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The Geography of Ethnocentrism

Andrew W. Bausch[1]

Abstract

Hammond and Axelrod use an evolutionary agent-based model to explore the development of ethnocentrism. They argue that local interactions permit groups, relying on in-group favoritism, to overcome the Nash equilibrium of the prisoner's dilemma and sustain in-group cooperation. This article shows that higher levels of cooperation evolve when groups are dropped from the model, breaking the link between ethnocentrism and cooperation. This article then generalizes Hammond and Axelrod's model by parameterizing the underlying geographical assumptions they make about the evolutionary environment. This more general model shows that their findings are sensitive to these assumptions and that small changes to the assumed geography of reproduction significantly affect the probabilities of finding "ethnocentric" behaviors. The model presented here indicates that it is not local interactions, per se, but settings where interactions are highly likely to be with close relatives that lead to "ethnocentrism" as modeled by Hammond and Axelrod.

Keywords

prisoner's dilemma, ethnocentrism, agent-based models, evolutionary models, contingent cooperation

Hammond and Axelrod (2006; hereinafter HA) present an agent-based model to show how ethnocentrism can develop in a system in which multiple groups structure social interaction and find that in-group favoritism can support high levels of

[1] Department of Social and Decision Sciences, Carnegie Mellon University, Pittsburgh, PA, USA

Corresponding Author:
Andrew W. Bausch, Department of Social and Decision Sciences, Carnegie Mellon University, Pittsburgh, PA, USA.
Email: bausch@nyu.edu

cooperation. Their model is based on local interactions that give rise to behaviors in which agents tend to act cooperatively toward members of their own group but do not cooperate with members of other groups. They argue that this differentiation between an agent's group and the out-group allows within-group interactions to overcome the Nash Equilibrium of the prisoner's dilemma (PD), as group members tend to behave cooperatively toward each other. HA call this in-group favoritism "ethnocentrism."

HA build their definition of ethnocentrism off of the work of LeVine and Campbell (1972), who stress cooperation in in-group interactions and the lack of cooperation in out-group interactions. Likewise, Bizumic and Duckitt's (2012) conceptualization of ethnocentrism stresses a sense of ethnic group self-centeredness, including a preference for an individual's own group. A within-group preference that makes co-ethnics more likely to cooperate is a common theme in discussions of ethnocentrism (LeVine and Campbell 1972; Taylor and Jaggi 1974; Peres and Schrift 1978; Berry and Kalin 1995). Habyarimana et al. (2007) argue that cooperation between co-ethnics is likely due to in-group reciprocity norms and the ease of finding and sanctioning noncooperative group members.

Habyarimana et al.'s (2007) emphasis on identification and sanctioning coincides with the results of several reputation based-models of social cooperation (Nowak and Sigmund 1998, 2005; Mohtashemi and Muri 2003). These reputation-based models rely on memories of which agents have defected in the past to punish cheaters, selecting cheaters out of the population and creating long-term advantages for agents willing to cooperate. Similarly, Fearon and Laitin (1996) use a game-theoretic approach to show how reputation and the fear of punishment can sustain in-group cooperation in a one-shot PD, while group reputation and in-group policing of out-group defections can maintain interethnic cooperation. Building on that model, Nakao (2009) argues that the success of interethnic cooperation hinges on the ability of groups to monitor and punish wrongdoers within their own group.

In contrast, the HA model is "history free" in that current interactions are not conditioned on the past actions of agents, which are not even remembered. The advantage of HA's approach is that they make minimal assumptions about agents' cognitive abilities and agents are endowed with bounded, rather than perfect, rationality. HA argue that local interactions and agents' abilities to distinguish between groups are enough to generate widespread ethnocentric behavior. However, HA's model is evolutionary and their reproduction mechanism, in which children locate next to their parents, creates neighborhoods of interaction that are not merely ethnically homogeneous but primary made up of close relatives. In effect, most interactions are within an agent's "radius of particularized trust," or the subset of a person's ethnic group, in particular family members, within which high levels of trust are expected (Fukuyama 2000; Bahry et al. 2005). In an evolutionary system, neighborhoods where trust is high and exploitation is low allow cooperation to develop, as the strategies of agents in those neighborhoods begin to spread. For example, Macy and Skvoretz (1998) show that the less often agents interact with strangers in a series of one-shot PD, the more likely cooperation is to emerge in a system. Meanwhile, Janssen (2008) demonstrates that when agents are given the ability to learn to recognize trustworthy partners, cooperation evolves and is maintained in the system. Thus, frequent interactions among close relatives, where particularized trust is high, should lead to high levels of cooperation.

HA use a restrictive definition of local interaction and a narrow assumption with regard to children placement, preventing their model from supporting their claim that ethnocentrism enhances cooperation. Because most interactions are with close relatives, what appears to be cooperation emerging through ethnocentric behavior may be simply cooperation among family members (or genetic clones). Therefore, the model's geographic assumptions may be driving cooperation, regardless of ethnic groupings. In fact, spatially structured interactions with no group differentiation have been previously shown to promote cooperation (Nowak and May, 1992, 1993; Nowak, Bonhoeffer, and May 1994; Killingback, Doebeli, and Knowlton 1999; Ifti, Killingback, and Doebeli 2004; Doebeli and Hauert 2005). Spatial structure allows cooperating agents to meet more often than by chance, which appears to be the key to sustaining cooperation in a population (Grafen 1985; Doebeli and Hauert 2005; Hruschka and Henrich 2006; Németh and Takács 2007). Using a similar model to HA, Axelrod, Hammond, and Grafen (2004) find that some spatial structuring of interactions is necessary for in-group cooperation to occur, although they do not rigorously examine the entire parameter space of their model.

