·, ·) 8(T- 1, ·, ·, ·, 0, ·, ·, ·)

pFigu r e 4: I n tim e t + 1, 1 is r an d om ly as s ign ed to p lay 4. 4's cou nter in d icated that p layer 1 d es er ved Tr ou n d s of p u n is h m ent, s o 4 p u n is h ed 1 (gr een). S u p p os e 1 co op er ated (b lu e). 2,8,3 an d 5 als o lear n th is an d u p d ate th e p layer 1 s lot of th eir cou nter s . E ver yon e's cou nter r ed u ces by on e r ou n d .



T im e t + 2:

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4 5

- 2, ·, ·, ·, 0, ·, ·, ·) 2(Tp- 2, ·, ·, ·, 0, ·, ·, ·) 3(Tp- 2, ·, ·, ·, 0, ·, ·, ·) 4(Tp- 2, ·, ·, ·, 0, ·, ·, ·) 5(Tp- 2, ·, ·, ·, 0, ·, ·, ·) 6(Tp- 2, ·, ·, ·, 0, ·, ·, ·) 7 (0, ·, ·, ·, 0, ·, ·, ·) 8(T- 2, ·, ·, ·, 0, ·, ·, ·)

Figure 5: In time t + 2, 1 is randomly assigned to play 7. 7's counter indicated that player 1 deserved 0 rounds of punishment, so 7 failed to punish 1 (blue). Suppose 1 cooperated (blue). 2,8 and 6 also observe the game. Everyone's counter reduces by one round.

To preview some comparative statics, notice that holding the number of neighbors constant, the number of people who remain uninformed about a defection and hence the probability that a player will have a free round of cooperation when he should have been punished, is increasing in the size of the network. Likewise, holding the size of the network constant, the probability that a player will have a free round of cooperation instead of deserved punishment is decreasing in degree. Finally, the probability that a defector will be punished in the subsequent round is

[10]hig he r if his de fe c tio n wa s a g a ins t a n in- g r o up me mb e r tha n ag a ins t a n o ut- g r o up me mb e r .

C o op er at ive E quilibr ia

Whe n the g o s s ip ne two r k is inc o mple te , playe r s may b e unc e r ta in a b o ut whe the r the ir o pp o ne nt de s e r ve s punis hme nt. He nc e , the ir payo ffs may de p e nd o n uno bs e r ve d info r ma tio n. Howe ve r , b o th the g o s s ip ne two r k a nd the r o s te r o f who is a s s ig ne d to play who m e a ch p e r io d a r e c o mmo n k nowle dg e . B y c o nditio ning s tr a te g ie s o n info r ma tio n in the ne two r k s tr uc tur e a nd r o s te r o f pa ir ing s , playe r s ' s tr a te g ie s de p e nd o nly o n o bs e r ve d a c tio ns . Co ns ide r the fo llowing s y mme tr ic s tr a te g y :

Al l i ndi vi dual s fo l l ow the s trate g y $s_{pig\ pn}$, de fine d as fo l l ow s . Pl ay C i n al l o utg ro up pai ri ng s . Fo r i n- g ro up pai ri ng s , i f b o th pl aye rs have re ce i ve d any i nfo rm ati o n ab o ut e ach o the r i n the l as t T_pp e ri o ds , al ways pl ay C w i th any partne r no t know n to b e i n puni s hm e nt phas e , and al ways pl ay D ag ai ns t any partne r know n to b e i n puni s hm e nt phas e re g ardl e s s o f ow n s tatus . A pl aye r e nte rs (o r re s tarts) the puni s hm e nt phas e fo r T_p e ri o ds by de fe cti ng w he n pai re d w i th an o ut- g ro up m e mb e r o r a co e thni c w ho i s no t i n puni s hm e nt phas e . If e i the r pl aye r has no t re ce i ve d any i nfo rm ati o n ab o ut the o the r, b o th pl aye rs pl ay C re g ardl e s s o f ow n s tatus .