Despite the importance of the spatial structure to their argument, HA do not parameterize the geography of their model and use the most restrictive definition possible of local interaction. This calls into question the robustness of their findings, since it may be that the extremely local interactions they specify are influencing their results. Furthermore, HA's tight reproduction assumption in which children locate immediately adjacent to their parents may also drive their results. Again, HA neither parametrize the placement of children in the model nor discuss its possible implications for their results.

In this article, I generalize the HA model by examining the geographies of both social interaction and reproduction. I show that HA's key results can be generated even when there are no ethnic groups in the model, demonstrating that geography rather than group identity is producing the high levels of cooperation they find. In addition, I parameterize the distance over which the agents interact and the distance children locate from their parents. The HA "ethnocentrism" finding is robust when interactions follow a power-law distribution in which most interactions are local but some are not. However, I show the HA findings are not robust to changes in assumptions about where children locate in relation to their parents. In short, generalizing the very specific geographic assumptions built into HA's agent-based model reveals that these assumptions are critical to their key substantive results about ethnocentrism.

This article attempts to make both a substantive and a conceptual contribution. Substantively, I argue that it is not local interactions, per se, that lead to ethnocentrism but settings where interactions are likely to be with closely related co-ethnics

Table 1. Payoff Matrix.

	C	D
C	2, 2	−1, 3
D	3, −1	0, 0

that lead to ethnocentrism. Conceptually, I show how assumptions about interactions and reproduction, that is, a model's geography, can drive cooperation.

Model

A full description of the agent-based model of ethnocentric social interaction can be found in HA. Here, I summarize the main components of their model and then discuss how I generalize the model by parameterizing key assumptions. Each agent occupies a cell in a 50×50 toroidal grid and may have up to four other agents in their Von Neumann neighborhood, with whom they interact in a PD game.[1] Each agent also has a "probability to reproduce" (PTR) and three traits. The PTR is the key endogenous parameter of the evolutionary model and is updated based on the outcome of the PD games each round. The first trait specifies an agent's group identity. The second trait specifies whether the agent cooperates or defects when meeting another agent of its own group, while the third specifies whether the agent cooperates or defects when meeting an agent of a different group. HA interpret an agent who cooperates with its own group but defects with the other groups as being ethnocentric.

The core game of the model is a PD. Each round, agents are paired with all of the other agents in their Von Neumann neighborhood and play either cooperate (C) or defect (D) according to their strategy. The payoffs of the game are listed in Table 1.

The payoffs from the game are added to the agent's PTR that is reset at the beginning of each period of the model. Each period of the model consists of four phases: immigration, interaction, reproduction, and death.

In the *immigration* phase, an agent with random traits enters at a random empty site, if there is one. The model begins with all sites empty. In the *interaction* phase, each agent interacts with its neighbors in a one-move PD game and its PTR is updated according to the outcome of the game. In the *reproduction* phase, agents are selected in random order and given the chance to reproduce with probability equal to their updated PTR. If selected for reproduction, the agent creates a clone of itself with respect to the three traits discussed previously. However, there is a small probability that mutation can occur through which one or more of the child's traits is different from its parents'. The child is then placed in an empty cell in the Von Neumann neighborhood of the parent, if there is one; if there is no such empty cell, a child cannot be born. Finally, agents have a probability of dying randomly with a probability unconnected to the individual agent's PTR.

A key feature of the HA model is thus that both the interaction and the reproduction phase involve strong geographic assumptions. I start by addressing the reproduction phase since the issues are more straightforward. Allowing the "child" to be placed only in the Von Neumann neighborhood of the reproducing agent is problematic. The substantive motivation behind this assumption is that children stay close to their parents, allowing local clans, and consequently ethnocentric behavior, to emerge. However, placing children only within their parents' Von Neumann neighborhood is the most restrictive assumption possible about where children live in relation to their parents.[2] Furthermore, this assumption creates a system in which agents are primarily interacting with clones of themselves, identical in both ethnicity and strategy for playing the PD game. This setup leaves us unable to determine if it is group identity that is driving cooperation or if cooperation would still emerge if the group trait was dropped from the model and players simply played with close relatives with typically identical strategies. In the following, I examine whether cooperation in the model is the result of the spatial structuring of clones by running the model with the group trait removed.

In addition, I address this problem of the clustering of agents of identical strategy by respecifying and parameterizing the model to assume that children may locate at any random empty site within an exogenously specified Euclidean distance from the parent, which I label *child-distance*. By parameterizing this distance, I can determine whether ethnocentrism arises purely due to local interactions, as argued by HA, due to local reproduction, or whether both are necessary. Using a specified cutoff point for the distance a child can be placed from the parent keeps the model proposed in this article nearly identical to the HA model, which can be nested within my model by setting *child-distance* at 1 in the computer simulation.

However, specifying a sharp cutoff point is an unnecessarily restrictive modeling assumption. If a child can easily locate at a Euclidean distance of three from the parent, for example, it is unclear that why this distance could never be 3.1. To address this concern, I respecify the model with the more realistic assumption that child-distance is a random draw from a power-law distribution. The child then locates at a random empty site within this distance. By using a power law, I can bias the *child-distance* to be close to one, capturing the Von Neumann neighborhood, but also allow the possibility that a child will be placed farther away without arbitrarily defining a boundary.[3]

The immediate effect of increasing *child-distance* should be to lessen geographically concentrated group propagation, breaking down the neighborhoods of perfect clones that form in the original model. This allows us to distinguish between ethnocentrism per se, and ethnocentrism as modeled by HA, which involves an intense geographic segregation of agents with similar strategies and groups. As Read (2010) argues, once agents are no longer primarily interacting with clones of themselves, we expect cooperation in the system as a whole to fall. As *child-distance* increases, the percentage of out-group interactions increases as well because agents from different groups can locate next to each other more easily. In out-group interactions, there is no mechanism that promotes mutual cooperation and so agents who cooperate will be exploited. Most out-group interactions should then result in defect–defect outcomes, lowering the overall level of cooperation in the system.

Furthermore, even in interactions with coethnics, cooperation is likely to decrease as *child-distance* increases because agents become more likely to locate next to a member of the same group that is not a genetic clone. If their second trait, which specifies whether an agent cooperates or defects when meeting another agent of its own group, differs, the agent who cooperates will be exploited by the agent who defects. Previously, agents playing the ethnocentric strategy were highly likely to locate in neighborhoods where they only interacted with genetic clones that were, therefore, also of the same group and ethnocentric. Now, however, an increased *child-distance* increases the probability an ethnocentric agent interacts with a member of the same group playing the Nash Equilibrium strategy. In the original model, an ethnocentric agent might encounter an agent playing the Nash Equilibrium through random mutation or immigration. Cooperation with the ethnocentric agent's other neighbors would allow it to recover the loss incurred by being exploited by only one neighbor. With an increased *child-distance* separating clones from themselves, ethnocentric agents are less likely to play with their children or other close relatives, and therefore less likely, ceteris paribus, to meet neighbors from the same group who are also ethnocentric. These coethnics fall outside of an agent's radius of particularized trust, meaning they are just likely as non-co-ethnics to defect in the PD game. In the long run, this creates an advantage for agents playing the Nash Equilibrium of unconditional defection that, in effect, exploits ethnocentrics of their own group.

Thus, with an increased percentage of out-group interactions and in-group cooperation more difficult to sustain, I hypothesize that as *child-distance* increases, both cooperation in general and ethnocentrism in particular should decrease.

In the interaction phase of the HA model, each agent only interacts within its Von Neumann neighborhood, which is the narrowest possible definition of local interaction. This restricted area of interaction for agents biases the model in favor of cooperation in areas where two ethnic groups border each other geographically. In such places, agents that are on the border interact with non-co-ethnics. However, agents slightly inside the border are likely to never meet a non-co-ethnic despite their proximity. Thus, the HA assumptions about the distance over which interactions occur create an artificially rigid border that decreases out-group interactions, inflating the level of cooperation in the system. Furthermore, the HA assumption about interactions also prevents nearby groups of co-ethnics with different PD strategies from meeting. Because Nash Equilibrium players exploit ethnocentrics, this assumption may bias the HA findings in favor of ethnocentrism.

To generalize and parameterize HA model assumptions about the geography of social interactions, I specify assumptions equivalent to those concerning the geography of birth locations. First, rather than having agents interact only in their Von Neumann neighborhood, I allow them to interact with a randomly selected agent within an exogenously given radius that I term the *interact-distance*. Alternatively, before each interaction, agents randomly select an *interact-distance* from a power-law distribution and then interact with a randomly selected agent within that distance. Again, using a power law allows me to make local interactions more probable while nonetheless allowing longer distance interactions to occur. Moreover, Gonzalez, Hidalgo, and Barabasi (2008) argue that the best fit to empirically observed patterns on human mobility is given by a power law, providing further support for the assumption that the geography of human social interactions follows a power law.[4]

Using random interactions inside a set distance requires a nontrivial revision of the original HA model. In the original model, partners for interaction are chosen deterministically. Each agent interacts with all other agents in its Von Neumann neighborhood each round. Introducing a larger neighborhood renders unrealistic the HA assumption that all agents interact with all neighbors every period. For this reason, I generalize the model to make interactions probabilistic, with the assumption that each agent selects one random partner for interaction each period. Thus, agents are guaranteed one interaction each period, provided there is an agent within *interact-distance*. When agents are densely clustered, each will be selected for interaction by another agent once on average. Thus, on average, each agent participates in two PD games each period. This is different from the HA model, where, in densely populated areas, agents play four PD games each period. Clearly, the assumption about how many interactions in a given period an agent participates in makes explicit an otherwise implicit assumption about the calibration of periods in the model to real time. As discussed later, I address this matter by running the model for more periods when testing the effect of an expanded *interact-distance* on the development of ethnocentrism.[5]

Conditional on forcing children to locate within their parents' Von Neumann neighborhood as in the original model, increasing *interact-distance* will gradually increase the percentage of interactions outside of an agent's ethnic group. This changing pattern of interactions should lower overall levels of cooperation, as agents increasingly interact with non-co-ethnics. Furthermore, ethnocentric agents will interact more frequently with members of their own group that are not close relatives. Because increasing *interact-distance* weakens the ability of ethnically homogeneous neighborhoods to promote in-group cooperation, agents playing the Nash Equilibrium strategy can exploit ethnocentric agents of their own group until they dominate the system. Thus, consistent with the argument of HA, I hypothesize that as *interact-distance* increases, cooperation and ethnocentrism should decrease.