[p]This s tr a te g y c a n b e s a id to b e a c o ur te o us a nd c a utio us in- g ro up punis hme nt s tr a te g y. The s tr a te g y is c a utio us b e c a us e playe r i will o nly punis h playe r j if i is c e r ta in j is a de fe c to r , a nd e r r s o n the s ide o f c o o p e r a tio n. The s tr a te g y is c o ur te o us b ec a us e punis hme nt is o nly p o s s ible in the e ve nt tha t b o th playe r s have r e c e ive d a ny info r ma tio n a b o ut the o the r . This me a ns tha t if i k nows j de s e r ve s punis hme nt but j ha s r e c e ive d no info r ma tio n a b o ut i , i do e s no t punis h j . i c a n o nly punis h j if i k nows j de s e r ve s punis hme nt an d if j ha s r e c e ive d s o me pie c e o f info r ma tio n a b o ut i in the la s t T_p e r io ds . Re fr a ining fr o m punis hing a k nown de fe c to r whe n tha t de fe c to r k nows no info r ma tio n a b o ut yo u c a n b e tho ug ht of a s c o ur te o us ly r e fr a ining fr o m s o me thing like a " s ucke r punch" o r " che a p s ho t" : punis hme nt c a n o nly b e inflic te d o n tho s e who ha d a n o pp o r tunity to de te r mine if yo u de s e r ve punis hme nt to o . Anyo ne who ha s le a r ne d

[10]N eighb ors of t h e d efect or and of t h e v ict im can sp read n ews of t h e d efect ion ; wh en t h e v ict im b elon gs t o t h e ot h er et h n ic grou p , t h e v ict im can n ot sp read in format ion t o memb ers of t h e d efect or's et h n ic grou p .

no information about you cannot know if you deserve to be punished.

If the gossip network is complete, $s_{ig\,pn}$ collapses to the in-group policing strategy in Fearon and Laitin (1996). When the gossip network is incomplete, the amount of punishment is attenuated by two factors. One, as discussed above, some players may not learn about a defection at all or in time to punish, so opportunities to play D against someone deserving punishment may be missed. Two, it could be that a player who deserves punishment will be matched with an opponent who knows she deserves punishment but she has received no information about her prospective punisher. In this case, the prospective punisher refrains from taking what could be considered a cheap shot. Hence, we would expect punishment to be more difficult to sustain in equilibrium when the gossip network is incomplete.

Because the game is an infinite multi-stage game, and because all actions on which strategies are conditioned are observed, conditions under which $s_{ig\,pn}$[11] is subgame perfect can be found using the one-stage deviation principle (Fudenberg and Tirole, 1991). Appendix 1 shows that $s_{ig\,pn}$ is a subgame perfect equilibrium of the game if and only if

$$d_{T_p} = \max \left(2a - 1 (1 - p) Q z_{p\,out\,T} (\beta + 1), \; 2\beta (1 - p) Q z_{in\,T_p} (\beta + 1) \right)$$

and

$$p < \max \left(Q 2 z_{in\,T_p} 2 (1 + \beta) - \beta Q z_{in\,T_p} (1 + \beta), \; Q 2 z_{p\,out\,T} 2 (1 + \beta) - a + 1 Q z_{p\,out\,T} (1 + \beta) \right)$$

with probability $z_{p\,out\,T}$ that a player's defection against an out-group member will be known T_p periods after the defection occurs, probability $z_{in\,T_p}$ that a player's defection against an in-group memb[…] after the defection occurs, and probability Q that a pla[…] mation about any randomly selected other player in […]

Q_2[13] is the probability that both a player and her opponent have received information about each other. i has received information about j […] hbor of i, if j has played a neighbor of i, if j has played […] hbor of i, if j has played someone

Even though not all actions are observed when the gossip networ[…] condition their actions on is observed.

[12] See Appendix 1 for the proof that these conditions are necessa[…] ion.

[13] For the class of regular graphs, Q_i = Q for all players. Regularity ensures symmetry.