While increasing either *child-distance* or *interact-distance*, holding the other constant at its value in the original HA model, should lead to decreases in cooperation and ethnocentrism, there are potential interaction effects. Increasing *child-distance* should always lead to less dense groupings of clones and, in turn, lead to less cooperation and ethnocentrism. Regardless of the level at which *interact-distance* is fixed, increasing *child-distance* will result in less cooperation due to more out-group interactions and less ethnocentrism due to more interactions between agents of the same group that are not clones. As hypothesized previously, these dynamics favor the Nash Equilibrium, so cooperation and ethnocentrism will decrease. Likewise, when allowing children to locate at a distance from their parent, increasing *interact-distance* should further decrease the frequency with which cloned agents interact. This mechanism again should favor agents playing the Nash Equilibrium strategy and decrease cooperation and ethnocentrism. Thus, when increasing *child-distance* and *interact-distance* at the same time, the effects should reinforce each other and further decrease cooperation and ethnocentrism.

Having reviewed HA's model and discussed my generalization, extension, and related hypotheses, I now discuss the computational methods used to explore the differences between the models.

Methodology

Because the evolutionary dynamics make the model intractable analytically, HA use an agent-based simulation technique. Wilensky (1999, 2003) has previously implemented the HA model in NetLogo and I build on his code.[6] After re-coding the model to specify *child-distance* and *interact-distance* as described previously, I first attempt to retrieve the original HA findings, as discussed in online Appendix A. Overall, the results suggest the original HA model is well captured by the re-coded versions.

To test whether it is group identity per se that is driving cooperation, or whether cooperation is the result of the spatial clustering of agent types generated by the reproduction mechanism, I drop the group trait from the model and run it without any ethnic groups.[7] I compare the mean level of cooperation of these runs with no groups to the results from the original HA model, which has four groups.

Having examined the effect of removing the group trait from the model, I evaluate the effect of the key new model parameters, *child-distance* and interact-distance.[8] I begin by keeping interactions in the Von Neumann neighborhood while varying *child-distance*. Each time an agent reproduces, it draws a unique child-distance from the power-law distribution $\frac{1}{c \times y^k}$, where y is drawn randomly from a uniform distribution between 0 and 1 each reproduction, and where c and k are exogenously defined prior to the beginning of the run as described later. Children locate randomly on any open cell within the radius defined by that function.[9] I follow Laver and Sergenti (2011) in using a Monte Carlo parameterization of the power law that specifies *child-distance*. I run the model 100 times, varying the parameters of the power law such that, on the low end, 50 percent of children locate within two cells of their parent and, on the high end, 50 percent of children locate within eight cells of their parents.[10] The level of cooperation and the percentage of ethnocentric agents

Table 2. Percentage of Agents Playing Each Type of Strategy.

Strategy	Four-group model	No-group model
CC	14.7	42.5
CD	75.1	37.7
DC	1.9	10.3
DD	8.4	9.6
Total C when meeting own group	89.8	80.2
Total D when meeting own group	10.3	19.9

Note: The first letter of the strategy indicates whether an agent Cooperates (C) or Defects (D) when meeting a member of its own group, while the second letter indicates whether an agent Cooperates (C) or Defects (D) when meeting a member of another group.

are then plotted using fractional polynomial plots because the nonlinear nature of the results prevents the use of standard statistical techniques.

Next, I evaluate the effect of *interact-distance*, fixing *child-distance* at 1. I run the model 100 times using the power law described previously such that, on the low end, 50 percent of the interactions are with a partner within two cells and, on the high end, approximately 50 percent of interactions occur with a partner selected at random from the population with no regard to geography.[11] I explore *interact-distance* over a wider interval than *child-distance* because preliminary runs of the model suggested that this parameter was less sensitive to small changes.[12]

Finally, the results of 200 runs when *child-distance* and *interact-distance* vary independently of each other over the same intervals are addressed in the online appendix.

Results

Dropping Groups from the Model

Given that spatial patterns of reproduction and interaction in the HA model produce a system in which agents are primarily interacting with clones of themselves, HA are unable to show how much group identity in itself is contributing to cooperation or to rule out the possibility that cooperation would be just as high when there is no group identifier, simply because of the local geography of agent reproduction. I repeated the HA experiment with no ethnic groups to address this issue and found high levels of cooperative behavior generated, in the absence of ethnic diversity, simply by spatial patterns of interaction and reproduction. In short, the clustering of agent types arising from the geography of reproduction generates intense geographic segregation by PD strategy, such that cooperators will tend strongly to play with other cooperators and defectors with other defectors. Since the PTR payoff for mutual cooperation exceeds that for mutual defection, cooperators will tend to prosper in this evolutionary environment. The results for the model with no ethnic groups showed that 81.1 percent of interactions were cooperative, which is significantly more cooperation than in the four-group HA model.[13]

Furthermore, as indicated in Table 2, the combined percentage of CC and CD agents in the four-group model is greater than the percentage of agents playing C in the model with no group distinction.[14] Though there are more agents that cooperate within group in the four-group model, the prevalence of defection when meeting out-group members results in the lower levels of overall cooperation reported in the previous paragraph. Thus, ethnic groups, and the resulting ethnocentric behavior, are not contributing to cooperation but inhibiting it.

In fact, the high levels of cooperation that emerge when running the model with no ethnic groups suggest that the geographic assumptions about reproduction and interactions, in contrast to group differentiation, are accounting for a large portion of HA's results on cooperation. The cooperation induced by the spatial structuring of reproduction and interaction demonstrates that group identity, which is the basis of ethnocentrism but not relevant in the no-group model, is not driving the HA results. Furthermore, in models with more than one group, homogeneous neighborhoods develop through the reproduction mechanism. While the third trait of ethnocentric agents is important on the borders of these neighborhoods, it is much less important in the middle of these neighborhoods since non-co-ethnics meet only rarely, as a result of mutations. Thus, the high levels of "ethnocentrism" reported by HA are inflated by children of agents who carry the ethnocentric gene, but never actually engage in ethnocentric behavior because they never interact with members of other groups. As reported in Table 2, the 37.7 percent of agents with a strategy of CD when there are no ethnic groups and the second trait is redundant provide evidence of this type of inflation.

Overall, dropping the group distinction from the HA model severs the connection between ethnocentrism and cooperation proposed by HA. Two key geographic assumptions, that children are born near their parents and agents interact locally, are enough to produce high levels of cooperation. When ethnic groups are added to the model, cooperation falls. This decreased level of cooperation when group identity is included in the model shows that it is not the agents' ability to distinguish between meeting an in-group and out-group member that promotes cooperation. Removing groups from the model demonstrates that local reproduction and interaction, rather than ethnocentric behavior enabled by group distinctions, are driving cooperation.

The Effect of Child-distance

I now discuss the new parameters I added to the model, beginning with the results of varying *child-distance* while retaining the HA assumption that interactions occur deterministically within the Von Neumann neighborhood. Figure 1 shows that as *child-distance* increases, the proportion of ethnocentric agents in the system decreases, and indeed approaches the low level that would arise simply by random immigration. Furthermore, as Figure 2 indicates, the level of cooperative behavior

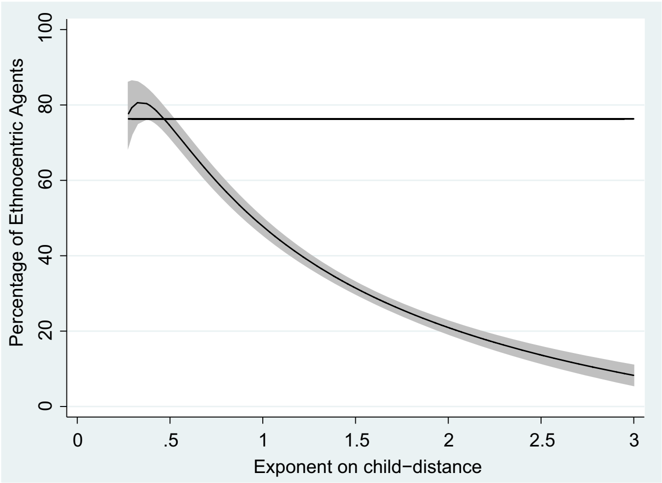

Figure 1. Predicted percentage of ethnocentric agents as *k* increases for *child-distance*.
Note: The shaded area around the curve represents a 95 percent confidence interval.

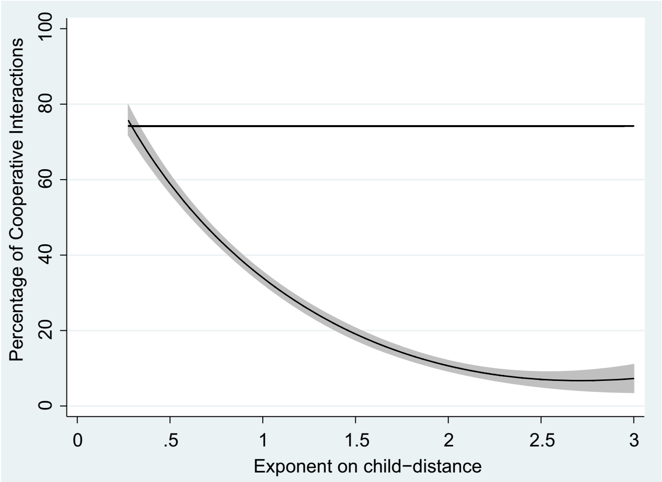

Figure 2. Predicted percentage of cooperation as *k* increases for *child-distance*.
Note: The shaded area around the curve represents a 95 percent confidence interval.

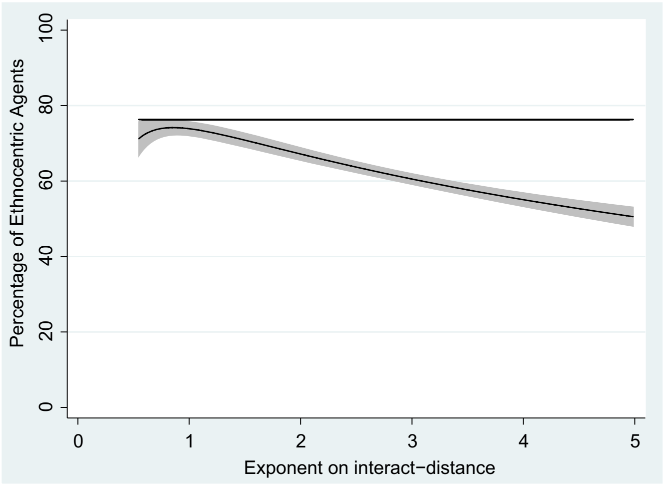

Figure 3. Predicted percentage of ethnocentric agents as *k* increases for *interact-distance*.
Note: The shaded area around the curve represents a 95 percent confidence interval.

falls off at the same rate, implying that agents playing the Nash Equilibrium strategy begin to dominate the system. When *k* equals 1, parents have a fifty-fifty chance of placing their child within a Euclidean distance of 2 from themselves. Despite this tight reproductive spacing, at approximately *k* equals 1, the predicted percentage of ethnocentric agents has already fallen by about one-third. Moreover, by *k* equals 1, cooperation has already fallen to about half of its level in the original model. Taken together, we see a tendency toward a reversion to the Nash Equilibrium, confirmed by the consistent decline in both cooperative and ethnocentric behaviors as *child-distance* increases. These findings show that the emergence of ethnocentrism and cooperation both depend sharply on assumptions about the geography of reproduction. As children locate farther from their parents, ethnocentric agents are separated from their ethnocentric parents and exploited by agents of the same ethnicity that defect on co-ethnics. Within-group cooperation cannot be sustained, as children locate farther away from their parents and ethnocentric agents give way to agents that always defect. Thus, neighborhoods of close relatives formed as a result of children locating next to their parents appear to be necessary for ethnocentrism and cooperation to emerge.