$_p$who playe d s o me o ne who playe d a ne ig hb o r o f i , a nd s o o n. No te tha t e ve n if i ha s r e c e ive d s o me info r ma tio n a b o ut j fr o m within the pa s t T_pp e r io ds a nd j de fe c te d s o me time within the la s t T_2p e r io ds , i may no t k now tha t j is a de fe c to r . It c o uld b e tha t i o bs e r ve d a r o und in which j 's o pp o ne nt did no t k now j de s e r ve d punis hme nt, s o i 's o bs e r va tio n o f tha t g a me wo uld no t r e ve a l tha t j de s e r ve d punis hme nt. This wa s the c a s e with playe r 7 in the e xa mple a b ove , who play s 1 in t + 2 a nd s o ha s r e c e ive d s o me info r ma tio n a b o ut playe r 1 by t + 3 . 1 a nd 7 k now e no ug h a b o ut e a ch o the r to b e a llowe d to punis h e a ch o ther witho ut punis hme nt b e ing c o ns ide r e d a che a p s ho t. Howe ve r , e ve n tho ug h 7 is a llowe d to punis h, he do e s n't have e no ug h info r ma tio n to k now 1 de s e r ve s punis hme nt a s o f t + 3 . In o the r wo r ds , Qg ove r ns whe the r playe r s a r e a llowe d to c o ns ide r punis hme nt, a nd z g ove r ns whe the r playe r s will b e c a pa ble o f punis hing (i.e . if the ir c o unte r s c o nta in a c c ur a te info r matio n r e g a r ding punis hme nt s ta tus).

1 = z_{in}

5 T_p

D isc ussion

F

ir s t, no te tha t fo r the s p e c ia l c a s e o f a c o mple te g o s s ip ne two r'k , Q = z_po ut T

= 1 , a nd a s e x p e c te d, the c o nditi
6). Ne x t, c o ns ide r the c la s s o f r -
Ho lding a ll e ls e c o ns ta nt, inc r e a
t o pp o ne nts k now so me thing a b o
, b o th a g a ins t in- g r o up a nd a g a
e a te r the de g r e e o f a r e g ula r ne
e r a tio n in e q uilibr ium a nd s o the m
ult is no t to o s ur pr is ing , a nd s q ua
a itin (1 9 9 6). Co o p e r a tio n is e a s
tio n tr avels mo r e wide ly a nd q uick l
Ne x t, c o ns ide r the p o pula tio n s iz
s b o th the pr o ba bility tha t playe r s a
playe r s a r e c a pa ble o f punis hing .
the s o ur c e o f a lot o f info r ma tio n:
pa ir e d with a no de a nd his ne ig hb o
o ut who m he k nows s o me thing a no
ut a de fe c tio n. A la r g e r p o pula tio
pula tio n a b o ut who m info r ma tio n
c r e as e s the pr o ba bility tha t playe
p e r a tive e q uilibr ium is e a s ie r to s

[14]population. Fearon and Laitin (1996) draw the opposite conclusion. They argue that smaller groups may have a higher rate of interethnic pairings (higher p), which can undermine the force of in-group sanctions and create need for border policing. My claim is that this overlooks the potentially off-setting benefit of group cohesion that small groups tend to enjoy. Ethnic groups with small populations are more likely to have dense gossip structures.[15]People in a population of 100 are more likely to be kept abreast of who is doing what than people in a population of 1,000,000. The cohesiveness of small groups may allow them to more easily sustain cooperation with in-group policing than larger groups with more sparse communication.

[16]Given the possible relationship between group size and cohesiveness, this model may also shed light on when groups are more likely to be welcoming to new members and when they are likely to be insular. Consider a small group with a relatively dense gossip network. This small group's ability to threaten coordinated punishment and prevent conflict relies on the density of the network. Suppose the group has 20 members, and each gossips with 10 other members. The addition of a 21st member who initially gossips with few others may significantly damage the group's ability to sustain cooperation. The effect of an additional member with few contacts on a group of size 100, even if everyone in this large group also gossips with 10 other members, is much smaller. Small groups may have a greater incentive to be insular and exclude new members.