The Effect of Interact-distance

I now constrain the placement of children to the HA assumption of the Von Neumann neighborhood and examine the effects of increasing *interact-distance*. Figures 3 and 4 show that increasing *interact-distance* systemically decreases the levels of both

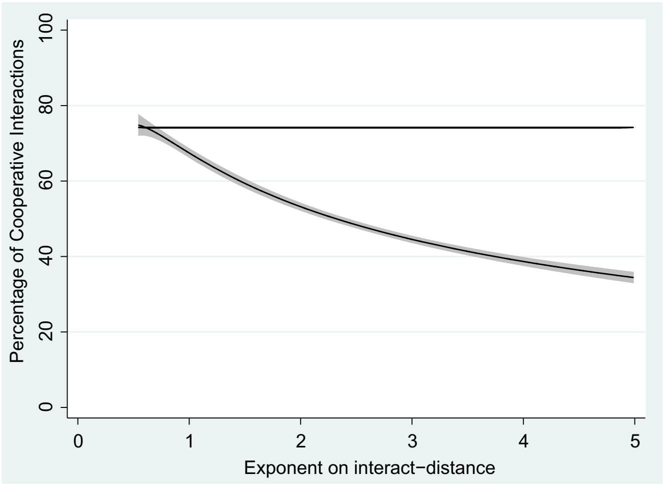

Figure 4. Predicted percentage of cooperation as *k* increases for *interact-distance*.
Note: The shaded area around the curve represents a 95 percent confidence interval.

ethnocentrism and cooperation, though this decline is less striking than that associated with increasing *child-distance*. Using a power law biases local interactions in such a way that even if a majority of interactions are between agents far apart, a substantial percentage remain quite local. For example, even when *k* is set as high as 5, 25 percent of interactions will take place at a Euclidean distance of less than 4.3 from the agent. It is likely that this area is filled primarily with an agent's clones, giving clusters of ethnocentric agents a reproductive advantage. While the substantial level of within-cluster interactions helps ethnocentric clones, these clusters protect themselves through defection in interactions with non-co-ethnics. Moreover, they interact with clones of themselves often enough to overcome any exploitation by members of the same ethnic group who play the Nash Equilibrium strategy. Therefore, even when some interactions are not local, ethnocentrism can be sustained. This is confirmed in Figure 3, which shows that appropriately 50 percent of agents are ethnocentric when *k* equals 5. Overall, these results demonstrate that expanding the distance over which it is possible for agents to interact decreases, but does not eliminate, ethnocentrism due to the amount of relatively local interactions that remain.

Cooperation can also be sustained when *interact-distance* is high, but not to the same degree as ethnocentrism. As *interact-distance* increases, fewer interactions tend to be with co-ethnics, and so we should expect lower levels of cooperation than ethnocentrism. When *k* is 5, Figure 4 shows that less than 40 percent of interactions are cooperative, approximately 10 percent less than the percentage of ethnocentric agents. This result indicates ethnocentrism can emerge even when high levels of interactions occur with out-groups.

Discussion

This article attempts to make both a substantive and a conceptual contribution. Substantively, I explore the effects of geography on the development of ethnocentrism. By separating the effect of local interaction from the effect of local propagation of groups, the revised model shows that it is not merely local interactions that lead to ethnocentrism. Rather, it is settings where interactions are likely to be with closely related co-ethnics that lead to ethnocentrism. In fact, when dropping ethnic groups from the model entirely, but forcing extremely local interaction and reproduction, the spatial structuring of interaction and reproduction produces higher levels of cooperation than running the model with multiple groups. Thus, cooperation is revealed to be the result of the assumptions about the geography of reproduction and interaction rather than the result of agents' ability to distinguish between groups.

Furthermore, in contrast to the findings of HA, who stress the importance of local interactions, the model presented here suggests that the geographical contiguity of close relatives is at least as important to the development of ethnocentrism as the distances over which agents interact. As the distance children locate from their parents increases, neighborhoods of closely related agents cannot develop, without which in-group trust cannot develop and neither ethnocentrism nor cooperation can be sustained. Even placing children small distances from their parents decreases ethnocentrism. However, the model presented here does confirm that, when placing children next to their parents, the HA results are robust to allowing long-distance interactions as long as a sizable portion of interactions occur within an agent's neighborhood of close relatives.

Conceptually, this article shows the importance of geography in the development of cooperation and ethnocentrism. The model with no ethnic groupings clearly shows that geographic assumptions about interactions and reproduction alone are enough to evolve cooperation. Meanwhile, the parameterization of the HA model with respect to the distance children locate from the parents and the distance over which agents interact has important implications for the study of ethnocentrism. Taken together, the introduction of these parameters demonstrates "ethnocentrism" is most likely to emerge when geography allows a large percentage of interactions to occur between closely related agents.

Finally, this article presents a methodological challenge to agent-based modelers to explore more fully the effects of the, often implicit, geographic assumptions in their models. Lacking a clear link between the geography of the simulated system and the real system we are trying to model, modelers should recognize that the geography chosen for a model becomes a parameter of the model. Rather than making firm assumptions about geography, we should explicitly parameterize geographic assumptions and systematically investigate their effects. At a minimum, this serves as a robustness check, but, as this article demonstrates, precise geographic assumptions may be critical to key results.

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Notes

1. The Von Neumann neighborhood consists of the cells to the immediate north, south, east, and west of the agent, in contrast to the Moore neighborhood, which includes those four cells and the four cells diagonally adjacent to the agent.
2. Moreover, agents with the highest likelihood to reproduce will fill their Von Neumann neighborhood with their own children in a shorter number of periods, on average, than agents with lower likelihoods to reproduce. Once all four of an agent's adjacent squares are filled, that agent's probability to reproduce effectively falls to zero until a neighboring agent dies. For certain geographical patterns of agents, biases can occur in favor or against specific types of agents. However, there is no reason to believe these patterns appear systematically and so the overall effect of this restriction on reproduction is unlikely to bias the results.
3. Little empirical work has been done on how far children tend to live from their parents. Using the 1987 National Survey of Families and Households, Rogerson, Weng, and Lin (1993) and Lin and Rogerson (1995) present summary statistics on how far adult children in the United States live from their parents. While their goal is not to evaluate the distribution, it appears their data can be well approximated by a power-law distribution. For discussions of the determinants of the distance adult children live from their parents, see the work of Smith (1998), Michielin and Mulder (2008), Malmberg and Pettersson (2008), and Pettersson and Malmberg (2009).
4. Gonzalez, Hidalgo, and Barabasi (2008) further argue that a truncated power law may be a better fit. For a discussion of what distributions human mobility tends to follow, see the work of Brockmann, Hufnagel, and Geisel (2006); Song et al. (2010); and Rhee et al. (2011). They have in common that some sort of scale-free distribution best models human mobility.
5. The results also indicated that changing to probabilistic interactions introduced a bias in favor of cooperation into the system. While not directly relevant to argument presented in this article, I believe this bias is produced by long-term feedback effects that result when cooperating agents meet by chance more than expected in a given round. This bias is not necessarily problematic for two reasons. First, as long as runs using probabilistic interactions are only compared to runs using probabilistic interactions and runs using deterministic interactions are only compared to runs using deterministic interactions, the bias is accounted for. Second, the probabilistic model is most likely more realistic when we

consider a larger area of interaction since interacting with every agent within that area every period seems impractical.

6. The Wilensky code is provided in the model library distributed with NetLogo.
7. These 10 runs were done with my modified code that places children according to a Euclidean distance fixed at 1 and uses deterministic interactions within an agent's Von Neumann neighborhood. The number of groups was set to 1 for these runs, making the group trait irrelevant to the outcome.
8. All results discussed in the main body of the article included four groups.
9. I focus on drawing *child-distance* from a power law, but also examined drawing child-distance from a uniform distribution. Those results suggest the original model is even more sensitive to the placement of children than the results presented in the following.
10. More specifically, c is fixed at 1 for all runs and k varied randomly between .25 and 3. As k increases, children locate farther away from their parents.
11. More specifically, c fixed at 1 for all runs and k varied randomly between .25 and 5.
12. As mentioned previously, models with *interact-distance* set greater than 1 were run to more time steps than other models. Other models, including the original HA model, were run to 2,000 time steps, by which point they had reached a stochastic steady state. Models with *interact-distance* set greater than 1 were run for 8,000 time steps. See the online appendix A for evidence that the latter model was fully burnt in by 8,000 time steps.
13. The model with no groups had a mean of 81.1 percent cooperation with a standard error of .7 while the four-group model had a mean of 74.2 with a standard error of .5. The difference is highly statistically significant.
14. Of surviving agents, 80.2 percent have the strategy of playing C in the no-group model while 89.8 play either CC or CD in the four-group model. A direct comparison to the HA results here is not possible because they only report the percentage of ethnocentric agents, not the percentage of all four possible types of agents. The result presented in the table for the four-group model are from the Wilensky coding.

References

Axelrod, R., R. Hammond, and A. Grafen. 2004. "Altruism via Kin-selection Strategies that Rely on Arbitrary Tags with Which They Coevolve." *Evolution* 58 (8): 1833-38.

Bahry, D., M. Kosolapov, P. Kozyreva, and R. Wilson. 2005. "Ethnicity and Trust: Evidence from Russia." *American Political Science Review* 99 (4): 521.

Berry, J., and R. Kalin. 1995. "Multicultural and Ethnic Attitudes in Canada: An Overview of the 1991 National Survey." *Canadian Journal of Behavioural Science* 27 (3): 301.

Bizumic, B., and J. Duckitt. 2012. "What Is and Is Not Ethnocentrism? A Conceptual Analysis and Political Implications." *Political Psychology* 34 (5): 693-4.

Brockmann, D., L. Hufnagel, and T. Geisel. 2006. "The Scaling Laws of Human Travel." *Nature* 439 (7075): 462-5.

Doebeli, M., and C. Hauert. 2005. "Models of Cooperation Based on the Prisoner's Dilemma (PD) and the Snowdrift Game." *Ecology Letters* 8 (7): 748-66.

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

Fukuyama, F. 2000. *Social Capital and Civil Society*. Number 2000–2074. Washington, DC: International Monetary Fund.

Gonzalez, M., C. Hidalgo, and A. Barabasi. 2008. "Understanding Individual Human Mobility Patterns." *Nature* 453 (7196): 779-82.