These findings square with a set of experimental results examining the role of caste status on willingness to punish norm violators in India (Hoff and Fehr, 2010). The authors find that members of high castes are more willing to punish members of their own caste when they defect against fellow high caste members than are members of low castes, and that members of high castes are more willing to punish members of low castes when low caste members defect against high castes. If high castes are smaller and more cohesive (which appears to be the case), then high castes with their denser gossip networks have experienced greater benefit to punishing than low castes have. Also, Hoff and Fehr (2010) find that members of particular high castes are more

[14]Varshney (2003) makes this argument in contrast in grural and urban environments: urban environments tend to have larger populations, which would require a geometrically increasing number of links in the gossip network to be complete.
[15]The effect of group size on punishment strategies may explain the experimental results in Hoff and Fehr (2010). See below for further discussion.
[16]Ethnic groups vary in the rules they use to ascribe kinship and in the norms governing treatment of visitors. An interesting research project would explore whether this variance can be explained by group size or cohesion.

e x c lus ive a b o ut the b e ne fic ia r ie s o f the ir punis hme nt: the y a r e le s s like ly to punis h o n b e ha lf o f o the r pa r tic ula r hig h c a s te s . This te nde nc y to b e e x c lus ive may b e a na tur a l c o ns e q ue nc e o f le a r ning the va lue o f a s ma ll, we ll- inte g r a te d g r o up.

Ne x t, c o ns ide r the le ng th o f the punis hme nt pha s e , T_{pp}. Whe n the g o s s ip ne two r k is c o mple te , the r ig ht ha nd s ide o f the c o nditio n is inde p e nde nt o f T. Sinc e d$T_{pp}$is de c r e a s ing in T, if the r e e x is ts a s ubg a me p e r fe c t e q uilibr ium, it will ho ld fo r T_{pp}= 1 , a s ing le r o und o f punis hme nt fo r e a c h de fe c tio n. Whe n the g o s s ip ne two r k is not c o mple te , the r o le o f $T_p$is mo r e c o mplic a te d. The pr o ba bility tha t a n o pp o ne nt in t + T_pk nows a b o ut a de fe c tio n a g a ins t a n ino r o ut- g r o up me mb e r in t is we a k ly inc r e a s ing in T_p. Sinc e Q is the pr o ba bility tha t a playe r k nows s o me thing a b o ut a no the r playe r fr o m the pa s t Tp e r io ds , Q is a ls o inc r e a s ing in T_{pp}. Whe the r the c o nditio n ho lds fo r s ma ll Tde p e nds o n whe the r $Q^2 Z_p$o ut Tor $Q^2 Z$in T_pb e c o me s to o s ma ll.

$_p$A mo r e inte r e s ting r e la tio ns hip b e twe e n the s us ta ina bility o f c o o p e r a tio n a nd the le ng th o f the punis hme nt pha s e , T_pe x is ts fo r e a r ly p e r io ds o f the g a me . B e c a us e Q is ba ck wa r d- lo o k ing , Q de p e nds o n t fo r t < T_pa nd c a n intr o duc e c ur io us b e g inning - o f- g a me e ffe c ts . Q ta ke s its minimum in r o und t = 0 , inc r e a s e s thr o ug h t = Ta nd ho lds this va lue fo r t > T_{pp}. Fo r s ma ll t , Q may b e to o s ma ll to s us ta in c o o p e r a tio n. Se tting Tla r g e e no ug h e ns ur e s tha t Q e ve ntua lly b e c o me s la r g e e no ug h to s us ta in c o o p e r a tio n. This o p e ns up the p o s s ibility o f a s e t o f pa r a me te r s s uch tha t in e q uilibr ium, playe r s de fe c t in the fir s t fe w r o unds a nd the n s witch to full c o o p e r a tio n. Fur the r inve s tig a tio n he r e c o uld b e inte r e s ting , e s p e c ia lly s inc e this c o uld s he d lig ht o n why s o me g r o ups ‘r e la ps e ’ into fig hting : it c o uld b e tha t a n e x o g e no us s ho ck r e s e ts the g a me in s o me way, a nd s e tting t = 0 move s the e q uilibr ium ba ck into a ll de fe c tio n fo r a fe w p e r io ds .

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