Grafen, A. 1985. "A Geometric View of Relatedness." *Oxford Surveys in Evolutionary Biology* 2: 28-89.

Habyarimana, J., M. Humphreys, D. Posner, and J. Weinstein. 2007. "Why Does Ethnic Diversity Undermine Public Goods Provision?" *American Political Science Review* 101 (4): 709-725.

Hammond, R., and R. Axelrod. 2006. "The Evolution of Ethnocentrism." *Journal of Conflict Resolution* 50 (6): 926-36.

Hruschka, D., and J. Henrich. 2006. "Friendship, Cliquishness, and the Emergence of Cooperation." *Journal of Theoretical Biology* 239 (1): 1-15.

Ifti, M., T. Killingback, and M. Doebeli. 2004. "Effects of Neighbourhood Size and Connectivity on the Spatial Continuous PD." *Journal of Theoretical Biology* 231 (1): 97-106.

Janssen, M. 2008. "Evolution of Cooperation in a One-shot PD Based on Recognition of Trustworthy and Untrustworthy Agents." *Journal of Economic Behavior & Organization* 65 (3): 458-71.

Killingback, T., M. Doebeli, and N. Knowlton. 1999. "Variable Investment, the Continuous prisoner's dilemma, and the Origin of Cooperation." *Proceedings of the Royal Society of London. Series B: Biological Sciences* 266 (1430): 1723-1728.

Laver, M., and E. Sergenti. 2011. *Party Competition: An Agent-based Model*. Princeton, NJ: Princeton University Press.

LeVine, R., and D. Campbell. 1972. *Ethnocentrism: Theories of Conflict, Ethnic Attitudes, and Group Behavior*. New York: John Wiley.

Lin, G., and P. Rogerson. 1995. "Elderly Parents and the Geographic Availability of Their Adult Children." *Research on Aging* 17 (3): 303-31.

Macy, M., and J. Skvoretz. 1998. "The Evolution of Trust and Cooperation between Strangers: A Computational Model." *American Sociological Review* 63 (5): 638-60.

Malmberg, G., and A. Pettersson. 2008. "Distance to Elderly Parents: Analyses of Swedish Register Data." *Demographic Research* 17 (23): 679-704.

Michielin, F., and C. Mulder. 2008. "Geographical Distances between Adult Children and their Parents in the Netherlands." *Demographic Research* 17:655-78.

Mohtashemi, M., and L. Mui. 2003. "Evolution of Indirect Reciprocity by Social Information: The Role of Trust and Reputation in Evolution of Altruism." *Journal of Theoretical Biology* 223 (4): 523-31.

Nakao, K. 2009. "Creation of Social Order in Ethnic Conflict." *Journal of Theoretical Politics* 21 (3): 365.

Németh, A., and K. Takács. 2007. "The Evolution of Altruism in Spatially Structured Populations." *Journal of Artificial Societies and Social Simulation* 10 (3): 4-18.

Nowak, M., S. Bonhoeffer, and R. May. 1994. "Spatial Games and the Maintenance of Cooperation." *Proceedings of the National Academy of Sciences* 91 (11): 4877-4881.

Nowak, M., and R. May. 1992. "Evolutionary Games and Spatial Chaos." *Nature* 359 (6398): 826-29.

Nowak, M., and R. May. 1993. "The Spatial Dilemmas of Evolution." *International Journal of Bifurcation and Chaos* 3: 35-78.

Nowak, M., and K. Sigmund. 1998. "Evolution of Indirect Reciprocity by Image Scoring." *Nature* 393: 573-77.

Nowak, M., and K. Sigmund. 2005. "Evolution of Indirect Reciprocity." *Nature* 437 (7063): 1291-98.

Peres, Y., and R. Schrift. 1978. "Intermarriage and Interethnic Relations: A Comparative Study." *Ethnic and Racial Studies* 1 (4): 428-51.

Pettersson, A., and G. Malmberg. 2009. "Adult Children and Elderly Parents as Mobility Attractions in Sweden." *Population, Space and Place* 15 (4): 343-57.

Read, D. 2010. "Agent-based and Multi-agent Simulations: Coming of Age or in Search of an Identity?" *Computational & Mathematical Organization Theory* 16 (4): 1-19.

Rhee, I., M. Shin, S. Hong, K. Lee, S. Kim, and S. Chong. 2011. "On the Levy-walk Nature of Human Mobility." *IEEE/ACM Transactions on Networking (TON)* 19 (3): 630-43.

Rogerson, P., R. Weng, and G. Lin. 1993. "The Spatial Separation of Parents and their Adult Children." *Annals of the Association of American Geographers* 83 (4): 656-71.

Smith, G. 1998. "Residential Separation and Patterns of Interaction between Elderly Parents and Their Adult Children." *Progress in Human Geography* 22 (3): 368-84.

Song, C., T. Koren, P. Wang, and A. Barabási. 2010. "Modelling the Scaling Properties of Human Mobility." *Nature Physics* 6 (10): 818-23.

Taylor, D., and V. Jaggi. 1974. "Ethnocentrism and Causal Attribution in a South Indian Context." *Journal of Cross-cultural Psychology* 5 (2): 162-71.

Wilensky, U. 1999. Netlogo. Center for Connected Learning and Computer-based Modeling. Evanston, IL: Northwestern University. Accessed January 24, 2011. http://ccl.northwestern.edu/netlogo/.

Wilensky, U. 2003. *NetLogo Ethnocentrism Model*. Evanston, IL: Center for Connected Learning and Computer-based Modeling, Northwestern University. Accessed January 24, 2011. http://ccl.northwestern.edu/netlogo/.